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BUREAU OF PUBLIC ROADS

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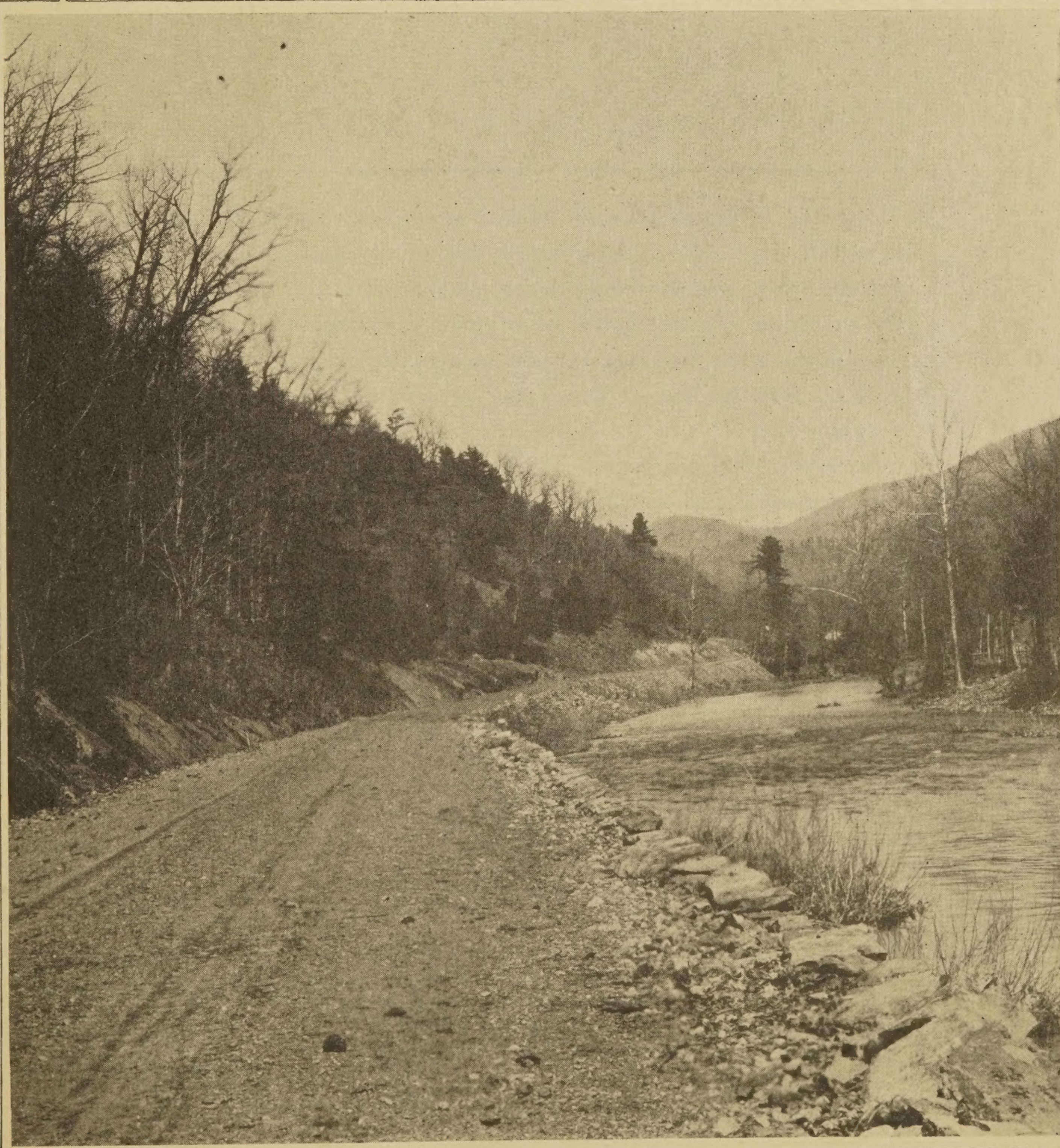

WEST VIRGINIA PROJECT NO. 3—A GRAVEL ROAD

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U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

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THE STORY OF ONE GRAVEL ROAD.

By B. E. GRAY, Senior Highway Engineer, Bureau of Public Roads.

IN THE Washington office of the Bureau of Public Roads the history of West Virginia Federal-aid project No. 3 is recorded somewhat after this fashion:

State	West Virginia.
County	Pendleton.
Project No	3.
Type	Gravel.
Length	4.2 miles.
Estimated total cost	$29,944.20.
Federal aid	$14, 972. 10

To one who happens upon it in its place in the files among the 4,500 other projects it is simply another gravel road of which there seem to be so many—or too many, if one is inclined to be critical.

Down here they don't know it as project No. 3 at all, but as the Franklin-Petersburg pike. Not many can tell you how much it cost or how much of the cost was paid by Uncle Sam. What they can tell you, and will—if you give them half a chance—is that here was a road, their principal connection with the railroad 30 miles away, which because of its terrible conditions was largely responsible for the backwardness of their community. This road, thanks to the help of the State highway department and the Government at Washington, has been lifted up out of the river bed where it had lain for a century and has been broadened and smoothed and protected from the spring torrents so that it can be used with certainty the year around. If it is a mistake to build gravel roads, they will say "Let us have more and more mistakes."

The Washington records show that the project is located in Pendleton County, which lies between the Shenandoah and the Alleghany Mountains in the eastern section of the State. If you refer to the atlas you will find that the county has an area of 700 square miles and a population of 9,652, and that the town of Franklin, its county seat, has only 320 people.

VALUE OF A ROAD NOT ALWAYS TO BE JUDGED BY STATISTICS.

These are the cold statistics, but to really appreciate the importance of the road to the community and the State you must know something more than the statistics show. You must know, for example, that this section of the State is potentially one of its richest agricultural sections, and that its backwardness is due principally to its lack of transportation facilities. Its nearest railroad point is at Petersburg, 30 miles north of Franklin by way of the Federal-aid road, and the second nearest point is at Harrisonburg, Va., 40 miles easterly. Thirty miles by way of the Franklin-Petersburg pike in its former condition was a pretty effectual barrier to free communication, yet in spite of that the two banks of Franklin have deposits of nearly a million dollars. Beyond Petersburg the road leads to Cumberland, Md., where it connects with the Maryland road system, and to the southward it connects with Hot Springs, Va., the famous resort. The whole region is one of the most picturesque sections of West Virginia, and when finally opened for through automobile traffic will undoubtedly attract tourists from far and near.

THE OLD ROAD OFTEN FLOODED.

The old road followed the South Branch of the Potomac River. The alignment was poor and the grades heavy, and it was in extremely bad condition. In places it followed the bed of the river itself until, coming to a sharp bluff, it would turn in toward the bank and after making a climb of 10 to 12 per cent for several hundred feet would pitch down again on the other side into the river bed. In times of high water it was flooded from 2 to 10 feet deep and all communication between the county and the outside world would cease. Even in summer the road was often closed to traffic for days at a time as a result of heavy rains which convert the tributaries of the South Branch into mountain torrents.

In 1917, in order to conform to the requirements of the Federal-aid law, the legislature passed a road bill, which provided for a two-headed commission to have supervision of Federal and State-aid work. On account of the limited State funds provided it was necessary to supplement them by county levies, and Pendleton County was one of the first to supply funds for the purpose.

A meeting was held with the county court in the fall of 1917 and they were induced to pass a court order appropriating $12,500 to be matched by a similar amount of Federal aid. At the time the county had no highway engineer, nor anyone versed in the building of highways, so an engineer was loaned by the Bureau of Public Roads to make a preliminary survey of the proposed project. He found the people rather skeptical as to the outcome of the whole procedure. They had seen so much money wasted under the old county supervisor system that they could not help but feel that this method offered only a quicker means of getting rid of the money.

HIGH-TYPE SURFACE VERSUS EXTENSION OF MILEAGE.

Some of the county court desired a short piece of road with a high-type surface, but looking at the situation from the viewpoint of the general welfare

THE CONDITION OF THE ROAD IN MARCH, 1921. EXCELLENT MAINTENANCE HAS PRESERVED THE CROWN AND THE SURFACE UNDER THE CONTINUOUS TRAFFIC OF MOTOR TRUCKS WHICH CARRY OVER THE ROAD ALL SUPPLIES FOR FRANKLIN AND THE LOWER END OF THE COUNTY.

of the people it was evident that the first thing to be done was to build bridges over the streams tributary to the South Branch, which would at least permit uninterrupted summer travel, and next to build an earth road on a location and grade that would be above high water, and would permit travel the entire year around.

The first need was met by a State project for which automobile funds were matched against local county funds, and a number of bridges were built over the most frequently flooded streams. A survey was then made of 6 miles (and later 4 additional miles) of the road from Franklin extending northerly. Two locations were possible—either to follow along the mountain side above the river, and cut out an entirely new road, or to follow generally the old roadbed with certain modifications in alignment and grade, building embankments to a height that would put them above flood-water levels and protecting the banks from erosion by retaining walls or riprap. At first glance it seemed that the hillside route would be preferable, and a survey was made on this location, following a natural shelf. This survey showed, however, that there would be considerable difficulty in building the higher line, on account of the large percentage of ledge encountered, and when the estimate was made up it proved to be cheaper to follow the old location.

The work was advertised for bids in March, 1918, and one contractor was brave enough to travel the 30 miles from the railroad to appear at the letting. The cost of putting in an outfit was so great that, instead of bidding a unit price, he made a cost-plus proposition to the county. This was very fair and was accepted. He agreed to put his equipment on the work, consisting of steam shovel, teams, drills, etc., and to receive as compensation cost plus 10 per cent, and plant rental at 1¼ per cent per month, not to exceed eight months. The Federal agreement estimate price was 90 cents a cubic yard, and as labor was $2.50 a day and teams $5, it was felt that the work could be done at these figures. All materials and supplies had to be hauled the 30 miles from the railroad station. The steam shovel was carried in by sections, as it was impossible to carry the whole shovel over a steel bridge crossing the river at a point midway between Petersburg and Franklin.

LOCAL LABOR EMPLOYED ON THE WORK.

Construction was begun in the early summer of 1918 and has continued to the present time, using local labor drawn from among the farmers themselves, nearly all of whom are well to do. For most of them it was their first experience in working under a contractor's foreman, and they found the discipline somewhat harsh. They complained so effectually that, finally, to keep the peace the energetic foreman was transferred to another job and a local foreman was put in his place. It was not long, however, before the new man, by his very leniency, had caused more trouble than the former, who though strict had been absolutely impartial; and the men themselves requested the return of their first foreman. He is still in charge, and the excellent construction is in a large measure due to his untiring, conscientious efforts. He has built up an "esprit de corps" which is remarkable. The men have been fired by his enthusiasm. They look upon the road as their road and they seem intent upon putting forth their best efforts to obtain high-class workmanship.

The original Federal-aid contract, 4 miles in length, was completed in 1920. On the 4 miles the Government paid $14,972.10, approximately half the total cost. The cost of the grading was a little under $1 per cubic yard. The people of the county felt that this was expensive and demanded that another letting be held for the next section of the work. Only one bid was received, and that, which offered to do the work at $1.75 per cubic yard, was rejected. The original contractor is still carrying on the work at cost plus 10 per cent, with a low rental charge for equipment.

IN MANY PLACES THE OLD ROAD LAY IN THE RIVER'S BED.

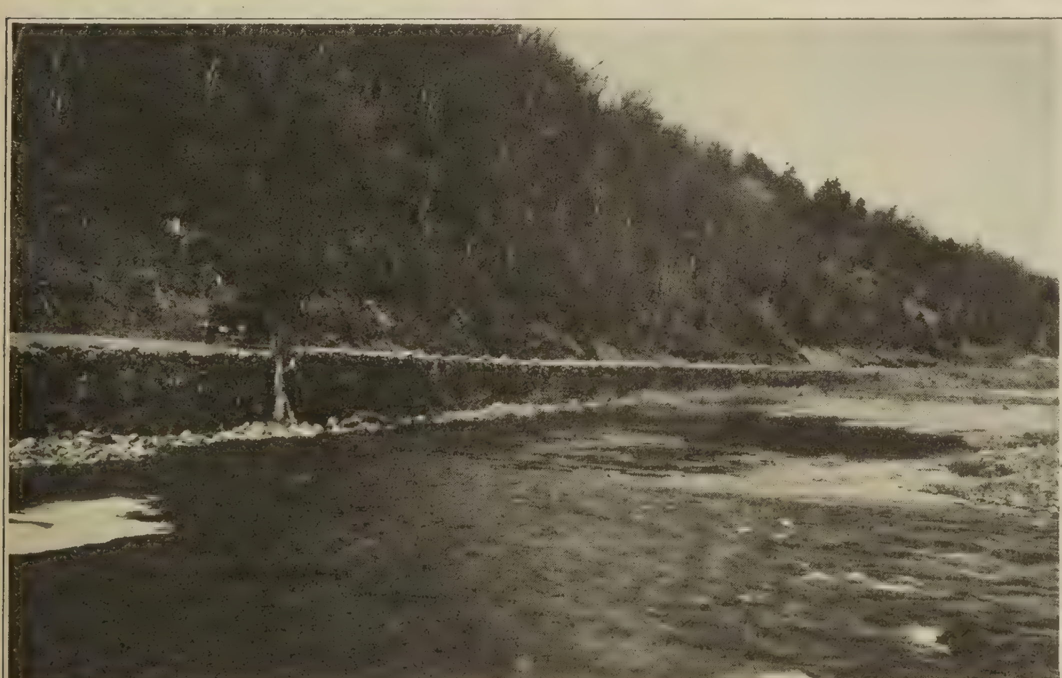
Nearly 8 miles have now been completed and about 80,000 cubic yards of material moved. The riprap and rubble walls, which protect the embankment from the stream, have been constructed from excavation material, the percentage of rock running in places as high as 80 per cent. In addition the road has been surfaced with gravel 8 inches thick at the sides and 12 inches thick at the center, and under the maintenance of a regular patrolman is kept in excellent condition. The county also has an engineer who directs the work on this and another Federal project on the Petersburg end.

