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ROADS

By H. S. FAIRBANK,
Senior Highway Engineer, Bureau of Public Roads.

ONE of the advantages of Heaven, according to Milton, is a "broad and ample road." The farmer who has to haul half-loads of produce because of the mud between his fields and the market, or the automobilist who has to pull out of a hole by means of a rope passed around a roadside tree, is excusable if he is tempted to envy the disembodied spirit traveling luxuriously along Milton's star-paved highway. He may even wish himself there audibly and in no uncertain tones. But the reason for this feeling is rapidly passing away. We have entered a new era, in which the bad road is giving way to the good, and the good road is being pushed forward into places where no roads have ever been before. Everywhere in the United States good roads have come to be regarded as indispensable to the welfare of the community. State and Federal Governments are cooperating in a great nation-wide endeavor to change the country thoroughfare from "a rough, a weary road" to a smooth, well-graded, well-kept highway. In the year 1921 alone the Bureau of Public Roads will be responsible for the expenditure of \$100,000,000 of the Government's money, and more than an equal amount appropriated by the States.

It is an interesting commentary upon the growth of the "good roads" movement that the Office of Public Road Inquiry, which was the name by which the Bureau of Public

Roads was first known, was created in 1893 with an annual appropriation of \$10,000—nearly enough to build a quarter of a mile of modern highway. But it established itself in the front of the fight for better roads, the work grew, and its supporters have multiplied a thousandfold. For more than a score of years its rôle was that of the searcher after knowledge. The testing and research work which it carried on during this period laid the foundation of the structure of modern highway engineering, and much of the testing apparatus which is now used the world over to measure the value of road materials was developed during this fruitful period.

Sand and Clay.

Offhand, sand-clay doesn't sound very promising when you ask about the road ahead. But if you know what the Bureau of Public Roads has done with these materials you will take heart. Until the possibilities of this type of construction became known the public roads of a large section of the Southern States had never been improved. Its discovery and development marked the first impulse toward rural development in that region; and from 1900 to 1912 hundreds of thousands of square yards were built under the direct supervision of Public Roads engineers sent out to assist local county and district road authorities.

Every other type of road construction adaptable to rural conditions was carefully studied and the simplest and best methods of constructing them were taught to the local road builders of counties all over the United States.

The Automobile Brings New Troubles.

When the automobile came to demand a further improvement in the character of the roads which were being built, the testing division of the Bureau of Public Roads did more than any other single agency to develop the intelligent use of asphalts and tars with which to settle the clouds of dust raised by the new vehicle. The bituminous materials which solved this problem had never before been used in road construction. In chemical composition they are extremely complex and variable, and no one knew what composition was needed for any particular highway use. The adjustment of

these materials to their new use and the standardization of manufacturing processes was a work which is comparable to the development of such basic structural materials as steel and cement.

The development of these materials definitely solved the problems of the dust nuisance and of surface wear. Though the traffic which uses our roads has increased from five to ten fold in the last decade, the highway builder still finds no difficulty in building roads which are practically dustless and which are scarcely perceptibly worn down by the passage of the hundreds of thousands of vehicles which use them each year.

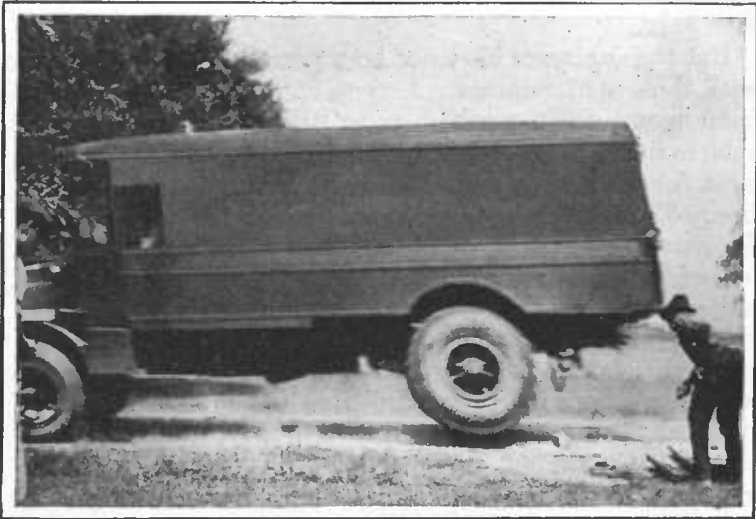
But the engineers have not been permitted to rest content with these achievements. A type of vehicle has come into use almost in a day which is so different from any other vehicle that has ever traveled the highways as to require the most fundamental alterations in standards of road construction. This vehicle—the motor truck—carries twice as much freight at a single load as ever has been hauled by road before. Formerly the heavier loads were drawn by plodding horses at the pace of 3 miles an hour, but these marvelous vehicles can go five times as fast. Their great weight and speed have taught us that roads which formerly were thought to be smooth are full of small depressions and inequalities of surface. The trucks, as they rumble over the small elevations and fall into the adjoining depressions, deliver great hammer-like blows, the effect of which upon the roads is greater far than the weight of the vehicle and its load. Anyone who has stood near by as one of the huge Army trucks was passing, and has felt the road quiver under the punishment of its solid rubber tires, can appreciate the tremendous destructive force which they exert.

