ever, in most states, where funds are not nearly sufficient to do needed and desired work, the decision is not easy. Unless one has gone through the experience, it is hard to realize the pressure that is placed upon an administrator from various groups who sincerely believe that the projects they desire are more important than any others. These organized groups are of various types. We have the chamber of commerce groups, rural mail carriers, farmers, school authorities, politicians, church congregations, salesmen of equipment and materials, and various other types of promoters. In a highway administrator's office a number of these groups pay visits every day urging the surveying and construction of projects in which they are interested.

I do not want to be misunderstood and decry the need of a long-term plan, because that is certainly necessary to get anywhere toward perfecting a modern highway system, but I do want to show that there are other factors that sometimes have to be considered in the picture. Highway administration calls for the utmost diplomacy, and its problems presented every day are numerous and varied.

JOINT HIGHWAY-RESEARCH PROJECT BETWEEN INDIANA STATE HIGHWAY COMMISSION AND PURDUE UNIVERSITY

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The Joint Highway-Research Project between the Indiana State Highway Commission and Purdue University is authorized by an Act of the Legislature with an appropriation of $50,000.00 a year for highway research and highway extension, beginning July 1, 1937. The purpose of this act is to assist Purdue University and several counties of the state in developing different methods of construction and maintaining the highways of the state and the respective counties. The provision for highway extension includes the Annual Road School under operation today at Purdue University. The act also provides that the county and state highway officials, in co-operation with Purdue University, may hold joint road meetings in the various sections of the state.

The activity of Professor Petty in highway extension during the summer of 1937 included visits to fifteen counties of the state. Twenty-seven public educational meetings were held, attended by over 1,000 individuals. Over 1,500 miles of highway were inspected in company with county highway officials who are helped in their duties by such unbiased counsel. The more skillful and economical maintenance of county roads will be one result of such conferences.

The atmosphere of a university is friendly to the studious nature of research. Here the special preparations of experts in the several fields of chemistry, physics, and engineering are available to shed light on the research problems of highway design and maintenance.

It is probably not necessary to stress the importance of a careful and systematic research into the materials and construction of our highways and the operation thereof. Large industrial enterprises have devoted 2½% to 4% of their budgets to scientific examination of this nature. A statement that the state of Indiana is spending in the neighborhood of $20,000,000.00 for highway construction and maintenance each year (including counties, nearer $30,000,000.00) will justify the expenditure of the amount provided for research by the Legislature.

ORGANIZATION

Early in 1937 a limited staff was employed and equipment purchased, to be installed in the generous amount of laboratory and office space provided by the University.

The organization of the co-operative work at the University enjoys the counsel of an Advisory Committee comprising three representatives of the Highway Commission, Messrs. Keefe, Bookwalter, and Feldman, and three representatives of the University, Professors Petty, Hatt, and Crepps. This Advisory Committee assists in planning a limited program in the wide field of research. It holds monthly meetings. The operative staff includes the Director and staff researchers.

This project is placed in the Engineering Experiment Station of the University. Reports go to the Director of the Station, Dean Potter, and through him, to the President and the Board of Trustees. Reports, also, are made to the Indiana State Highway Commission. The expenditures under the budget, which is fixed by the Advisory Committee, are in exact accordance with the procedure in the office of the Controller of the University.

After July 1, 1937, work proceeded on two portions of our program: *first,* studies directed to the problems of immediate importance to the Highway Commission, and *second,* those directed to the development of underlying fundamental relations between materials and their services in road construction and maintenance, a more deliberate progress. Results of the investigations will be published when released by the Advisory Committee.

PROJECTS OF IMMEDIATE USEFULNESS

To speak briefly of the work of immediate usefulness, in 1936 over 3,000 miles of surface treatments were inspected, and over 200 samples from these surface treatments were

collected for laboratory analysis. These samples were brought to the laboratory and photographed, their thickness was measured, and the surface was separated from the base. The bitumen was extracted, its percentage was computed, and gradation was run on the aggregate. This gradation was in no case the same as the original supplied during construction, but was much finer because of degradation. The surface area of the aggregrate was computed for each sample, and an attempt was made to correlate this surface area with the percentage of bitumen.