Costs for the whole work, averaged over three construction seasons, are $1.10 per cubic yard for unclassified excavation; riprap, $4.50 per cubic yard; class A concrete (bridges), $22 per cubic yard; and 15-inch culvert pipe, $2 per foot.

SKEPTICS CONVERTED BY GOVERNMENT STANDARDS.

The standards of the Bureau of Public Roads governed all the construction, and the excellence of the work obtained made "good roads" boosters of even the most skeptical. Project No. 3 is typical of the kind of construction which will be needed in West Virginia for several years to come; and it is because of this project and other similar Federal projects completed or placed under construction in the past three years that the road sentiment is as strong in West Virginia as it is to-day.

How strong that sentiment is may be judged from the fact that the "Good roads amendment" to the State constitution, providing for a highway commission with real powers and authorizing the issuance of bonds up to $50,000,000, was carried last November by nearly five to one. The overwhelming vote in favor of the amendment was a tribute to the efficiency of the present State highway commission, even while operating under the narrow constitutional limitations of the old law. The legislature is now (March, 1921) at work drafting a new highway law, which codifies all the general road laws and embodies the provisions of the constitutional amendment. By 1922 West Virginia should be in the forefront of the States carrying on an intensive highway development program.



THIS STRETCH WAS KNOWN AS THE "HOG TROUGH." AT TIMES OF HIGH WATER IT OVERFLOWED FROM TWO TO TEN FEET. THIS WALL HAS GONE THROUGH TWO SEASONS WITHOUT ANY DAMAGE FROM FLOODS.

Whatever criticisms may be directed against the Federal-aid law as it now stands, it can not be denied that it has been largely responsible for such a change in public sentiment as has occurred in West Virginia, and which is evidenced by the vote of 1920. It has established standards of construction and obtained them. It has put improved roads in counties that had never

(Continued on page 12.)

THE TRAFFIC CENSUS AND ITS USE IN DECIDING ROAD WIDTH

By A. N. JOHNSON, Dean, Engineering College, University of Maryland.

IN A PAPER by the writer delivered before the December, 1920, Convention of the American Association of State Highway Officials the importance and value of a traffic census were discussed. As an appendix to this same paper a summary of the traffic counts that have been made in the various States was included. The full text of this article appeared in Public Roads for December, 1920. At the present time the writer is engaged upon a study of the traffic census reports made by the State Roads Commission of Maryland. During this study certain considerations as regards highway traffic in general have been forced upon the author's attention which it may prove worth-while to give some thought.

HOW WIDE SHALL FUTURE ROADS BE?

What traffic will our highways be called upon to carry? Are our present roads wide enough, or shall we need much wider roads that will carry three or four instead of two lanes of traffic? These questions are being asked by the public as well as by the highway engineers. Manifestly, it is important to find some answer. If it can be shown that the traffic that may be expected is within certain limits the plans for various State highway systems can be more accurately and scientifically made. It is not sound planning that makes provision for a wider highway than a reasonable expectation of the traffic to be accommodated justifies.

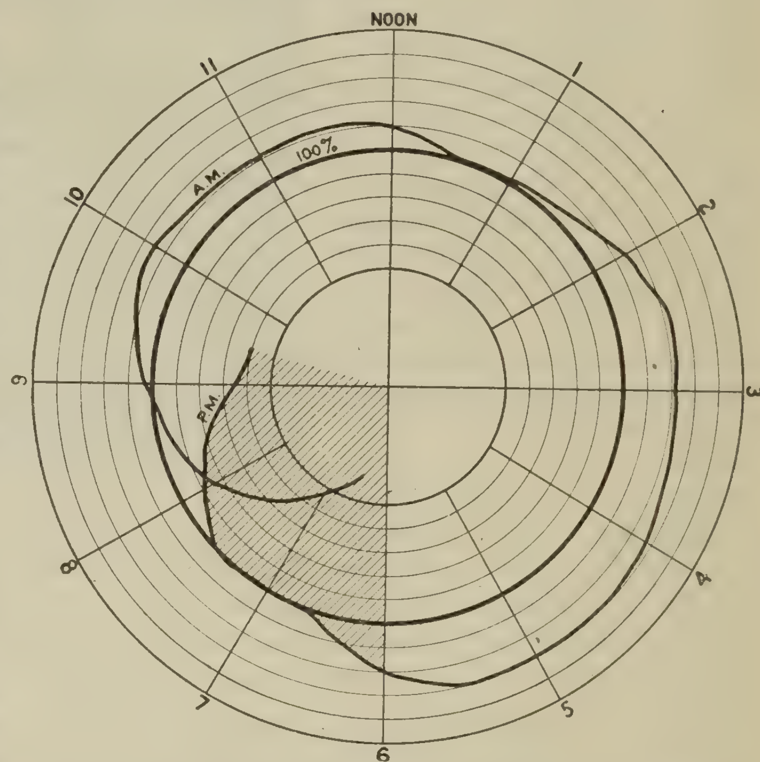


FIG. 2.—HOURLY VARIATION OF TRAFFIC, ADAPTED FROM DATA, PAGE 136 OF REPORT ON CALIFORNIA HIGHWAY SYSTEM BY U. S. BUREAU OF PUBLIC ROADS, 1920. FULL CIRCLE IS THE HOURLY AVERAGE TAKEN AS 100 PER CENT.

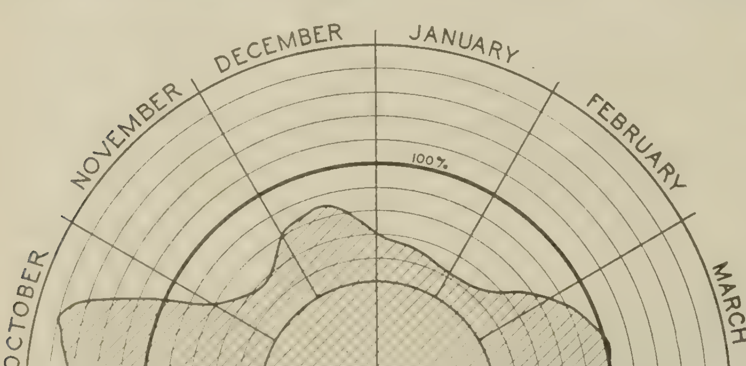


FIG. 1.—SEASONAL VARIATION OF TRAFFIC ON THE WASHINGTON-BALTIMORE ROAD AT ST. DENIS, NEAR BALTIMORE. PLATTED AS PER CENT OF DAILY AVERAGE FOR YEARS 1917, 1918, 1919, AND 1920. FULL CIRCLE IS THE SEASONAL AVERAGE TAKEN AS 100 PER CENT.

As a basis upon which to attack the problem there are presented three factors which govern the amount and density of traffic upon the highways. These are (1) the number of vehicles that use the highways, (2) the mileage actually made by these vehicles in a given time, and (3) the mileage of highways that is available for traffic. The larger the first two of these factors and the smaller the third factor, the greater will be the number of vehicles to be accommodated per mile of highway in a given unit of time. Keeping in mind the effect upon the resulting number of vehicles per mile per unit of time that will come upon our highways, the following statistics become very significant.

The total number of motor vehicles, including motor cycles, in the United States, from the latest available information as compiled by the United States Bureau of Public Roads, is placed at 9,471,043. While this number includes taxicabs and many other motor vehicles that seldom use highways outside of city limits, no deduction is made from the total as here given in the discussion which follows.

The average mileage made in a given time, say one year, by each motor vehicle is not known with any great degree of accuracy. From data in the possession of the officials of the American Automobile Association it is estimated that an average value of 6,000 miles yearly may be taken as reasonably approximate, while the Bureau of Public Roads places it nearer 4,500 miles per year per vehicle. Let us take the higher value of 6,000 miles and apply it to the total number of motor vehicles. There results a yearly mileage of approximately 57,000,000,000 vehicle-miles. As this total includes all vehicles, whether confined to city streets or using the highways, it is fair to assume that the highways as a whole, to-day, do not develop a total motor traffic in excess of 57,000,000,000 vehicle-miles per year.

The total mileage of highways in the United States, excluding city streets, is given by the United States Bureau of Public Roads as 2,478,552 miles.

ONE-TENTH OF ROADS CARRY THREE-FOURTHS OF TRAFFIC.

From studies that have been made in various parts of the country it is generally the opinion of those who have given the subject close attention that 20 per cent of the total mileage of all the highways carries not less than 90 per cent of all the traffic. As it may be some time before any considerable number of States will have improved 20 per cent of their total highway mileage, and as most State highway systems under construction to-day seldom exceed 10 per cent of the total highway mileage in the State (see Table I), it will be more significant to the present discussion to consider the amount of traffic that may be carried upon 10 per cent of our highways. The opinion generally prevails that we may expect 10 per cent of the highways if judiciously laid out to form a comprehensive State highway system to carry 75 per cent of all the traffic.

TABLE I.

State.	Total mileage of roads.	State highway system.	
		Miles.	Per cent of total.
California	61,039	5,560	9.1
Illinois	95,647	4,800	5.5
Iowa	104,074	6,619	6.4
Maryland	16,459	1,726	10.0
New York	79,398	3,772	4.7

Upon these data it is practicable to determine the traffic that would develop to-day on State highway systems were they completed. Seventy-five per cent of the total traffic is approximately 43,000,000,000 vehicle-miles per year, which is to be carried upon 250,000 miles of highways, or a traffic per mile per year of 172,000 vehicles. There thus results an average traffic per mile per day a little under 500 vehicles. It is evident from the rather large values given the factors that control this result that the actual traffic is probably well within the value here found.

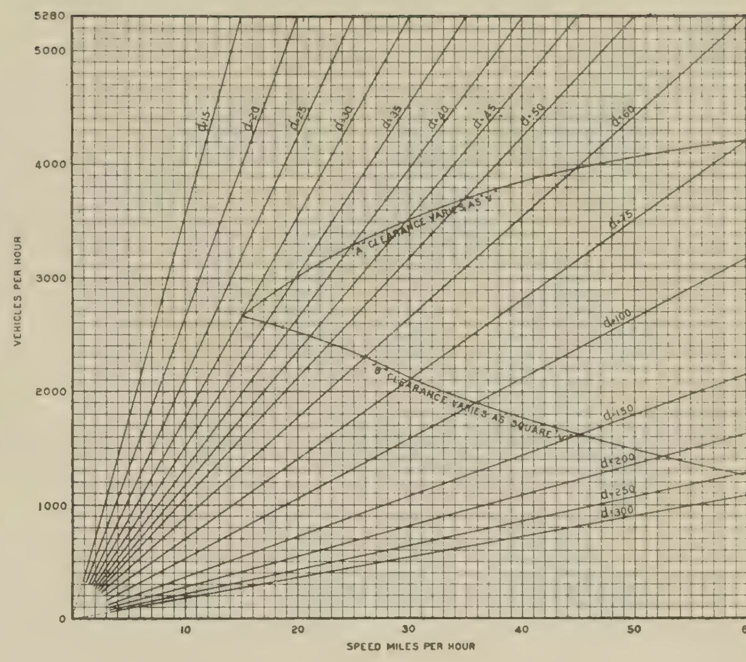


FIG. 3.—TRAFFIC DISCHARGE DIAGRAM. d=DISTANCE CENTER TO CENTER OF VEHICLES. d-15=CLEARANCE BETWEEN VEHICLES.

TRAFFIC VARIES WITH SEASON AND TIME OF DAY.

The average daily traffic throughout the year does not give the number of vehicles that should be provided for due to the seasonal and hourly variations in the volume of traffic. A road must carry comfortably the usual increase over the average traffic that comes regularly at certain seasons and during certain hours of each day.

The seasonal variation will depend upon climatic conditions. The seasonal traffic variations on the Baltimore-Washington road in the vicinity of Baltimore are shown in figure 1. From this diagram it may be noticed that from the middle of June until the middle of October the daily traffic is about 135 per cent of the average daily traffic for the year. The traffic records available in Maryland do not show the hourly variations which, however, are brought out by the data presented in the report on the California highways by the United States Bureau of Public Roads [1] and these data have a fairly wide application. In this report the results are plotted to rectilinear coordinates, which are here shown (fig. 2) plotted to polar coordinates. From this curve it may be seen that the maximum hourly traffic is about 30 per cent in excess of the average hourly traffic for the day. It is this high average hourly traffic occurring during the months of high average daily traffic for which provision should be made. If the average daily traffic for the year is 500 vehicles, the daily traffic during the heavy traffic months is 675, according to the Maryland figures. Based on a 12-hour day, this gives an average hourly traffic of 56 vehicles and a high average hourly traffic of 73 vehicles, applying the California factor. If the

[1] Report of a study of the California Highway System by the U. S. Bureau of Public Roads, pp. 136 and 137.

daily average is 1,000 vehicles, then an hourly traffic of 146 vehicles may be expected.

It will now be interesting to compare with these figures the traffic discharge of a two-track road, i. e., a road which accommodates two lanes of traffic. During the rush hour on many roads a large proportion of the traffic at a given point is in one direction—just what proportion can not be stated without much more data at hand than are available. It will be assumed, however, that all of the traffic is in one direction and is confined to a single lane.

TRAFFIC DISCHARGE DEPENDS ON SPEED AND SPACING OF VEHICLES.

