JOINT HIGHWAY RESEARCH PROJECT

JHRP-78-19

SUMMARY OF RESEARCH FINANCED BY
INDIANA STATE HIGHWAY COMMISSION
THROUGH THE JOINT HIGHWAY
RESEARCH PROJECT AT PURDUE
UNIVERSITY, FY 1975-1978

H. L. Michael

78-19

Special Report

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THROUGH THE JOINT HIGHWAY RESEARCH PROJECT AT PURDUE UNIVERSITY
FY 1975-1978

TO: J. F. McLaughlin, Director
Joint Highway Research Project

February 28, 1978

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

File: 10-3-2

Attached is a Special Report titled "Summary of Research Financed by Indiana State Highway Commission Through the Joint Highway Research Project at Purdue University, FY 1975-1978". The attached contains information about the benefits received from all projects completed during the last three years or those anticipated from current research activities. As a consequence the Report attached provides a complete inventory of recent and active research projects to December 1977. Information on findings, applications, benefits to Indiana and publications of the research are summarized.

The Report was prepared by Harold Michael from research reports, from abstracts of research reports as prepared after each such report, and from material provided by the many members of the JHRP staff who were or are principal investigators of the projects. The assistance of each of these members of the JHRP staff is greatly appreciated. Most responded quickly and completely to an urgent appeal for help in preparing the document.

The Report is submitted to the Board as a useful summary of JHRP research. It should be helpful in evaluation of activities of JHRP, in further implementation of research findings, and in development of improvements in the initiation, approval and utilization of findings of future research projects.

My reaction to the Report is one of satisfaction with the beneficial effects ISHC research at Purdue through JHRP is providing to Indiana citizens.

Respectfully submitted,

Harold L. Michael
Associate Director

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Special Report

SUMMARY OF RESEARCH FINANCED BY INDIANA STATE HIGHWAY COMMISSION THROUGH THE JOINT HIGHWAY RESEARCH PROJECT AT PURDUE UNIVERSITY, FY 1975-1978

The Joint Highway Research Project (JHRP) at Purdue University is a cooperative (Indiana State Highway Commission and Purdue University) research activity in the area of highway transportation. Much of the annual research of the Indiana State Highway Commission is conducted by the Project. This publication is a brief summary of each of the research projects which were completed by the Project during the fiscal years 1975, 1976 and 1977 and those which were active in fiscal year 1978.

Research in the Joint Highway Research Project is funded by the Indiana State Highway Commission (ISHC) and by Purdue University. ISHC funds all direct costs of each research project and activity. The typical overhead costs of JHRP (space, office equipment, utilities, etc.) are borne by Purdue University. This cooperative activity is truly a joint endeavor, hence the use of that word in the name.

Two types of research projects are conducted by the JHRP. One is with totally ISHC funding and in the other type ISHC uses a portion of federal funds available to it for a portion of the cost. Research studies in the first type are called JHRP studies while those of the latter type are referred to as HPR studies. The JHRP Advisory Board and management selects the type of study a specific proposed study will be.

Projects selected for state funding are typically small studies of short duration requiring a total expenditure of \$15,000 or less and are concerned with problems unique to ISHC or are feasibility studies to determine if an idea for solution of a problem has a reasonable chance of success and to develop the background material required for the development of a major project with federal funding. Available funds of course are also considered as ISHC has in recent years established \$450,000 as the maximum amount to be used for federally supported research. As ISHC has other research commitments and requirements not funded through JHRP, only about \$300,000 annually in federal funds is available.

All research projects, however, (both federal and state financed) are concerned with problems of the ISHC. Appendices A and B contain a listing of all JHRP projects completed or active the past three years. The seventeen (17) completed projects in Appendix A are also further detailed as to the Indiana Problem they tackle, the major findings of each study, the application by ISHC, the benefits to Indiana and the available publications from the research. Clearly the benefits have been substantial, the problems important and the research successful. Appendix B details the nine (9) active (1978) JHRP studies. Although the research is not complete, the Indiana Problem is stated and anticipated benefits discussed. One of these active projects is a long-term one but as it is concerned with engineering soils mapping of the state the products are of benefit only to Indiana, as a consequence ISHC funding is used.

Appendix C lists the eleven (11) completed HPR studies which were completed during the last three fiscal years (75, 76 and 77) and provides information on estimated benefits ISHC and Indiana have obtained and will continue to enjoy. Appendix D is a listing of the eighteen (18) active (FY 78) HPR studies at Purdue University. The Indiana problems being researched here are important ones and the benefits will also be significant.

Research studies of both types are concerned with cost saving approaches to engineering problems and are potentially valuable to the ISHC and a highly desirable method of utilizing research funds. An HPR study is typically much larger and of longer duration than a JHRP project which is totally state funded. HPR projects typically are for about four (4) years with a total budget of \$70,000 each. JHRP projects on the other hand are one (1) to two (2) years in length on the average with a budget of \$10,000.

In FY 77, the amount funded on HPR research at Purdue in the JHRP was just over \$270,000. The FY 77 funding by ISHC for JHRP projects was \$230,000. Funding during the fiscal year FY 78 is \$260,000.

An example of how a low-cost, short-term JHRP study may progress into a higher cost, longer term HPR study is item #3 in Appendix A, research on ultra-high strength, low porosity concrete. This JHRP study was a feasibility study and is being expanded into a federally funded HPR Study with excellent potential of very great savings to the ISHC and Indiana.

This example is, in fact, a perfect example of the desirability of multi-state and federal cooperation in research. Some initial development activity for this type of concrete was funded by the New York State Department of Transportation, with FHWA assistance. The Indiana JHRP project was a preliminary study, done at a low cost, primarily to check the properties of such concrete and evaluate its properties. The successful conclusion of this project has provided enough background that a full-scale project, funded at the level of about \$80,000 has been proposed for federal participation. Field trials have also been proposed as soon as feasible. The result is that for a relatively small expenditure, Indiana and other states may share in significant financial benefits far outweighing the relatively minor initial Indiana cost and may share in them a year or more sooner than otherwise.

Although JHRP and HPR research are always concerned with an Indiana problem, the results of any research are also made available to other states and throughout the world. In turn ISHC and Indiana obtains from research in other states the findings of their research and the subsequent benefits. The borders of the state are not usually the boundaries of problem areas and one does not subsidize other states' taxpayers if knowledge produced transcends state boundaries, free flow across boundaries exists, and production of that knowledge occurs in every state. Fortunately these conditions are typical throughout the US and Indiana wisely participates.

Although some research in Indiana on traffic safety is funded by the Bureau of Traffic Safety and Vehicle Inspection with federal funds, safety research is also an important part of JHRP and HPR research. Traffic safety research funding and responsibility by law lies with both the Federal Highway Administration and the National Highway Traffic Safety Administration at the Federal level. FHWA is primarily responsible for safety as related to highway facilities and NHTSA for safety related to the driver and the vehicle. Major Federal funding responsibility is also assigned along these lines. NHTSA funds are also available for education and enforcement and JHRP for each of the last two years has conducted traffic engineering training conferences, supported by the Bureau of Traffic Safety and Vehicle Inspection with federal funds at a \$50,000 annual rate.

The Indiana Legislative Act which outlines the responsibilities to be fulfilled at Purdue University with ISHC funds also authorizes holding of the Purdue Road School, programs of highway extension, and dissemination of knowledge to the various sections of the state. These, of course, are also activities of JHRP and obviously utilize a sizeable portion of the funds made available each year to JHRP by ISHC.

The JHRP also conducts financial and economic research as typified by item #6 in Appendix A, "State Highway Finance and User Taxation in Indiana". A summary of the study is there provided. It filled a need which existed at the time of the research in a very economical manner. The results were of important value to legislators and to the up-dated needs study then being conducted. The School of Civil Engineering at Purdue has qualified personnel in the finance and economics areas and the JHRP also utilizes expertise as required for its various research projects from the host of other disciplines at Purdue.

Included in the economic studies are such studies as item #5 of Appendix B, "Evaluation of Benefits of the Indianapolis Innerbelt System". The Indiana problem and objective of the research are there discussed. The engineer is not only responsible for design performance evaluation but also is responsible for evaluation of other impacts resulting from the facility and its design. Impact studies (evaluation of benefits and disbenefits) are normal activities of engineering research organizations. Engineers must know the impact of what they build if wise decisions are to continue to be made - and these impacts must also be known to the public if wise decisions are to be implemented. The most important concern here is not for that which is already complete but with that which is yet to be built. Certainly the greatest benefits to the State are only possible with full knowledge about past experience.

It is always of value to ISHC to evaluate the benefits received from work done by the Joint Highway Research Project. That is the purpose of this Report. The summary of all JHRP Projects completed during the last three years and current ones with benefit statements are given in Appendices A and B. For all HPR projects these are given in Appendices C and D. Other research studies totally or partially funded by ISHC are listed in Appendix E. Included are planning studies and studies financed with other Indiana agencies. All projects are directed at Indiana problems of ISHC. Major benefits have resulted from many projects and some benefits from almost every one. The value of the benefits in dollars to Indiana is far greater than the costs of the research.

The projects have been balanced in the areas of planning, construction, design, operations and maintenance as we believe they should be. They should not be oriented toward one function of ISHC. They should also be in problem areas of the ISHC. The objective of each research project has been to reduce costs of ISHC responsibilities or to expand the benefits accruing to Indiana citizens. The projects have produced such benefits and should continue to do so. We have no doubts but that more than an adequate number of research projects currently exist to be done which will be of significant benefit to the taxpayers of Indiana that funding available for ISHC research should not be reduced. The facts are that the taxpayers of Indiana continue to lose significant benefits because annual research funding is too little.

Harold L. Michael
Associate Director
Joint Highway Research Project

HLM:ms

cc: J. F. McLaughlin, Director

APPENDIX A

JOINT HIGHWAY RESEARCH PROJECT
COMPLETED RESEARCH PROJECTS*
FUNDED BY INDIANA STATE HIGHWAY COMMISSION
1975-1977

<u>Item No.</u>	<u>Project Title</u>
1	"Computerized Slope Stability Analysis for Indiana Highways"
2	"An Investigation of the Final Construction Contract Payment Procedure for the ISHC"
3	"Studies on Cement Paste and Concrete Both Made with Low Porosity Cement"
4	"Development of an Instrumentation Program for Studying Behavior of a Segmental Concrete Box Girder Bridge"
5	"The Effect of Pavement Skid Resistance on Wet Pavement Accidents in Indiana"
6	"State Highway Finance and User Taxation in Indiana"
7	"The Use of Skewed Speed Distributions to Locate Points of High Accident Potential on Low Volume Two Lane Rural Highways"
8	"Right Turn On Red: Utilization and Impact"
9	"Characteristics of Heavy Truck Accidents"
10	"Effect of Film Thickness, Voids and Permeability on Asphalt Hardening in Asphalt Mixtures"
11	"The Effects of Bottom Ash Upon Bituminous Sand Mixtures"
12	"A Methodology for Evaluating the Impact of Railroad Abandonment on Rural Highways"
13	"An Evaluation of the Traffic Engineering Functions in the Small Municipalities of Indiana"
14	"Evaluation of Continuously Reinforced Concrete in Indiana"
15	"Warrants for Location and Design of Local Service Roads"
16	"Computer Analysis of General Slope Stability Problems"
17	"Evaluation of the 55 mph Speed Limit in Indiana"

Items #1 and #16

"Computerized Slope Stability Analysis for Indiana Highways" (77)

"Computer Analysis of General Slope Stability Problems" (75)

Indiana Problem

These two research studies were directed at a difficult problem with many Indiana soils encountered in the construction or improvement of highways in the state - the frequent instability of slopes in cuts and fills which result in failures. The objective of the research was the development of a single computerized slope stability analysis, which would accommodate all problems of this type encountered by the Indiana State Highway Commission. Among the complexities which had to be covered were: multiple slope ground surfaces; any arrangement of subsurface soil types; any flow domain or excess-of-equilibrium pore pressures; boundary loads and pseudostatic earthquake loadings; and any shape or position of a potential sliding surface.

Findings

The first of these studies developed a computer program, STABL, which was expected to cover all conditions which might be found and to produce a stability assessment for any slope. The second refined the computer program, tested applications in the state, and continued development of techniques which would meet the needs of the Indiana State Highway Commission for efficient, versatile and accurate computational methods for the problem. Such techniques were developed in cooperation with operating personnel of the Highway Commission.

Application

The developed computer programs and computational techniques have been placed on the ISHC computer and are currently available for routine use whenever slope stability analysis is desirable.

Benefits to Indiana

Slope failures along Indiana highways for current and future highway improvements will be materially reduced. Savings to Indiana will be reduced closure of highways because of slope failures and less costs of repair of such failures.

Publications

1. Ronald A. Siegel, "Computer Analysis of General Slope Stability Problems", Final Report, JHRP-75-8, June 1975.
2. Ronald A. Siegel, "STABL User Manual", Interim Report, JHRP-75-9, June 1975.
3. Eva Boutros, "Computerized Slope Stability Analysis for Indiana Highways", Final Report, JHRP-77-25, December 1977.

Item #2

"An Investigation of the Final Construction Contract Payment Procedure for the ISHC" (77)

Indiana Problem

In March 1972 a law was passed by the Indiana General Assembly which requires the State of Indiana to pay an interest penalty to contractors if final payment is not made to them within 180 days after contract acceptance. Since enactment of this law the total amount of interest penalties paid to contractors has increased each year, with an estimated total of \$44,000 for 1977. The major objective of this Study was to determine if this increasing cost was likely to continue, the reasons why penalties were occurring and measures which ISHC might take to reduce the penalties.

Findings

Evaluation of the payment process concluded that all penalties could not be eliminated but that they could be greatly minimized, considering the 180 day grace period allowed. The primary cause for penalties was determined to be the project engineer (often city and county engineers) who failed to submit paper work in a timely manner. The Division of Materials and Tests of ISHC in some cases also contributed to the problem by not providing necessary data when desirable. Recent reorganization within this Division, however, may alleviate this situation.

Several recommendations were made to improve communication between involved ISHC personnel and thereby improve the final payment procedure.