While no definite relations were established, it was found that those samples which contained a smaller amount of bitumen had ravelled more, and that a wide variation existed in the grading of the aggregate and the percentage of bitumen. The percentage of bitumen in these samples varied from 3 to 12 per cent, while the surface area of the aggregate varied from 1,000 to 7,000 sq. cm. per 100 grams.

Studies were also made of the 100 miles of roads surface treated under contract in 1936, and a condition survey was made of these roads early in 1937. This survey showed that there is a definite relation between the time of construction, weather conditions, and service behavior of these surface treatments. In general, those surface treatments completed earlier in the season, during favorable weather conditions, and those having a higher bitumen content were better able to resist ravelling. Increased ravelling accompanied construction during the late fall when weather conditions were unfavorable. Thus, it is indicated that the percentage of bitumen and weather conditions at time of construction affect the quality of the surface.

During the 1937 working season, advantage was taken of contracts for surface treatments on roads, with approximately the same traffic and exposure, in which two classes of aggregates were used and two varieties of bitumen. The original sampling of the surface was followed by subsequent sampling in November. These roads will be resampled after extended service to find out just what happens to the materials under exposure to traffic and climate. One condition was evident, namely, that the action of the roller and traffic brought about a marked breaking down of the aggregate, and thus an accumulation of fines. The so-called surface area of the aggregate had increased as much as five times. These fines, when embedded in bitumen, serve to seal the surface better. The effect of these findings on the design of the materials and mixtures is a matter for consideration by the Highway Commission.

STRIPPING OF BITUMEN

Similarly, an investigation has been under way to find out why some bitumens strip from the aggregate during exposure

and some do not. The laboratory test is performed by shaking, during one-half hour, coated aggregates in jars containing distilled water.

Fundamental laws of these relations are under development. The report of findings is being formulated. However, the tests are sufficiently advanced to permit the following indications. According to the information now at hand, here and elsewhere, the mineralogical character of the aggregates is of primary importance. Aggregates, such as quartz, for instance, which is silicious and of an acid nature, attract water in preference to bitumen and will strip in the case of some classes of bitumens. Matters under investigation include smooth vs. rough surfaces, the amount of bitumen necessary for complete coating, relative adhesion and cohesion. Possibilities of improvement of aggregates to prevent stripping have suggested themselves.

Furthermore, the moisture condition of the aggregate at the time of coating as it affects the adhesion of bitumen is important—that is, whether it is completely dry, or saturated, or saturated and then allowed to surface dry.

TECHNIQUE OF TESTS

The field of the technique of testing of bitumens by standard physical tests, and the relation of such data to the serviceability in roads exposed to climate and traffic, is of importance. The nature of the elements entering into what is called asphalt are matters receiving close study by the highway commissions of the United States and the industries. The Joint Highway-Research Project is contributing in this field.

The recent approach to the concerted attack on the technique of research into bitumens on the part of engineers of tests is instanced by the two papers presented before the recent meeting of the Highway Research Board in Washington, namely, by Lang of the Highway Commission of Minnesota, who examined asphalts by a combination of simple chemical, physical, and mechanical tests, and by Benson of Missouri, who watched, by transmitted light, the changes that went on in thin bituminous films under several agencies.

It has occurred to many of us who are not bitumen chemists that it might be possible to analyze an asphalt into its agreed upon, if conventional, constituents, and then determine which of these were found to be most important in resisting the effects of exposure in service, and so to write specifications for the purpose of limiting unfavorable constituents. This process has been in operation in one inorganic material, Portland cement, as, for example, by limiting the chemical element that was attended with liberation of excess heat upon hydration. However, this process would be much more difficult in the case of an organic compound.