The number of vehicles that pass over a given road will be designated as the vehicle discharge. The number of vehicles that may pass a given point in single file or the total discharge of a single lane of traffic depends upon the velocity and the spacing or interval between the vehicles. If the velocity is expressed in miles per hour and the distance from the center of one vehicle to the center of the next in feet, the total number of vehicles

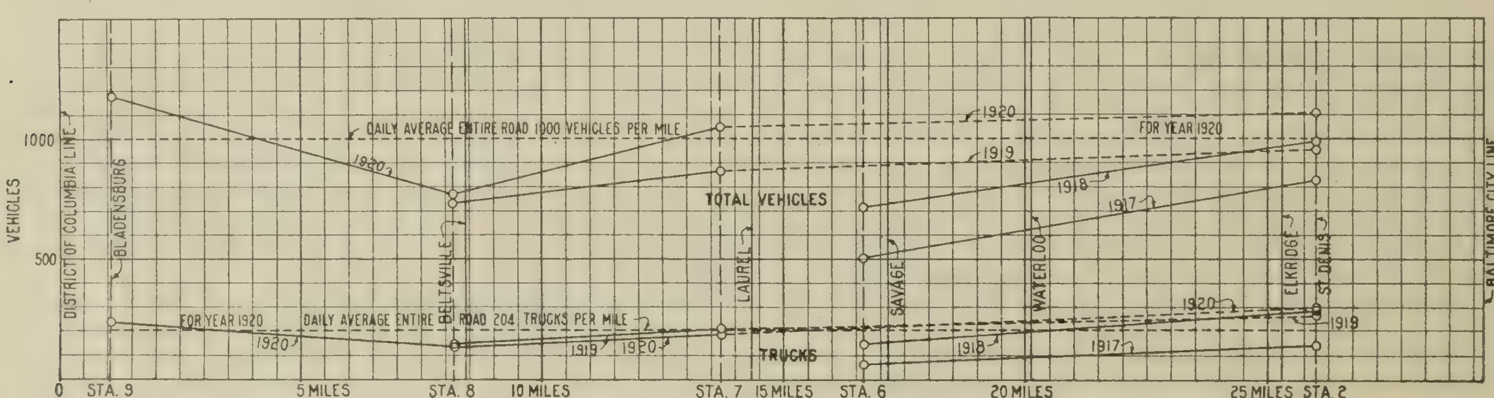


FIG. 4.—BALTIMORE-WASHINGTON ROAD. AVERAGE DAILY TRAFFIC.

that will pass a given point in one hour is equal to 5,280 times the velocity in miles per hour divided by the distance in feet from the center of one vehicle to the center of the next, or

$$N = \frac{5280\ V}{D}$$

The traffic discharge diagram (fig. 3) enables comparisons to be made readily under varying conditions. If the distance from center to center of vehicles remains constant, then it is clear that the number of vehicles passing a given point will vary according to speed in miles per hour, and we have the series of straight lines as shown in the diagram. Thus, taking the average over-all length of vehicles as 15 feet and a clearance of 15 feet, D becomes 30, and for a speed of 15 miles per hour the discharge of a single traffic lane will be 2,640 vehicles per hour. This point on the diagram has been taken as the starting point for the two discharge curves A and B. In curve A the clearance between the vehicles is assumed to vary directly as the velocity; thus, if the speed is to be increased to 30 miles per hour, the clearance is increased 15 feet, or a total distanee of 45 feet, and the total number of vehicles that pass in an hour is 3,500. For the lower curve B the clearance between the vehicles is taken to vary as the square of the velocity; thus, at 30 miles per hour as compared with 15 miles per hour the clearance is to be increased 4 times, or 60 feet. Add to this the length of one vehicle and we have the distance from center to center, D, equal to 75 feet, and the number of vehicles passing as 2,150 per hour.

From some observations made on traffic on the Washington-Baltimore road during a special rush hour it was observed that vehicles moving 25 to 30 miles an hour in groups of 6 or 7 maintained an average spacing of not less than 50 to 60 feet, or, allowing for the length of the vehicle, the distance between centers was about 75 feet. It was also observed that vehicles moving 10 to 15 miles per hour frequently were spaced as close as 15 feet, or about 30 feet center to center. This indicates that the clearance between vehicles may be taken to vary as the squares of the velocities within practical road speeds.

If the clearance between vehicles does vary as the squares of the velocities we have the interesting fact that a larger number of vehicles will pass a given point at a speed of 15 miles per hour than at 30 miles per hour.

1,000 VEHICLES PER HOUR NOT TOO MUCH FOR TWO-LANE ROAD.

As a matter of fact, the greatest number of vehicles observed on the Baltimore-Washington road did not exceed 400 per hour, the average speed being about 25 miles per hour, which would indicate an average spacing of 330 feet. If 1,000 vehicles were to pass in a single file in one hour at a speed of 25 miles per hour the spacing center to center of vehicles would be 132 feet. Thus, a highway paved for a width to accommodate two lanes of traffic can readily handle a total traffic in both directions of 1,000 to 1,500 vehicles per hour, and temporarily during a special rush may handle over twice these amounts.

Let us now glance at figure 4, showing the traffic on the Baltimore-Washington road at different stations for the past four years. The traffic for 1920 is somewhat in excess of that for 1919 and 1918. The area under the traffic curves is the total vehicle-mileage, which divided by the length of the road in miles gives the average number of vehicles per day per mile, which is found to be 1,000 for 1920.

In figure 5 are shown the curves of increase in traffic at various points on this same road for the past few years. All of these diagrams are based upon traffic counts taken for a period of 12 hours during one day each month, although at some of the stations during certain months no counts were made. A diagram similar to figure 5 has been made for the York road as shown by figure 6. The York road leads northerly from Baltimore, but carries little, if any, through traffic, i. e., traffic from one large center of population to another, as the Baltimore-Washington road does. On the York road a slight decrease in traffic has occurred during the past years.

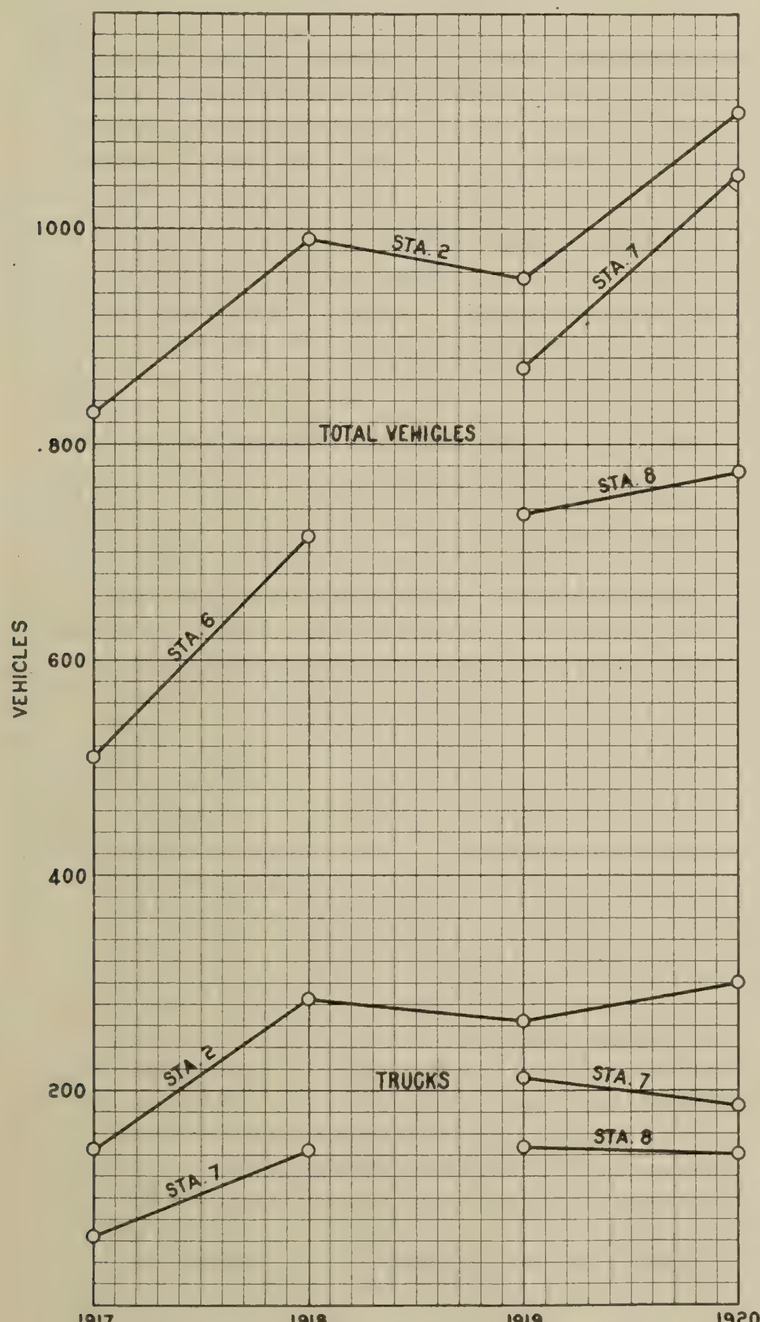


FIG. 5.—BALTIMORE-WASHINGTON ROAD. AVERAGE DAILY TRAFFIC FOR YEARS AND STATIONS AS INDICATED.

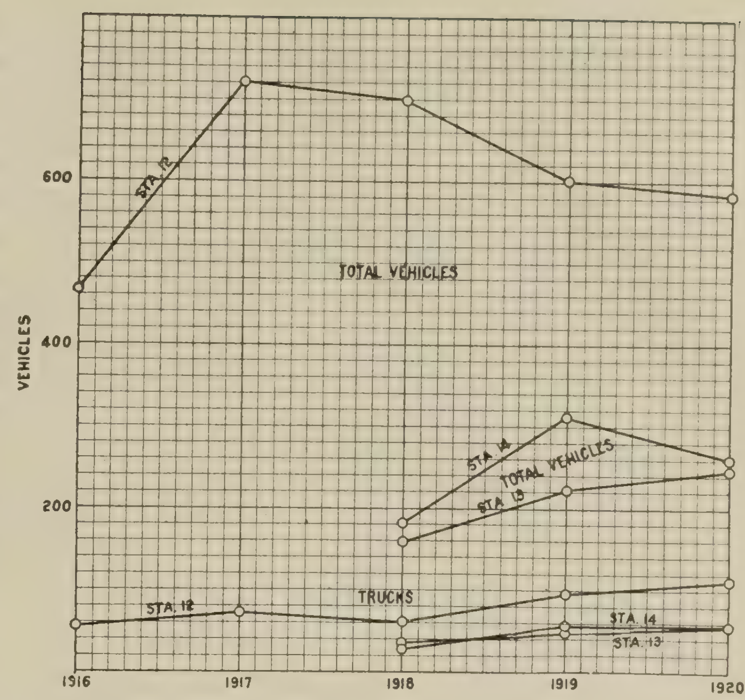


FIG. 6.—YORK ROAD. AVERAGE DAILY TRAFFIC FOR YEARS AND STATIONS AS INDICATED.

The following data are presented for comparison with similar data presented in the first part of this paper: There are in Maryland (1920) 125,693 motor vehicles and a State highway system of 1,726 miles practically built so that the traffic may be said to have found the roads and the roads have received their traffic. On the basis before assumed that each motor vehicle travels 6,000 miles a year and that 75 per cent of all such travel comes upon our State highway system (that of Maryland being very close to 10 per cent of all the highways) we have a total travel of 525,000,000 vehicle-miles, or a daily average of 900 vehicles per mile. This agrees closely with the traffic noted on the Baltimore-Washington road, which was seen to be about 1,000 vehicles per day on the average throughout its length. The York road averages much less. Time has not permitted careful analysis of the traffic records of all the roads of the State highway system of Maryland, but it is to be noted that there are some roads averaging well over 1,000 vehicles per day, while the larger portion of the State system receives much less traffic. Thus it is probable that the traffic as here computed to come upon our State highway systems is a reasonable estimate.

NUMBER OF MOTOR VEHICLES LIMITED BY MAN POWER.

The traffic upon the roads of the Maryland highway system is not increasing at an extraordinarily rapid rate, in fact in some instances 1920 observations show actual decreases. The explanation is not difficult to find. The number of motor vehicles is reaching a practical limit of man power to drive them, the number of owners possessing more than one motor vehicle is

(Continued on page 23.)

UNUSUAL DRAINAGE CONDITIONS IN PUBLIC ROADS DISTRICT No. 12

By E. E. KIDDER, Senior Highway Engineer, and A. B. BROWN, Highway Engineer, Bureau of Public Roads.

THE area covered by Bureau of Public Roads District No. 12 includes, for post-road work, the States of Nevada and Utah. For forest-road work it includes, in addition, the northwest corner of Arizona, southern Idaho, and western Wyoming, identical with Forest District No. 4.

Within this area the Federal aid which is applied to post roads is limited to the main lines of travel, such as the interstate and main State routes. These connect the larger centers of population and carry the heaviest traffic; and as they lie mostly in the valleys, good alignment and grades may usually be obtained. The survey problems of location are not generally as difficult as on the forest projects, but the selection of routes is more often subject to competition between communities. Where it is feasible the locations are made on the north side of the valleys and the south side of the hills, where the snow melts sooner and allows longer seasons of travel. Through cuts and high summits are avoided where possible, so as to prevent snow trouble.

The forest roads generally cross mountain ranges to connect valley settlements. As a result they reach high elevations, frequently cross timbered areas, and encounter much more rock excavation than the post roads. The main functions of the forest roads are to develop timber, ore, coal, and grazing resources; to simplify fire control; connect isolated communities, and give access to scenic and recreational areas. In some instances they form links in transcontinental routes. Usually they are light-traffic roads; and, though the grades are generally limited to 6 or 8 per cent, in a few cases a maximum grade of 12 per cent has been permitted.

CLIMATE AND TOPOGRAPHY OF THE DISTRICT.

These are the principal locational features of the two classes of roads, and it will be remarked that they are not strikingly different from the similar features of roads in other parts of the country. In the design of the drainage, however, problems are encountered which are widely different from any which are met with in other sections of the country; and the means which are adopted to effect drainage are correspondingly unusual.

The unusual drainage conditions result naturally from the unusual climate and topography of the section, which contrast strongly with the better understood eastern conditions. Precipitation, in the valleys of the section covered by the district, varies from practically zero to 20 inches. The higher mountains catch much more than this in the form of snow and make possible the irrigation of a small part of the total area. Though the whole section is arid, the southern part of it is extremely dry.

Nevada has less rainfall than other parts of the district, a condition which is due to the facts that the Sierra Nevada Mountains stop moisture from the west coast and the few large mountain masses within the State catch and store little snow. About one-third of the State receives less than 6 inches of precipitation.

