The Pay-Off in Highway Research

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INTRODUCTION

This is an era of research and development. The methods used in engineering and the entire industrial and agrarian mechanism are constantly being improved through the development of new materials, new ideas, new procedures, and new and better ways of doing things Industry methodically budgets large sums for research and development, variously estimated from 3 to 10 percent of the total operational budget.

In the field of transportation, the railroads, the aircraft industries, the trucks and bus lines, the automobile manufacturers, and many related industries spend huge sums on research. This is the result of the ever increasing demand for more efficient high-powered engines which can be operated at low cost, lighter and more comfortable riding vehicles which can be constructed at low cost, and the development and incorporation of greater safety features in all types of vehicles.

This same pattern has not always been followed in the development of the highway transportation system. The automobile, the truck, the bus, and other types of motor-propelled vehicles were developed before the existence of a road system adequate to carry these vehicles. Through the years of the development of the road systems, the vehicle, in general, has continued in a more advanced stage of design than has the road system.

In the early days of road-building, there was little time for research and development, nor was this considered extremely vital. Those pavements which we had the know-how of constructing were built and placed into service immediately. The design features incorporated in them were the result of very limited engineering observation and experience. Research and development have come gradually into the highway picture, noteworthy developments being made by many state highway departments and universities, by the Bureau of Public Roads, by many of the highway materials groups, and by the National Safety Council and others interested in the use of the highway.

The state highway commission of Indiana has been progressive in its attitude toward research and development. Even so, the Joint Highway Research Project budget for the period 1937-1949 amounted to less than ¼ of 1 percent of the total state highway budget, and at the present time this budget is only about ½ of 1 percent of that budget.

It is a well-known fact that the financial conditions of the state highway commission, of the counties, and of the cities are far from satisfactory. Ever-increasing mileages of primary and secondary roads and streets are being added to the systems of the state without proportionate increase in revenue. Adding to the difficulty is the lowered purchasing value of the present-day dollar. The fact that the revenue for roadwork in Indiana for various road systems today is only a little greater than 20 years ago, requires not only the best in engineering, in planning, and in road use, but also in research and development. For only by the latter can better materials, better specifications, better highways in general, and the best in road use be had.

The highway research organization located here at Purdue University has had more than a dozen years of highway research background. It is appropriate that periodic statements of progress be given at the Purdue Road School (1, 2, 3). By this means the engineering and administrative personnel charged with the responsibility of developing the road and city street systems within the state of Indiana have an opportunity to evaluate the research findings.

It is also appropriate to ask the questions: (1) "What has highway research produced for the benefit of the counties, the cities, and the state highway commission of Indiana?"; (2) of what benefit has this research work been to the state through educational programs at Purdue University? It is the purpose of this paper to describe the organizational procedures of the Joint Highway Research Project and to discuss the various aspects of these two questions.

THE RESEARCH ORGANIZATION

The Joint Highway Research Project of the Purdue Engineering Experiment Station was established in 1936 as a result of special efforts by members of the state highway commission of Indiana. The first major research project was a study of the causes of the numerous failures which occurred that year, particularly on secondary roads. During the first year the commission budgeted $25,000 for carrying on the activities of the project. On March 11, 1937, an act of the state legislature made it possible for the commission to expend from its funds

a sum not to exceed $50,000 annually for research at Purdue. In 1949 the legislature revised the 1937 act, raising the permissive amount which the commission may allocate to the university to a maximum of $150,000 a year. Currently, the research organization is operating on a $100,000 a year budget. The 1937 act provides, in addition, that a portion of these funds may be used for holding the annual Purdue Road School, for the dissemination of information, and for highway extension.

At the present time, the research organization is divided into seven departments, namely, Soils, Concrete and Concrete Pavements, Bituminous Materials and Bituminous Pavements, Airphoto Interpretation, Chemical, Traffic, and Economics and Administration. Each department head administers the graduate work in his area, teaches graduate course, and supervises research programs. Currently, there are 15 full-time men on the research staff, and half-time graduate research assistants number from 15 to 30 per year. Twenty to fifty undergraduates are employed on a part-time basis to assist in the research programs in the various laboratories. If the research worker also teaches classes, either graduate or undergraduate, the proper portion of his salary is paid from teaching funds.

