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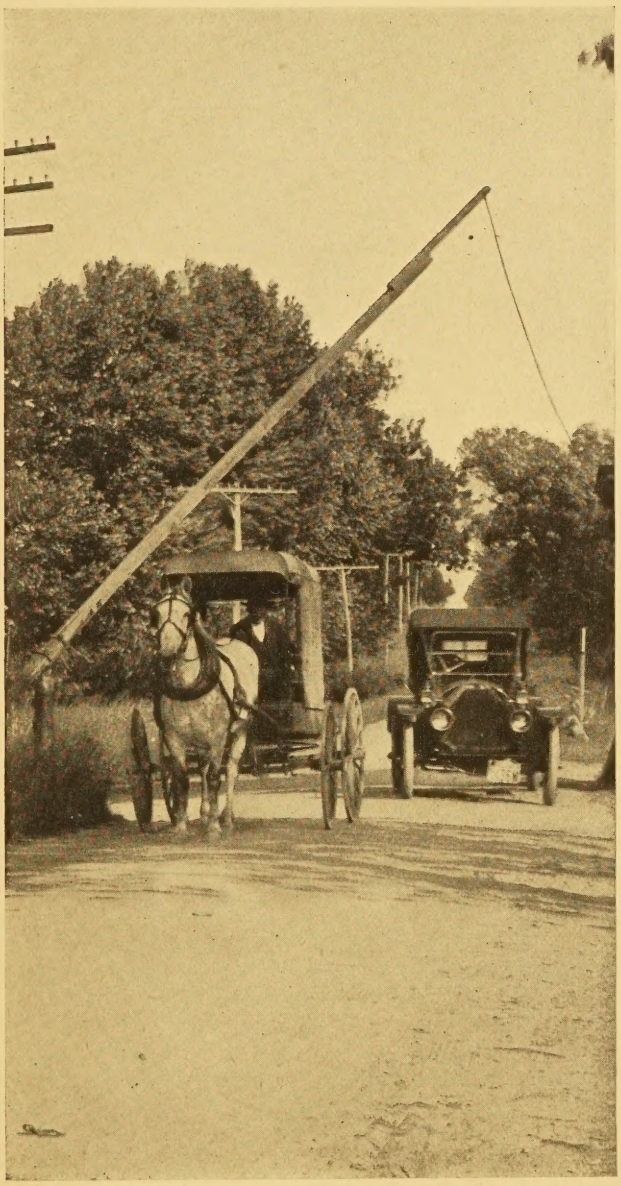