Application

The findings of the Study submitted in November 77 are already (January 78) being implemented by the Division of Construction, ISHC. Some of the findings, as noted above, were actually implemented by the Division of Materials and Tests before completion of the Study.

Benefits to Indiana

The savings from the improved management of final payments for construction contracts could save the ISHC up to \$25,000 annually.

Publications

David L. Mays, "An Investigation of the Final Construction Contract Payment Procedure for the Indiana State Highway Commission", Final Report, JHRP-77-20, November 1977.

Item #3

"Studies on Cement Paste and Concrete Both Made with Low Porosity Cement" (77)

Indiana Problem

Concrete bridge decks throughout Indiana are suffering from premature and accelerated deterioration due to spalling traceable to corrosion of reinforcing steel, and aggravated by extensive use of salt on bridges as required by Indiana winters.

The magnitude of the problem is marked by the fact that ISHC is currently faced with replacing or extensively repairing 250 to 300 bridge decks per year, with the number that require repair increasing at an accelerated rate. Many bridges involved are almost new and are on major interstate routes. A specific example is the White River crossing of I-65 in Indianapolis, which started to spall very soon after being placed in service, and required major repairs to the deck four years after being built, at a cost estimated in excess of \$1,000,000. The current bridge deck reconstruction and repair program (250 bridges at an approximate average cost of \$150,000) is conservatively estimated to run about \$37,000,000 per year, and is not keeping up with accelerating needs.

Findings

This study was a feasibility study to determine if an experimental type of cement (low porosity Portland cement), capable of being mixed at low water contents, could produce hardened cement of low porosity, low permeability, unusually high strength, and high alkalinity, and that concrete could be designed to reflect these favorable characteristics. On the basis of the positive findings a proposal has been approved for federally-assisted funding for research to provide information on the suitability of such concretes to resist accelerated deterioration in bridge decks.

Application

No application is as yet possible since considerable research must still be done under the approved federally funded study. A field trial is included in the study for early construction if the laboratory findings permit design of a bridge deck with probability of success.

Benefits to Indiana

Savings of many millions of dollars in future bridge deck repair costs are possible should be experimental concrete prove to be as resistant to the spalling problem presently experienced.

Publications

Carlos Gomez-Toledo, "Studies on Cement Paste and Concrete Both Made With Low Porosity Cement", Final Report, JHRP-77-10, July 1977.

Item #4

"Development of an Instrumentation Program for Studying Behavior of a Segmental Concrete Box Girder Bridge" (77)

Indiana Problem

Segmental construction of bridges was developed and has been utilized extensively in Europe. Interest in this type of construction in the United States has grown recently, with Indiana in a leadership role - to date four segmentally constructed concrete bridges have been constructed in our state. This type of construction is well suited to sites requiring long spans, where site-imposed constraints would otherwise dictate use of very costly temporary falsework.

Because this method of construction received most of its initial development in Europe, American engineers and contractors were, until recently, unfamiliar with it. Access to information has been somewhat limited because many of the European structures have been built under design - build contractual arrangements; design criteria, computer programs, etc. have, therefore often been considered proprietary information. In general, then, knowledge of the behavior of structures of this type to responsible Indiana ISHC engineers is very incomplete. The result is that the most economical design for adequate safety is not possible.

The objective of this Study was to develop a plan for instrumentation of a segmental bridge to be constructed near Turkey Run State Park in Indiana. The objective of the instrumentation was to permit the collection and analysis of transverse bending of the bridge cross-section, daily and seasonal temperature variations in the cross-section, the longitudinal and transverse deformations and stresses due to temperature changes, and time dependent deformations.

Findings

A plan for and actual installation of the necessary measurement devices were completed in the Turkey Run bridge. The study was performed as a fully state funded project because of the short time available between the request from ISHC to perform this Study and beginning of bridge construction. The measurement devices had to be installed during construction for best possible results. A proposal for data collection and analysis to fulfill the objectives of the instrumentation has been approved for federal funding and is continuing under such a research project.

Application

The complete plan for installation of measurement devices was installed in the Turkey Run segmental bridge during its construction.

Benefits to Indiana

Knowledge derived from this study could lead to cost savings both through reduction in materials requirements for initial construction, and through efficiencies introduced into the construction process. Savings to Indiana taxpayers will be the end result whenever segmental construction is the (competitively determined) choice of bridge type for a particular site. From initial results, it appears that for suitable sites the competitive edge is slightly in favor of precast segmental construction over other alternatives when economically designed from findings of this Study.

It should also be noted that initial temperature data has already been useful to the contractor in making adjustments during the construction process.

Publications

R. J. Holman, "Development of an Instrumentation Program for Studying Behavior of a Segmental Concrete Box Girder Bridge", Final Report, JHRP-77-4, March 1977.

Item #5

"The Effect of Pavement Skid Resistance on Wet Pavement Accidents in Indiana" (77)

Indiana Problem

Slippery pavements are known to be a significant cause of highway accidents and ISHC plans include the resurfacing of slippery pavements to minimize these accidents.

The Research and Training Center of ISHC is currently involved in skid testing all state highways. For these test results to be of maximum use, the research attempted to find the minimum level of skid resistance acceptable for driving safety.

The research studied ninety-four road sections throughout Indiana. Data collected for each section included length, traffic volume, pavement type, number of intersections, and skid test results. Accident data for each section over a three year period (1973-1975) was collected and included 4416 accidents.

Findings

A statistically sound analysis could not determine the minimum level of skid resistance (skid number) that could be declared as hazardous for all types of surfaces. The analysis did find, however, that Interstate sections had little increase in accidents on wet surfaces compared to dry conditions. This is probably due to the high geometric and access control standards used in their construction. Four-lane non-interstate sections showed reducing values of the skidding ratio for increasing skid numbers. A five point moving average for the skidding ratio versus skid number allowed the fitting of two regression lines to the data. A critical minimum skid number value was determined by the intersection of the two lines at a value of 44.

Two-lane roads showed a relationship between the wet accident index and skid number when grouped by traffic volume and geometrics. This relationship indicated that slipperiness was of greater importance on moderate volume roads (3000-5000 vpd), and roads with moderate geometrics. The effect of skid number was less on roads with very good or bad geometrics and on roads with high or low volumes.

The research concludes that there are several factors involved in specifying minimum skid number values and that there is no single value which applies to all road sections. The type of road, its volume, geometry and amount of access control should all be considered in determining minimum skid number standards.

Application

The results indicate that skid number used in conjunction with other variables, especially geometrics and volume, can be used to determine the locations where most effective corrective action should be applied. Moderate traffic volume roads and those with moderate geometrics (neither good nor bad) were found to have the highest wet accident index. These are the road sections requiring the best skid number. This information is useful in developing a maintenance program to improve skid resistance of highway surfaces.

Benefits to Indiana

The knowledge obtained permits ISHC to better develop an annual program of resurfacing for now it can better evaluate all candidate sections and select those where, among other factors, reduction in accident rates because of slippery surfaces would be highest.

Publications

J. L. Levy, "The Effect of Pavement Skid Resistance on Wet Pavement Accidents in Indiana", Final Report, JHRP-77-1, January 1977.

Item #6

"State Highway Finance and User Taxation in Indiana" (76)

Indiana Problem

Indiana over the past several years has been plagued with rising highway maintenance costs with little increase in highway revenues. A legislature directed study commission was directed to update an Indiana Needs Study conducted several years earlier. This update was contracted to a consultant. Information on what other states were doing to solve similar problems and an evaluation of income trends in Indiana under various financing plans were the objectives of this research.

Findings

A survey of the financing methods and plans of other states for highway revenue was conducted. The results were reported. A study of past and current revenues together with forecasts of expected revenues under existing and several other financing plans (from currently used or under consideration by other states) was also made and the results reported.

Application

The information developed was provided to the contractor performing the Needs Study for his use, to the Legislative commission for its use, to members of the Indiana Legislature, and to others in the state for guidance in developing highway finance policy.

Benefits to Indiana

The information provided data for some of the questions often asked by those directly involved in highway finance policy in Indiana, thus permitting decisions to be made with fuller understanding of the subject - a condition very desirable for legislative action to be of optimal benefit to the citizens of Indiana.

Publications

John R. McCarthy, "State Highway Finance and User Taxation in Indiana", Final Report, JHRP-76-26, October, 1976.

Item #7

"The Use of Skewed Speed Distributions to Locate Points of High Accident Potential on Low-Volume Two-Lane Rural Highways" (76)

Indiana Problem

High-accident locations on rural highways often cannot be determined without costly and time consuming study until several years experience results in a significant number of accidents at a particular spot. This certainly is undesirable as it often results in loss of life and injury as well as considerable property damage. The objective of this study was to test an idea that characteristics of speed distribution at locations of possible accident potential could identify probable high accident locations before the occurrence of accidents.

Findings

It was found that sites having high accident frequency histories also exhibited skewed speed-frequency distributions. Sites having low or no accident histories exhibited normal speed-frequency distributions. The comparison of the day and night data and directional data found that while certain parameters such as mean speed and deviation did change, the relative shape of the frequency distribution curve did not if perceptual accuracy did not change.

The merging of this information with the perception-response characteristics of drivers resulted in the development of the concept that where a driver had difficulty in perceiving the hazard or where he perceived the hazard incorrectly the probability of an accident occurring was greater and also resulted in abnormal speed patterns on the approach to such a hazard. The result would be skewed speed-frequency distributions from the normal.

Application

The developed technique is easy, inexpensive and now enables the ISHC to test suspected locations for their probability of becoming high-accident locations and to correct deficiencies before accident experience identifies the site.

Benefits to Indiana

High accident locations now have a high probability of being identified before a number of costly accidents occur. As the cost of an average accident in Indiana is in excess of \$500 and as the elimination of a minimum of three (3) accidents at each site where the method is used will result, the location of only six (6) such sites will result in a savings of at least \$6,000 annually (using an estimated \$500/site for conducting the study) to motorists of the state.

Publications

Robert J. Krzeminski, "The Use of Skewed Speed Distributions to Locate Points of High Accident Potential on Low Volume Two-Lane Rural Highways", Final Report, JHRP-76-22, August 1976.

Item #8

"Right Turn On Red: Utilization and Impact" (76)

Indiana Problem

In 1973 the Indiana Legislature mandated that effective July 1, 1974, ISHC implement the Right-Turn-On-Red (RTOR) traffic movement. It also required that all intersections be studied by ISHC to determine those locations where RTOR should not be permitted. Warrants had not as of that period been accepted by traffic engineers as to when such movements should be or not be permitted. The ISHC Division of Traffic Engineering requested research help in providing such warrants and evaluation of the potential impact on safety.

Findings

The result of studies at RTOR intersections found that accident potential did not usually increase at intersections where turning vehicles had adequate visibility of approaching vehicles, that delay to turning vehicles was materially reduced, and that pedestrian conflicts were not significantly affected. On the basis of these findings warrants for prohibition of the RTOR maneuver were developed in 1974. In 1976 an evaluation of the use of the RTOR maneuver in Indiana by motorists and the quality of RTOR prohibition by road and street authorities were made. The findings confirmed that the original warrants for RTOR as proposed and implemented by ISHC and other authorities in Indiana were reasonable, were not resulting in increased accidents, had been implemented at 88% of the signalized intersections in Indiana and were causing few flow or safety problems. On the basis of the evaluation, slight modifications were found to be desirable in the RTOR prohibition warrants.

Application

The recommended RTOR prohibition warrants were implemented throughout Indiana by ISHC and local authorities. The warrants developed for Indiana were subsequently utilized by several other states for similar action in their state and in general were adopted as the suggested needed warrants for any state by the national standard in this area, the Manual on Uniform Traffic Control Devices.

Benefits to Indiana

The results of this study enabled ISHC officials and local road and street authorities in the state to quickly and smoothly implement the RTOR law in Indiana without major problems in safety or in flow and to quickly make the minor revisions desirable as found in the utilization study.

Publications

1. Ronald L. May, "RTOR: Warrants and Benefits", Final Report, JHRP-74-14, August 1974.
2. M. S. Mamlouk, "Right Turn On Red: Utilization and Impact", Final Report, JHRP-76-17, June 1976.

Item #9

"Characteristics of Heavy Truck Accidents" (76)

Indiana Problem

Following implementation of the 55 mph maximum speed limit in Indiana, it was soon apparent to highway officials and drivers that the speeds of heavy trucks had decreased less from the previous higher speed limit period than had automobiles. This condition caused fears that the relatively faster-travelling heavy trucks were resulting in increased accidents.

The objectives of this research were to determine accident rates for heavy trucks on rural interstate and primary highways in Indiana before and after the 55 mph maximum speed limit and to determine the characteristics of heavy truck accidents.

Findings

The following results were found:

1. A decrease in average heavy truck accident rates after the 55 mph speed limit was significant on Interstate and other four-lane highways, however, it was not significant on two lane highways. The amounts of reduction in accidents per 100 MVM were 18 and 50 for Interstate and four-lane highways respectively.
2. A decrease in rear-end collisions was significant on Interstate and other four-lane highways but was not significant on two-lane highways. The amounts of reduction were 11 and 21 on Interstate and other four-lane highways respectively.
3. The changes in average rates of ran-off-road and side-swipe accident were not significant on the three classes of highways.
4. The decrease in average right-angle heavy truck accident rates was significant on other four-lane as well as on two-lane roads. The amounts of reduction in accident rates were 14 and 9 respectively for the two highway classes.
5. Heavy truck and passenger car rates were very similar under the 55 mph speed limit on the three classes of highway. Before the 55 mph speed limit, a heavy truck was much more involved in accidents than a passenger car on Interstate highways. On the other hand, a passenger car was found to be much more involved in accidents than a heavy truck on two-lane highways.

Application

The initiation of an accident reduction program directed at heavy trucks as feared by some to be desirable because of higher relative truck speeds was found to not have a basis in fact. The more similar speeds after the 55 mph speed limit of trucks and automobiles had actually resulted in a greater reduction in truck accident rates after the 55 mph than for automobiles. This finding is also valuable to legislators in determining policy relative to different speed limits for trucks and automobiles. A policy of similar speeds for both results in the safest travel.