They do not greatly wear the surface of the roads, but they do a damage which is far worse. Roads which were built for the traffic of five short years ago are literally shattered to pieces by the herculean blows of their wheels. The deterioration is not, as formerly, a product of many vehicles and long periods, but may result from the passage of a single heavy vehicle, in the same way that a bridge will collapse under a load which is too heavy for it. To prevent this damage is the new highway problem.

Defense Against Motor-Truck Impact.

The blows a motor truck delivers to a road, like the shells a big gun hurls into a fortress, can be withstood only if the force of the impact is accurately known in advance and adequately provided for. The first move in solving the problem of road building for motor-truck traffic was to find out how much force the truck puts into a blow.

Researches conducted at the Arlington Experimental Farm near Washington have given highway engineers the



Measuring Motor Truck Impact at the Arlington Experimental Farm.

basis for the design of highway surfaces which will withstand the impact of motor trucks, by measuring the intensity of the blows delivered. It has been found, for example, that a 5-ton truck equipped with solid rubber tires and traveling at a speed of 15 miles per hour, striking a surface depression only one-quarter inch in depth, delivers a blow to the road equivalent to four times its actual weight. Carrying the research a step farther, it has been found that the intensity of the blow delivered is enormously reduced by the use of pneumatic instead of solid rubber tires.

Having measured the intensity of the blows of the truck wheels, and having developed entirely new apparatus by

which such measurements can be made by others, the Bureau of Public Roads is now proceeding to examine, in detail, the effects of the trucks upon different types of roads, expecting in this way to be able to propose definite new standards of construction to replace those which have been outgrown. How important these researches are may be judged from the fact that the president of the American Association of State Highway Officials, a body composed of the leading highway engineers of the country, referred to them recently as the outstanding accomplishment of the year. The cost to the people of the United States was about one-hundredth of 1 per cent of the amount of money that was spent for road construction in the country during the year.

A Tremendous Job.

To know what kind of roads ought to be built is very important. But actually to build them throughout a country like the United States is another thing. A long step toward the first goal has been made at small expense by a small force of earnest men. To do the second requires an army of men and a pile of money. The Federal aid and national forest road work constitutes the greatest program of road construction ever undertaken under single control in the history of the world. The appropriations now available provide for the construction of roads which will cost nearly twice as much as the Panama Canal.

The law under which this great work has been conducted since July 11, 1916, is known as the Federal-aid road act. As the name of the act implies, the roads constructed under it are not built by the Federal Government alone, but by the States and the Government in cooperation. The framers of the law recognized the success which had crowned the efforts of the States with highway departments to supervise the construction of their roads, and one of the principal provisions of the law was designed to encourage the formation of adequate highway departments in all the States. The duty of actual supervision of the construction of the Federal-aid roads is laid upon the highway departments of the States, and no State can receive aid under the law unless it has such a department adequate in the opinion of the Secretary of Agriculture to perform the functions expected of it.

Far-Reaching Results.

To this requirement of the law are due some of its most far-reaching results. In order to comply with it, 17 States, which previously had either no State department at all or departments insufficiently equipped to perform necessary functions, have been led to establish adequate departments of the State government to care for the important work of highway construction. In one year after the passage of the act more constructive highway legislation was placed on the State statute books than had ever before been enacted in a similar period in the history of the country; and a condition was brought about which otherwise would not have been reached in less than 5 or 10 years.