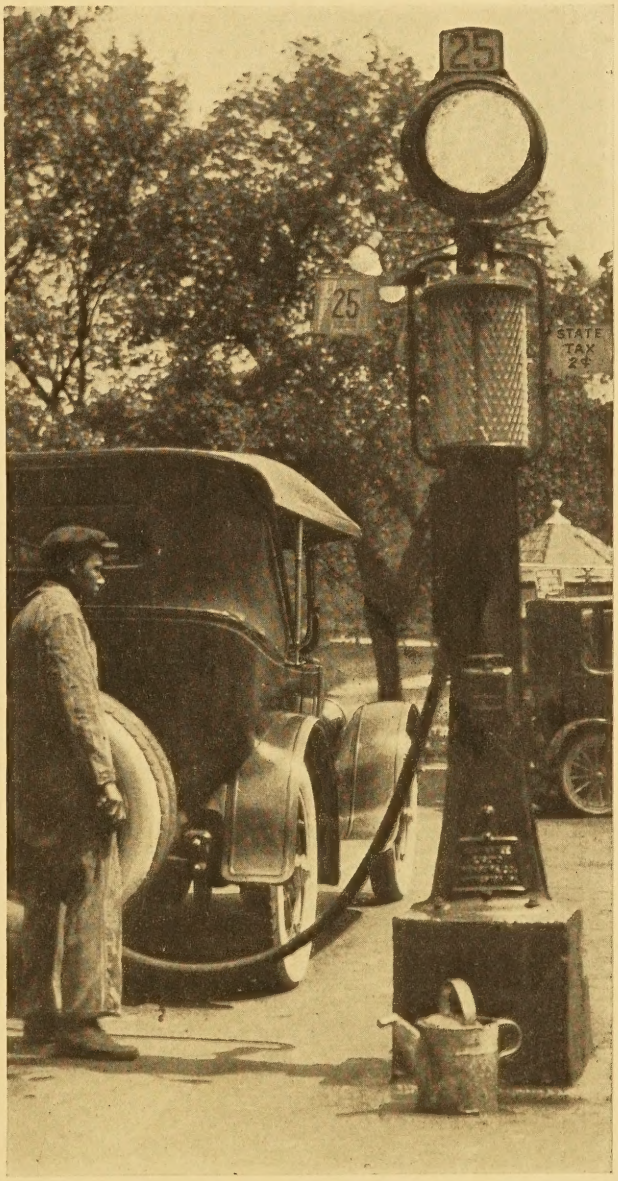

THE OLD WAY TOLL - AND THE NEW

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THE INCIDENCE OF THE HIGHWAY TAX BURDEN

By HENRY R. TRUMBOWER, Economist, U. S. Bureau of Public Roads

THE TOTAL income for all rural highway purposes in 1921 was $1,149,437,896, according to a survey of rural highway mileage, funds and expenditures in each of the 48 States made by the United States Bureau of Public Roads. This amounts to a per capita contribution on the part of the people of the United States of $10.90, based upon the population figures of the 1920 census. The highway income was derived from a number of sources and can not be considered as having been levied as a uniform burden upon the taxpayers and public in general.

That there is a marked tendency to collect a larger proportion of highway funds from the owners and users of motor vehicles is noted in analyzing the various sources of these highway funds and comparing them with similar sources in previous years. A survey of highway revenues and expenditures made in 1914 showed that, out of a total highway income of $240,262,784, the collections from motor vehicles amounted to $12,382,031, or 5.1 per cent of the total. In 1921, seven years later, the motor vehicle owners and operators paid $118,942,706 in motor-vehicle fees and $3,685,460 in gasoline taxes, a total of $122,626,166, or 10.6 per cent of the total income for highway purposes. A similar compilation of the payments made by owners and operators of motor vehicles for licenses and permits in 1923 shows a total contribution on their part of $188,970,992. In the same year the taxes upon the sale of gasoline levied by 35 States amounted to $36,813,939. The motor vehicles, accordingly, contributed a total of $225,784,931.

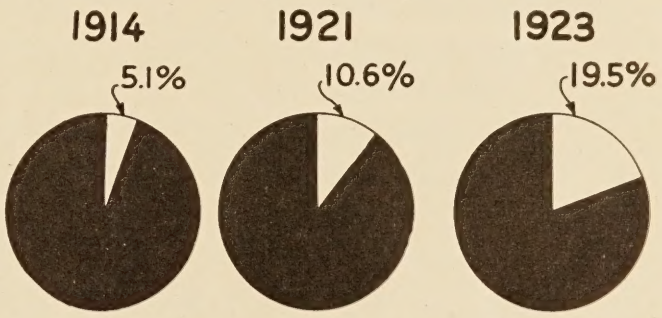
It is estimated that the highway income and expenditures for 1923, based upon facts and information thus far obtained, were substantially the same as for 1921. It follows, therefore, that in 1923 the contribution of the motor vehicle towards the total highway income was about 19.5 per cent. This shows a very substantial increase in the relationship of motor-vehicle revenues to the total highway income, as compared with 1914, when it was only 5.1 per cent. Between 1921 and 1923, it is observed, the ratio almost doubled. This increase in the contribution made by the motor vehicle is accounted for by the increase in the total number of vehicles registered and in the payment per vehicle, which rose from $11.70 in 1921 to $15 per vehicle in 1923.

Another very substantial part of the total highway income was derived from the sale of bonds, both State and local; $438,109,273, or 38.1 per cent, was obtained in this manner. This amount, which represents a deferred payment of $4.15 per capita, includes all receipts from the sale of highway bonds during 1921 and all cash from previous bond sales on hand at the beginning of the year. At the end of the year the total amount of State and local bonds outstanding was $1,222,312,300, a per capita issue of $11.50, or slightly more than the total of a single year's income. The interest on this amount and the requisite provision for retirement constitute a current obligation which must be paid in addition to the costs of highway construction and maintenance from the highway revenues. The Census Bureau reports at the end of 1922 a total indebtedness of $8,695,906,000 for the country as a whole, including State, county, local, and municipal indebtedness. The highway bonds amount to about 14 per cent of this total indebtedness.

The income for all rural road purposes includes also payments to the different States by the Federal Government amounting to $79,333,226 made in accordance with the provisions of the Federal-aid act, a contribution on the part of the Government which amounts to an assessment of approximately 75 cents per capita.

