

**THE VALUE OF THE WORK OF THE BUREAU OF PUBLIC ROADS
TO THE CIVIL ENGINEERING PROFESSION**

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Under several names and with a gradually evolving sphere of activity, the Bureau of Public Roads has had a continuous existence as a branch of the United States Department of Agriculture since 1893.

It was created in that year by the Secretary of Agriculture to carry out an act of Congress that directed the Secretary "to make inquiries in regard to the systems of road management throughout the United States, to make investigations in regard to the best methods of roadmaking, to prepare publications on this subject suitable for distribution and to * * * * assist the agricultural colleges and experiment stations in disseminating information on this subject * * *".

From the date of its creation until 1912 the Bureau's functions were those of investigation and education only. In that year it was charged with administration of the construction of the Federal post roads for which provision was made in the amount of \$500,000 by the Post Office Appropriation Act for the fiscal year 1913; and the administrative experience thus acquired, together with its long contact with the development of the movement for road improvement led to its designation as the Federal agency

to cooperate with the highway departments of the States when, in 1916, the principle of Federal aid for road building was inaugurated. The work then begun has continued and grown in importance and volume; and now constitutes the largest of the Bureau's activities.

Thus, historically, the Bureau of Public Roads was first an agency of investigation, then an administrative agency. But it has not permitted the multiplication of administrative duties to stifle the spirit of investigation with which it has been imbued from the beginning; and it is significant of its attitude toward research that at its insistence the section of the law making provision for the cost of administering the Federal-aid road work, also provides for necessary highway research.

Though the change in the Bureau's duties has somewhat altered the motive of its researches, it has not essentially changed their character. It does not now and never has looked upon itself as an agency of research in pure science. All of its investigations, tests, and studies have had a practical object - if not immediately in view, at least not far removed. The central object, underlying all of its researches is the devising of ways by which highway transportation may be made more efficient, and that is true whether the study in hand be the testing of concrete or the solution of a problem of finance. The aspects of physical and economic phenomena investigated are studied by no other government agency, and the Bureau studiously avoids any work which can be more advantageously done by

such other agencies. Always the application to the road and to highway transport is the thing that holds the Bureau's interest.

While, in consequence of its deliberate concentration upon objects of interest to the highway engineer and transportation specialist, the results of its investigations are of special interest to a particular branch of the civil engineering profession, there are naturally ramifications and by-products of its work which touch upon the interests of those engaged in other fields. These are sufficiently numerous and useful to justify the suggestion that members of all branches of the profession may find it worth their while to acquire a general familiarity with the Bureau's resources of information and data, some of the more important items of which are briefly catalogued in this paper.

Physical Data

Subgrade soil studies.- Perhaps the most generally useful of the physical researches is that which deals with the properties of soils in relation to their suitability as subgrades and foundations for road surfaces and structures. In this field the Bureau has endeavored with considerable success to supplant the inadequate and uncertain empirical data of common knowledge with facts, rationally and experimentally developed, bearing upon the behavior and mechanical properties of soils and soil constituents. On the basis of the facts thus developed it has already proposed

a general classification of soils with respect to their efficiency as subgrade and foundation materials, and by further researches it is providing the means of closer definition. It has developed laboratory and field tests which permit of a fairly accurate identification of different soils; and has made some progress in the development of methods for improving unsatisfactory soil materials.

The results of this work already obtained constitute a body of factual material previously unavailable and highly valuable to all branches of the engineering profession having to deal with the design of structures of all sorts resting on the soil.

Distribution of pressure through earth fills and earth pressures on culvert pipe.- Similarly useful are the results of studies of the distribution of pressure through earth fills resulting from the application of concentrated loads at the surface, and the pressure of earth on culvert pipes laid under various conditions. In the latter studies the Bureau has cooperated with Dean Warston of the Iowa State College and with Dean Braune of the University of North Carolina, and a large body of usable data has been obtained under the immediate direction of these two authorities.

The study of the distribution of pressure through earth fills not only resulted in the determination of the governing laws, but also, as a by-product, the development of a pneumatic pressure cell, known as the Goldbeck Soil Pressure Cell which, when embedded

in an earth mass and connected by tubing to the external recording gage, is capable of measuring the static pressure applied to it with an accuracy of a tenth of a pound per square inch. This apparatus has also been used by the Bureau to measure pressures back of retaining walls, and by others in various other ways, notably by the Miami Conservancy District to determine the progress of solidification of puddled cores in earth dams as a control of the rate of construction.