The insistence of the Government upon the construction of Federal-aid roads under the supervision of the State departments has resulted in placing a much larger part of the road work of the country under skilled engineering supervision. Thus, in 1915, the year before the act was passed, only 30 per cent of the money spent for roads and bridges in the United States was expended under the supervision of State highway departments. In 1921 the State departments will exercise control over fully 80 per cent. In this respect the act has exerted a powerful influence for economy and efficiency in the administration of the road work of the country.

The funds appropriated by the act may be used only for the construction of roads, the duty of maintaining them after they are constructed being laid upon the States. As a means of enforcing proper maintenance the law gives the Government authority to withhold future allotments of Federal aid in case any road constructed is not maintained in a manner satisfactory to the Secretary of Agriculture.

The amount of aid which may be granted to any one piece of construction is limited to 50 per cent of the cost of the labor and material employed, and to \$20,000 per mile, exclusive of bridges of more than 20 feet clear span.

The Money.

The original act with its amendment appropriates a total of \$275,000,000 for Federal-aid roads and \$19,000,000 for



A. A concrete road near Easton, Pa.

B. This road in Texas is not as expensive as the Pennsylvania road, but it will serve its purpose just as well.



Federal-Aid Roads Are Built to Carry the Traffic.

the construction of roads and trails in the national forests. The amount appropriated for aided roads by the original act was \$75,000,000, and this amount was made available in five annual installments beginning in July, 1916, with \$5,000,000 and increasing by \$5,000,000 annually to July, 1920. This method of appropriating the money was adopted to give the States an opportunity to expand their organizations and handle the greatly increased funds.

Only the allotments for the first two years were appropriated according to this original schedule, however, because in February, 1919, the Congress appropriated \$200,000,000 additional, which it made available concurrently with the first appropriation, \$50,000,000 for the fiscal year 1919, and \$75,000,000 for each of the two years 1920 and 1921. This

made the total appropriations for these years, \$65,000,000 for 1919, \$95,000,000 for 1920, and \$100,000,000 for 1921.

The method of appropriating the money by years is clearly shown in the following table, which also shows how the \$19,000,000 for forest roads was appropriated.

Method of appropriating Federal-aid and forest-road funds by fiscal years, beginning July 1, 1916.

Fiscal year.	Federal-aid funds.			Forest-road funds.		
	1916 appropriation.	1919 appropriation.	Total.	1916 appropriation.	1919 appropriation.	Total.
1917.....	\$5,000,000	.....	\$5,000,000	\$1,000,000	.....	\$1,000,000
1918.....	10,000,000	.....	10,000,000	1,000,000	.....	1,000,000
1919.....	15,000,000	\$50,000,000	65,000,000	1,000,000	\$3,000,000	4,000,000
1920.....	20,000,000	75,000,000	95,000,000	1,000,000	3,000,000	4,000,000
1921.....	25,000,000	75,000,000	100,000,000	1,000,000	3,000,000	4,000,000
1922.....	.....	.....	.....	1,000,000	.....	1,000,000
1923.....	.....	.....	.....	1,000,000	.....	1,000,000
1924.....	.....	.....	.....	1,000,000	.....	1,000,000
1925.....	.....	.....	.....	1,000,000	.....	1,000,000
1926.....	.....	.....	.....	1,000,000	.....	1,000,000
Total.....	75,000,000	200,000,000	275,000,000	10,000,000	9,000,000	19,000,000

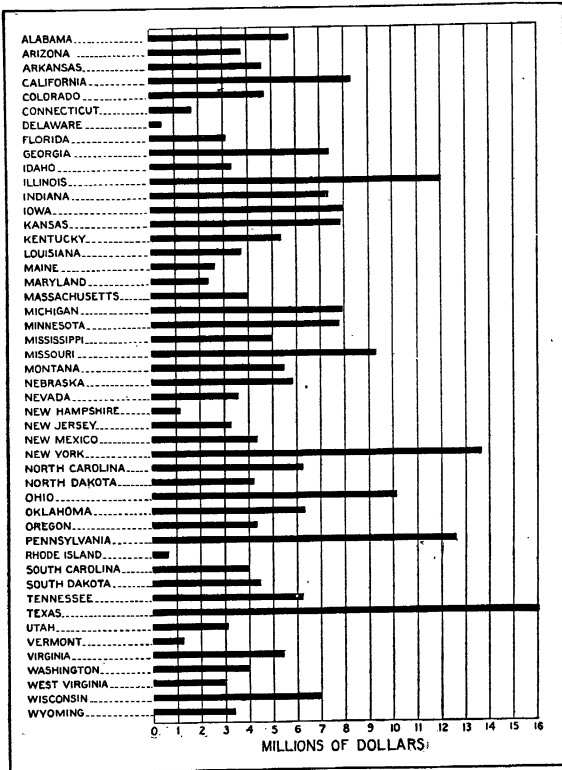
Three per cent of these annual amounts may be deducted by the Secretary of Agriculture to pay for the administration by the Federal Government, after which the balance is divided among the States. The division or apportionment is made in accordance with a rule laid down by the act itself—a rule so ingeniously devised as to make sure that there can be no unfairness in the distribution of the money. According to this rule each State gets a part of each annual allotment which bears to the total allotment the same ratio as the area, population, and mileage of rural delivery and star postal routes in the State bears to the total of these factors for the United States as a whole. The diagram on the next page shows the total amount allotted to each State for the whole 5-year period covered by the acts.