LESS THAN ONE-HALF OF HIGHWAY INCOME RAISED BY PROPERTY TAXES

General property taxes contributed $415,680,010 to the year's total highway income. In addition, $93,689,221 was derived from other sources, a large part of which amount consisted of appropriations from funds in the respective State treasuries, which in turn had their sources in tax levies. For our present purposes we may consider both of these items as having been payments made by the general public and may therefore be regarded as taxes although a small portion was derived from other sources which could not be clearly segregated. The sum of these two items, $509,369,231 or 44.4 per cent of the total highway income is regarded in this analysis as the direct contribution of the public towards the cost of highway construction and maintenance and towards the principal and interest payments of the bonds outstanding. The per capita tax burden for highway purposes is, therefore, $4.83. The total highway income for 1921 is divided and allocated as follows:



Ratio of motor-vehicle revenues to total highway income in 1914, 1921, and 1923

Total highway income, 1921

Source	Amount	Per capita
Motor vehicles	$122, 626, 166	$1. 17
Bonds	438, 109, 273	4. 15
Federal aid	79, 333, 226	.75
General property taxes and other sources	509, 369, 231	4. 83
Total	1, 149, 437, 896	10. 90

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The Census Bureau in a recent publication reports that in 1922 the revenues of all the States for governmental purposes were $4,224,541,865. This includes general property taxes, special taxes, poll taxes, licenses, permits, and special assessments collected by the States and by all of their political subdivisions. It is not unfair to assume that the public revenues for 1921 were approximately the same as those reported for the subsequent year and the following comparison is made on that basis. In deducting from the year's total public revenues, $122,626,166 collected as motor-vehicle license fees and gasoline taxes, there is left $4,101,915,699 as the amount received from other sources or a contribution for governmental purposes of $38.80 per capita. Of this total amount, exclusive of motor-vehicle revenues, $509,369,231 was collected from the public for highway purposes of $4.83 per capita. It follows, therefore, that of every dollar collected by the States, counties, cities, townships, and other taxing districts only 12.4 cents was used for highway purposes.

ONE-QUARTER OF NEW ENGLAND ROAD BILL PAID BY VEHICLE OWNERS

On account of the wide variations which exist in different parts of the country as to density of population, road mileage, character of road construction, amount of highway traffic, etc., it is essential in order to make worth while comparisons to make an examination of the incidence of these highway costs in the different groups of States.[1] In the six states comprising the New England division the total highway income was $46,455,284 in 1921, or $6.25 per capita. Of this amount $11,629,091 or 25.1 per cent, consisted of license fees contributed by the motor vehicle. The revenues derived from the sale of bonds were $5,889,745 which constituted only 12.7 per cent of the total highway income; and amounted to only 80 cents per capita.

The amount received from the Federal Government as Federal aid was $2,904,636, or 6.2 per cent of the total. The general property taxes and revenues derived from other sources were $26,031,762; this constituted 56 per cent of the total highway income and amounted to $3.52 per capita. According to the report of the Census Bureau the States and their political subdivisions collected $374,743,288 in taxes, fees, licenses, etc. After deducting the motor vehicle license fees there is left $363,114,197 as the total public revenues derived from all other sources, or about $49.00 per capita, of which amount $3.52 was collected and used for rural highway purposes. This indicates that 7.2 cents of every dollar collected by State and local governments was devoted to highway purposes.

The total highway income of the three States comprising the Middle Atlantic division was $168,305,433, or $7.50 per capita. Of this amount $22,340,418, or 13.3 per cent, was obtained from motor-vehicle license fees. Bond sales furnished the source of $59,543,258 of the total, or 35.4 per cent; this was an obligation of $2.68 per capita for the year. The Federal Government contributed $7,441,515, or 4.4 per cent of the total amount. The general property taxes and the revenues derived from other sources were $78,980,242, which was 46.9 per cent of the total highway income and constituted a per capita burden of $3.52. The total amount of public revenues collected in these States by the State and local govenments was $1,056,916,160, after making a deduction for the amount representing motor-vehicle license fees. The total per capita collections made for all purposes amounted to $47.30. As already indicated, of this amount $3.52 per capita was credited to highway funds, which means that out of every dollar collected from the public only 7.5 cents was used for highway purposes.