Coordination of the research work between the commission and the university is achieved through the use of an advisory board composed of five department heads of the commission and five members of the staff of the School of Civil Engineering and Engineering Mechanics. The board functions to outline policy relating to the research activities, to recommend the establishment of research projects, to consider reports on research projects, to recommend release of research data as they mature, and to recommend to the commission and the university the quarterly allocation of funds for research. The commission representatives on the board, through their intimate knowledge of the program and the results, are in an excellent position to see that research is directed toward their most pressing problems, and to put newly acquired knowledge to use in design and maintenance.

WHAT BENEFITS MAY HIGHWAY DEPARTMENTS EXPECT FROM HIGHWAY RESEARCH?

The answer to this question in regard to what benefits may be expected from highway research is concise and direct. The highway department representing the counties, the cities, and the state of Indiana can reasonably expect the development of information which can be used in the planning, design, construction, operation, and maintenance

of the various road systems in producing more permanent, safer, and more economical roads. Secondly, the programs of highway research should contribute to the educational background of undergraduate students, graduate students, and engineers so that these men in turn can contribute still more to the highway industry, in general, than would have been possible otherwise. Finally, it is reasonable to expect that the results of research, at least the mature findings, shall be disseminated through such facilities as the Purdue Road School, technical journals, and periodic reports to the commission.

In short, the highway industry of the state should expect returns on its investment through (1) research findings which have monetary value, (2) research findings with academic value, (3) the release of men who have had graduate work and advanced training in highway research, and (4) published reports which summarize the more important findings.

The results obtained from several of the research studies which have been undertaken by the Joint Highway Research Project are important examples of the monetary value of highway research. To be highlighted among these are the extensive examinations of the causes of failures in flexible pavements, the design studies of expansion joints, the materials investigations of aggregates, the work on pavement failures caused by excessive loads, the extensive work on subgrade soils as these soils have contributed to failures, and finally, the development of techniques for identifying soils with aerial photographs, and the use of these photographs for making drainage maps.

In the spring of 1943 more than 800 miles of bituminous surfaces—located mostly on secondary roads—were destroyed, either in part or almost completely. Assuming that the cost to recondition these roads to bring them up equal to their original condition before the spring breakup was from $2,500 to $5,000 a mile, the total cost to the state for this one spring breakup was between $2 and $5 million. Detailed field work directed to determine the causes of these failures indicated that serious spring breakups can be predicted on the basis of heavy fall and winter precipitation followed by weather predominated by temperatures below freezing (4). This condition points to the possibility of posting some highways during certain spring seasons to keep all heavy loads off these pavements until the subgrade-base-surface has regained adequate structural capacity. Such research has also developed information on the overall thickness requirements for different types of roads constructed on various classes of subgrade soils.

In the early days of the Joint Highway Research Project, work was done on bituminous-surface treatments (5), the adhesion of bituminous

films to aggregates (6), the characteristics of rock asphalts (7), and the degradation of aggregates under road rollers (8). Collectively, these studies have developed information useful in obtaining proper design of bituminous-aggregate mixtures for specific road use, and in developing data on thickness requirements of bases and bituminous surfaces. In the last two or three years, two additional important studies have been completed covering the use of local sands and sandstones for low-cost bituminous surfaces and for base-course construction for primary roads (9, 10). At the present time, research programs are being developed to improve and further implement flexible pavement design.

Another important project is in the field of concrete pavement design. In 1943 engineers of the state highway commission requested the Joint Highway Research Project to conduct a study to determine the merits of expansion joints in rigid pavements. Extensive field surveys made during the period 1942-1944 showed that blow-ups in rigid pavements was directly related to the source of coarse aggregate employed rather than to the joints (11). Since expansion joints were required originally as a device to provide space for expansion, it is obvious that, if control over the aggregates used in the concrete can be obtained, such joints are not needed. The findings of this project have made it possible for the commission to eliminate the use of expansion joints in rigid pavements and thus to improve performance. It has been estimated that the saving in this one change in design practice alone is amounting to $100,000 to $200,000 a year, or an amount equal to double the present highway research budget.* In addition, the public is provided with a smoother riding surface and a pavement which is less susceptible to faulting and pumping, thereby decreasing the potential maintenance costs.