The mountains are timbered at the higher elevations and on the northern slopes, where coolness and moisture favor the growth; but at the lower levels the prevailing aridity discourages tree growth. In general, scanty vegetation and overgrazing promote quick run-off, and make the usual run-off formulæ of little value in determining the area of drainage openings. The location of the drainage structures is rendered difficult by the fact that the streams, after emerging from the mountains, often spread over the valleys without definite channels, a condition which is due to the newness of the geological features.

CLOUDBURSTS A BIG PROBLEM.

An all-important drainage problem in this territory is that of handling the sudden flows of water occasioned by cloudbursts. These cloudbursts occur most frequently in July and August and are generally nothing more than heavy summer thundershowers. But as producers of maximum floods from small and medium areas they are more to be feared than the spring thaw. In certain sections, often limited to a few square miles in Nevada, but generally larger areas in Utah, they are an annual occurrence; and road construction is almost useless unless it take full account of them. In other sections, especially in Nevada, they may come only once in 4 or 5 or 10 years, or even less frequently. In general, the driest regions are the ones most affected.

A thunderstorm may concentrate a large rainfall in a small area. The water runs off swiftly on account of the scant cover and floods the dry washes and streams, picking up bowlders and drift in its path. This mass of water and débris may come, with a rumble which can be heard before its arrival, to a locality, perhaps, where no rain has fallen. Where the drainage channels are well defined there is no great difficulty involved in the design of the road drainage structures. But where the flood spreads out over a delta or a valley in which the channels have not been defined it is a problem to so locate the line and drainage structures that the latter will effect their purpose and save the road from destruction.

In the sections where the floods occur at infrequent intervals and are confined to small areas, especially in view of the generally light traffic and limited wealth of the territory, economy in design limits the protective measures which are adopted to temporary expedients and to confining the damage. Where the floods are of more frequent occurrence and where the traffic and other conditions justify it more complete protection must be provided.

Often the problem is of such importance as to form the major element in determining the location of the highways. Fortunately it is often possible to fix the location in accordance with the drainage requirements, particularly in the unoccupied public lands, where the engineer has a free hand to obtain the best location without being hampered by right-of-way problems.

WIDE BERMS PROTECT EMBANKMENTS WHERE FLOODS SPREAD.

In sections where the lack of definite channels permits the floods to spread out, and where the washes are crossed by loose dirt embankments, a wide berm on each side of the roadway makes a substantial protection. The borrow pit not only provides material for the embankment, but serves, also, as a diversion drain, with the result that the heavy flow of water is against a slope of solid earth instead of a loose fill. This results in less danger of scour and destruction of a portion of the road. A berm of considerable width can frequently be used in this territory without having any effect on the right of way, since the roadways lie for the most part through public lands.

The different conditions encountered and the various means of protection which are adopted can best be illustrated by referring to a few specific cases for which surveys have been completed.

CONCRETE AND GRAVEL DIPS USED ON WALKER LAKE PROJECT.

This project, known as Nevada No. 23, presented a variety of problems. For some distance the location lies along a steep rocky mountain side rising from the lake, which is of such great depth as to preclude all possibility of side embankment. Through such stretches the watercourses for the most part were well defined and susceptible of drainage across the road in the ordinary pipe or box culverts. In other cases the probable occasional flood is so great that a short concrete dip was used for the purpose of passing the water over the road in a comparatively wide and shallow flow instead of under it. A dip is simply a pavement extending the full width of the roadway and protected at each edge against undermining by a cut-off wall extending 18 inches below the bottom of the pavement They vary from 30 to 60 feet in length, and generally are of symmetrical profile each way from the center, with cross sections warping from the normal, at each end, to a plane surface slightly sloping in the direction of the flow at the middle station. By reason of the smoothness of the surface and the short lengths, fairly steep grades, as high as 6 to 10 per cent, were used on the dips themselves.

At other sections the slope of the ground traversed is much less steep, the mountains are further back from the water's edge, and the location is crossed at frequent intervals by extensive fan-shaped areas or deltas built up by the heavy flow following cloudbursts, which occur in this vicinity at frequent intervals. The gullying of the surface of the deltas indicates that the run-off is confined to no particular portion. The ordinary drainage structures of whatever size and type are, therefore, out of the question, as the flow might come first to one location and then another.

The condition seemed to call for a "dip," but the great extent of the deltas in many cases, and the possibility of the run-off occurring at any point throughout its width, rendered the cost of concrete design prohibitive. The so-called gravel "dip" was therefore designed as a means of solving the problem to as great an extent as was feasible in advance of the actual necessity for permanent drainage structures.

The gravel dip consists, as in the case of the concrete structure, of two grades descending toward the center, usually symmetrical, the downstream or "run-off" edge protected by a concrete wall or curbing flush with the pavement and extending 2 feet or more below the underside, preferably to rock. Most of the deltas are composed largely of rock fragments washed from the adjacent mountain sides and gullies. Quantities of material of a size suitable for surfacing are close at hand for use in constructing the dips in the first instance and for future maintenance if required. This condition is an expecially fortunate one in view of the length of construction necessary in most cases.

In connection with the drainage dips a V-shaped system of dikes and ditches converging toward the road was used where it was desired to lead the flow from two or more washes to a single dip and diverging toward the road where it was desirable to split the flow of a single stream to more than one "dip."

ST. THOMAS-LAS VEGAS PROJECT.

The St. Thomas-Las Vegas project, known as Federal-aid No. 37, consists only of grading and drainage structures. It lies in the southeastern part of Nevada, where cloudbursts are also prevalent. It is proposed to cross the washes nearly at right angles at points where they appear least likely to shift. The location is left on the ridges as far as possible, and the dry-wash crossings will be constructed of gravel dips as described in the Walker Lake project. The channels are very wide and not well defined, but the rush of water is of such short duration that it is unlikely to cause much delay to traffic. This type of construction permits an adequate road improvement. Permanent bridges, or even concrete dips, would involve prohibitive expense. The territory traversed for 70 miles is uninhabited, and available water supplies are 60 miles apart.

LOCATION GOVERNED BY DRAINAGE REQUIREMENTS ON NEVADA FEDERAL-AID PROJECT NO. 19.

This project lies between Zola and Mill City, Nev., paralleling the Southern Pacific Railroad. The territory through which the road passes is a wide valley running in a northeasterly and southwesterly direction, with the Humboldt River flowing about in the center of it. The ground has a gradual slope toward the river, flat near the river and rolling toward the mountains on the south side, where the road is located. The mountains are scantily covered with low vegetation. This whole territory is affected by cloudbursts, and the washes from these streams have formed deltas in steps; that is, the ground has formed in a series of long flat areas with sudden drops between them. Where these flats are encountered the stream has spread, and there are no well-defined channels. Where the ground drops away fast deep, narrow channels are formed where culverts may be easily constructed. The location was made to avoid as much as possible the ground where the water spread. Where this was not feasible, dips were used. Where the channels were well defined structures suitable to carry what would be considered an average flow were placed.

SOME FOREST-ROAD EXAMPLES.

One of the problems encountered on the forest roads is that which results from the snowslides which occur in the mountains of the northern part of the district. No structure will stand in their path unless it is a small culvert walled up so the slide can run over it like a dam. Fortunately their paths carry but little water.

Another troublesome feature of mountain roads is that a line running along a main drainage stream encounters the streams from the side valleys or canyons. After their steep descent down their courses they drop their load of sand, gravel, and débris. This forms a delta on which there is no definite channel. One has a choice of running along the steep sides above the main stream and crossing the side streams where they enter the valley, or of locating at a lower elevation across the deltas, constructing dikes and ditches to confine the streams to definite channels and directing them to proper culverts. In the first case undesirable breaks in the grade and expensive work may be necessary; in the second the stability of the controlling channels is doubtful.

In these mountain streams affected by cloudbursts very large bowlders and driftwood will come downstream, lodging in some narrow part of the channel and forming a jam, raising the water above the normal height of the flood flow. The only safe way to locate the road under such conditions is on the sides of the valley, allowing a factor of safety above the high marks of the flow. This condition is greatly aggravated by overgrazing, resulting in a too rapid run-off and erosion of the soil. Many small streams have cut 10 to 25 feet in a few years. These features necessitate more frequent drainage structures, and the adapting of the grade to such conditions results in considerably increased earthwork quantities.

PENNSYLVANIA COMMISSIONER URGES ECONOMY.

State highway commissioner Lewis S. Sadler has called the attention of all employees of the department to the need for economy in handling every phase of the department's work.

"The economics of this work under existing conditions are of paramount importance," he says, "and in our efforts to obtain a result with pride and satisfaction, we must always keep in mind the cost."

The State highway commissioner calls particular attention to the economies that can be effected in the use of office supplies, furniture, and printed matter. The department forces throughout the State are urged to be careful in the use of electric lights; and they are notified that where a letter will answer the same purpose, telephone calls or telegrams are to be discouraged. The indiscriminate use of automobiles owned by the State is forbidden.

"The material and labor market to-day is such," says the highway commissioner, "that we should avail ourselves of every advantage it is possible to secure in this respect; and considering the general business depression and the unemployment situation, we are in position to expect closer buying and higher-grade service than heretofore.

"Without entering into details, there are many ways in which, through skill in the management of your work, you will be able to take advantage of these things, which will have a very beneficial effect upon our road program in every respect."

(Continued from page 5.)

before had improved roads, and whetted their desire for more of the same kind. It is liberal enough to permit the ecomomical type of construction. If the law had required so-called permanent surface construction it would have been possible with the funds available to have built about 2 miles of high-type surface on project No. 3. But what good does 2 miles of such a road avail, when 28 miles are impassable four months in the year, and the need is to cover the 30 miles or none? The general improvement which has followed the construction of this project as a graded earth road with gravel surface bears witness to the soundness of the policy which has been very generally adopted in States like West Virginia, where slips are common and newly graded roadbeds do not become stabilized for several years.

THE PATROL SYSTEM A SUCCESS IN GRANT COUNTY, WASHINGTON

By A. F. MORRIS, Highway Engineer, Bureau of Public Roads.

THE "ROAD FIXER" HITCHED TO A ONE-YARD TRUCK. THIS OUTFIT IS SAID TO BE MOST EFFICIENT FOR MAINTAINING GRAVEL ROADS.

IN 1917 the Legislature of the State of Washington passed an amendment to the State highway law providing for the maintenance of primary highways at the expense of the permanent highway maintenance fund under rules, regulations, and requirements to be prescribed by the State highway board. The board accordingly prescribed rules and regulations requiring the board of county commissioners of each county, including any constructed section of primary State highway, to make provision for its maintenance and the payment of the cost from the funds available as set forth in the law. By these rules the counties were required to delegate the direct supervision of highway maintenance to the county engineer or a specially appointed maintenance engineer. The board of county commissioners was required to provide and the engineer to supervise the establishment and keeping up of an adequate organization and working force, providing for a continuing maintenance patrol and service organization whereby each section of constructed primary highway should be examined and repaired throughout its length at least once each week and also immediately after each rainfall.

COUNTY HAS EXPERIENCED ENGINEER.

These regulations were evidently variously interpreted by the different engineers appointed by the several counties, but Grant County was singularly fortunate in securing the services of a very competent engineer who had had previous experience with the patrol system. He interpreted the regulation requiring a patrol system literally and proceeded to organize one along the general lines of those of certain Middle Western States.

Other counties have attempted to maintain the roads mainly by the "gang system," assigning to each gang a long section upon which they make repairs where they appear necessary and casually drag the surface of gravel or crushed rock roads at intervals, generally after rains, provided they get around to them in time. Only in Grant County is there a real patrol system which provides for the continuous patrolling of every mile of road. There the plan is to prevent a road from getting into bad condition rather than to make repairs.

There are now 87.83 miles of constructed primary highways in the county, and these are divided into 13 patrol sections. With the exception of two sections on the Sunset highway, which are combined under one patrolman, each section is in charge of a patrolman who is constantly working on his particular piece of road. These sections are from 6 to 10 miles in length, and each man is made to feel that he alone is responsible for the condition of his section. While these men work under the direction of the county engineer, the details are left largely to their judgment, and full and free discussion is invited. In this way each man is made to look upon his work not as a mere job for so many hours a day, but is encouraged to take pride in trying to make his patrol section look a little better than the next one.

These patrolmen receive a compensation of $5 per day except one who furnishes his own truck. This man receives $6 per day. When helpers are needed they are employed at about $3.50 per day, but the patrolmen generally work alone on general maintenance, extra help being needed only when making extraordinary repairs, resurfacing, etc. Two-horse teams are to be had for $3 per day.

"ROAD FIXER" THE PRINCIPAL IMPLEMENT.

Each section is provided with a specially constructed light drag or road planer which has been well described as the missing link between a road grader and a road

SURFACED WITH 500 CUBIC YARDS OF SAND PER MILE, THIS ROAD IS AS HARD AND SMOOTH AS A PAVED HIGHWAY.

drag. It is known as a "road fixer," and it is the best all-round implement ever used in this locality for light dragging and planing of gravel or earth roads. The principal merits of the machine lie in its long wheel base and its two cutting blades, so connected with the carrying frame of the machine as to allow no up-and-down movement. By this arrangement the blades are held down on the high points by the weight of the machine and carried over the low points of a road, thereby cutting down the high places and filling up the chuck holes. The rear end of the machine is carried on two wheels on separate axles, each controlled by a separate lever which allows the operator to lift one side and lower the other as desired, and in this way maintain the crown of the road, regardless of its width. By this arrangement the operator can clean the dirt out from the gutter at the side of the road and run it toward the center to fill up the wheel marks. A lever in the center of the machine enables the operator to tilt the blades forward or backward when necessary. The frame may also be raised or lowered to give it any desired pressure on the blades, which can be set at any angle desired by moving the chain connecting hook to one side or the other. The connection between the blades is so arranged that it will keep the ends of the blades always parallel and cause the rear blade to follow directly behind the front blade. The front trucks will pass under the main frame when necessary to make a short turn. The wheel base is 168 inches, the width between rear wheels is 5½ feet, and between front wheels 18 inches. The total weight is 960 pounds. As shown in the photograph the "fixer" is hitched behind the truck after having been set to the required angle and depth by the patrolman. Whenever the condition of the road is such as to require frequent change in the set of the blade an assistant can ride and operate the machine, but generally both truck and road planer are operated by one man working alone.