Benefits to Indiana

The direction of the Indiana safety program could be more wisely determined with the findings of the study. Costs of such a program could be directed at potentially more effective elements. An important item of information was also obtained which is beneficial to maintenance of the long-time Indiana legislative policy of the same speed limits for trucks and cars. This policy through the years has been frequently attacked as not the safest. The findings of this study indicate such attacks are not warranted.

Publications

A. E. S. Radwan, "Characteristics of Heavy Truck Accidents", Final Report, JHRP-76-18, June 1976.

Item #10

"Effect of Film Thickness, Voids and Permeability on Asphalt Hardening in Asphalt Mixtures" (76)

Indiana Problem

This study addressed a specific Indiana problem associated with the economics of asphalt mixture design and use. Because of Indiana aggregate characteristics, economical asphalt mixture design results in the use of "open" mixtures which require a different approach to mixture design in the durability or asphalt hardening regime than is the case for ordinary "dense" mixtures.

Findings

The results of the study validated the above statement and quantified the effects of film thickness, voids and permeability. These design parameters were evaluated from the point of view of the mixture's durability or resistance to weathering. This has made it possible for Indiana to design "open" mixtures with the confidence that they will be durable even though their void content may exceed criteria established for "dense" mixtures.

Application

ISHC includes the information found in this study in its design of asphalt mixtures.

Benefits to Indiana

The cost of this study (about \$10,000) is saved at least each year if only the cost of the testing for durable mixture design is considered. If benefits derived from savings that accrue due to increases in durability for mixtures that are placed in service are included, many times the cost of the study is saved annually by ISHC.

Publications

Arun Kumar, "Effect of Film Thickness, Voids and Permeability on Asphalt Hardening in Asphalt Mixtures", Final Report, JHRP-76-19, June 1976.

Item #11

"The Effects of Bottom Ash Upon Bituminous Sand Mixtures"

Indiana Problem

Several regions of the state have a minimal remaining supply of quality aggregates for use in highway construction. Concurrently the depletion of the nation's oil reserves has directed attention toward the use of coal as an energy source. Due to this disappearance of quality aggregates and the increasing supply of coal waste products, it seems reasonable to direct efforts toward utilization of these waste products in highway construction.

Findings

Certain classes of power plant bottom ash proved suitable for inclusion in bituminous paving mixtures. Characteristics required of such ash to permit desirable paving mixtures were evaluated. The effect on stability of the mixtures and on the skid characteristics of the mixture as a surface material were also evaluated and some acceptable ash in the state determined.

Application

Limited use has already been made of these waste products. Increasing amounts will be used in the future as the balance of supply of quality aggregates and amounts of bottom ash changes.

Benefits to Indiana

The use of suitable locally available materials will almost always reduce costs of the finished pavement over those requiring transport of materials over long distances. A savings on future contracts as locally available quality aggregates become scarce of at least \$1/ton of aggregate appears to be probable. With thousands of tons of aggregates needed for many paving jobs, the total savings will be substantial where acceptable ash is available.

Publications

T. S. Shuler, "The Effects of Bottom Ash Upon Bituminous Sand Mixtures", Final Report, JHRP-76-11, March 1976.

Item #12

"A Methodology for Evaluating the Impact of Railroad Abandonment on Rural Highways" (76)

Indiana Problem

With the passage of the 1973 Railroad Reorganization Act, Indiana is confronted with the prospect of losing a considerable portion of its railroad trackage. The purpose of this project was to develop a methodology that can be used by governmental agencies (especially the ISHC) in assessing the following questions.

- a. Are the existing highways capable of accepting the diverted rail traffic?
- b. With the additional load volume being placed on the highways, what will be the actual cost of increased highway maintenance?

Findings

The developed methodology includes practical procedures to be utilized for determining railroad abandonment's effects on both highway pavements and bridges. With regard to highway pavements, formulas were developed which express rail service discontinuance's impact on a rural highway in terms of additional thickness of asphaltic concrete overlay. In order to minimize the number of computations required in using these formulas, graphs were prepared that would provide directly the amount of additional bituminous concrete overlay which can be attributed to a railroad line's closing.

The procedure for estimating possible effects of increased truck traffic on rural highway bridges involves analyzing data obtained from secondary sources of information in conjunction with personal inspection of structures likely to be affected by railroad abandonment. In addition to the aforementioned procedures, the evaluative methodology includes not only techniques to be used for meeting the system's data requirements but also a means of determining the financial impact of a branch line's closure on affected rural highways.

Application

Application of the procedure to two rail corridors in Indiana indicated that results obtained were realistic and practical of use. The developed procedures were utilized by the consultant in preparation of the 1976 update of the Indiana Highway Needs Study. They are available for use in studies still to be made as more rail abandonment or rail maintenance decisions become necessary. The required highway improvements by ISHC for rail abandonment corridors will be possible of determination.

Benefits to Indiana

The existence of the proven methodology will permit wiser decisions to be made on rail abandonment or highway improvement in affected corridors more quickly. Planning can be better performed and future development of the states transportation system will be enhanced.

Publications

Lynn O. Purnell, "A Methodology for Evaluating the Impact of Railroad Abandonment on Rural Highways", Final Report, JHRP-76-4, January 1976.

Item #13

"An Evaluation of the Traffic Engineering Functions in the Small Communities of Indiana" (76)

Indiana Problem

Many small communities in the state do not have expertise available in the area of traffic engineering and do not utilize required standards for traffic control devices or for their use. The objectives of this study was to determine the seriousness of this problem and possible means of minimizing it.

Findings

The study found numerous instances in most small communities of improper installation and use of traffic control devices. It found that the quantity and quality of the traffic engineering utilized declined as the population of the community decreased. This poor performance was attributed primarily to the lack of knowledge of municipal employees and the governing bodies, both in how to perform the TE functions and the effects of performing or not performing a specific function. Another major problem was the lack of funds needed for the initial upgrading of a municipalities traffic control devices and funding for the maintenance of a traffic engineering program within the municipality.

Application

The personnel of the transportation area of the School of Civil Engineering developed, submitted and obtained approval of two traffic engineering conferences each year to provide training in traffic engineering to those responsible for performing the traffic engineering functions for governmental units within the state. Funds obtained were Federal safety funds through the Indiana Office of Traffic Safety. Training to over 100 such governmental employees has been provided during 1976 and 1977. Continued training in each year is anticipated for future years.

Benefits to Indiana

Improved utilization of sound traffic engineering results in improved traffic flow (and lessened fuel consumption), reduction in numbers of accidents (and resulting deaths, injuries and property damage), and reduced opportunities for liability judgements against a community resulting from negligence in the performance of required traffic engineering functions. Such benefits are without doubt substantial.

Publications

James R. Mekemson, "An Evaluation of the Traffic Engineering Functions in the Small Municipalities of Indiana", Final Report, JHRP-76-5, January 1976.

Item #14

"Evaluation of Continuously Reinforced Concrete Pavements in Indiana" (75)

Indiana Problem

In the 1960's, the Indiana State Highway Commission, with the concurrence of and encouragement by the Federal Highway Administration, embarked upon a program of constructing continuously reinforced concrete pavement on the major arterial roads in the state. These were by and large on the Interstate System and were constructed between the years 1966 and 1971. A total of about 700 two-lane miles of pavement were constructed.

The purpose of building this type of pavement was to provide a smooth riding surface since joints were eliminated from the design. Construction of this pavement was in line with the trend in design and construction throughout the United States.

Starting about 1970, a considerable amount of distress was noted on these pavements in Indiana. By the summer 1972 about 1/3 of the mileage showed major distress. This pavement is built using a large amount of steel, and as a result the cost of repairing the pavement is high. The original cost of the pavement was about \$10 per square yard but the cost of patching is in excess of \$100 per square yard. Indiana State Highway Commission officials requested that the Joint Highway Research Project investigate the problem and make recommendations for methods of reliable and economical repair and design of such pavements.

Findings

The research project, originally established in 1972, was a continuing one over a period of three years.

The results of the study pinpointed several factors which contributed to the poor performance of this type of pavement in the state. The first of these was the subbase. Recommendations were made to the state for changing their subbase specifications and this was done. The second factor found to be significant was steel percentage; a third was the method of steel placement; and the fourth was the thickness of pavement that was adopted for the design. Recommendations were made to the State on changes which should be made in the design and construction of such pavements.

Application

The recommendations made as a result of this study have been incorporated into design requirements for any future pavements of this type.

Benefits to Indiana

The ISHC has not built this type of pavement since development of the problems. Major emphasis has been placed on repairing and maintaining the hundreds of miles of pavements constructed prior to 1972. Knowledge of the causes of the failures has enabled savings in their maintenance. These savings, in fact, will be substantial. A conservative estimate is hundreds of thousands of dollars over the next ten years. A study is also currently (1978) in progress using federal funds to evaluate the most efficient method of repair for major failures in such pavements. Some of the savings indicated above will result from knowledge being gained on that study. In addition, the knowledge is now available on the proper design of such pavements in Indiana so that the costly premature deterioration experienced over the last six years would not occur if Indiana initiates construction again of this type of pavement.

Publications

Asif Faiz, "Evaluation of Continuously Reinforced Concrete in Indiana", Final Report, JHRP-75-17, October 1975.

Item #15

"Warrants for Location and Design of Local Service Roads"

Indiana Problem

Although local access roads have been demonstrated in other states to be of considerable value in controlling congestion and conflicts with traffic on high volume rural and suburban arterial highways, communities in Indiana have resisted the use of such facilities. The purpose of this research project was to identify differences in operation and safety of highways with service road access control as opposed to direct access; to determine which traffic and geometric factors affect the operation and safety of the service road and highway at their points of intersection; and to apply these factors as criteria for the layout of various service road configurations.

Findings

Analysis of data collected on service roads in Indiana and on highways without such roads provided insight into many design details which were valuable on local service roads. Expected volumes using the service road were found to be a variable which indicated a number of warranted design conditions.

Application

The findings of the study were utilized to prepare a recommended design of service roads for a 2-mile section of SR 26 between I-65 and US 52 at Lafayette, Indiana. The plan for service roads at this location was subsequently adopted by the Area Plan Commission as the plan for the area with the intent its construction will be required as development occurs and makes necessary.

Benefits to Indiana

Benefits from application of the findings to the 2-mile section of SR 26 at Lafayette will insure that the traffic flow capabilities of this new facility and its safety characteristics will be materially maintained for the expected life of the facility rather than almost totally destroyed in a much shorter time period because of heavy commercial development in this corridor. Such benefits are substantial for this over one million dollars per mile type of highway construction. Similar benefits will accrue for other similar application of the findings of this research.

Publications

Carl B. Baughman, "Warrants for Location and Design of Local Service Roads", Final Report, JHRP-75-18, October 1975.

Item #17

"Evaluation of the 55 mph Speed Limit in Indiana" (75)

Indiana Problem

One of the major reasons which might have encouraged continued violation of the 55 mph maximum speed limit in its early days was the absence of understanding by the driving public of the benefits resulting from the limit and the uncertainty of many drivers as to the real need for such controls. The purpose of this study was to evaluate the effect of the 55 mph speed limit on typical measures of speed, compliance of the public to posted limits, accident rates, and anticipated relative gasoline savings on rural primary highways in Indiana.

Findings

An analysis of traffic volumes for the first six months of 1974 indicated that they were 13% less than the projected volumes for 1974 and 6.5% less than the volumes for the first six months of 1973.

Accident data was collected on 125 sections of rural primary Indiana highways. Traffic volumes for the sections were used to find accident rates for interstate, other four-lane, and two-lane highways. Accident rates for the first six months of 1974 were compared to rates for the first six months of the three previous years. The rate for each class of highway significantly decreased in the first six months of 1974.

The reduced observed speeds and traffic volumes suggested a 55 million gallon gasoline savings in the first six months of 1974 over the first six months of 1973.

Application

The impact in Indiana of the 55 MPH speed limit on travel, accidents, speed and fuel consumption were investigated factually. The results were useful in placing the effects in better perspective than emotional personal evaluations which the press was typically reporting. Considerable press coverage of the findings of this study were obtained in the state and elsewhere.

Benefits to Indiana

The educational information provided to the citizens of the state may have been of value in obtaining early appreciation of the value of the speed limit in the areas of accident reduction and fuel savings. Such appreciation should have resulted in some better achievement of the objectives of the 55 mph speed limit.

Publications

Tim M. Borg, "Evaluation of the 55 MPH Speed Limit", Final Report, JHRP-75-6, March 1975.

APPENDIX B

JOINT HIGHWAY RESEARCH PROJECT
ACTIVE RESEARCH PROJECTS
FUNDED BY INDIANA STATE HIGHWAY COMMISSION
January 1978

<u>Item No.</u>	<u>Project Title</u>
1	"Delay and Accident Effects of Unwarranted Traffic Signals"
2	"Identification of Frost Susceptible Aggregate"
3	"Effect of Binder Characteristics on Limiting Tensile Strain for Bituminous Mixtures"
4	"Studies of the Behavior of Simply-Supported, Multiple Span Reinforced Concrete Bridges"
5	"Evaluation of Benefits of the Indianapolis Innerbelt System"
6	"Application of the UTCS-1 Network Simulation Model to Select Optimal Signal Timing in a Multi-Linear Street System"
7	"County Engineering Soil Mapping"
8	"The Use of Self-Protecting Steel as Concrete Reinforcement in Potentially Corrosive Situations"
9	"Design Parameters of Asphalt Treated Bases in Rigid and Flexible Pavement Systems"

Item #1

"Delay and Accident Effects of Unwarranted Traffic Signals"

Indiana Problem

Although the traffic signal is recognized as a very desirable traffic control device where experience and engineering studies shows it is warranted, many traffic signals in Indiana have been placed at intersections where they result in great delay, much waste of fuel and a sizeable number of accidents. The proper control device at such intersections is most likely the STOP SIGN on the minor street. Furthermore many ill-advised individuals continue to pressure for more traffic signals with the belief they are the solution to all traffic and accident problems.

The objective of this Study is to evaluate the increase in delay, wasted fuel consumption and increased accidents which result when traffic signals are installed where volumes of traffic are not sufficient to warrant them.