How It Is Done.

The administration of those vast sums, of course, calls for a large organization. That the organization can never be overdeveloped, however, is assured by the 3 per cent limita-

tion on administrative funds. As the Federal funds must be met by at least an equal appropriation of State money, the allowance is really only $1\frac{1}{2}$ per cent of the whole fund administered.

Instead of centralizing all authority in Washington, the United States has been divided into 13 districts, with a dis-



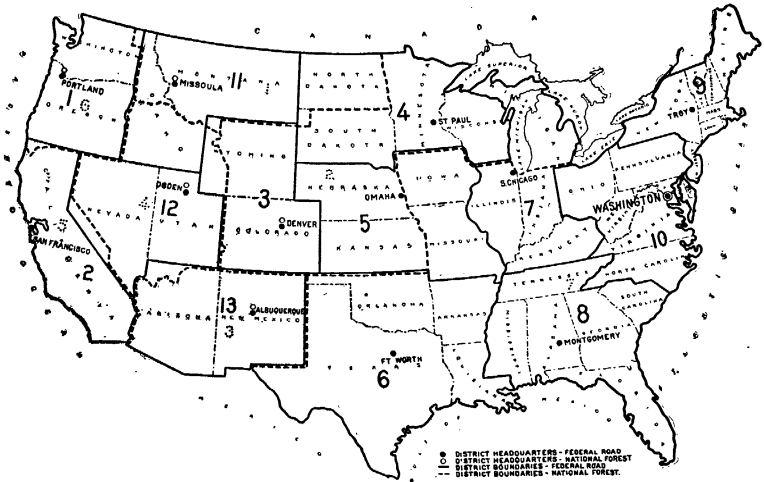
Federal Aid Apportioned to the States to July 1, 1920, Inclusive.

trict engineer in charge of each, who is authorized to deal directly with the State departments in his district. Where the work is sufficiently heavy to warrant it, one or more resident engineers have been placed in a State. By thus decentralizing the organization, much closer relations can be maintained with the State departments than it would be possible to bring about through a single remote organization located in Washington. And as the district engineers are authorized to approve plans submitted by the States, a great

deal of time is saved which would otherwise be lost in sending plans and documents back and forth to Washington.

The central organization at Washington is comparatively small, consisting only of the chief of bureau and chief engineer and a staff of reviewing engineers maintained to coordinate the work of the various districts and to act as a check upon the district offices.

According to recent reports, over half of the projects handled are passed by the district offices in an average of five



Federal-Aid Districts and District Headquarters.

days. Greater delay at this stage is generally due to the necessity for careful investigation to determine whether the road proposed is of sufficient importance to warrant the expenditure of Federal money upon it. When these doubtful points are cleared up the prompt passage of the project to approval by the Secretary of Agriculture is practically assured, as 90 per cent of all projects received at Washington are passed by the Bureau of Public Roads in an average of four days.

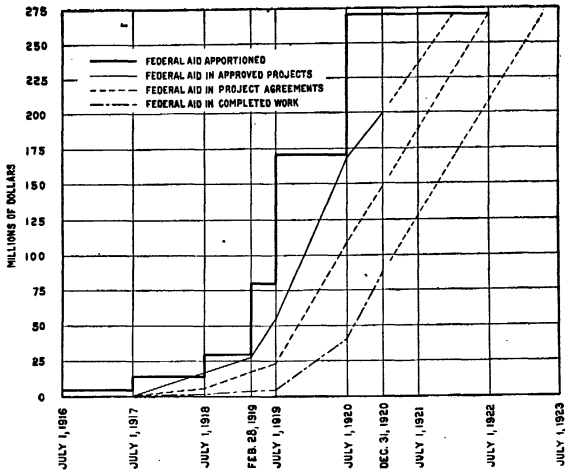
The Progress of the Work.