Motor truck impact investigations.- For more than ten years we have been engaged in a study of the intensity of impacts delivered to road surfaces by motor trucks and other vehicles. This work has resulted in a mass of conclusive data with regard to the intensity of such impacts in relation to the weight of the sprung and unsprung loads, the effects of spring stiffness, wheel design, speed of vehicles, and road roughness, the relative cushioning properties of solid, pneumatic, and cushion tires, and to a certain extent the effect upon road surfaces. A large part of the work has been done in cooperation with the Society of Automotive Engineers and the Rubber Manufacturers' Association. Aside from the direct value of the measurements in their particular application to motor vehicle and highway and bridge design, the measuring apparatus designed, developed, and calibrated for the work, and the knowledge of the possibilities and limitations of such apparatus acquired in the course of the investigation, is of pronounced

value to anyone concerned with problems of investigation involving impact of any kind. Of particular value in the section is the study of various types of accelerometers completed with the cooperation of the Bureau of Standard

Of the instruments and apparatus employed in this four were developed for this special purpose by engineers Bureau. These are, (1) a practical machine for applying blows of varying intensity, (2) an instrument for the measurement of impact forces by the deformation of small cylinders calibrated under static load, (3) a space-time device for the graphical measurement of deceleration of and (4) a coil spring accelerometer, useful for the same

Studies of cement concrete.- Numerous studies of properties of cement concrete conducted by the Bureau have developed data of special interest to road builders; but these data are so fundamental in character as to have equal interest for all engineers. Among the items of information this character are measurements of the expansion and contraction of concrete when subject to temperature and moisture changes; determinations of the effect of alternate freezing and thawing during and subsequent to the setting period; determination of effect of time of mixing in full-size paving mixers on the strength and uniformity of the product; the effect of alkali salt and water on concrete with which they come in contact; a

of protecting the concrete against alkali attack by bituminous paint coats.

Among the most useful of the Bureau's studies of this character are those dealing with the effect of the kind and proportion of coarse aggregate upon the strength and density of the resulting concrete. These investigations, not yet entirely completed, give promise of supplying, when fully analysed, new knowledge of the effects of these concrete factors comparable in importance to the discovery of the effects of the water-cement ratio.

Another interesting group of investigations of the same general class, is that which includes several studies of the various methods of concrete curing, the latest of which has recently been completed in cooperation with the Tennessee Department of Highways.

Practically all curing methods thus far proposed were tested in this investigation, which was carried out on a section of Tennessee highway 15 miles in length. One-half of the pavement, throughout the entire length of the road, was cured with wet earth, and the character and behavior of the concrete thus treated has been taken as the standard of comparison by which the relative effects of other curing methods used on the other half of the pavement have been determined. The several bituminous curing methods, surface applications and admixtures of calcium chloride, sodium silicate applications, ponding, wet burlap and sisalkraft coverage, and

tar paper laid on the subgrade are all included among the methods tested. The criteria of strength and frequency of cracking have both been employed in determining their relative effects; and the report to be published in just a few days will provide some of the most illuminating data yet disclosed with regard to this question which is of interest to all who have to deal with concrete in any of its various uses.

To mention just one more of the Bureau's studies of concrete which may have application outside of the special field of our interest, I would refer you to the tests of the abrasive resistance of concrete slabs, composed of various types of coarse aggregate and mixed in several proportions, completed several years ago. The weighted rubber-tired wheels, to repeated passages of which the slabs were first subjected, and the subsequent application of the same wheels equipped with steel non-skid chains were chosen as the wearing agent because of their special appropriateness for a test of pavement concrete; but the relative wear of the various kinds of concrete under any other abrasive action would probably not differ greatly from the values determined by these tests.

Studies pertaining to the design of concrete pavement and bridge slabs.- As the result of 15 years of continuous effort to rationalize the design of concrete road slabs, the Bureau has experimentally evaluated practically every factor involved except the important one of subgrade support; and the light that has

appeared in the subgrade investigations in recent months, has encouraged the strong belief that a practical solution of this last important problem is not far off.

As matters now stand, our experiments have yielded all necessary data with reference to the contraction, expansion, and warping of the slab under various conditions of temperature and moisture. Differences of temperature between the top and bottom of the slab, occurring daily and seasonally have been accurately measured and reasonable design limits determined. The coefficients of friction between the slab and various subgrades have been determined with all necessary accuracy. The distribution of pressure to the subgrade from loads applied at various points on the pavement has been measured quite adequately by soil pressure cells. The related effects upon pavement stresses of joint spacing, subgrade friction, and kind and position of steel reinforcing have been fully explored. And, finally, the distribution of stress induced in the slab by applications of both static loads and impact forces has been studied to a definite conclusion, qualified only by the as yet undetermined influence of subgrade variation.

All these factors have been determined experimentally and the experimental results have been found to accord remarkably with the results of mathematical analysis.

A similar and even more perfect accord exists between the conclusions reached by experimental and mathematical processes

in the determination of the distribution of stress in bridge floor slabs resulting from loads applied in various positions relative to the abutments and sides. In this case the methods of design have been completely evolved.

Another useful bit of information to bridge designers is the determination of the distribution of abutment pressures for skew arches; and the tests of the full-size open-spandrel concrete arch bridge over the Yadkin River, conducted in cooperation with the North Carolina Highway Commission and with the advice of representatives of this Society in 1927, are perhaps already familiar to most of you.