SMALL GRAVEL MAKES BEST SURFACE.

The patrolman carries the necessary small tools for clearing weeds, trimming shoulders, cleaning ditches, etc., and for handling surfacing material, and in addition has two rakes for raking off loose pebbles. One is a common garden rake for light work, and the other a heavy asphalt rake. After dragging a road and thus making it smoother than would generally be required, the patrolman goes over the newly dragged section and carefully rakes off all pebbles as large as 1 inch in diameter so that the surface is as smooth as a concrete pavement. It has been found that for economical maintenance there should be no stone or gravel in the top 4 inches of a road larger than 1 inch in largest dimension. In fact, some of the very best roads are built entirely of gravel much smaller. An example is shown in one of the accompanying photographs of a secondary highway surfaced entirely with sand little of which would be retained on a one-fourth inch screen. Where such fine material is used, however, it should be applied lightly. The particular road shown received about 500 cubic yards of sand per mile and is as smooth as a pavement.

The rainfall in Grant County is very light, the annual precipitation being only 6 or 7 inches, so that, except for a short time when snow is melting and the ground is thawing in the spring, there is but little moisture to aid in shaping the road surface. By constant attention, however, ruts are prevented from forming with the result that Grant County has graveled roads second to none in the State. It is specially interesting to note that the cost of this system of maintenance is no more, and in fact rather less, than other counties pay where roads receive attention "only when they need it."

In 1918, 26.69 miles of primary highway was maintained at a cost of $295 per mile. This was the first year under the new system and the roads were in poor condition to begin with. In 1919 the cost of maintenance on 54.56 miles averaged $250 per mile. In 1920 there was 84.95 miles of primary highway and the average cost was $230 per mile. In 1921 there is being patrolled a total of 87.83 miles and, basing the cost per mile for the year on the expenditure to date, the estimated average is $223. This is lower than in most localities where roads receive only casual attention.

At first the people of Grant County protested when the engineer began to "garden" the roads, but now all are enthusiastic boosters for the patrol system.

(Continued on page 23.)

TESTS FOR SUBGRADE SOILS.

By A. T. GOLDBECK, Engineer of Tests, and F. H. JACKSON, Senior Assistant Testing Engineer, Bureau of Public Roads.

IT IS well known to road engineers that identical types and designs of roads are not equally successful in carrying like traffic in different parts of the country. Even though constructed with equal care some road surfaces fail utterly, while others carry equal traffic with little maintenance expense. The explanation of this difference must lie in the difference in support offered by the subgrade to the road surfaces. Practical road engineers know in a general way that certain types of soils when saturated with water have very little bearing value and that others have comparatively high bearing value. They also know in general that certain soils are impervious but that when once saturated are extremely hard to drain, and further that other soils owing to their porous structure drain very readily.

It would serve a very useful purpose if the differences in these soil types which affect the stability of the road surface could be definitely and accurately recognized through the medium of laboratory tests, and it is the aim of this paper to discuss briefly some of the tests which are being investigated at the present time by the Bureau of Public Roads in an effort to determine which of them are most satisfactory.

The laboratory has worked out a series of tests designed to give some information regarding the following physical properties of subgrade materials: Gradation; water-holding capacity; moisture equivalent; vertical capillarity; air shrinkage; slaking time; cementing value; and the percentage of colloidal material as determined by adsorption. The relative bearing power of the soil under various conditions of density and moisture content is also being investigated.

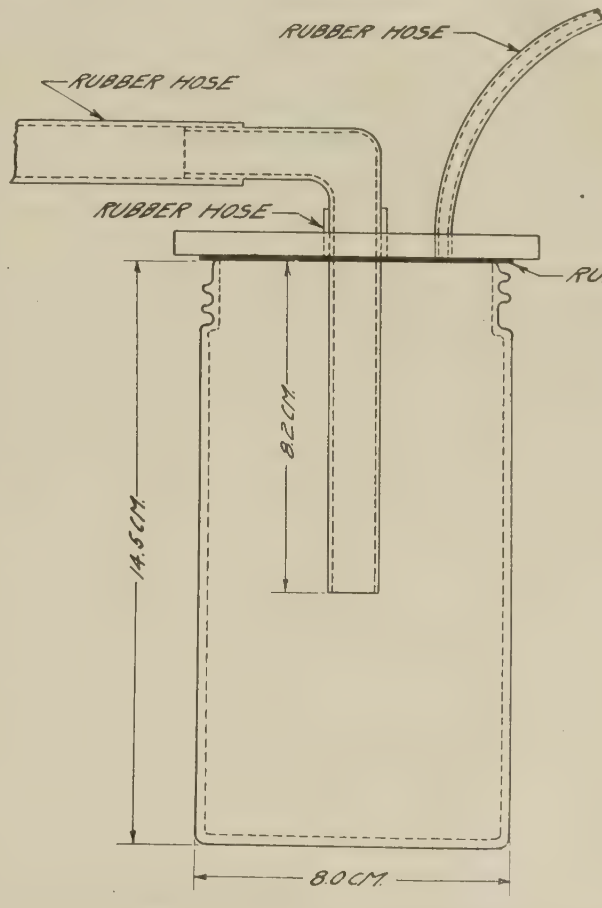


FIG. 1.—GLASS JAR USED IN WASHING SOIL SAMPLES.

PREPARATION OF SOIL SAMPLES.

One of the most difficult problems in connection with the laboratory examination of soils is that of preparing materials so that they may be accurately sampled and studied. Many soils when received in the laboratory are so lumpy, due to the clay content, that it is exceedingly difficult to break them up without actually crushing some of the grains. It has been found, however, that most soils if handled carefully may be prepared for testing substantially in accordance with the following scheme:

A one-fifth cubic foot sample of the soil as received from the field is broken up in a porcelain mortar, using a rubber-covered pestle, until the lumps of clay are small enough to pass through a one-fourth-inch screen. Great care must be exercised, especially with certain materials containing soft or friable sand, to prevent crushing of the grains. That portion of the sample which is retained on the one-fourth inch screen is considered as gravel and is not used in connection with any study of the physical properties of the soil except in determining its mechanical analysis and bearing power. The material passing the one-fourth inch screen, consisting of sand and clay, is then passed through a soil pulverizer which consists essentially of two electrically operated, adjustable rubber rolls between which the soil is fed. The rolls are adjusted to allow the soil to pass through them without clogging and yet with sufficient pressure to pulverize the clay fragments. By feeding the soil through very slowly it has been found possible satisfactorily to reduce most of the soils so far encountered. In especially obstinate cases it may be necessary to complete the preparation of the soil by rolling it out in a very fine layer on a rubber pad. It must be borne in mind, however, that the preparation of a clay soil for testing is an operation requiring great patience and care. The accuracy of the results of many of the tests depends largely on whether the sample has been reduced to its ultimate degree of fineness, at least in so far as it is possible to accomplish this end by mechanical means.

MECHANICAL ANALYSIS.

The method of mechanical analysis used is a modification of the method of soil analysis developed many years ago by the United States Bureau of Soils. Unlike the latter, however, no attempt is made to separate the extremely fine sizes, a process which requires either prolonged sedimentation or centrifuging. The object of this test is simply to separate the fine silt and clay from the sand so that a sieve analysis of the latter may be made. The method also gives by difference the amount of combined clay and fine silt in the soil. The procedure is as follows: A 500-gram sample of the soil obtained by quartering the material prepared as previously described is passed through a 10-mesh sieve, and the material retained thereon is recorded as coarse sand over 10-mesh. In case there is an appreciable quantity of gravel in the soil its percentage is computed from the weight of material retained on the one-fourth-inch screen as obtained during the preparation of the sample. A 50-gram sample of the soil which will pass a 10-mesh sieve is then obtained, great care being taken to sample accurately. The sample is placed in a glass jar about 15 cm. in height and 8 cm. (see fig. 1) in diameter and provided with an aluminum screw top. Two hundred c. c. water and 5 c. c. dilute ammonia water are added and the jar is revolved in an agitator for one hour for the purpose of disintegrating any aggregations of soil particles which exist. The agitator consists of a wooden frame holding 6 jars so placed that they revolve about an axis perpendicular to the long axes of the jars. A view of the agitator is shown in figure 2. The contents are thus thrown from end to end of the jars twice during each revolution, thus insuring maximum agitation, and the jars revolve at the rate of 16 revolutions per minute. The function of the ammonia is to prevent floculation of the clay particles. When the jar is removed from the agitator the contents are allowed to settle for 8 minutes, after which the water containing the material in suspension is siphoned off to a depth of approximately 8 cm. (See fig. 1.) The soil is again brought into suspension by means of a fine water jet under approximately 20 pounds pressure and the above process repeated. The operation of washing, sedimentation, and siphoning is continued until the wash water is approximately clear after 8 minutes sedimentation. A few drops of ammonia water are added sfter each washing. The soil in the jar is then dried at 100° C. and a sieve analysis made, using standard 20, 50, 100, and 200 mesh sieves. It will be noted that the above process divides the soil into 4 grain sizes, which may be designated as "sand"; one (the material which will pass the 200-mesh sieve by analysis) which may be designated as "silt," and one (the material removed by washing) which is a combination of fine silt and clay. The maximum grain size remaining in suspension after 8 minutes is approximately 0.03 mm. as determined by the method of the Bureau of Soils.

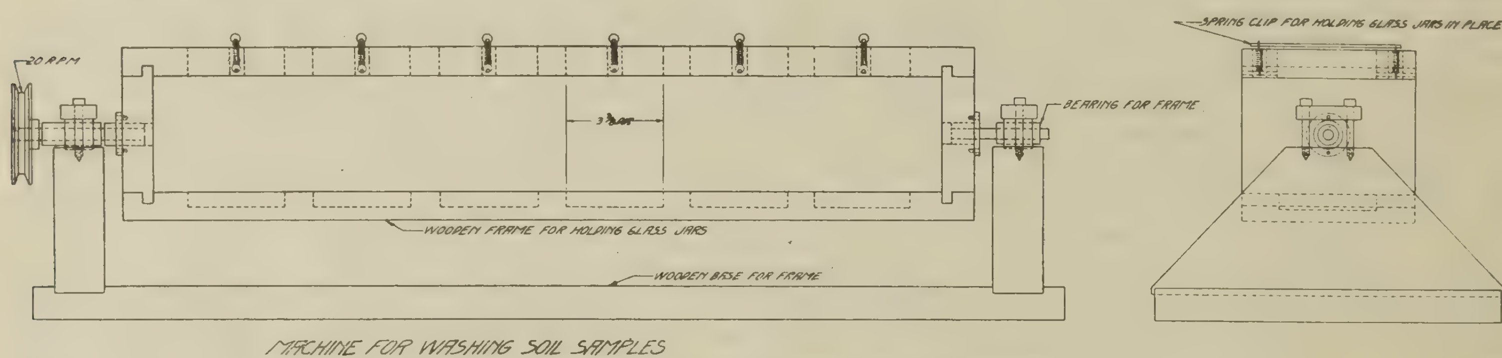


FIG. 2.—MACHINE FOR WASHING SOIL SAMPLES.

WATER-HOLDING CAPACITY.

The water-holding capacity of a soil may be considered as the maximum percentage of water which it is capable of retaining under any circumstances. It is determined in the laboratory in the following manner: A sample of the soil which has been prepared as described above is placed in a brass cylindrical box 1 cm. high and approximately 6 cm. in diameter. The bottom of the box is perforated with 150 holes, each one thirty-second inch in diamater. The top of the soil is struck off by means of a fine straightedge and, after weighing, it is placed in a pan of water on a brass triangle and submerged just below the surface of the water for one hour. (See fig. 3.) The surface water is then blotted off and the sample immediately weighed. The water-holding capacity is determined on the basis of the dry soil.

MOISTURE EQUIVALENT.

The purpose of the so-called moisture equivalent determination is to obtain a measure of the power of the soil to retain moisture against the action of gravity. In other words, it may be considered as an index of the difficulty which is likely to be encountered in draining the soil by ordinary methods. The term "moisture equivalent" has been defined by Briggs and McLane[1] as the percentage of moisture which is retained by a soil when it is subjected to a centrifugal force equal to 1,000 times the force of gravity. In the preliminary work of the Bureau of Public Roads a centrifuge rotating at a speed of 2,000 revolutions per minute when filled has been used. The centrifugal force produced by this machine is approximately 750 times the force of gravity, so that all the determinations for moisture equivalent which have been made are somewhat higher

[1] U. S. Bureau of Soils Bull. 45.

than the true moisture equivalents of the soil. For purposes of comparison, however, the results serve the useful purpose of indicating the relative degree to which various soils will retain moisture. This determination is made on a 5-gram sample of the soil which has been prepared as previously described. The soil is placed in a Gooch crucible and allowed to take up water by vertical capillarity until saturated. The crucible is then placed in a Babcock cup containing a small rubber stopper to serve as a cushion and provided with a hole sufficiently large to take the water thrown out during centrifuging. The cup is provided with a brass cap to prevent evaporation. An arbitrary limit of one hour has been fixed as the time of centrifuging. This time is not in every case sufficient to throw out the maximum amount of water at the speed used. It is considered to be sufficiently accurate, however, for the work in hand. Moisture equivalents are obtained by weighing the soil after centrifuging, drying to constant weight in an oven at 100° C. and again weighing. The moisture equivalent is the percentage of water, based on the dry weight of the soil, which is retained after centrifuging.

VERTICAL CAPILLARITY.