Anticipated Benefits to Indiana

Traffic engineers in Indiana will upon completion of the study have factual evidence from Indiana of the detrimental impacts which occur when traffic signals are installed before they are required. This should improve their ability to discourage the installation of signals where the result would be hours of wasted time, hundreds of gallons of unnecessarily used fuel and increased accidents each day. The benefits to motorists would be large.

Item #2

"Identification of Frost Susceptible Aggregate"

Indiana Problem

A necessity for exterior concrete in Indiana is aggregate which will resist repeated exposures to freezing and thawing without disrupting the integrity of the concrete. This includes nearly all of the concrete used in Indiana's highway pavements, bridges and drainage structures. (It also includes other concrete used in housing, agriculture and industry.) The average ready mixed concrete truck, full of concrete, is carrying approximately 9 tons of aggregate. Due to the costs of transportation, it is economically desirable to use aggregates from locations close to the concrete production plants. In many regions of the State of Indiana, quality aggregates are in poor supply and often sources known to be good by their past performance record are becoming of limited supply. Alternate aggregate of lesser overall quality might be feasible for many uses if it performs well in freezing and thawing. An effective test to identify such aggregate would greatly reduce the high costs of premature concrete failure due to poor aggregate performance in freeze-thaw, and, also, by identifying locally available aggregate heretofore not believed to be suitable for use in concrete.

The test method under development in this research involves the concept that accurately measured microstrains of the aggregate as it is subjected to conditions very much like those experienced within concrete when it freezes can be used to determine effectively aggregates which will or will not perform adequately under freeze-thaw conditions.

Anticipated Benefits to Indiana

Large cost reductions for the ISHC in two very costly areas - reduced premature failures of concrete pavements which are occurring in the state and identification of quality local aggregates which previously had been thought to be unsuitable for use in concrete.

Item #3

"Effect of Binder Characteristics on Limiting Tensile Strain for Bituminous Mixtures"

Indiana Problem

Many millions of dollars are spent annually in Indiana for highway construction and maintenance in which bituminous mixtures are used. Such mixtures are subject to tensile cracking from forces induced by low temperatures. The goal of the original research in this area was funded with federal funds and was to determine characteristics of the bituminous material which minimized such cracking and prolonged pavement life.

The original research noted above attacked the fundamentals of the problem. Indiana materials and specifications were used. From these studies it was learned that, contrary to what is being done in some areas of the country, the problem cannot be substantially helped by a more restrictive selection of available asphalts (which would in itself result in increased cost).

The results of these fundamental studies were then applied specifically to Indiana conditions in this study. The research is still in progress, but results to date indicate that Indiana concepts of incorporating modified asphalt binders through the emulsification procedure is a viable approach to the problem and that the use of such materials should be expanded.

Anticipated Benefits to Indiana

Large cost reductions for ISHC and other Indiana street and highway agencies by increasing the life of pavements constructed with bituminous mixtures.

Item #4

"Behavior of Simply-Supported, Multiple Span Reinforced Concrete Bridges"

Indiana Problem

Within the last few years, the ISHC has been confronted with a unique problem which is occurring on certain Indiana bridges. A number of simply-supported reinforced concrete girder structures have exhibited spalling and structural distress at the beam ends. As many as 50 bridges may be involved, with distress at various stages of development. This research is attempting to find the cause(s) of the progressive deterioration. Remedies for those bridges which are not badly damaged at present may then be relatively simple and economical and design actions should be available which would virtually eliminate the problem for future bridges.

The project goals are to identify the bridges which may not need repairs as well as those which can still be repaired without great cost and to identify the critical parameters causing the problem. Correspondence with Highway Officials in other states indicates that this is a problem unique to Indiana, possibly due to the wide variety of design and detailing practices, climatic conditions, or other factors still to be identified.

Anticipated Benefits to Indiana

Large savings by ISHC in reducing or eliminating the repair of future bridges if the causes can be identified. The damage to several bridges has already been considerable and major repairs have been necessary on a few. The cost of such repair was at least ten (10) times the total cost of this study (about \$10,000).

Item #5

"Evaluation of Benefits of the Indianapolis Innerbelt System"

Indiana Problem

Traffic congestion and accidents are the two major problems confronting motorists in urban areas. In large urban areas because of the large volumes of vehicles in major corridors of travel these problems are severe and also result in much wasted fuel and concentration of air pollutants. A proven type of highway facility which results in significant reduction in all these problems is the limited access freeway. Unfortunately, freeways because of space requirements also result in social problems which can be serious and which must also be evaluated. Obviously the decision of an urban area as to whether to construct a freeway should be based on reliable estimates of the anticipated consequences - both benefits and disbenefits - of such construction. Estimation of benefits or disbenefits, however, should be based on reliable experience from past freeway construction.

The first complete and sizeable freeway network in Indiana was completed in Indianapolis in 1975. The purpose of this study is to evaluate the benefits or disbenefits resulting to traffic (congestion and accidents) of the several major portions of this system - the Inner Belt and the Outer Belt. Research should also be conducted on the social and economic impacts of the system.

Anticipated Benefits to Indiana

As the urban areas in the state grow, solution to the congestion and safety problems will be demanded. Freeway systems will be one of the methods for solution proposed. Only by the assembly and analysis of factual information on benefits and disbenefits from freeway experience will authorities and people of the urban area be able to decide wisely what the decision should be, especially when the importance of the decision to the future of the community is so very great.

Item #6

"Application of the UTCS-1 Network Simulation Model to Select Optimal Timing in a Multi-Linear Street System"

Indiana Problem

The major cause of traffic delay and wasteful fuel consumption in urban areas is the traffic signal when it is not operating in the most efficient manner. Efficiency is obtained through proper timing and synchronization of adjacent signals so as to minimize delay and fuel consumption. Proper timing, especially in a multi-linear network of several signals - at least one such system exists in almost every city in the state of over 10,000 population - is complex and must be frequently redone. Very few, if any, efficiently operating signal systems currently are operating in Indiana because of the complexity.

The purpose of this research was to develop procedures and adapt an available computer program to permit ISHC and city traffic engineers to easily and effectively time traffic signal systems in the state. The adapted computer program is to be placed on line in the ISHC computer system and a manual for use of the program to time such signal systems is to be prepared.

Anticipated Benefits to Indiana

Although the research is still in progress, application of the adapted computer program and developed procedures in a case study (West Lafayette, Indiana) indicated that each week day of the year the savings to motorists in this single city would total 173 hours, 150 gallons of fuel and almost 100 kilograms of carbon monoxide emission. These benefits are obtained by simply resetting the signal controller timing dials as indicated by the computer output resulting from use of the developed procedures. The ISHC Division of Traffic Engineering plans to implement the system when the research has been completed.

Item #7

"County Engineering Soil Mapping"

Indiana Problem

The planning and design of transportation facilities and other public works and structures is done most economically and effectively if full information is available on the engineering characteristics of the soils which will serve as the foundation for the development. In the 1940's, a technique for the interpretation of aerial photographs to obtain engineering characteristics of soils was developed, largely at the Joint Highway Research Project at Purdue.

Shortly after the development of the interpretation technique and proving its validity, the JHRP Advisory Board authorized the initiation of a long-term continuing project to develop an engineering soils map of each of Indiana's 92 counties. Special corridor maps were also authorized and have been prepared during the project for new highways in the planning and design stages by ISHC. As of January 1978, 62 county maps have been completed and several are in various stages of completion.

Anticipated Benefits to Indiana

The maps already prepared are used extensively in Indiana by ISHC and local authorities and by consultants in the planning and design of transportation and other facilities. Approximately 500 copies of completed maps have been sold during the last ten years and others have been made available to ISHC. The latter uses the maps extensively in the selection of highway locations and to develop subsurface exploration plans. Local authorities and consultants use the maps in a similar manner. It is conservatively estimated that at least \$1000 per county is saved each year in planning and design costs. With 62 county maps available, this totals to about \$60,000 savings per year for Indiana. Currently, additional counties are being mapped at the rate of about three (3) per year at a cost of about \$20,000 annually.

Item #8

"The Use of Self-Protecting Steel as Concrete Reinforcement in Potentially Corrosive Situations"

Indiana Problem

Many, perhaps most, reinforced concrete bridge decks in Indiana are experiencing progressive distress from deicing-salt induced corrosion of reinforcing steel. This distress eventually requires the closing of the bridge for major repairs costing hundreds of thousands of dollars per bridge. In addition, there are large road-user costs stemming from attendant travel delays and detours. This study is designed to determine the feasibility of using a type of steel that may be resistant to this problem and that can, potentially, solve this huge maintenance problem. This is the same problem for which another JHRP Study was recently completed in the feasibility phase and was accepted for federal funding in a major research phase. The magnitude of the problem and huge costs to Indiana fully justify the investigation of any possibility which might minimize this problem.

Anticipated Benefits to Indiana

The state is currently spending millions of dollars per year to repair bridges suffering from reinforcing steel corrosion problems. The taxpayers are spending additional money in increased road-user costs due to detours for the repairs. If the results of this study show that the special steel can resist corrosion the need to repair future corrosion problems in bridge decks would be minimized and large savings would occur. The cost of this study is very nominal, estimated to be about \$6,000.

Item #9

"Design Parameters of Asphalt Treated Bases in Rigid and Flexible Pavement Systems"

Indiana Problem

Extensive study under another JHRP completed study determined that treated base courses under continuously reinforced concrete pavements were desirable. It was also found, however, that some of the asphalt treated bases were not performing as they should. As a result a research project was initiated to evaluate the factors which contribute to poor performance of this type of material in a few cases. Original research under the Study was federally funded and many valuable results were obtained.

The ISHC makes extensive use of Asphalt Emulsion Treated Mixtures (AETM) because of economical and environmental advantages. It was desired, therefore, that the properties of AETM and mix design procedures and criteria for AETM be studied. Because of the complexity of this mix behavior under different loading and environmental conditions, a thorough understanding of the role of each of the AETM components is also needed. This study as a consequence with JHRP funding to develop the desired information was initiated.

Anticipated Benefits to Indiana

The findings when available will permit the ISHC to develop better designs of AETM which will provide reductions in maintenance costs as AETM will then be more effectively used. The economical and environmental advantages of this mixture can then be more fully realized.

NOTE: The original research study of this title was federally funded and terminated before completion because of available federal funds and desire of ISHC to restrict the final phase to unique Indiana problems. The following publications resulted during the federal funding.

Publications

1. A. A. Gadallah, "A Study of the Design Parameters for Asphalt Emulsion Treated Mixtures", Interim Report, JHRP-76-30, October 1976.
2. Bradley Saxton, "A Laboratory Evaluation of the Influence of Crushed Stone, Aggregate Top Size and Binder Type on AETM Properties", Final Report, JHRP-77-9, July 1977.

APPENDIX C

JOINT HIGHWAY RESEARCH PROJECT
COMPLETED RESEARCH PROJECTS
FUNDED BY INDIANA STATE HIGHWAY COMMISSION AND
FEDERAL HIGHWAY ADMINISTRATION
1975-1977

<u>Item No.</u>	<u>HPR Project Title</u>
1	"Concrete Compaction by Internal Vibration"
2	"A Low-Cost Maintenance Program for Indiana Roadsides"
3	"Predicting Pavement Performance Using Time Dependent Transfer Functions"
4	"Fundamental Studies of Portland Cement Concrete"
5	"Pavement Blowups of Portland Cement Concrete Beneath Bituminous Overlays"
6	"Development of Techniques for Plant Establishment on the Roadside"
7	"Use of Precast, Prestressed Concrete for Bridge Decks"
8	"Cracking in Bituminous Mixtures"
9	"Pore Size Distribution and Its Effect on the Behavior of Compacted Clayey Soils"
10	"Effect of Retarders on Volume Changes of Portland Cement Concrete"
11	"Soil Stabilization for Erosion Control"

Item #1

"Concrete Compaction by Internal Vibration" (77)

Indiana Problem

This project was concerned with the quality of construction, especially of concrete pavements. A good concrete must be well consolidated, i.e. without large voids. The fewer the voids, the stronger the concrete. To accomplish this internal vibrators are used in the fresh concrete.

Current economical construction methods (slip form pavers) require the use of concrete which is relatively stiff and, if correct vibrating procedures are not used, the results will be concrete containing voids, especially around reinforcing steel. This nullifies the value of the steel and frequently results in a pavement failure under heavy highway loadings.

Findings

This study identified requirements for good vibration - hence consolidation of concrete. A further part of the investigation was the evaluation of a nuclear density probe for determining the adequacy of consolidation of fresh concrete while it is still plastic and possible to correct. This would help to eliminate pavement failure especially those commonly associated with construction joints.

Application

On the basis of identified requirements for good vibration, ISHC specifications for concrete slump and for vibrators were reviewed and some changes were made. The nuclear density probe for determining the adequacy of consolidation is still experimental. The technique for using the probe for such purposes as developed by this study has been recommended to ISHC for further testing and evaluation on construction sites.

Benefits to Indiana

Final estimates of total benefits must await the further experimentation by ISHC to evaluate the nuclear testing technique. Savings in maintenance of concrete pavements because of the slump and vibrator revisions in ISHC specifications will certainly result. Total cost savings from this research could easily be as much as \$50,000 per year.

Publications

1. O. T. Olateju, "Laboratory Evaluation of the Response of Reinforced Concrete to Internal Vibration", Final Report, Phase I, JHRP-73-28, December 1973.
2. C. F. Scholer, "Evaluation of a Nuclear Probe to Measure Density of Fresh Concrete", Final Report, Phase II, JHRP-78-4, March 1978.

Item #2

"A Low-Cost Maintenance Program for Indiana Roadsides" (77)

Indiana Problem

The Indiana problem the study attacked and its seriousness in terms of costs to Indiana taxpayers.--Rising costs of roadside maintenance involving mowing operations and the need to conserve energy and fossil fuel make it imperative to consider options to multiple mechanical mowing as a solution to maintenance of turfed roadsides. Two possibilities are available with present technology:

- a) Reduced mechanical mowing
- b) Chemical mowing by spraying chemical retardants of grass growth

It is to the first of these options, reduced mechanical mowing, that this project was principally directed.