The monetary value of certain research findings is further illustrated by the work which has been underway for many years on the determination of those physical and chemical properties of aggregates which produce excessive expansion in portland cement concrete pavements. In 1945 the project staff released a report entitled "Pavement Blowups Correlated with Source of Coarse Aggregate" (11) which showed that blowups not only could be correlated with the source of coarse aggregate employed but also that this type of failure could be

* Based on an estimated cost of contraction joint of $.70 per foot, a cost of expansion joint of $.80 per foot, a change in design from a 20-foot spacing of contraction joints with a 120-foot spacing of expansion joints, to a 40-foot spacing of contraction joints with no expansion joints, and an estimated 100 miles of new construction per year.

correlated with map-cracking and short life of concrete pavement. Extensive laboratory work has been conducted during the past five years under request of the state highway commission of Indiana to develop specifications which can be used in eliminating inferior materials (12, 13, 14, 15). Such a specification has been developed (16, 17).

In table 2, page 162, of the 1945 report (11), 284.32 miles are listed with "significantly bad performance" records and an additional 86.72 are listed with "bad performance" records. If the life of these 370 miles of pavements alone was diminished one-third by the use of inferior materials which met commonly employed acceptance specification requirements—and this assumption is conservative—it can be seen that this study is directed toward a problem which has already cost the state between $5 and $10 million, or at the rate of $150,000 to $350,000 a year. It is important to note that this estimate does not include those projects with inferior performance which had already been retired. Work has also been directed toward the development of procedures for the use of inferior materials when better materials are not economically available.

Again, as a result of requests made by engineers of the commission, the staff of the research laboratories has been engaged in studying pavement damage as related to the intensity of loads. Several reports have been published on this study (18, 19, 20). In the 1943 report, 243.4 miles were listed as showing pumping in various degrees (18). The 1947 report (20) showed the state highway system with almost 500 miles of pavements damaged in seven years through pumping action caused by heavy concentrations of loads—many of which were overloads. Assuming that the life of these pavements has been shortened 25 to 50 percent, this one problem alone has cost the State Highway Commission of Indiana between $7½ and $15 million in rigid pavement destruction in the seven-year period from 1940 through 1946—at a rate of from $1 to $2 million per year! No attempts have been made to estimate the extensive damage done by overloads to flexible pavements (4).

Research has not only pointed up the problem of pumping and loads, but it has also developed procedures for correcting the action (21, 22). In addition, data have been collected which are being used to design roads which will withstand even illegal loads (23, 24, 25). It is important to note that presently-used designs and those which have been used by the commission since about 1945 for rigid pavements on the primary system, although more costly than pre-war design, are adequate structurally to withstand present conditions of loadings in Indiana.

In all the field studies and in many of the laboratory studies, the problem of subgrade soils has been brought into the picture (26, 27, 28, 29, 30, 31). One of the early reports of the project (32) dealt with the characteristics of the major soil areas of the state and provided the highway industry with information applicable to the overall problems of design and location of materials of construction. Work continues on soil stabilization for low-cost roads and for bases for flexible and rigid pavements on the primary system.

The work on airphoto interpretation procedures has been reported before this group on many occasions (33, 34), and the first paper on this program is the latest in such a series of reports. The exact value of this type of research is difficult to determine, and the same may be said concerning drainage maps (35, 36). However, if these maps can be used to eliminate even one bridge failure through the proper use of drainage information, it is apparent that the savings will cover the entire cost of the airphoto research program. The drainage maps are used for a variety of purposes other than for highways. Some of the agencies showing considerable interest in these maps include the Flood Control Commission, State Board of Health, Conservation Department, most of the county surveyors and county engineers throughout the state, city engineers, many of the railroad companies, and many federal agencies.

In traffic engineering, many studies have been completed (37, 38, 39, 40, 41, 42), and it is anticipated that in the years to come this area of research will be developed further. During the past few months a Department of Economics and Administration has been added to the organization, and it is expected that studies in this field will be of much use to the counties, the cities, and to the commission.

Summarizing the monetary benefits of highway research, it is apparent that any one of several completed studies is already paying dividends equal to the entire yearly cost of the annual highway research program. It is likewise apparent that the surface has only been scratched, and there is every reason to believe that the dividends will be much greater in the years to come than in the past. The paper on flexible pavements presented as this session represents research in which data have been accumulated for many years—in time, important results are certain to occur.

HOW DOES THE STATE BENEFIT FROM HIGHWAY RESEARCH THROUGH EDUCATIONAL PROGRAMS

The basic purpose of any university is to train and educate young people for productive living. Research activities are a vital aid to the attainment of a good student program, particularly in the graduate field. Instructional programs are vitalized and stimulated by the presence of worthy research projects accompanied by funds adequate for their substantial development.