Up to December 31, 1920, 3,630 projects involving a total of 35,045 miles of road had been approved by the Secretary of Agriculture. The preliminary estimate of cost upon these projects was \$473,852,216.96, of which \$198,966,230.37 will

be approved as Federal aid. On the same date 817 projects representing 4,302 miles had been entirely completed, and 2,034 additional projects were in various stages of construction. The projects that were under construction include 17,219 miles, and they were reported as being 45 per cent completed on December 31.

Including the aid allotted to the projects entirely completed and that allotted to the completed portions of projects under construction, the work which had been done up to the end of the calendar year involved \$83,000,000 of Federal aid, and the total cost of this completed work has been estimated at \$193,000,000.

The accompanying diagram shows graphically the principal steps in the expenditure of the Federal appropriations.



Federal-Aid Progress.

The heavy stepped line indicates the annual allotments to the States, increasing in amount from \$4,850,000 (\$5,000,000 less 3 per cent) the first year to \$97,000,000 for the fiscal year 1921, the total amount allotted during the five years being \$266,750,000.

The solid line next to the right shows the amount of Federal aid allotted to projects approved by the Secretary of Agriculture. The dotted extension beyond December 31, 1920, indicates that by December 31, 1922, the Secretary of Agriculture will probably have approved enough projects to absorb the whole Federal appropriation now available.

The dashed line shows the amount of Federal aid involved in the projects for which formal cooperative agreements had been entered into at any time.

The last line—the dotted line—indicates the amount of Federal money involved in the work completed at any given stage.

Character of Federal-Aid Roads.

No effort has been made to encourage the construction of any particular type of road. Though there have been those who have urged that no roads should be constructed except of the highest and most expensive types, the legal requirement that the roads shall be "substantial in character" has not been thus interpreted.

It has been recognized that the heavy and expensive construction which is necessary in New York, Massachusetts, and Pennsylvania is not suitable or necessary for the less exacting traffic of Nevada, Idaho, and the Dakotas. A number of other considerations have influenced the choice of type in many cases. It is frequently found that suitable local materials are so much less costly than better materials imported from a distance that the construction of a lower class of work with the local material is justifiable; and as it is important to develop material sources throughout the country on as large a scale as possible, approval of the use of local materials is not infrequently given for the purpose of encouraging local production. There are also peculiar conditions affecting the methods of construction. For example, in parts of the far west the entire absence of water along a right-of-way and the expense of piping an adequate supply for 20 or 30 miles often make it necessary to approve a type of construction which can be built without the use of large quantities of water.

With these and other similar conditions in mind, the initial decision as to the type of a particular road is made by the State highway department. Its decision is reviewed by the Bureau of Public Roads after an independent study of the conditions, and the type of road finally decided upon is that type which in the judgment of the engineers of the State department and of the Bureau of Public Roads is the most suitable under the circumstances.

The types of road selected and constructed in this manner have included practically all the well-known forms of construction from earth to concrete, brick, and bituminous concrete. The lower types—earth, sand-clay, and gravel—predominate in mileage, including about 66 per cent of all the

road constructed. The intermediate types—water-bound and bituminous macadam, etc.—constitute about 7 per cent of the mileage, and the higher types involve about 24 per cent.

In point of cost the order is reversed. The higher types, including cement concrete, brick, and bituminous concrete, which account for only 24 per cent of the mileage, have called for 60 per cent of the money. The earth, sand-clay, and gravel roads, which make up 66 per cent of the mileage, have used only about one-quarter of the money.



In Wisconsin the Federal Money is Going Into Such Works As This Road and Bridge.

Forest Roads.

In addition to the administration of the Federal-aid work, the Bureau of Public Roads is also responsible for the construction of roads and trails in the national forests, for which \$19,000,000 have been appropriated by Congress.

In this work the Bureau of Public Roads cooperates with the Forest Service. Within the national forests are approximately 15,000 miles of roads which form connecting links for State and county highway systems. As the States have no jurisdiction over these roads Uncle Sam must see that they are kept in good condition.

The improvement of these roads and the construction of a supplementary system of roads and trails for purposes of