In 1972, studies were initiated to evaluate possible reduced mowing practices. The objectives of the study were as follows:

- a) To identify unnecessary mowing cycles so that such cycles might be eliminated.
- b) To schedule those mowing cycles which provide the most benefit at times when they most contribute to the effectiveness of the fall-spring spraying program for control of weeds implemented in 1970.
- c) To evaluate reduced or limited mowing practices, including unmowed areas, to determine effects on turf and other features.
- d) To inspect actual mowing operations to determine how mowing practices might be improved to enhance appearance and efficiency, to minimize mowing acreage, and optimize the production of a healthy turfed roadside.

Additionally, the project was concerned with the evaluation and development of suitable herbicide mixtures for use to control growth of brush and woody plants in areas where mowing could be reduced or eliminated.

At the time this project was initiated, it was determined that approximately 75,000 acres of roadside in Indiana was included in a mechanical mowing program. Since the cost of roadside mowing normally exceeded \$30 per acre per season, the total cost to the State of Indiana was approximately \$2,250,000 annually. The potential magnitude of cost savings in roadside mowing were, therefore, considerable.

Findings

The findings of the study which have been applied in Indiana to relieve the problem--The 5-year evaluation of roadside mowing practices in the State of Indiana was completed in 1976. The findings showed that the first mowing cycle was the most critical. This mowing if done too early was wasted because the most rapid growth of grass occurs in early spring. If carried out too late or when the grass is wet, injury to turf may result from piling up of grass and smothering. The optimum height for the first mowing cycle was determined to be between 18 and 24 inches. To prevent scalping and to avoid piling up and smothering of grass, the grass should be mowed to a height of 4 to 5 inches. The second cycle of 3-cycle mowing was determined to be less critical and could be eliminated most seasons if the first cycle were delayed. The last cycle could

be delayed so no more than about 12 inches of growth occurred before winter. This left the roads with a well-maintained appearance during the winter months but with enough growth to protect the grass from winter killing but not so much growth that either fall or spring spraying with herbicides to control broad-leaf weeds is interfered with.

Unmowed roadsides remained in good condition over the 5-year observation period when combined with the fall-spring spraying rotation for control of broad-leaf weeds. A major problem was that brush began to take over in some areas. Addition of a brush control agent to the fall-spring spraying rotation for these areas was indicated or as an alternate 1-cycle mowing at least every other year.

Application

The recommendations based on the findings were implemented on a state-wide basis by ISHC in 1977. After one year of implementation the evaluation is that some areas were able to get by on 1 cycle mowing, most areas required only 2 cycle, restricted mowing but that some areas where esthetics or safety was an issue required the full 3 cycles. Starting in 1978 areas that were not mowed will be sprayed with a brush control agent at least once every 3 years.

Benefits to Indiana

Savings to the taxpayers of Indiana annually by implementation of the findings - compared to standard 3-cycle mowing, the reduction to approximately 2-cycle mowing in 1977 reduced the actual acreage mowed by about 1/3 corresponding to a savings of \$750,000 the first year.

Publications

1. D. James Morre and Jane Eberle, "A 5-Year Evaluation of Highway Mowing Practices: Summary and Recommendations", Interim Report, JHRP-75-31, December 1976.
2. D. James Morre, "Chemical Control of Brush and Environmental Safety of Roadside Vegetation Management Chemicals", Interim Report, JHRP-75-32, December 1976.
3. D. J. Morre, "A Low-Cost Maintenance Program for Indiana Roadsides", Final Report, JHRP-77-13, July 1977.

Item #3

"Predicting Pavement Performance Using Time Dependent Transfer Functions" (77)

Indiana Problem

With the limited funding available and the necessity of providing highways to meet the needs of Indiana motorists, the major pavement problem today is not how to design new roads but rather it is how to evaluate, maintain and upgrade the existing system. In addition, it is mandatory that this be done so as to optimize performance, minimize costs and reduce to a minimum the closing of highways.

Current pavement evaluation procedures suffer from several shortcomings. All present techniques are either destructive in nature or apply to only small areas of the pavement. Further, these methods use loadings quite unlike those induced by actual traffic and the conduct of the test requires considerable performance time. Consequently, at best, present methods can only provide diagnostics at limited sample points and these at considerable cost in time and money.

This research project sought to transfer technology gained from large scale airfield pavement studies using prototype aircraft loadings for the U.S. Air Force to Indiana highways.

Findings

In brief, for the first time ever, the response of pavements was obtained under actual moving vehicular loadings without the measuring device making contact with the pavement. The non-contact mode was a consequence of using light emitting diodes (LED) and monitoring their reflection from the deflected pavement surface. In addition, analytical procedures were developed that produced parameters that indicated the condition of the pavement, given the deflection basin, and a measure of its serviceability.

Application

The research has been proposed for an additional federally funded study to further develop and evaluate the technique and make it operational in the ISHC.

Benefits to Indiana

In that the procedure is rapid and non-destructive, the possibility exists for evaluating large expanses of the Indiana system and of providing a systematic and rational basis for scheduling maintenance. The possibility is good that this can be achieved and that maintenance scheduling can be more wisely programmed than is possible with present methods. Considerable cost benefits from optimizing pavement costs and reducing motorist costs by permitting better maintenance will result.

Publications

M. E. Harr and G. Y. Baladi, "Nondestructive Testing and Evaluation of Flexible Highway Pavements", Final Report, JHRP-77-6, May 1977.

Item #4

"Fundamental Studies of Portland Cement Concrete" (76)

Indiana Problem

Concrete produced in Indiana for highway and related purposes is on balance, about as satisfactory as concrete produced in other states. All do the essential job, but are subject to various difficulties, including shrinkage cracking, slower strength gain than might be desired, and susceptibility to eventual breakdown by weathering, freezing and thawing effects, and chemical attack by various substances.

Use of various chemical admixtures to provide improved concrete properties is widespread in Indiana, but these are not always effective and occasionally result in creating more problems than they solve.

Many of these practical problems encountered with concrete in Indiana highways and related structures are difficult to solve because certain characteristics of concrete as a material are not well understood, especially those relating to the pore structure and microstructure of the hardened cement in the concrete, and to the bonding of interfacial zone that develops to tie the hardened cement to the aggregate. This study was aimed at providing new fundamental understanding of these matters.

Findings

The findings constituted basic research information that was not designed for direct application, but rather as background for problem solving in connection with durability, admixture, and other problems arising in Indiana and elsewhere.

Application

The findings have been (and are being) communicated to experts in the field who are called upon to solve the practical problems that arise. The findings of this project will be utilized by these experts, including those on the staff of JHRP, to permit reductions in the problems with concrete noted above.

Benefits to Indiana

Since the findings are basic information not directly applicable, it is not possible to project a dollar savings figure. However, since highway concrete accounts for a significant share of the expenditure for materials by the ISHC, the tangible benefit of avoiding difficulties with the material is apparent. The findings of this research will help provide for avoiding some of these difficulties.

Publications

1. D. N. Winslow, "The Pore Size Distribution of Portland Cement Paste", Final Report, Phase I, JHRP-68-31, December 1968.
2. D. W. Hadley, "The Nature of the Paste Aggregate Interface", Interim Report, JHRP-72-40, November 1972.
3. B. D. Barnes, "Morphology of the Paste-Aggregate Interface", Volumes I and II, Final Report, JHRP-76-13 and JHRP-76-14, March 1976.

Item #5

"Pavement Blowups of Portland Cement Concrete Beneath Bituminous Overlays" (76)

Indiana Problem

Bumps extending across a concrete pavement are common to all Indiana travelers. A concrete pavement eventually reaches the point where even in the best of circumstances it is no longer sufficiently smooth riding. To upgrade the rideability, a bituminous overlay is frequently applied. This was believed by some experienced highway personnel to aggravate the problem of blowups, hence nullifying the anticipated smooth ride. The objective of this study was to determine if this belief were true and if so the causes of it being true.

Indiana has many interstate highways, as well as others, approaching the age when overlaying is contemplated. If such may aggravate pavement performance, an alternative may be more economically justifiable.

Findings

Overlaid pavements always had a higher degree of saturation than that of a comparable bare pavement. The overlaid pavement did not dry out as much as did bare pavements although they did have a detectable moisture gradient within the overlaid pavement slab thickness.

Overlaid pavements had moisture levels greater than the critical degree of saturation all winter while bare pavements reached their level only in the latter part of the winter.

Measurements of overlaid pavement length indicates a continued small expansion while bare pavements had periods of slight contraction.

Overlaid pavement had a slightly reduced coefficient of thermal expansion.

Complex interactions exist between temperature, moisture and thermal expansion. Coefficient of thermal expansion measurements on "wet" concrete were significantly larger when the temperature was increasing rather than decreasing.

Pavement designs were found to be an important factor in the occurrence of blowups. Overlay thickness appeared to have little effect on blowup occurrence.

Application

The most important finding for application is that moisture is a major contributor to the occurrence of blowups on overlaid pavements. Pavement designs which will reduce the amount of moisture available to a pavement whether new or reconstructed will reduce the potential of blowups. Several suggested means of doing this are noted in the report.

Benefits to Indiana

Benefits of reduced blowups or bumps result from lower maintenance costs, lower user costs due to wear on vehicles, and probably improved safety. The potential saving in maintenance costs would be large.

Publications

1. P. T. Foxworthy, "Statewide Survey of Blowups in Resurfaced Concrete Pavements", Interim Report, JHRP-73-3, February 1973.
2. David L. Gress, "Blowups on Resurfaced Concrete Pavements", Final Report, JHRP-76-25, August 1976.

Item #6

"Development of Techniques for Plant Establishment on the Roadside" (76)

Indiana Problem

Though not unique to Indiana, the establishment of plants on the roadside is a current problem. Seedings on some slopes fail and erosion occurs. Often this requires the reworking of slopes and reseeding which of course is an added expense to the taxpayers of Indiana. Even reseeding does not guarantee success. The actual dollar costs involved are difficult to ascertain since the correction of slope erosion problems is left primarily up to the individual districts in Indiana.

Also, the establishment of landscape plants on landscape sites represents a large dollar investment for the taxpayer. Successful initial establishment and future growth of the plants is essential if the desired effects are to be achieved. In recent years, initial survival has not been a problem, but subsequent growth has not always been satisfactory to achieve the desired landscape results. Every plant failure costs the taxpayer dollars or at least a failure to achieve roadside beautification results that are desired.

Findings

Seeding techniques were developed to permit the stopping of eroding slopes without the necessity of reworking the slope prior to reseeding. Several different nitrogen fixing species were found to be suitable for addition to Indiana's seed mixtures to help improve the chances of success on initial seedings. The use of many highly touted fertilizers for use when establishing trees and shrubs on the roadside did not prove beneficial. Nitrogen fixing trees and shrubs are the best in landscape plantings since they will be more able to develop normally on poor soils.

Application

The findings noted above have been incorporated into ISHC practice or ISHC practice, such as fertilization on plant establishment, was found to be in need of no change.

Benefits to Indiana

Actual dollar value to the taxpayer cannot be estimated since plant loss and failure to develop is an aesthetic value. However, from a public (taxpayer's point of view) healthy landscape plants that are growing are essential for our roadsides if the initial dollars for landscaping are to be wisely spent. Improvements in seeding techniques to minimize reworking of the slope has reduced maintenance costs but the amount is not known. An estimate of several hundred dollars per slope, however, is conservative.

Publications

1. P. L. Carpenter, "An Evaluation of Several Mulch Materials on Landscape Plant Growth, Weed Control, Soil Temperatures, and Soil Moisture", Interim Report, JHRP-75-14, July 1975.
2. Robert E. McNiel, "Factors Influencing Nitrogen Fixation by Several Woody Shrubs and Trees", Interim Report, JHRP-76-6, January 1976.
3. P. L. Carpenter, D. F. Hamilton, R. E. McNiel, and Nancy Levinskas, "Landscape Plant Response to Different Levels of Four 'Slow Release' Fertilizers", Interim Report, JHRP-75-33, December 1976.
4. P. L. Carpenter, David Hensley, Deborah Newbill and Nancy Levinskas, "Evaluation of Several Methods of Establishing Plant Cover by Seeding on the Roadside", Interim Report, JHRP-75-34, December 1976.
5. P. L. Carpenter and David Hensley, "Development of Techniques for Plant Establishment on the Roadside", Final Report, JHRP-75-35, December 1976.

Item #7

"Use of Precast, Prestressed Concrete for Bridge Decks" (75)

Indiana Problem

The repair of concrete bridge decks on many of our highways is an expensive and complex problem. This research project was initiated with laboratory work which provided excellent data and techniques for precast, prestressed bridge deck construction. The design and construction of two full scale bridges followed as part of the study. One was a new bridge and the other a replacement of an existing bridge.

Findings

Each of the two bridges was installed in 1970 and has been in operation now for 7 winters and measurements and data collected have been evaluated and reported to state and national agencies. These bridges in a recent field check were in excellent condition. The method was found to be practical and to produce a durable bridge deck.

Application

The results of this work have led to the use of this method for bridge replacement in several counties in Indiana. In addition this procedure has been adopted and modified and used in various forms throughout the nation. Illinois uses precast plank on all of its prestressed I-Beam bridges as a means of slab support and an integral part of the deck. This system was also used to replace a large bridge in New York across the Manhattan River with construction done at night and open for traffic during the daytime.

Benefits to Indiana

The amount of time and money savings to the state is very large with the use of this method. Where time (because of bridge closing) is an important factor this system is excellent. It can be used to great advantage on county bridges and will save considerable monies. The total benefits will depend on the number of bridges built which employ the scheme developed. The one bridge already built in Allen County using the method was estimated to have been done at about one-half cost of conventional repair schemes - a savings of ten's of thousands of dollars per bridge.

Publications

1. J. H. Ford, "Use of Precast, Prestressed Concrete for Bridge Decks", Interim Report, JHRP-69-20, July 1969.
2. Peter K. Kropp, "Use of Precast, Prestressed Concrete for Bridge Decks", Interim Report, JHRP-73-7, March 1973.
3. Peter K. Kropp, Edward L. Milinski, M. J. Gutzwiller and R. H. Lee, "Use of Precast-Prestressed Concrete for Bridge Decks", Final Report, JHRP-75-15, July 1975.