This determination is made for the purpose of ascertaining the average percentage of water which will be lifted a distance of 20 cm. in a column of dry soil 25 mm. in diameter. It is of value for comparative purposes only and does not necessarily bear any relation either to the total capillary lift of the soil or the maximum percentage of water which it is capable of holding by capillary attraction. A sample of the soil prepared as described is poured loosely into a 25-mm. glass tube and the tube is jarred until a height of 20 cm. has been reached and no further settlement takes place. A piece of cheesecloth is fastened to the lower end of the tube to hold the soil in place. The lower end of the tube is then just immersed in water. When capillary water reaches the top of the soil column the tube is weighed and the amount of water taken up by capillarity thus determined. This weight expressed as the percentage of the dry weight of the soil may be considered as the average percentage of moisture which will be taken up by capillarity under these conditions.

AIR SHRINKAGE.

The maximum contraction in volume which will take place in a given soil when dried in air at ordinary temperatures is of interest in connection with the study of the physical properties of soils. An approximate determination may be made in the following manner: A sample of soil passing the 10-mesh sieve is mixed with a quantity of water approximately equal to its moisture equivalent. The soil is then placed in a small flat cylindrical porcelain dish approximately 6 cm. in diameter and 1 cm. high, struck off level with a small trowel and weighed. The sample is then placed in a desiccator and weighed at frequent intervals until no further loss in weight is recorded. The percentage of the final volume in terms of the original volume is determined by filling the pan containing the dried soil sample with mercury. Knowing the volume of the pan and the volume of the mercury required to fill it

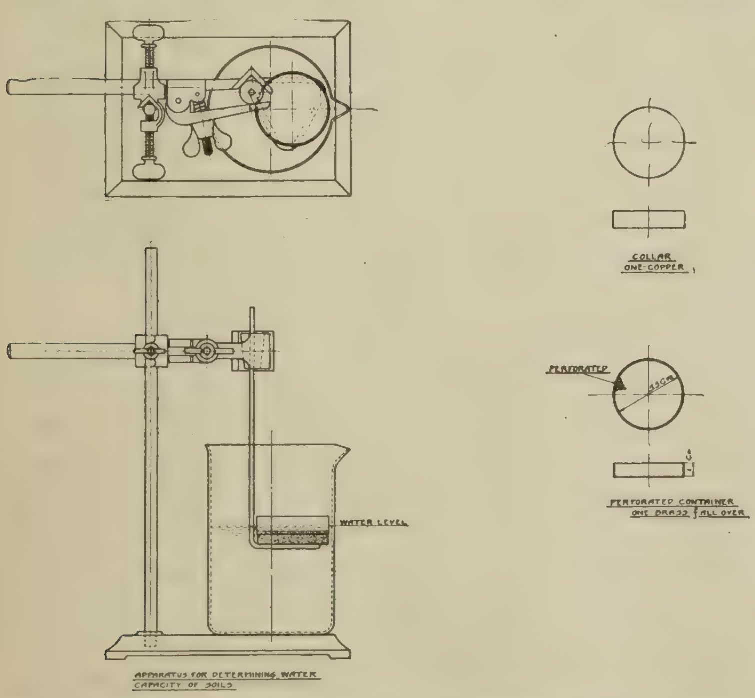


FIG. 3.—APPARATUS FOR DETERMINING WATER-HOLDING CAPACITY OF SOILS.

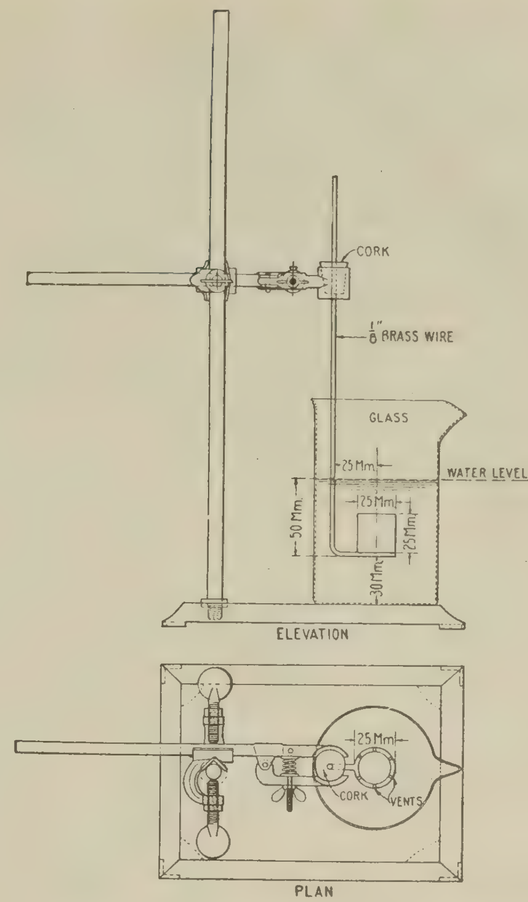


FIG. 4.—APPARATUS FOR DETERMINING SLAKING VALUE.

FIG. 5.—APPARATUS FOR ADSORPTION TEST.

after contraction of the soil has taken place, the percentage of contraction may be calculated. The volume of mercury in the container is controlled by means of a glass plate which is pressed down firmly over the top of the pan, thus squeezing out the excess.

TIME OF SLAKING AND CEMENTING VALUE.

The time required to slake in water may be considered as an indication of the character of the clay content of the soil. The determination is made in the following manner: A mixture consisting of equal parts by weight of soil and powdered quartz both passing a 200-mesh sieve is mixed with 20 per cent water and molded into 25 by 25 mm. briquets under a pressure of 130 kg. per square centimeter. The briquets are then dried in air for 20 hours and in an oven at 100° C. for 4 hours, after which they are cooled 20 minutes in a desicator and tested. For the slaking test the briquet is placed in a brass ring submerged in water, as shown in figure 4, and the time required to slake through the ring is recorded as the slaking time. For the cementing value test the briquets are tested in the Page impact machine in accordance with the method of the Bureau of Public Roads.[2]

[2] Dept. Agr. Bull. 347.

ADSORPTION TEST.

This test has been developed to determine the adsorptive properties of soils for basic aniline dyes as a measure of the colloidal content and plasticity of subgrade road materials. About 20 grams of soil is taken from the sample used in the bearing power test and after passing a 200-mesh screen is brought to constant weight at 100° C. From this sample one-fifth gram is carefully weighed out on a sensitive chemical balance and transferred through a wide neck funnel to a 30 c. c. globe-shaped separatory funnel (fig. 5) containing about 2 c. c. of the dye solution employed in the test. This solution consists of one part per thousand of commercial methyl violet in distilled water, and a convenient quantity should be made up in advance in order to maintain a constant strength during a large number of tests.

The weighed sample is then shaken in the separatory until the dye solution is completely decolorized and the material settles down in a flocculated condition, when it is run into a filtering tube closed at one end with filter paper (fig. 5) and the funnel washed clean with the dye solution and drained into the tube. This tube should measure about 7 inches by one-half inch inside diameter and be drawn at the lower end for a distance of 1 inch to a stem having a one-fourth inch inside diameter and connected by a straight ground-glass joint with a short stopper tube. This tube is required to insert the filter paper (disks three-eighths inch in diameter) snugly in place in the narrow ground-glass stem of the percolator, as well as to assure a uniform rate of flow of the dye solution through the material to be tested, and should be filled with water before beginning the test.

The test consists in determining volumetrically the maximum quantity of dyestuff adsorbed by one-fifth gram of clay and is carried out by allowing the dye solution to percolate slowly through the clay into a 25 c. c. graduate until a faint coloration appears in the liquid passing the filter paper, when the volume of the filtrate is read off (fig. 5). This value multiplied by 5 would indicate the number of cubic centimeters of a 1 : 1,000 dye solution adsorbed per unit weight of clay and may be termed the adsorption number. This number divided by 10 equals the per cent of dye adsorbed.

In the case of soils having exceptionally low adsorption it will be found desirable to increase the test sample to one-half gram. The adsorption number is then obtained by multiplying the volume of decolorized solution by 2. In some few instances where exceptionally plastic clays were encountered a graduate of 50 c. c. capacity was required to collect the decolorized solution, and in one instance 100 c. c. passed a one-fifth gram sample before the end point of the reaction was reached.

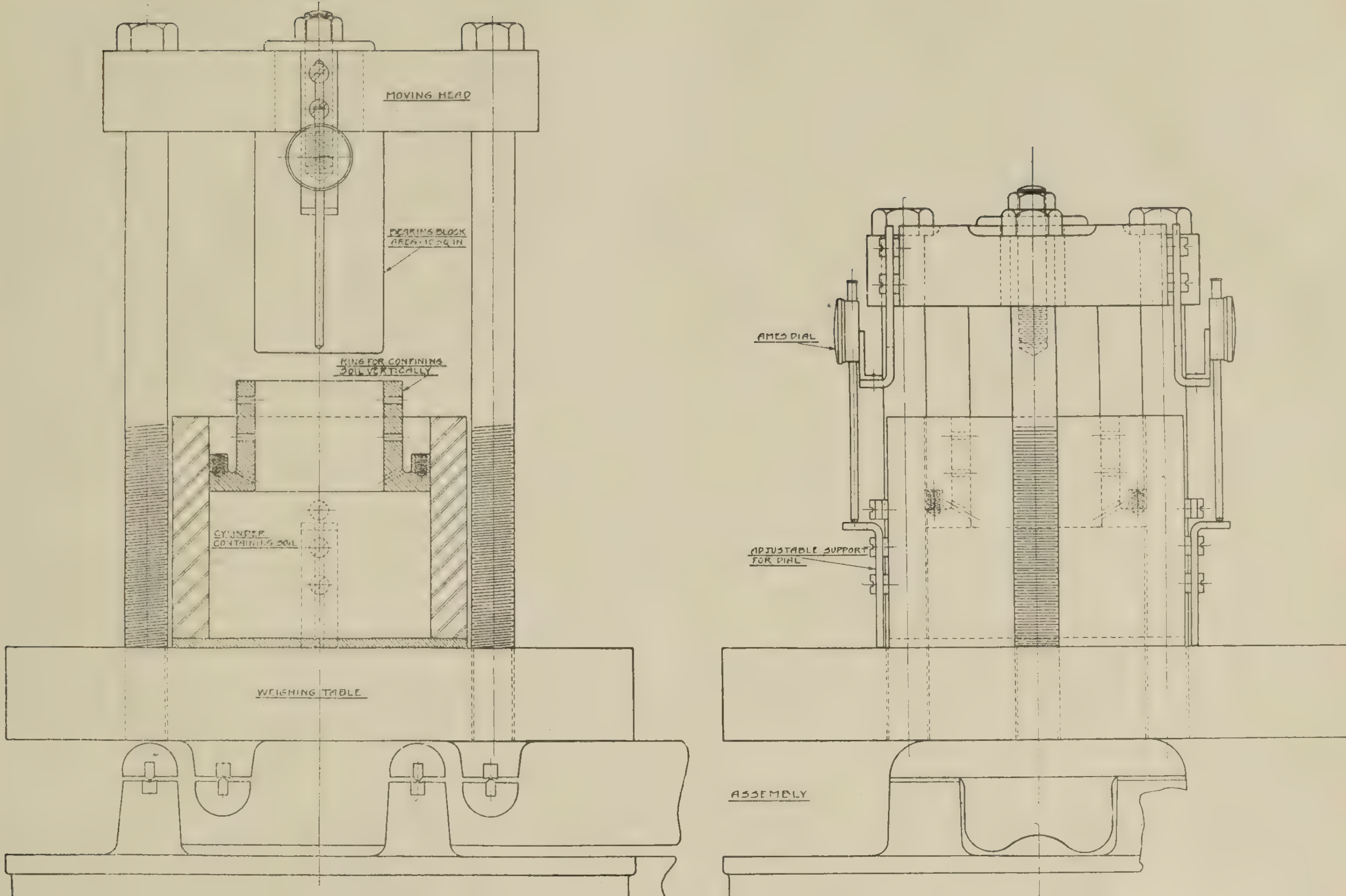


FIG. 6.—APPARATUS FOR DETERMINING COMPARATIVE BEARING VALUE OF SOILS.

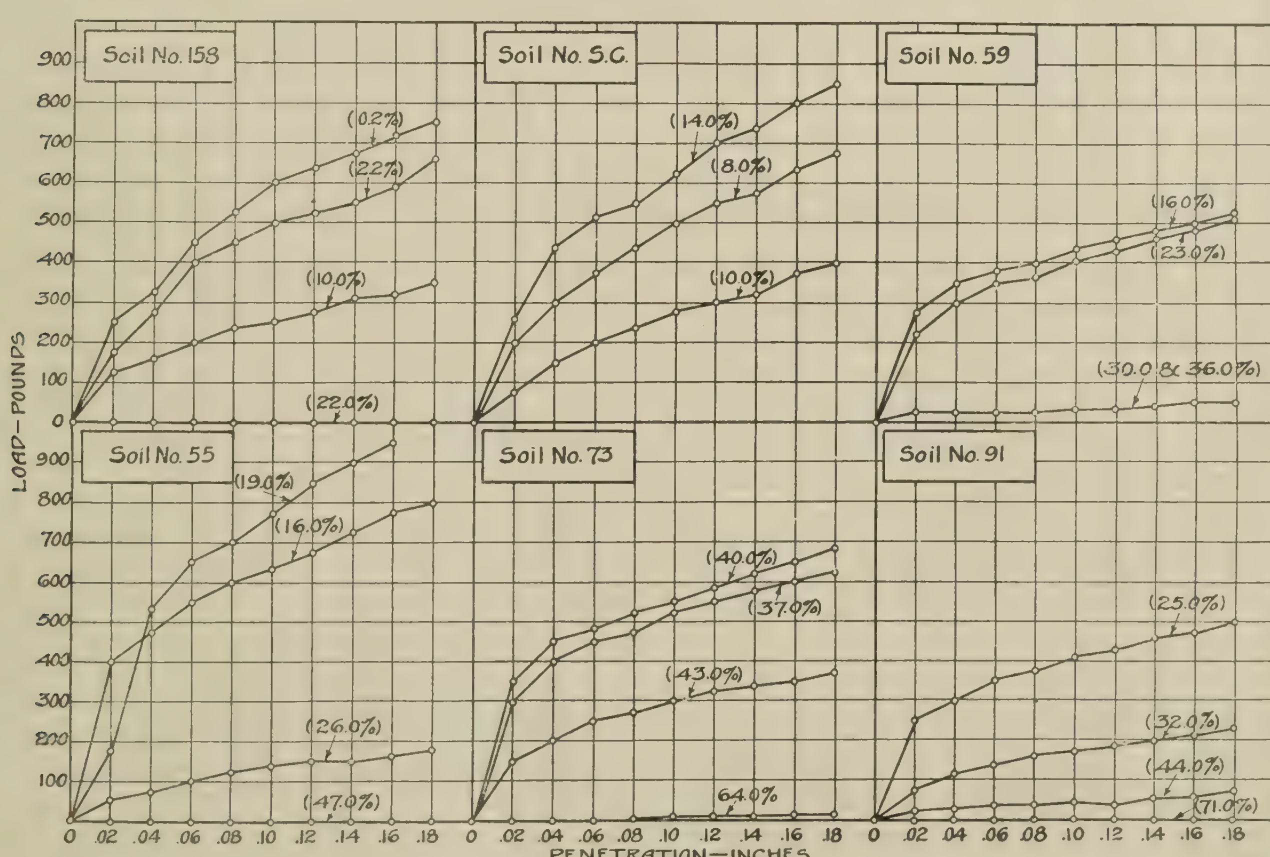


FIG. 7.—RESULTS OF TYPICAL BEARING POWER TESTS.