Teachers, associated with research activity have opportunity to develop instructional initiative and keenness far beyond that which ordinarily results from purely academic endeavor. The researcher is constantly aware of the imperfections of existing ways of doing things, and thus is under minimum hazard of falling into the familiar rut of routine. Abundant contact with professional societies and leading commercial organizations is a further byproduct of research activity. Universities all over the world have found that the practical balance afforded to theory by research is of tremendous benefit and advantage.

Universities are financed for instruction at the bacheler's degree level, but they are not able, in general, to subsidize graduate work. Since most students are likewise not equipped to finance an educational program at the master's or doctorate level, the use of research funds for thesis projects makes possible the development of graduate programs. Research can be performed at very reasonable cost and at the same time the student can receive much needed financial assistance.

As graduate students receive their advanced degrees and leave the university, their activities—be they good or bad—will reflect ultimately on the overall reputation of the state and university. It is appropriate, therefore, to consider the current status of former students who have received financial assistance and research training through the facilities of the Joint Highway Research Project.

By February, 1950, a total of 69 men had received M.S. or Ph.D. degrees while working under either a part-time or full-time status on research with the project. In addition, 15 men are now working on advanced degrees. Of these 69 men who have received advanced degrees, 32 are now employed in universities, including Cornell, Florida, Oklahoma, Notre Dame, Wayne, North Carolina State College, University of Iowa, Kentucky, Illinois, Virginia, Wyoming, California, Virginia Military Institute, and Purdue.

Fourteen of these 69 men are employees of state highway departments or of city or county governmental units, in West Virginia, Ken-

tucky, Virginia, New Jersey, New York, Toronto (Canada), Jamaica (West Indies), Cincinnati, Arlington County, Va., and the Hawaiian Islands.

Eight are in private engineering practice or are employees of engineering firms doing work related to highway engineering. Seven are employed in departments of the federal government. These include the navy, the Corps of Engineers, the Bureau of Reclamation, and the U. S. Geological Survey. Of the remaining eight, three are pursuing additional graduate work at other institutions, three are foreign students, and two are doing work not related to highway engineering.

DISSEMINATION OF INFORMATION

The dissemination of research data is an important function of any research organization. The facilities of the Purdue Road School have been used for many years for the release of many research reports. During the past 10 years, 52 papers have been made available through this medium alone (43).

Various members of the staff have been active in the work of national research committees of such organizations as the Highway Research Board, the American Concrete Institute, the Association of Asphalt Paving Technologists, the American Society for Testing Materials, and the American Society of Civil Engineers. As a result of these activities, new ideas are brought to the university, and new procedures for solving old problems are frequently found. Likewise, many of the research papers are released at the annual meetings of such organizations, being then published in proceedings. The Proceedings of the Highway Research Board contain a total of 30 papers authored by representatives of the project staff. The figure for A.S.T.M. is 5; for A.C.I., 2; for A.A.P.T., 4; for A.S.C.E., 2. Papers have received special awards and one member of the staff has received the Distinguished Service Award from the Highway Research Board.

Members of the staff also contribute papers for road schools throughout the United States (28, 44, 45, 46), to such organizations as the International Conference on Soil Mechanics (50), and many others.

OUTSIDE CONTRACTS

As a result of the work done in the field of highway research, many organizations have brought their problems to the university for solution. The Engineering Experiment Station has assigned a large number of research contracts to members of the staff who are also members of the Joint Highway Research Project. Included is work for such organi-

zations as the Civil Aeronautics Administration (47, 48), the Calcium Chloride Association, the Corps of Engineers—particularly in connection with the permafrost investigation—(49), the Owens Corning Fiberglas Corporation, the Association of American Railroads, and the National Lime Association. The total amount of these contracts is approximately $300,000. These outside funds not only increase the research budget, but also the results of the studies generally supplement the work being done in the field of highway research.

SUMMARY

In summary, 14 years of highway research experience indicate that both the state highway commission of Indiana and the state at large are receiving important dividends on their investments to date. Included are important data which have direct monetary value, vital academic research which has long-range economic significance, and the assistance given to young engineers through the use of research funds, to obtain a well-balanced education and research training—of great eventual benefit to the highway industry in general and the state of Indiana in particular.

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