Item #8

"Cracking in Bituminous Mixtures" (75)

NOTE: This is the original research study noted under Item #3 of Appendix B where the fundamentals found are being applied to the specific Indiana situation. See that item for more details.

Publications

1. D. A. Anderson, "Mechanical Behavior of Asphalt-Mineral Powder and Asphalt-Mineral Interaction", Interim Report, JHRP-71-5, February 1971.
2. R. D. Pavlovich, "Limiting Strain as a Failure Criterion for Bituminous Mixtures", Final Report, JHRP-75-12, June 1975.

Item #9

"Pore Size Distribution and Its Effect on the Behavior of Compacted Clayey Soils" (75)

Indiana Problem

In Indiana as elsewhere considerable variation results from the construction compaction process. Some of this probably is a result of the absence of an adequate measure of soil compaction. This project was basic research to develop a new parameter of compacted soil in terms of the pore size distribution resulting from variations of the soil compaction variables, and of the changes in this parameter arising as a result of exposing compacted soils to soaking under a moderate surcharge, thus partly simulating service conditions.

Findings

The mercury intrusion technique was used to obtain pore size distributions on dried specimens of a number of naturally occurring soils, each compacted at a number of water contents by the Standard Proctor method and/or by 3 levels of compactive effort in the Modified Proctor method. The wet specimens were dried by transforming soil water to water vapor in the critical region without effecting change in the total porosity and probably in the size distribution of pores.

It was shown that different soils compacted to a given percentage compaction, but to different total porosities, on the dry side of Standard Proctor optimum moisture contents have significantly different pore size distributions. On the other hand, these soils compacted at Standard Proctor optimum moisture contents to different total porosities had pore size distributions similar to each other except that the content of pores below 0.1 m varied with the clay fraction, and to some extent the type of soil.

Application

The research findings provide considerable insight into the soil compaction process in terms of pore size distribution. Variations in some soil compaction variables did result in variations in the distribution of pore sizes and several findings indicate means for control of pore size distribution as desirable. Research continues toward solution of the compaction problem at Purdue and elsewhere utilizing these findings.

Benefits to Indiana

As application must await additional research, benefits are not yet possible of estimation.

Publications

1. Syed Ahmed, "Pore Size Distribution and Its Effect on the Behavior of a Compacted Clay", Interim Report, JHRP-71-16, September 1971.
2. R. N. Bhasin, "Pore Size Distribution of Compacted Soils After Critical Region Drying", Final Report, JHRP-75-3, March 1975.

Item #10

"Effect of Retarders on Volume Changes of Portland Cement Concretes" (75)

Indiana Problem

Indiana has specified retarders for use in concrete on bridge decks for over ten years. The question of the effects of retarders, commonly used in Indiana, on volume change properties of concrete was evaluated. Drying shrinkage is often influenced by the use of retarders and can result in undesirable cracks on the resulting concrete deck.

Findings

Sixty-five different chemicals were evaluated, as were three varieties of proprietary retarders (ASTM Type D) for setting times, molecular configuration related to the effectiveness of the retarders, the over dry shrinkage of the paste, non-evaporable water and the specific surface of the paste.

The retarders were found to cause changes in the shrinkage which were paralleled by changes in the specific surface of the paste. These changes were of most significance during early ages.

Concrete specimens were prepared to evaluate the long term drying shrinkage of the proprietary admixtures which had been evaluated as pastes. Long term shrinkage of concrete was not appreciably affected by the admixtures tested.

Plastic drying shrinkage of paste was evaluated from the completion of mixing until approximately initial set. The proprietary admixtures were used in this investigation. Retarding admixtures were found to increase plastic shrinkage. The amount varied with the variety of admixture and an interaction was found between admixture variety and drying condition (humidity).

Application

Information gained shows a number of materials can safely be used as retarders. The specific surface determination on hardened paste and the results of plastic shrinkage of pastes both indicate the desirability of good curing during the early ages of a concrete, i.e. up to 40% hydration. Most recommended construction practices, if carried out, will assure such curing. Hence retarders may be used in concrete construction without fear of excessive shrinkage problems. Attention to good curing practices, however, is desirable. The continued use by ISHC of those retarders which were shown not to provide shrinkage problems was encouraged by the findings.

Benefits to Indiana

As the major use of the findings of the study was to confirm a use already being used by ISHC, no economic benefits can be claimed. The assurance, however, that what was being used was correct may well have served to stabilize continued use of retarders and eliminate changes in use because of the absence of knowledge of the influence of retarders on shrinkage.

Publications

1. Yasuhiko Yamamoto, "Retarders for Concrete, and Their Effects on Setting Time and Shrinkage", Interim Report, JHRP-72-51, December 1972.
2. W. L. Dolch and C. F. Scholer, "The Influence of Retarding Admixtures on the Drying Shrinkage of Concrete", Interim Report, JHRP-74-13, August 1974.
3. C. F. Scholer, "Effect of Retarders on Volume Changes in Portland Cement Concrete, Final Summary Report, JHRP-75-21, October 1975.

Item #11

"Soil Stabilization for Erosion Control"

Indiana Problem

Rainfall-induced soil erosion from construction sites bare of cover and to a lesser extent from highway cuts and embankments occur in Indiana, although not as severe as in some states because of the generally flat topography. The direct costs of removing the eroded material and regrading are minor, but the environmental problems that can ensue, particularly in local areas where significant amounts of bare construction sites combine with hilly topography, can be severe. Downstream water pollution by sediment runoff is a major nuisance to municipal and other water supply sources, to lake and stream recreation groups, and to other agencies and individuals. This project was aimed at determining whether this nuisance can be averted by inexpensive treatment of exposed soils with lime or portland cement, and whether such stabilization could be combined with or partly replace normal highway slope vegetative and mulch treatment.

Findings

Lab erosion tests and auxiliary studies indicated that incorporation of a few percent of lime or of portland cement and reasonable compaction would render most Indiana soils erosion resistant even in severe rainstorms.

Application

A field study to check out how this works in practice has been established on a new section of Indiana 43 near Crawfordsville, and is currently being monitored.

Benefits to Indiana

Not possible to estimate at this stage, but probably minor in financial terms. Considerable possible return in terms of cleaner operations, and especially in good will from citizens and municipalities that otherwise would have been subjected to water quality degradation.

Publications

1. Sidney Diamond and Mitsunori Kawamura, "Soil Stabilization for Erosion Control", Interim Report, JHRP-74-12, August 1974.
2. George Macha, "Stabilization of Soils for Erosion Control on Construction Sites", Interim Report, JHRP-75-5, March 1975.
3. S. Diamond, "Methods of Soil Stabilization for Erosion Control on Construction Sites", Final Report, JHRP-75-20, October 1975.

APPENDIX D

JOINT HIGHWAY RESEARCH PROJECT
ACTIVE RESEARCH PROJECTS
FUNDED BY INDIANA STATE HIGHWAY COMMISSION AND
FEDERAL HIGHWAY ADMINISTRATION

January 1978

<u>Item No.</u>	<u>HPR Project Title</u>
1	"Treatment of Sanitary Wastes at Interstate Rest Areas"
2	"Bridge Vibration Studies"
3	"Superior Bluegrasses for Roadside Turf"
4	"Performance of Pipe Culverts Buried in Soil"
5	"Design and Construction Guidelines for Shale Embankments"
6	"Improving Embankment Design and Performance"
7	"Expansive (Self-Stressing) Cements in Reinforced Concrete"
8	"Analysis of Hardened Concrete for Admixture Content"
9	"Maintenance Methods for CRC Pavements"
10	"Improvement of Non-Durable Aggregates in PC Concrete"
11	"The Effects of Pore Size Distribution on Permeability and Frost Susceptibility of Selected Sub-Grade Materials"
12	"Thin, Applied Surfacing for Improving Skid Resistance of Concrete Pavements"
13	"An Investigation of Recycling Bituminous Pavements"
14	"Study of the Segmental Box Girder Bridge at Turkey Run"
15	"Evaluation of Design and Control Alternatives to Improve Safety of Intersections of Multi-Lane Highways with Minor Highways"
16	"Development of a System for the Evaluation of Pavements in Indiana"
17	"Chemical Mowing: A New Maintenance Concept for Indiana Roadsides"
18	"Fabric Reinforced Soil Mats for Embankments"

Item #1

"Treatment of Sanitary Wastes at Interstate Rest Areas"

Indiana Problem

The problem of supplying water for treating the wastewater from rest stops on the interstate highway system as well as other locations has been a continual problem for many years. Rest stops have to be located in many cases where water is available rather than where they most properly should be placed. In all situations, they must be located near a stream or a municipality where a treated effluent or the raw wastewater can be discharged. In the near future, with the ever increasing stringency of state and federal pollution laws, the quality of the effluent discharged from current systems will not be adequate and will require expenditures of as much as 1/4 to 1/2 million dollars to upgrade each existing rest stop or this much additional expense on the construction of a new one. The type of facility being developed by this project can be used on a once through basis and through a simple system be able to produce an effluent capable of meeting all known future standards for discharge to receiving waters. Another type of facility being researched is one in which the treated effluent is recycled for toilet flushing and by so doing makes it possible to have a self contained system with no treated discharge at all.

An experimental system employing the recycle technique and another using the once through procedure have been constructed as field installations and are being evaluated. Several difficulties have been encountered during the early part of the research as might have been expected when one goes from a laboratory to a full scale system for the first time.

Anticipated Benefits to Indiana

If one considers the potential of these systems in light of the existing and future rest stops needed, many millions of dollars in construction costs and operating labor may be saved for the taxpayers of the state.

Publications to December 1977

1. J. E. Etzel, D. W. Hawkins, K. M. Cho, "Treatment of Sanitary Wastes at Interstate Rest Areas", Interim Report, JHRP-72-26, September 1972.
2. J. E. Etzel, A. J. Steffen, D. W. Hawkins, John Heckler, "Compilation and Evaluation of Performance and Cost Data of Existing Waste Disposal Systems in Use at Rest Stop Areas in Indiana", Interim Report, JHRP-72-27, September 1972.

Item #2

"Bridge Vibration Studies"*

Indiana Problem

Bridge traffic vibrations which are annoying to pedestrians and to bridge maintenance workers have been experienced on many of Indiana's bridges. Present design specifications do not directly control the bridge characteristics which can cause the annoying responses. Some economic advantages of using high-strength materials are lost due to the requirements of the present specifications.

The findings of this project will be used to develop suggested revisions for ISHC bridge design specifications which will attack the bridge vibration problem more directly.

Anticipated Benefits to Indiana

Cost savings will result by using appreciably smaller bridge girders with relatively little increase in objectionable vibrations as bridge response can be more directly tailored to the situation requirements. Cost savings of perhaps 3-5% may be realized for the affected bridges.

Publications to December 1977

1. Trakool Aramraks, "Highway Bridge Vibration Studies", Interim Report, JHRP-75-2, February 1975.
2. J. F. Lipkey, F. C. Chuck, "The Selection of Bridges, Field Testing Procedures, Equipment and Field Measurement for Bridge Vibration Study", Interim Report, ISHC Research and Training Center, January 1975.
3. P. K. Kropp, "Experimental Study of the Dynamic Response of Highway Bridges", Interim Report, JHRP-77-5, March 1977.
4. Ali Shahabadi, "Bridge Vibration Studies", Interim Report, JHRP-77-17, September 1977.

*This research was conducted as a joint project with the ISHC Research and Training Center.

Item #3

"Superior Bluegrasses for Roadside Turf"

Indiana Problem

The roadsides of the state utilize grass as the primary growth material. Maintenance of these roadsides is heavily dependent on mowing requirements, weed infestation, and erosion. Current available grasses for roadside use tend to be tall growing requiring extensive mowing and slow developing allowing weed infestation and erosion. The purpose of this research was to develop a grass which would provide a dense stand rapidly and have lower height characteristics. Such a grass, largely developed under a previous project, was further evaluated in this research and large roadside experimental sites are being established. The first demonstration plot of about 10 acres of this new bluegrass, Wabash, has been established near Rockville on U.S. 41 by ISHC. Expansion of seed is also in progress in the Northwest United States and a patent application is in process.

Anticipated Benefits to Indiana

A vigorous grass will renew itself after the necessary resurfacing and/or re-edging of roads. A reduction in infestations of annual grassy weeds would also be apparent and reduction in erosion or filling of drains will be of value equal to the cost of repair. Mowings may be reduced. The estimated cost savings may be substantial if the new grass Wabash is found to be better in aggressive characteristics than existing turf.

Publications to December 1977

W. H. Daniel and H. L. Michael, "Superior Bluegrasses for Roadside Turf", Interim Report, JHRP-77-3, January 1977.

Item #4

"Performance of Pipe Culverts Buried in Soil"

Indiana Problem

Indiana, as other states spends a lot of money each year on culverts. Little, however, is known about how to most economically design a culvert which will have a predictable life.

One objective of the research program is to develop a procedure for rational design of buried culverts; i.e. to establish realistic performance criteria and to develop procedures to predict reliably whether a proposed design and construction procedure meets these criteria. Phase I involved developing the analytical prediction procedure. It has been essentially completed.

Phase II of the Study is primarily concerned with evaluation of the developed analytical procedures through controlled experiments on a large model culvert. This Phase is in progress.

Anticipated Benefits to Indiana

Considerable cost savings as a result of improved design practices are anticipated. The amount cannot yet be estimated with accuracy.

Publications to December 1977

1. M. B. Roy and G. A. Leonards, "Predicting Performance of Pipe Culverts Buried in Soil", Interim Report, JHRP-76-15, May 1976.
2. M. B. Roy, "FINLIN User Manual", Interim Report, JHRP-76-16, May 1976.