One study of immediate interest is on rock asphalt, in particular to determine, among other things, what period of so-called curing, when necessary, should be specified to prepare this material for construction.

These examples will indicate some of the investigations now under way and directed to the accumulation of information of immediate usefulness to the Highway Commission, which, it is hoped, will improve the service of our roads and reduce the cost of maintenance.

FUNDAMENTAL STUDIES

Research into fundamental relations, a slow process, usually results in basic explanation of phenomena which are now not well understood. Clarity of view leads to correct principles and a definition of the underlying relations between the forces of nature and the behavior of materials in service.

One of such fundamental studies is in the field of clay soils, directed especially to the behavior of clay subgrades under climatic conditions, and to the improvement of these clay subgrades by admixtures to the end that they may be stabilized against variations of moisture. At Purdue, this study has taken two directions: *first,* the construction, about two miles northwest of the University, of a length of highway as an outdoor experiment upon a difficult clay subgrade, and *second,* laboratory tests on the materials used in the road.

The road is of standard section, twenty feet wide with shoulders and ditches. Upon the clay subgrade has been placed six inches of natural clay or modified clay. One half of the width is exposed to the weather and the other half, treated like the first half, is covered with six inches of gravel.

As it was not possible to use a road mix, the clay, whether natural or modified, was run through a concrete mixer (with partial success) and tamped into place by hand. In the length of the road, there are sixteen different sections, each twenty feet long. The admixtures include three classes of bitumens, several chemicals ordinarily used for the improvement or stabilization of soils, and portland cement.

Throughout the fall, winter, spring, and summer, the changing elevations of these modified clays will be observed along with change of moisture conditions and stability against the penetration of a Proctor needle. Just now, the effect of treating the clay is shown by lessening "frost-heaving."

In other words, this test road will determine the effect of climate alone without the complications which result when it is expected to solve two problems in one operation, as, for instance, the effect of climate and also the effect of traffic.

Later on, it is expected to eliminate some of these sections, if they turn out to be of no advantage, and then to build a longer test road which will be subjected to traffic.

In the second direction, accompanying this outdoor exposure, will be the standard laboratory tests on these same materials after they have been subjected to freezing and thawing, wetting and drying. Such laboratory work will, when compared to the outdoor experiment, tell us whether or not it is necessary to go through the actual construction of a test road in order to find out what may otherwise be predicted by the more simple and better controlled laboratory tests.

One attempt is to find stabilization with portland cement and also waterproofing with an additional admixture of bitumen, such as emulsified asphalt.

One outcome of this experiment might well be the choice of material for shoulders, or for bicycle paths. There has been some insistence on the part of planners that the highway is a transportation path for general traffic as well as for autos on the pavement. It is true, as Upham said, that the early engineers who located and designed highways carried over principles from the railroad field, and the foot passenger was left out of the design.

It is also expected that our laboratory research will investigate the effects of exposure on bitumens. Thin films of these bitumens will be exposed, for example, to ultra-violet light, which now seems to be the criterion of resistance of these bitumens.

Another useful field of investigation is a study of the testing process itself. At the present time, we have a number of tests for so-called stability, each one directed to find out the same property, as, for instance, the Hubbard-Field stability test, the ball test, the compression test, the Mini-track test, and the resistance of the materials to the forces which are generated either by the expansion of water into ice in freezing and thawing tests or the action of crystallization of materials like sodium sulphate. If it can be determined that one of these, the more simple test, will tell us what we want to know, there will be a great economy in laboratory operations.

In conclusion, I wish to express my appreciation of the helpful relations with, and cordial co-operation of, the Highway Commission and the Advisory Board. I desire to mention also the chairman of the former Highway Commission, Mr. James D. Adams, under whose responsibility this project was initiated.

DEVELOPING NON-SKID ROAD SURFACES

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During the past five years, tests have been conducted by the Iowa Engineering Experiment Station under the writer's