Routine tests of road materials.- For twenty-five years the Bureau laboratories have carried on continuously tests of road materials of all kinds submitted for the purpose from every part of the United States. The records of these tests are complete and available to anyone who wishes to consult them. Of particular usefulness are the records of tests of natural materials such as rock, gravel, and sand; and these have been gathered together and published from time to time in bulletins of the Department of Agriculture which together constitute a valuable source of information in regard to a large part of the country's resources of these materials.

Studies of the Efficiency of Road Construction Processes

Another department of the Bureau's research work which has produced results that should be valuable to members of the profession at large are the studies that have been made of the efficiency of road construction processes and equipment. These studies have thus far dealt mainly with processes of grading, and concrete and bituminous concrete pavement construction, although less extensive studies have been made of quarrying operations and bridge construction.

In this work stop-watch studies have been made of a very large number of actual construction projects in the effort to learn what preventable lost time and waste motion there may be in the various processes as commonly practiced, and what are the essential relations between the rates of operation of the various pieces of equipment and labor supply necessary to produce the maximum practicable efficiency. The findings of the stop-watch studies have been applied under the Bureau's direction on numerous jobs with truly remarkable results in increase of efficiency and output. Highway contractors have manifested great interest in this work and highway engineers are well acquainted with the demonstrated possibilities of this extension of scientific management to the sphere of engineering construction. But the principles evolved are equally applicable to construction outside

of the highway field, and engineers generally should acquaint themselves with the very interesting reports that have been published.

The studies of grading operations cover practically all available forms of equipment from the simple slip scraper to the usual combinations of power shovels and trucks, and in all of them the essential time relations have been established between the rate of operation of the key equipment and the supplementary equipment and labor supply.

Taking concrete pavement construction as an example of the character and effect of the studies, the analyses of this class of work begin with the mixer as the key equipment which must set the pace for the entire operation. The studies have first developed the length of the mixing period and corresponding length of the complete mixer cycle necessary for the production of a uniform concrete. They have then disclosed the various time losses, both preventable and unpreventable, that reduce the actual productive operation of the mixer and lower the theoretical maximum output. Next, they have devoted themselves to the eradication of avoidable delays; and finally, after the highest practicable rate of mixer operation has been determined, the studies have dealt with the proper adjustment of the truck supply, the operations of the batching and loading plant, and the placing and finishing operations to maintain the practicable maximum rate of the mixer.

The reports of these studies should be familiar to all engineers interested in having construction work under their direction carried out with a maximum of efficiency and economy.

Traffic Surveys, Economic, and Statistical Data

The highway traffic and transport surveys conducted by the Bureau in several States in cooperation with State and county officials as the basis for highway system planning provide another source of data that may be useful to a much wider group of engineers than those concerned directly with highway planning and traffic control. Reports of such surveys in Maine, New Hampshire, Vermont, Pennsylvania, Ohio, and in Cuyahoga and Cook Counties have already been published. Others dealing with eleven western States will shortly be published. In all will be found a wealth of information in regard to the traffic on the main roads of these States and counties. They also provide much useful information with respect to the origin and destination of traffic and other economic data which may serve as indices for use in the analysis of problems entirely apart from the highways.

The Bureau publishes a monthly journal of highway research which it calls "Public Roads." In this publication we endeavor to report regularly all available information in regard to the various lines of investigation under way. Unfortunately our budget strictly limits the size of the edition that can be

published for free circulation and the number of copies published is scarcely sufficient to meet the demand of highway officials and others directly concerned with highway work, so that it is impossible to supply it regularly to all classes of engineers. However, there are usually a few extra copies available which may be used to meet requests for particular back numbers, and the magazine can be obtained on paid subscription from the Superintendent of Documents at \$1.00 per year.

Certain classes of information, not published in full in the magazine, are published in special reports and bulletins, and these are generally available in sufficient numbers to comply with ordinary demands. There is also a statistical service which takes the form of separate one-sheet tables, dealing with the mileage and type of all roads constructed in the United States annually, the sources and amounts of highway revenue, the amounts and purposes of road expenditures, the registration of motor vehicles, and the revenue collected from owners of motor vehicles in the form of license fees and gasoline taxes. The statistical records of the wages of labor paid in the various sections of the United States on Federal-aid road work and the unit costs of materials used, which have been kept for several years, constitute one of the best available sources of data to serve as the basis of estimates of cost of reproduction and other studies requiring a knowledge of the fluctuation of labor and material prices over a period of years.

The Bureau will be glad at all times to furnish full information in regard to phases of its work to any one interested. Within the limits of this paper it has been possible to touch upon only the more important lines of our work. Whatever we have of fact or data or useful information will be placed at the disposal of any engineer who may need it, whenever it is within our power to do so, and we welcome the opportunity to serve the profession in every proper way.