Item #5

"Design and Construction Guidelines for Shale Embankments"

Indiana Problem

Several embankment failures occurred on I-74 near St. Leon, Indiana in the early 1970's. Among the contributing causes for these failures was the lack of a system for properly testing and classifying shales as regards to their long term behavior in embankments. As a result of these slides the east bound lanes of I-74 had to be closed for a period of time which resulted in much inconvenience on this busy stretch of pavement between Indianapolis and Cincinnati, Ohio. In addition the repair of each of these failures required the expenditure of several million dollars.

The purposes of this research are to investigate the various aspects of Indiana shale behavior relative to embankment construction problems, develop a classification system for Indiana shales, and develop a storage and retrieval system for Indiana shale data. The Project is being performed in close cooperation with ISHC Bureau of Materials and Tests and findings are being put into practice as developed.

Anticipated Benefits to Indiana

The savings must be examined in a negative sense. The early use of a proven testing procedure and classification system could hopefully have prevented the embankment failures on I-74. The money spent in correctional procedures, which was considerable, could have been spent in other ways. These types of failures due to the improper use of shale should be eliminated in the future as a result of this research.

Publications to December 1977

1. David R. Chapman, "Shale Classification Tests and Systems: A Comparative Study", Interim Report, JHRP-75-11, June 1975.
2. Michael J. Bailey, "Shale Degradation and Other Parameters Related to the Construction of Compacted Embankments", Interim Report, JHRP-76-23, August, 1976.
3. Dirk J. A. van Zyl, "Storage, Retrieval and Statistical Analysis of Indiana Shale Data", Interim Report, JHRP-77-11, July 1977.
4. R. R. Abeyesekera, "Stress-Deformation and Strength Characteristics of a Compacted Shale", Interim Report, JHRP-77-24, December 1977.

Item #6

"Improving Embankment Design and Performance"

Indiana Problem

Erosion of highway embankments is a frequent problem and results in much maintenance work. The cause of such failures is the present inability to determine in-service soil behavior of compacted embankments and subgrades - both leading to higher cost designs. The objective of the research is to reduce costs of future construction and rehabilitation. The study objectives include placing closer controls on compaction specifications. This should reduce some of the poor performance now caused by variability in compaction results.

Anticipated Benefits to Indiana

As the anticipated results will result in the development of more scientific specifications and better control of compaction variability, funds will be saved through less failures of embankments and subgrades. Maintenance costs will be lessened.

Publications to December 1977

1. John L. Peterson, "Improving Embankment Design and Performance: Prediction of As-Compacted Field Strength by Laboratory Simulation", Interim Report, JHRP-75-22, December 1975.
2. Martin F. Essigman, Jr., "An Examination of the Variability Resulting from Soil Compaction", Interim Report, JHRP-76-28, October 1976.
3. James C. Scott, "Examination of the Variability of the Soaked Strength of a Laboratory Compacted Clay", Interim Report, JHRP-77-8, May 1977.

Item #7

"Expansive (Self-Stressing) Cements in Reinforced Concrete"

Indiana Problem

The cost of building bridges is high. As many bridges constructed currently are concrete because that type is the most economical, this study is looking for possible cost savings in concrete bridge construction. The purpose of the study is to obtain a better understanding of the behavior of self-stressing reinforced concrete structures. A second objective is to determine the economic savings possible with the effective use of expansive cement under practical construction conditions.

Anticipated Benefits to Indiana

Initial work on the study indicates that expansive cements are not recommended for implementation for highway uses at the present time. It might be of economic benefit for some columns or piles; however the performance, physically speaking is inferior to conventional concrete and additional research is required before even these uses could be recommended.

Publications to December 1977

Hanume Gowda, "Expansive (Self-Stressing) Cements in Reinforced Concrete", Interim Report, JHRP-76-24, August 1976.

Item #8

"Analysis of Hardened Concrete for Admixture Content"

Indiana Problem

The use of organic admixtures as water-reducing, set-retarding and air-entraining agents in Portland Cement concrete has become common in the cement and concrete-making industry. Concrete that has proved unsatisfactory in Indiana or elsewhere, either from a strength or durability point of view, is frequently questioned as to whether it had added to it the amount of admixture called for in the specifications. The number and variety of marketed admixtures is large and combinations of these admixtures in the concrete coupled with the fact that sometimes the same compound can be used as both a grinding aid and an admixture, complicates any analysis of the concrete for the presence of these substances.

Present methods of analyzing hardened concrete for these components leave much to be desired. The methods are tedious, relatively inaccurate, and in some cases depend upon considerable intuitive insight and experience lacking in most analysts who may be called upon to perform the tests. New, and better techniques are needed for the accurate determination of the most common admixtures that may be present in hardened concrete.

Anticipated Benefits to Indiana

Some failures in concrete are due to failure of the concrete contractor to include the proper amount of adequate admixtures as required by specifications in the delivered concrete. This is not easy of detection during construction but is some times the claim after failure begins. The ability to test for the admixture after the concrete is hardened could assist in placing the fault where it belongs (and possibly collecting damages) and certainly would make more certain that the specified admixtures have been properly added. Savings could be substantial.

Item #9

"Maintenance Methods for CRC Pavements"

Indiana Problem

Indiana constructed a large mileage of continuously reinforced concrete pavements during the 1960's, and because of the poor performance of some of these pavements, it has been necessary to evaluate various methods for maintaining the system that exists at the present time. Costs of repairing these pavements are considerable. The primary method of repairing the pavement, as of the start of this study, was to use concrete patches which cost in excess of \$100 per square yard as compared to an original cost of about \$10 per square yard. As an average figure one typical patch of this type costs about \$1500.

To evaluate various methods of maintaining these pavements, a test pavement was constructed using various maintenance methods on I-65 south of Indianapolis. The purpose was to determine the most economical method for maintaining this type of pavement.

Anticipated Benefits to Indiana

Early results indicate several techniques to be effective and several to be ineffective. Final conclusions as to the most economical technique have not yet been obtained but it is clear more cost effective methods than concrete patches alone will be identified. Preliminary results indicate recommended methods will be about one-half of that for the currently used technique. This means a savings of about \$15,000 per mile of CRC pavements where considerable failure occurs.

Publications to December 1977

Robert H. Florence, "Design and Construction of Several Maintenance Techniques for Continuously Reinforced Concrete Pavements", Interim Report, JHRP-76-12, March 1976.

Item #10

"Improvement of Non-Durable Aggregates in PC Concrete"

Indiana Problem

The Indiana problem attacked is that of D-cracking and deterioration of Indiana pavements due to the action of frost on concrete containing non-durable aggregates. While not unique to Indiana, this is a problem that afflicts a comparatively small number of states, and it is certainly important to Indiana, since many of our pavements are presently experiencing this difficulty. Its pavements are presently experiencing this difficulty. Its costs, in terms of repair of deteriorating pavements and early resurfacing of them, is millions of dollars per year.

The cause of the difficulty is coarse aggregate that becomes critically saturated with water and that causes cracking when the water freezes. The aggregates that cause this lack of durability are generally porous and absorptive, with a consequent relatively low specific gravity, and with a comparatively small pore size. They are usually detected by the standard tests - absorption, soundness, and confined freezing and thawing. But in some instances they are not, and examples are known that produce failure in pavements in spite of "acceptable" performance in the standard tests.

Regardless of the reliability of test methods, the prospect is for the increased need to use aggregates of questionable quality with respect to freeze-thaw durability. Supplies of good aggregates are running short, especially in heavily populated regions where the demand is greatest. If aggregates of poor or marginal performance could be economically treated so as to improve their durability and make them usable, the result would be of great advantage to the concrete and construction industry and to the society in general.

The purpose of the Study is to evaluate ways of improving poor quality coarse aggregates so that they are not as susceptible to deterioration from freeze-thaw conditions.

Anticipated Benefits to Indiana

Cost savings resulting from less concrete pavement deterioration and from improving the supply of quality local aggregates could be substantial. The former would decrease the cost of maintenance by extending pavement life. The latter would decrease the cost of construction by permitting use of less costly local materials.

Item #11

"The Effects of Pore Size Distribution on Permeability and Frost Susceptibility of Selected Sub-Grade Materials"

Indiana Problem

Water has a large influence on the performance of pavement systems. This influence has caused extensive study of its effects, as well as extensive measures for its control in the field. Yet today one continues to see additional pavement performance problems in which the role of water could well be significant. The mechanisms that control the flow and retention of water in a pavement system lack proper understanding due to the handicaps inherent in the present prediction techniques that are based on grain-size data. Such handicaps in present techniques are to be expected because a soil of a given grain-size distribution can exhibit a wide range of behavior depending upon its natural or placed density and soil fabric.

Anticipated Benefits to Indiana

The results of this study could improve the pavement designer's capabilities for predicting permeability, i.e. drainability of pavement systems and allow a selection of gradations and placement conditions to yield specific levels of drainability.

The savings to the Indiana taxpayer will involve primarily a reduction in long range maintenance costs. Some saving in initial construction costs might be possible through the better understanding of the interrelationship of soil moisture, compactive effort and a desired soil fabric.

Publications to December 1977

M. A. Reed, "Frost Heaving Rate of Silty Soils as a Function of Pore Size Distribution", Interim Report, JHRP-77-15, September 1977.

Item #12

"Thin, Applied Surfacing for Improving Skid Resistance of Concrete Pavements"

Indiana Problem

Concrete pavements in Indiana become less skid resistant due to the wearing away of the textured surface created during construction. In addition many aggregates economical for use in Indiana pavements polish under traffic. The result is a dangerous, slippery pavement.

The most common correction is to apply a thin wearing surface of asphalt and aggregate. In some instances this may not be desirable and in others, especially with the increase in petroleum costs, it may not be the most economical. Grinding the surface will help for a period of time, but it is expensive and actually removes a portion of the pavement hence diminishes the structural capacity.

This project is investigating the potential of applying a very thin coating of a "mortar" to the surface of a slippery concrete pavement. By so doing a small amount of very select material, having exceptional resistance to skidding may be used. Indiana aggregates are being investigated for their capability of providing the desired skid resistance. Materials which look promising include slag and lightweight aggregate, both products of Indiana.

Anticipated Benefits to Indiana

Future benefits are a reduction in skid related accidents and a method of economically achieving the desired non-skid pavement surface. These will be considerable. Actual resurfacing costs, however, will probably not be reduced but the existence of a competitive alternative could result in smaller increases in resurfacing costs of other methods.

Item #13

"An Investigation of Recycling Bituminous Pavements"

Indiana Problem

Bituminous pavements need resurfacing every 10-15 years. If not resurfaced periodically they need reconstruction about every 20-25 years. As many Indiana roads have not been adequately maintained, they will need to be reconstructed. If the materials in the pavement could be reused (recycled) the costs of reconstruction would be reduced as less aggregate, less asphalt and less fuel for transporting these materials to the site and their processing before shipping would be required and an excellent pavement would be provided.

Anticipated Benefits to Indiana

The estimated savings in reconstruction costs through recycling bituminous pavements is about 20-25% of current new construction costs. This savings of \$40,000-\$50,000 per mile for the hundreds of miles which would be saved each year would provide for increasing the annual mileage maintained. Even greater savings by providing for life extension of more pavements through timely resurfacing would result.

Item #14

"Study of the Segmental Box Girder Bridge at Turkey Run"

NOTE: This is the continuation under federal funding of the research discussed in Item #4 of Appendix A. See that item for more details.

Item #15

"Evaluation of Design and Control Alternatives to Improve Safety of Intersections of Multi-Lane Highways with Other Highways"

Indiana Problem

This project was initiated at the specific request of the traffic engineering division of the Indiana State Highway Commission. The purpose of the project is to investigate the safety aspects of the intersections of multi-lane highways and other roadways. The high accident occurrence at such intersections is a serious operational problem. Furthermore, as accidents at these intersections are often serious because of the high speeds on the multi-lane highways, the result is a significant number of deaths, injuries and property damages.

The traffic division of the ISHC has indicated that it has experimented with many different control techniques - signing, marking, signalizing - but it has not been possible to find a combination which appears to improve the situation. This research is examining the problem in a detailed manner. The findings of the study are to include the cost effectiveness of each of the possible counter-measures that might be undertaken to improve safety.

Anticipated Benefits to Indiana

Implementation of the study findings will undoubtedly reduce the number of accidents at such intersections. The magnitude of the potential saving to the Indiana taxpayers can be estimated from the following example. At one of the study intersections (US 31 and National Road in Indianapolis) there were 50 accidents for the year 1975. On the basis of the average accident cost of \$2433 per accident in Indiana, an approximate saving to the motorists can be expected to be about \$50,000 for only this intersection if accidents are reduced by only 40%.

Publications to December 1977

P. A. Van Maren, "Correlation of Design and Control Characteristics with Accidents at Rural Multi-Lane Highway Intersections in Indiana", Interim Report, JHRP-77-22, December 1977.

Item #16

"Development of a System for the Evaluation of Pavements in Indiana"

Indiana Problem

Many hundreds of miles of State Highway System of Indiana is in need of repair and maintenance expenditures are expected to increase over the next several years. Indiana does not have a system for structural evaluation of these pavements to permit setting priorities of maintenance on a rational basis.

The purpose of this research project is to provide to the Indiana State Highway Commission a system for evaluating pavements and to permit them to establish better priorities for maintenance.

Anticipated Benefits to Indiana

The results of the research project should enable the Indiana State Highway Commission to establish priorities of maintenance on a rational basis. This will permit efficient usage of the monies available for maintaining the existing highway system and result in savings in maintenance costs through extended life of many pavements.

*This research was conducted as a joint project with the ISHC Research and Training Center.

Item #17

"Chemical Mowing: A New Maintenance Concept for Indiana Roadsides"

Indiana Problem

Mechanical mowing of roadsides is presently the most costly feature of roadside maintenance in Indiana. According to recent figures supplied by Kenneth Mellinger and Marion Bugh, Indiana State Highway Commission, there are still 26,000 acres/mowing cycle in the contract mowing program with an additional 40,000 acres/mowing cycle in force account mowing by State crews. This gives a total of nearly 66,000 acres mowed per cycle state wide in Indiana. With an approximate cost of \$10.00 per acre per cycle, mowing costs can be estimated to lie between \$1,000,000 and \$2,000,000 annually even with reduced mowing.