COMPARATIVE BEARING POWER.

The test which has been developed for determining the comparative bearing power of soils is only of value in so far as it offers a basis of comparison between soils of dissimilar nature. As it is practically impossible to prepare a soil in the laboratory so as to duplicate field conditions, it has been necessary to make the test on samples prepared in an arbitrary way. It is believed, however, that results obtained by this method will assist materially in determining which of the physical properties of the soil are of the most significance in determining its value for use as a subgrade material. The method may be briefly described as follows:

The soil prepared as previously described is mixed by hand with just sufficient water to enable it to be thoroughly kneaded and placed in the mold homogeneously. It is then subjected to an initial pressure of 30 pounds per square inch preparatory to making the bearing-power test. A tight fitting plunger is used for this purpose and is removed after the proper compression has been obtained. The apparatus for making the bearing-power test consists essentially of a brass cylinder (area 10 square inches) securely fastened to the moving head of a 20,000-pound Universal testing machine, a brass ring for confining the soil vertically and insuring perpendicular application of the load and two 0.001-inch Ames dials so mounted as to measure the penetration of the brass cylinder with respect to the cylinder containing the soil. A drawing of the apparatus is shown in figure 6.

Having subjected the soil to the initial pressure desired, the confining ring is clamped in position so as to just touch the soil. The apparatus is then lined up and the head of the machine run down until the brass cylinder is approximately one-eighth of an inch above the level of the soil. The two Ames dials are then adjusted to bear on the supports which are fastened to the cylinder containing the soil. The head of the machine is now run down at its slowest speed, care being taken to note the instant at which load is indicated by the weighing beam. Simultaneous readings of the dials and load are then taken at increments of 0.005-inch penetration up to 0.05 inch and at increments of 0.01 inch from 0.05 inch up to 0.2 inch. This completes the bearing-power test for the minimum moisture content and initial compression at 30 pounds per square inch. The soil is then removed from the cylinder, thoroughly kneaded by hand, subjected to 50 pounds initial compression and the bearing-power test made in the above-described manner. From the results obtained curves may be plotted showing the comparative bearing power of different soils for different conditions of moisture and initial compression applied. The weight of the soil and its volume before and after compression is also noted and from this information, and the specific gravity of the soil, values for density under different conditions of moisture and initial compression are computed.

Table I.—TYPICAL RESULTS OF TESTS OF SUBGRADE SOILS.

Sample No.	Locality.	Moisture equivalent.	Per cent moisture by capillarity.	Water capacity.	Mechanical analysis. Sand—Per cent between— 10–20	20–50	50–100	100–200	Per cent silt.	Per cent clay.[1]	Cementing value.	Time of slacking.	Adsorption number.	Bearing power—Load in pounds at 0.1-inch penetration. (1) Per cent water.	(1) Load.	(2) Per cent water.	(2) Load.	(3) Per cent water.	(3) Load.	(4) Per cent water.	(4) Load.
158	Maryland	2	10	22	27	51	16	3	1	2	......	......	......	2	600	2	500	10	250	22	0
29	California	9	34	30	1	41	23	13	13	9	33	6	50	......	......	......	......	......	......	......	......
S.C.	Maryland	10	16	......	19	45	7	3	6	19	14	4	......	4	625	8	500	10	275	......	......
80	Oregon	17	26	41	4	9	9	14	34	30	64	17	45	15	548	17	466	26	34	28	20
56	Missouri	19	33	47	1	3	3	3	69	21	......	......	25	14	420	19	440	33	0	......	......
55	Missouri	19	27	47	3	8	4	4	55	26	82	8	......	16	635	19	780	26	135	47	0
140	Ohio	20	33	44	5	11	5	6	47	26	11	180	......	13	495	20	285	33	0	......	......
9	Pennsylvania	20	29	......	......	1	1	1	58	39	9	4	10	11	445	20	440	29	25	......	......
51	Iowa	22	28	50	5	15	11	12	29	28	134	10	......	18	590	22	245	28	45	50	0
59	Illinois	23	30	55	......	3	5	3	63	26	358	11	80	16	440	23	407	30	35	36	35
50	Iowa	23	36	55	1	8	7	6	44	34	93	8	45	20	565	23	480	36	70	53	0
33	Minnesota	25	33	76	1	2	2	1	59	35	64	4	180	20	415	25	230	33	30	69	0
62	Illinois	25	30	53	5	17	8	6	24	40	132	14	55	22	530	25	440	30	225	52	0
63	Illinois	25	25	63	1	4	4	2	58	31	144	7	55	20	580	25	530	29	205	41	20
61	Illinois	26	32	56	1	11	7	5	18	58	46	31	75	22	500	26	515	32	200	43	20
70	Oregon	26	29	54	1	6	4	2	44	43	29	5	45	21	565	26	148	29	83	35	11
78	Oregon	26	31	50	2	15	17	21	28	18	51	6	45	20	525	27	465	31	329	43	30
89	California	29	42	......	......	......	......	......	......	......	470	13	......	18	713	22	686	29	205	39	68
67	Oregon	32	36	75	2	6	6	11	42	33	174	7	130	23	470	28	440	33	212	41	50
82	Oregon	33	33	55	......	2	2	4	55	37	63	6	60	24	540	32	110	39	45	41	15
91	California	34	44	71	2	2	4	15	38	38	370	10	10	25	410	34	175	44	45	71	0
73	Oregon	41	43	75	......	4	8	10	21	57	273	20	140	37	525	40	540	43	300	64	10

[1] The term "clay" as used in this table refers to the fraction removed by 8-minute sedimentation. It is in reality a mixture of very fine silt and clay.

DISCUSSION OF RESULTS OBTAINED.

Practically all of the time which it has been possible for the laboratory to devote to this subject has so far been taken up in studying suitable methods of testing. This applies particularly to the problem of designing a satisfactory laboratory test for bearing power. Then, too, the problem of properly preparing samples for test has given some trouble. It has not been possible, therefore, to take up as yet a systematic study of actual subgrade soils, although the tests outlined above have been made on quite a number of such materials. No attempt will be made, therefore, at this time to go into a detailed discussion of results, the purpose of the paper being rather to describe methods of testing. For the purpose of showing the general range in values which have been obtained a series of results for typical soils from various parts of the country is shown in Table I. In this table the relative bearing power of the soils is given as the load in pounds required to produce a penetration of 0.1 inch under the conditions of the test and with an initial compression of 50 pounds per square inch. Values for bearing value are given for four moisture conditions: (1) The minimum amount of water which can be worked into the soil, (2) the moisture equivalent, (3) the moisture determined by vertical capillarity, and (4) the maximum amount of water which can be worked into the soil.

The determination which apparently yields the greatest amount of information is the test for moisture equivalent. As has been noted, this test is supposed to be an indication of the moisture retentiveness of a soil. Results of tests so far would indicate that, in general, moisture equivalents increase with the percentage of very fine silt and clay in the soil. It has been possible, in fact, to work out an empirical formula which indicates a fairly definite relation between the moisture equivalent and mechanical analysis. There are sufficient exceptions, however, to indicate that certain other factors, possibly percentage of loam, etc., influence this relation.

Results of the tests would indicate also that the bearing power of most soils is not appreciably reduced by the addition of moisture up to the moisture equivalent. This apparently applies, moreover, to all types of soils from pure sand to heavy clays. When the soils become saturated beyond the moisture equivalent, however, a rapid reduction apparently takes place in bearing power, which usually disappears completely at or before the water-holding capacity of the soil has been reached. These general comments are given here simply to indicate possible existing relations and are in no sense definite conclusions, which manifestly can not be drawn without much additional study.

For purposes of illustration, the results of a number of typical bearing-power tests have been plotted in figure 7. These tests indicate in a general way the range in values obtained, as well as the influence of moisture on the bearing power.

In conclusion, the authors would emphasize the fact that the study of subgrade soils is a very important subject, upon the successful conclusion of which is involved economy in road construction. It seems apparent that much time and thought will be required before definite conclusions can be drawn. The authors present the above outline of test methods in the hope that others may be induced to take up the subject, devoting to it the time and attention warranted by its importance.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN MAY, 1921.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Alabama	24	Walker	9.590	Chert and gravel	May 24	$147,804.52	$73,902.26
	64	Pike	[1] 3.674	Sand-clay and gravel	May 5	[1] 52,065.75	[1] 26,032.88
	99	Shelby	23.090	Chert base, slag, asphalt wearing surface	May 24	529,484.67	264,742.33
Kansas	14	Ford	[2] 11.000	Brick	May 13	[2] 386,848.66	[2] 58,027.30
	63	Neosho	[2] 5.000	Gravel	May 9	[2] 95,342.50	[2] 47,671.25
	64	do	[2] 5.500	do	do	[2] 120,254.75	[2] 60,127.37
	78	Anderson	8.867	Earth	May 20	76,252.00	26,601.00
Maine	37	Franklin	2.560	Gravel	do	44,778.25	22,389.12
	38	Waldo	3.230	do	do	81,669.50	40,834.75
	41	Aroostook	3.959	Gravel surface, stone, and gravel foundation	do	68,178.00	34,089.00
Massacuesetts	56	Norfolk	2.141	Reinforced concrete	May 24	132,396.48	42,820.00
	57	Middlesex	3.042	Bituminous macadam	do	157,300.00	60,840.00
Mississippi	52	Oktibbeha	8.060	Gravel	May 20	89,551.00	44,775.50
Nebraska	170	Lincoln	26.400	do	May 24	91,998.72	45,999.36
	171	Fillmore and Clay	20.900	Earth	do	79,827.00	39,913.50
	172	Cuming	13.700	Earth and gravel	do	74,636.76	37,318.38
New York	123	Albany	3.530	Concrete	May 31	136,200.00	68,100.00
	125	Cortland	3.700	Bituminous macadam or concrete	May 14	178,600.00	73,910.00
North Carolina	115	Henderson	[2] 10.000	Sand-clay, shale, or gravel	May 26	[2] 100,903.20	[2] 50,451.60
Ohio	207	Licking	4.051	Concrete	May 31	250,000.00	58,800.00
Pennsylvania	99	Bucks	3.022	Reinforced concrete	May 12	238,504.86	60,440.00
Texas	243	Kerr	31.850	Gravel macadam	May 31	270,111.32	100,000.00
Virginia	38	Accomac	[1] 3.910	Bituminous macadam	May 28	[1] 223,121.25	[1] 111,560.62
	98	Charlotte and Halifax	14.600	Soil	do	104,857.50	52,428.75
	113	Fairfax	11.310	Bituminous macadam	May 12	357,362.50	178,681.25
	116	Surry	12.880	Soil	May 31	104,967.50	52,483.75
	121	Southampton	6.510	Concrete	do	239,818.83	119,909.41
Wisconsin	24	Jackson	[3] 1.660	do	May 5	[3] 66,353.55	[3] 22,116.80
	189	Chippewa	6.010	Earth	May 31	27,647.21	10,000.00
	190	do	2.810	do	May 28	20,282.05	9,000.00
	211	Grant	4.790	do	do	72,586.25	30,000.00
	217	Juneau	1.004	Gravel	May 26	45,934.24	20,000.00
	224	Marathon	13.900	Gravel or disintegrated granite	May 28	189,262.70	70,000.00
	228	Marquette	3.100	Gravel	do	26,824.90	6,966.69
	229	Monroe	3.760	Shale surfacing, earth	May 31	40,000.00	10,272.81
	244	Sawyer	5.180	Earth	do	28,376.81	11,000.00
	249	Vernon	1.880	do	do	30,000.00	7,500.00
	253	Waushara	6.530	Gravel	May 28	65,847.32	24,000.00
Wyoming	74	Converse	10.303	do	May 20	54,780.00	27,390.00
	89	Natrona	6.995	Selected material	do	58,465.00	29,232.50

[1] Revised statement. Amounts given are decreases over those in the original statement.
[2] Withdrawn.
[3] Revised statement. Amounts given are increases over those in the original statement.

STATUS OF FEDERAL AID, MAY 31.

FEDERAL-AID projects totalling 806 miles in length were placed under construction during the month of May and 543 miles were completed during the month, bringing the total length of projects under construction and completed to date up to 24,016 miles.

The Federal aid earned by the States on work completed during the month brings the total earned up to $111,164,021, of which $74,860,930 has been paid. This represents an increase over the figures for April 30 of $8,242,365 in amount earned and of $3,658,260 in amount paid.