To further reduce mechanical mowing is impractical or impossible due to the requirement to maintain adequate sight distances and highway safety. To achieve further cost savings, the obvious step is chemical mowing--use of a chemical retardant to slow growth of grass--in combination with the Fall-Spring Spraying Rotation of Chemical Weed and Brush Control and either 1-cycle mowing or complete elimination of mechanical mowing for most areas.

This project is to conduct research to design a low-cost chemical mowing program for Indiana Roadsides. The treatment must be inexpensive, effective, long-lasting, environmentally safe, and, except for retardation of growth, not injurious to turf.

Anticipated Benefits to Indiana

Once and if chemical mowing is realized, additional cost savings are projected to be as much as \$1,000,000 annually.

Item #18

"Fabric Reinforced Soil Mats for Embankments"

Indiana Problem

There are problems associated with constructing highway embankments on soft foundation soils and over localized weak zones in Indiana. The particular geologic history of the state (glaciation and limestone bedrock) as well as some activities of man (e.g. strip mining for coal) have resulted in some rather difficult localized support problems for highway embankments. Conventional solutions exist of course, and they have been applied in these areas, but they are very expensive, and sometimes they do not always produce satisfactory results. Another increasingly serious concern to ISHC soils engineers is the problem of upgrading existing highways constructed on poor foundations, especially when the roadway must be widened. Simply building a wider embankment with a new pavement often cannot be accomplished without excessive settlements and separation, faulting, or even the destruction of the new pavement along the joint between the old and new construction.

Anticipated Benefits to Indiana

Many of the noted problems have the potential of being solved with substantial cost savings by the current research work. The research project is concerned with the application of a very new idea in highway engineering. Consequently, very little data is available as to cost savings, since only a few of the techniques investigated utilizing fabric reinforcing have actually been tried, and then only in very few places worldwide. In those few cases, direct cost comparisons are not possible because the ground conditions, highway construction methods, etc., are not similar.

Annual cost savings in Indiana upon implementation of the research would depend on the construction (or reconstruction) program during the year and on the particular foundation and geologic conditions encountered at the construction sites. In some years, if particularly difficult foundation conditions were met even at only a few sites, the cost savings could be tremendous.

Application of a related earth reinforcing technique at a 1200 ft. long embankment constructed over limestone sinkholes in Pennsylvania was estimated by PENNDOT engineers to have saved \$500,000 (out of a total project cost of about \$5,000,000) over the conventional alternative of a reinforced concrete bridge-slab support system. Had fabrics been used instead of the significantly more expensive steel reinforcing elements, the cost savings would probably have been even greater.

APPENDIX E

JOINT HIGHWAY RESEARCH PROJECT
OTHER RESEARCH PROJECTS
COMPLETED AND ACTIVE
FUNDED BY INDIANA STATE HIGHWAY COMMISSION AND OTHERS

PLANNING PROJECTS
Funded by ISHC Planning Funds with Cooperation of
The Federal Highway Administration

<u>Item No.</u>	<u>Project Title</u>	<u>Status</u>
1	"Analysis of Travel Data for the Greater Lafayette Transportation Study"	Compl. 77
2	"Major Aspects of the Urban Transportation Planning Process"	Compl. 75
3	"Speed Trends for Indiana Highways"	Act. 78
4	"A Computerized Information Storage and Retrieval System for Soils in Indiana"	Act. 78

OTHER RESEARCH
Financed by ISHC with Joint Funding by
Administrative Building Council of Indiana

<u>Item No.</u>	<u>Project Title</u>	<u>Status</u>
5	"The Seismicity of Indiana and Its Relationship to Civil Engineering Structures"	Act. 78

Item #1

"Analysis of Travel Data for the Greater Lafayette Transportation Study" (77)

Indiana Problem

The Greater Lafayette, Indiana, Area Transportation and Development Study was originally initiated by the Tippecanoe County Area Plan Commission with the cooperation of the Indiana State Highway Commission and the Federal Highway Administration. The Study was conducted in accordance with an Operations Procedure Manual, a detailed work program for the study prepared by a consultant dated 1968. Progress was such that a First Incremental Work Program as contracted with the Tippecanoe County Area Plan Commission by the Indiana State Highway Commission was completed about September 1, 1971. This First Incremental Work Program primarily consisted of collection of data.

The Tippecanoe County Area Plan Commission informed the Indiana State Highway Commission and the Federal Highway Administration in 1972 of its inability to handle effectively certain personnel and financial problems of the Study. The Plan Commission continued to perform those aspects of the Study for which it was financially responsible, as noted in the Operations Procedure Manual, but it decided not to perform some aspects of the Study which were to be funded by the Indiana State Highway Commission but which by initial agreement were to be performed by the Area Plan Commission.

During discussions of these matters with the Greater Lafayette Highway Technical Committee, the suggestion was made that the Joint Highway Research Project, Purdue University be utilized to conduct the activities which the Area Plan Commission found it could not perform. Following several discussions of the status of the Study, the Division of Planning, Indiana State Highway Commission, proposed in a letter dated August 17, 1971, that the Joint Highway Research Project perform certain jobs and activities of the Greater Lafayette Area Transportation and Development Study.

A proposed Plan of Study to perform the desired analyses was prepared by the JHRP and approved for initiation by JHRP on January 1, 1972.

The objective of the work performed by the Joint Highway Research Project on the Greater Lafayette Area Transportation and Development Study was to conduct certain work items as listed in the Plan of Study. The jobs and activities to be performed were as defined in the Operations Procedure Manual for the Lafayette Study and consisted primarily of the analysis of the previously collected travel data and the preparation of planning models.

Findings

The travel data collected by the Area Plan Commission were analyzed and the necessary models successfully prepared.

Application

The data analysis resulted in numerous findings relative to improvement of existing streets to reduce accidents and improve flow. Many of these have been initiated by the cities of Lafayette and West Lafayette. The travel models have been utilized in preparing the transportation plans for the Lafayette SMSA area.

Benefits to Indiana

The transportation plan required by federal rules before transportation improvements can use federal funds in the Lafayette SMSA is the direct result of the data analyses and model building performed by JHRP in this Study. It is estimated the necessary work was completed with better reliability, even though many data errors existed, and at less cost than could have been done by other means.

Publications

1. E. C. Sword, Bernard O'Connor, and Harold L. Michael, "Greater Lafayette Transportation and Development Study Expansion, Adjustment and Adequacy Evaluations of Trip Data", Interim Report, June 1977.
2. P. E. Corsetti, H. L. Michael, and K. C. Sinha, "Traffic Characteristics and Immediate Traffic Engineering Improvements for the Urbanized Area of Greater Lafayette, Indiana - Parts I and II", Interim Report, August 1976.
3. J. W. Myers, "A Study of the Central Traffic District of Lafayette, Indiana Focussing on Immediate Traffic Engineering Improvements - Parts I and II", Interim Report, January 1974.
4. D. A. Hattery, K. C. Sinha, and H. L. Michael, "Calibration of Traffic Forecasting Models - Part I Trip Generation", Interim Report, February 1977.
5. S. A. Kambol, E. C. Sword, K. C. Sinha, and H. L. Michael, "Calibration of Traffic Forecasting Models - Part II Base Year Traffic Assignment", Interim Report, April 1977.
6. S. A. Kambol, and K. C. Sinha, "Calibration of Traffic Forecasting Models - Part III Trip Distribution and Total Model Testing", Interim Report, June 1977.

Item #2

"Major Aspects of the Urban Transportation Planning Process" (75)

Indiana Problem

The state of Indiana was charged with initiating the Urban Transportation Planning Process in all larger cities of Indiana (over 50,000 population). This long-term research, begun in 1966, was to assist in solving problems for Indiana conditions which were being encountered. The research dealt with several parts of the Urban Transportation Planning Process as follows:

- Part I - Study Organization and Design
- Part II - Trip Distribution
- Part III - Traffic Assignment
- Part IV - Trip Generation
- Part V - Simplified Procedure for Small Urban Areas

The purpose of research in each of the several parts was to develop procedures through which the Process could be improved as to accuracy, reliability, cost and time required.

Findings

Many findings and recommendations relative to improvements which should be considered in the Process were included in the many Reports produced. The publications listed at the end of this summary contain these many results. They are simply too voluminous to include here.

Application

A manual of study organization and design produced by Part I of the Study was distributed to each urban community involved in an Urban Transportation Planning Process in Indiana. The use of work trips as a satisfactory basis for distribution of total trips was shown by research of Part II to be acceptable and this approach has become a typical way of doing transportation studies in small urban areas and to update transportation plans. The research on trip assignment and generation proposed new techniques or measures which have been further considered in more recent research elsewhere. The research on development of a simplified thoroughfare planning procedure for small urban areas also complemented much work done elsewhere and the total has resulted in development of new acceptable procedures which are less costly, more rapid and of reasonable reliability.

Benefits to Indiana

The results of this long-term research provided educational benefits to Technical Committees in each SMSA in Indiana and provided input to new procedures which improved the planning process all over the nation. The greater reliability, lesser time and reduced costs of such planning have been of considerable benefit to Indiana through better planning in the state.

Publications

1. Hassan Ayad, "System Evaluation by the Simplified Proportional Assignment Technique", Interim Report, JHRP-67-13, June 1967.
2. G. A. Shunk, "The Journey to Work: A Singular Basis for Travel Pattern Surveys", Interim Report, JHRP-67-29, November 1967.
3. R. J. Hensen and W. L. Grecco, "An Information Manual on the Urban Transportation Planning Process for Technical Committees in Smaller Urban Areas", Interim Report, JHRP-68-19, September 1968.
4. D. K. French, "A Simplified Procedure for Major Thoroughfare Planning in Small Urban Areas", Interim Report, JHRP-68-29, October 1968.
5. Tammam Nakkash, "Activity-Accessibility Models of Trip Generation", Interim Report, JHRP-69-10, May 1969.
6. W. L. Grecco, "Interim Summary Report - Major Aspects of the Urban Transportation Planning Process", Interim Report, JHRP-69-14, May 1969.
7. R. J. Hensen and W. L. Grecco, "Evaluation of the Effectiveness of Transportation Planning in the Smaller Urban Areas", Interim Report, JHRP-70-2, February 1970.
8. A. D. Jones, "A Simplified Procedure for Major Thoroughfare Planning in Small Urban Areas", Interim Report, JHRP-72-18, July 1972.
9. A. D. Jones, "Study Design for Columbus, Indiana, Major Thoroughfare and Plan Development Study", Interim Report, JHRP-72-19, July 1972.
10. A. D. Jones, "Major Thoroughfare Study and 1990 Plan for Columbus, Indiana", Interim Report, JHRP-72-20, July 1972.
11. A. D. Jones and W. L. Grecco, "Procedure Manual for Determining Traffic Patterns for a Simplified Procedure for Major Thoroughfare Planning in Small Urban Areas", Interim Report, JHRP-72-21, July 1972.
12. W. K. Law, "Comparative Travel Patterns from Four Work Trip Data Sources", Final Report, JHRP-75-23, December 1975.

Item #3

"Speed Trends for Indiana Highways"

Indiana Problem

For many years the Joint Highway Research Project at Purdue University has performed for the ISHC and FHWA an annual speed study of free flowing traffic on Indiana State Highways. Twelve stations have been established where speeds were monitored annually during the summer months. Four of these are on inter-state highways, four on 4-lane divided state highways and four on 2-lane major state highways.

The imposition of the 55 mph speed limit has reversed the trend of recent years for increasing average maximum speeds. Interest in the future trends of speed indicates the desirability of more frequent speed studies. Evaluation of the obedience of drivers to the 55 mph maximum speed limit as outlined in the DOT Procedural Guide for Speed Monitoring also requires the development of a comprehensive program of speed monitoring. A plan of 70 measurement periods at 49 locations in Indiana for free-flowing traffic speeds was initiated in 1975 and is continuing.

Findings

The trend in speed and in percentage of drivers violating the 55 mph maximum speed limit are determined on the several classes of highway for each quarter and annually.

Application

The Governor of Indiana uses the annual report of the speed studies as one of the required documents for the annual certification that Indiana is abiding by the 55 mph limit.

Benefits to Indiana

Federal regulations relative to the 55 mph speed limit are followed and the possible penalty of loss of some federal aid funds for highways has not been assessed. Benefits to citizens from better observance of the limit and the resulting lower number of accidents and decreased fuel consumption also accrue.

Publications

A "Traffic Speed Report" is issued each quarter of each year.

Item #4

"A Computerized Information Storage and Retrieval System for the Soils in Indiana"

Indiana Problem

The ISHC has accumulated much engineering soil data over the years as investigations for highway and bridge construction are made. The data, however, has been poorly organized and hence inefficient for use on later nearby projects. The purpose of this research is to develop a computer information storage system for approximately 8,000 soil borings that ISHC has purchased in the last 20 years. These data were difficult to locate and correlate with new design problems in the same area. Computer storage and retrieval will make the data more accessible for use by design engineers.

Anticipated Benefits to Indiana

Data tapes are being placed in operation by ISHC as developed in this Study. A computer model for their storage and retrieval has been prepared and also placed on the ISHC computer. The ISHC highway personnel will now be able to use the existing data in planning and interpreting past subsurface investigations for new construction in nearby areas. South Dakota estimates an annual savings to its highway department of \$40,000 from a similar project.

Item #5

"The Seismicity of Indiana and Its Relationship to Civil Engineering Structures"

Indiana Problem

Indiana structures are not exempt from earthquake effects. Although the California earthquake of February 9, 1971 received much publicity, it was not a unique event, for more than 100 earthquakes of similar or greater intensity annually occur in the world. The reports of Study Panels of the National Research Council of the National Academy of Sciences emphasize that damage similar to that in California can occur in many other locations in the U.S., including Indiana. This research will identify potential earthquake damage in Indiana and recommend preventive measures for structures.

Anticipated Benefits to Indiana

The results of this study would supplement the seismic design provisions of the Uniform Building Code in the state of Indiana, as well as ISHC specifications for highway structures. Earthquakes do occur in Indiana, especially in the southwest corner of the state. Provisions which can be included for new structures to minimize earthquake damage could result in very great benefits for the state.

COVER DESIGN BY ALDO GIORGINI