The new contracts placed during the month call for $5,768,567 of Federal aid, leaving a balance of $95,129,774 available for new contracts. On April 30 there were 17,529 miles under construction which were reported as 50 per cent complete, and on May 31 there are 17,792 miles under construction which the district engineers report as 53 per cent complete.

At the end of April one State—Delaware—had taken up its entire apportionment of Federal aid in projects which had been placed under contract. During May one more State—Oregon—has crossed the line and now has no money standing to its credit for new contracts. Notable advances in amount of work under contract were made by Arkansas, Colorado, Georgia, Illinois, Iowa, Kansas, Kentucky, Missouri, Nebraska, New Jersey, New York, North Dakota, Oklahoma, Oregon, South Carolina, South Dakota, Tennessee, Texas, and Wisconsin, each o which placed under contract projects calling for from $100,000 to upwards of half a million dollars. New York contracted for a larger amount than any other State during the month, its new projects involving $701,585.

TABLE 1.—*Financial statement as of May 31, 1921.*

State.	Total apportionment of Federal aid.	Federal aid in work under construction and completed.[1]	Federal aid available for new contracts.	Federal aid in completed work.[2]	Federal aid in uncompleted work on projects under construction.	Amounts Federal aid paid States.	Balance Federal aid earned by States.
Alabama	$5,776,552	[3] $1,834,337	$3,942,215	$1,535,465	$298,872	$1,318,879	$216,586
Arizona	3,771,351	3,036,772	734,579	2,248,219	788,553	1,101,887	1,146,332
Arkansas	4,619,929	3,330,409	1,289,520	1,874,865	1,455,544	870,734	1,004,131
California	8,384,354	3,526,736	4,857,618	2,875,325	651,411	1,883,385	991,940
Colorado	4,780,064	2,488,400	2,291,664	1,566,965	921,435	1,262,171	304,794
Connecticut	1,689,324	981,823	707,501	313,070	668,753	168,647	144,423
Delaware	447,655	447,655	....	399,055	48,600	331,366	67,689
Florida	3,150,112	2,605,601	544,511	1,231,753	1,373,848	391,379	840,374
Georgia	7,407,579	6,920,900	486,679	4,997,898	1,923,002	3,876,068	1,121,830
Idaho	3,360,389	[4] 3,033,963	326,426	2,260,393	773,570	1,469,682	790,711
Illinois	12,024,267	11,736,133	288,134	9,416,405	2,319,728	6,559,319	2,857,086
Indiana	7,415,293	2,695,235	4,720,058	1,398,179	1,297,056	978,058	420,121
Iowa	7,939,343	6,776,534	1,162,809	3,781,809	2,994,725	1,531,780	2,250,029
Kansas	7,895,309	5,074,697	2,820,612	2,803,183	2,271,514	1,537,493	1,265,690
Kentucky	5,370,065	3,150,191	2,219,874	1,685,835	1,464,356	1,108,149	577,686
Louisiana	3,742,525	3,730,264	12,261	2,530,478	1,199,786	1,678,020	852,458
Maine	2,645,964	1,506,822	1,139,142	884,573	622,249	501,789	382,784
Maryland	2,390,749	2,064,166	326,583	[3] 1,700,421	363,745	1,414,256	286,165
Massachusetts	4,052,565	1,966,713	2,085,852	1,244,502	722,211	953,095	291,407
Michigan	7,961,296	[3] 4,367,839	3,593,457	2,502,280	1,865,559	1,458,963	1,043,317
Minnesota	7,815,383	[3] 6,799,534	1,015,849	4,886,905	1,912,629	4,297,822	589,083
Mississippi	4,951,542	2,169,341	2,782,201	1,289,757	879,584	928,681	361,076
Missouri	9,322,076	4,788,259	4,533,817	1,945,543	2,842,716	664,471	1,281,072
Montana	5,498,827	3,326,196	2,172,631	2,397,699	928,497	1,728,356	669,343
Nebraska	5,866,762	3,358,249	2,508,513	3,048,016	310,233	2,092,574	955,442
Nevada	3,527,276	1,258,384	2,268,892	1,010,040	248,344	774,155	235,885
New Hampshire	1,143,089	917,327	225,762	806,833	110,494	780,379	26,454
New Jersey	3,265,299	1,660,564	1,604,735	1,167,495	493,069	856,626	310,869
New Mexico	4,389,795	2,082,883	2,306,912	1,391,323	691,560	1,022,960	368,363
New York	13,688,802	2,768,423	10,920,379	377,121	2,391,302	213,827	163,294
North Carolina	6,270,691	5,818,571	452,120	3,934,348	1,884,223	2,719,240	1,215,108
North Dakota	4,222,488	1,964,838	2,257,650	1,364,679	600,159	809,294	555,385
Ohio	10,202,948	5,411,739	4,791,209	3,497,383	1,914,356	2,750,387	746,996
Oklahoma	6,338,246	3,488,408	2,849,838	1,441,526	2,046,882	555,663	885,863
Oregon	4,332,178	4,332,178	....	3,222,167	1,110,011	2,428,254	793,913
Pennsylvania	12,632,644	10,767,327	1,865,317	7,853,975	2,913,352	5,951,688	1,902,287
Rhode Island	641,166	450,081	191,085	301,584	148,497	265,050	36,534
South Carolina	3,946,618	2,231,148	1,715,470	1,645,278	585,870	1,141,294	503,984
South Dakota	4,452,883	3,099,352	1,353,531	1,588,030	1,511,322	903,454	684,576
Tennessee	6,228,138	4,624,051	1,604,087	1,451,352	3,172,699	455,761	995,591
Texas	16,100,405	10,201,638	5,898,767	6,210,168	3,991,470	3,188,358	3,021,810
Utah	3,117,206	[5] 1,817,919	1,299,287	960,039	857,880	464,344	495,695
Vermont	1,242,104	561,203	680,901	269,408	291,795	184,169	85,239
Virginia	5,451,730	2,934,837	2,516,893	[3] 2,129,293	805,544	1,166,117	963,176
Washington	3,971,676	3,908,189	63,487	3,661,833	246,356	3,378,033	283,800
West Virginia	2,922,504	2,902,504	20,000	1,777,455	1,125,049	1,390,845	386,610
Wisconsin	7,004,281	3,978,575	3,025,706	2,410,886	1,567,689	1,845,327	565,559
Wyoming	3,378,558	2,723,318	655,240	1,873,212	850,106	1,508,681	364,531
Total	266,750,000	171,620,226	95,129,774	111,164,021	60,456,205	74,860,930	36,303,091

[1] Includes projects entirely completed and paid for.
[2] Includes completed portions of projects under construction.
[3] Changes due to final adjustments.
[4] Changes due to projects withdrawn.
[5] Changes due to agreements amended.

TABLE 2.—*Status of construction work, May 31, 1921.*

State.	Projects under construction.					Projects on which construction is completed.		
	Total estimated cost.	Federal aid.	Miles.	Per cent complete.	Federal aid earned.	Total estimated cost.	Federal aid.	Miles.
Alabama	$1,239,634	$595,992	95	50	$297,120	$2,524,645	[3] $1,238,345	288
Arizona	4,108,545	1,833,845	197	57	1,045,292	2,459,600	1,202,927	126
Arkansas	10,245,304	3,164,226	875	54	1,708,682	413,096	166,183	67
California	3,525,149	1,760,569	157	63	1,109,158	3,612,392	1,766,167	198
Colorado	3,692,562	1,806,735	246	49	885,300	1,385,853	681,665	103
Connecticut	2,433,932	928,823	51	28	260,070	120,232	53,000	5
Delaware	210,143	54,000	6	10	5,400	[3] 1,694,315	393,655	28
Florida	5,275,301	2,497,906	138	45	1,124,058	215,389	107,695	27
Georgia	10,056,467	4,472,097	838	57	2,549,095	5,289,883	2,448,803	270
Idaho	5,039,616	[1] 2,344,153	277	67	1,570,583	1,397,135	689,810	149
Illinois	13,577,171	5,799,321	381	60	3,479,593	12,139,779	5,936,812	365
Indiana	4,971,694	2,447,276	137	47	1,150,220	505,752	247,959	13
Iowa	15,180,234	6,111,684	958	51	3,116,959	1,616,040	664,850	168
Kansas	15,349,970	4,285,875	386	47	2,014,361	2,060,470	788,822	65
Kentucky	5,824,622	2,816,070	254	48	1,351,714	711,405	334,121	28
Louisiana	7,241,381	2,999,464	555	60	1,799,678	1,521,931	730,800	150
Maine	2,687,892	1,296,352	74	52	674,103	420,942	210,470	19
Maryland	1,544,402	686,312	53	47	322,567	2,814,404	1,377,854	103
Massachusetts	2,973,583	1,362,662	81	47	640,451	1,272,356	604,051	47
Michigan	7,467,101	[2] 3,519,923	272	47	1,654,364	1,739,805	847,916	99
Minnesota	12,575,564	4,904,177	1,125	61	2,991,548	4,379,600	1,895,357	607
Mississippi	4,173,472	1,759,168	334	50	879,584	842,255	410,173	113
Missouri	10,383,130	4,660,190	595	39	1,817,474	332,659	[3] 128,069	30
Montana	4,710,337	[2] 2,264,628	486	59	1,336,131	2,197,523	[2] 1,061,568	149
Nebraska	6,271,344	3,102,327	1,200	90	2,792,094	717,046	255,922	73
Nevada	1,989,340	993,375	112	75	745,031	540,559	265,009	79
New Hampshire	581,552	290,774	37	62	180,280	1,258,068	626,553	85
New Jersey	2,828,140	880,480	50	44	387,411	1,758,690	780,084	45
New Mexico	2,881,499	1,440,750	347	52	749,190	1,284,266	642,133	131
New York	6,129,178	2,627,804	140	9	236,502	281,237	140,619	10
North Carolina	9,359,429	4,486,246	681	58	2,602,023	3,030,146	1,332,325	234
North Dakota	3,637,491	1,818,663	601	67	1,218,504	292,353	146,175	122
Ohio	12,412,716	4,073,097	336	53	2,158,741	[3] 3,817,284	1,338,642	138
Oklahoma	6,920,467	3,249,019	218	37	1,202,137	488,425	239,389	13
Oregon	6,305,775	3,054,316	298	62	1,944,305	2,572,838	1,277,862	190
Pennsylvania	19,726,145	7,105,737	351	59	4,192,385	8,245,870	3,661,590	200
Rhode Island	723,477	296,995	17	50	148,498	308,404	153,086	10
South Carolina	3,909,667	1,673,914	383	65	1,088,044	1,199,357	557,234	104
South Dakota	6,476,258	2,698,790	620	44	1,187,468	801,130	400,562	94
Tennessee	9,198,089	4,598,114	376	31	1,425,415	54,738	25,937	2
Texas	22,427,762	8,677,108	1,696	54	4,685,638	3,877,633	1,524,530	537
Utah	3,574,518	[1,2] 1,787,249	253	52	929,369	61,340	30,670	9
Vermont	941,276	470,637	37	38	178,842	181,131	90,566	10
Virginia	3,582,039	[3] 1,790,098	161	55	984,554	2,334,736	1,144,739	173
Washington	5,444,781	1,175,919	93	79	929,563	5,750,083	2,732,270	267
West Virginia	5,574,890	2,445,759	279	54	1,320,710	980,044	456,745	41
Wisconsin	8,544,353	3,073,900	542	49	1,506,211	2,720,894	904,675	233
Wyoming	4,569,779	2,179,758	393	61	1,329,652	1,088,454	543,560	207
Total	307,497,171	128,362,277	17,792	53	67,906,072	95,312,187	43,257,949	6,224

[1] Changes due to withdrawal of projects and addition of others. [2] Changes due to agreements amended. [3] Changes due to final estimate adjustments.

(Continued from page 9.)

increasing, thus decreasing the average yearly mileage made by each motor vehicle, and the use of roads other than the State highways is increasing. All of these conditions combine to retard the increase of traffic upon the main roads of the State.

In conclusion it may be stated that there is no reasonable expectation that our main roads, comprising the State highway systems, when completed and carrying their full quota of the traffic, will be called upon to carry, on the average, many in excess of 500 vehicles per day throughout the year, and that a highway paved for a width sufficient to accommodate two lanes of traffic will suffice for many years to come. It is not to be concluded that there are no sections of highways that will not require more than two traffic lanes, but the mileage of such roads is and will continue to be but a small fraction even of the restricted mileage of the State highway systems. Highway plans contemplating an extended system of highways of greater width than is required for two lanes of traffic are extravagant and have no economic basis.

(Continued from page 14.)

As a part of the organization the county maintains a garage and repair shop for keeping trucks and other equipment in good repair. This shop is in charge of a mechanic, steadily employed at a salary of $150 per month, who assists and instructs the patrolmen in making repairs to their equipment. The patrolmen are required to do most of this work themselves in order to familiarize them with their machines, as it is believed that the driver of a truck will have fewer breakdowns if he knows how it is made.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1917. 6c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.
Report of the Chief of the Bureau of Public Roads for 1920.

DEPARTMENT BULLETINS.

Dept. Bul. *105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
*230. Oil Mixed Portland Cement Concrete. 10c.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
*373. Brick Roads. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A Summary.
*393. Economic Surveys of County Highway Improvement. 35c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
*660. Highway Cost Keeping. 10c.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
*724. Drainage Methods and Foundations for County Roads. 20c.

*Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. *338. Macadam Roads. 5c.
505. Benefits of Improved Roads.
597. The Road Drag.

*Department supply exhausted.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. Design of Public Roads.
739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. *89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington, D. C. 5c.

Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918. 15c.
*Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918. 15c.
Vol. III, No. 25. Automobile Registrations, Licenses, and Revenues in the United States, 1919.
Vol. III, No. 29. State Highway mileage, 1919.
Vol. III, No. 36. Automobile Registrations, Licenses, and Revenues in the United States, 1920.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D–2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D–3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D–4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D–6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D–8. Tests of Three Large-Sized Reinforced-Concrete Slabs under Concentrated Loading.
Vol. 10, No. 7, D–13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D–15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D–16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

*Department supply exhausted.