In the East North Central division the 1921 total highway income was $281,139,024, representing a per capita contribution of $13.10. The motor-vehicle fees amounted to $27,432,261, or 9.8 per cent of the total. From the sales of bonds these States received $101,550,318, which was 36.1 per cent of the total highway income and a per capita obligation of $4.70. The Federal aid received by these States amounted to $11,887,987, or 4.2 per cent of the total highway income. General property taxes destined for highway purposes and the revenues from other sources were $140,268,558, or 49.9 per cent of the total highway income. They constituted a per capita burden of $6.50. After making a deduction of the motor-vehicle fees, the total public revenues collected in these States amounted to $972,279,786, or $45.20 per capita. Out of this per capita tax collection, $6.50 was credited to the highway account, which indicates that 14.4 cents out of every dollar of public revenues was used for highway purposes.

In the year 1921 the total highway income of the West North Central division amounted to $153,642,716 or $12.25 per capita. The motor-vehicle fees constituted $20,574,538 and represented 13.4 per cent of the total highway income. These States derived $34,291,178, or 22.3 per cent, of the total from the sale of bonds, which represented a per capita obligation for the year of $2.75. The revenues derived from Federal aid were $14,636,169, or 9.5 per cent of the total. General property taxes and revenues from other sources for highway purposes constituted $84,140,831, or 54.8 per cent of the total highway income, which resulted in a per capita burden of $6.70. The total public revenues in this division of States were $539,197,660 after subtracting the fees received from motor vehicles. These total collections from the public represented a per capita burden of $43.00, $6.70 of which was collected for highway purposes, which means that out of every dollar collected 15.5 cents could be designated as highway income.

ONE-SIXTH OF ALL TAXES FOR HIGHWAYS IN SOUTH ATLANTIC STATES

The 1921 highway income for the South Atlantic division was $137,657,698, or $9.85 per capita. The revenues derived from motor vehicle fees and gasoline taxes were $11,860,998, or 8.6 per cent of the total. These States received 49 per cent of the total highway income, or $67,406,730 from the sales of bonds, which amounted to a per capita obligation of $4.80. Of the total highway income Federal aid constituted 8.2 per cent or $11,267,126. The general property taxes and receipts from other sources were $47,122,844, which was 34.2 per cent of the total highway income, or a collection of $3.40 per capita. After deducting the reve-

[1] The various groups of States referred to in the article are listed as follows:
New England division: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.
Middle Atlantic division: New York, New Jersey, Pennsylvania.
East North Central division: Ohio, Indiana, Illinois, Michigan, Wisconsin.
West North Central division: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas.
South Atlantic division: Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida.
East South Central division: Kentucky, Tennessee, Alabama, Mississippi.
West South Central division: Arkansas, Louisiana, Oklahoma. Texas.
Mountain division: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada.
Pacific division: Washington, Oregon, California.

nues derived from motor-vehicle fees and gasoline taxes these States collected from the public the sum of $283,-145,170 or $20.10 per capita for all public purposes. Of this total income only $3.40 was devoted to highway purposes which means, however, that 16.8 cents out of every dollar collected from the public was credited to the highway account.

In the East South Central division the total highway income was $60,280,684 in 1921 which amounted to $6.80 per capita. The motor-vehicle fees and gasoline taxes, $5,108,387 represented 8.5 per cent of the total highway income. The revenues which accrued from the sales of bonds were $25,551,347, or 42.5 per cent; this was a capital obligation of $2.90 for that year. The States in this division received $5,281,475 as Federal aid which constituted 8.7 per cent of the total. General property taxes and collections from other sources supplied $24,339,475, 40.3 per cent of the total, or $2.70 per capita. In this division the total public revenues, exclusive of motor-vehicle fees and gasoline taxes, were $155,501,192, or $17.55 per capita. This total per capita tax collection included the $2.70 which went for highway purposes, which means that 15.3 cents out of every dollar collected were turned over to the highway fund.

The total highway income in the West South Central division was $138,504,160 which represented a per capita burden of $13.50. The motor-vehicle fees and gasoline taxes amounted to $7,496,965 and constituted 5.4 per cent of the total highway income. The receipts from the sale of bonds were $82,127,751, or 59.3 per cent, an obligation of $8 per capita. The aid derived from the Federal Government was $10,929,721, or 7.9 per cent of the total highway income. The general property taxes and the revenues derived from other sources amounted to $37,949,723 or 27.4 per cent of the total highway income, a per capital burden of $3.70. After making an allowance for the revenues derived from motor-vehicle fees and the gasoline taxes these States collected $235,959,540 or $23 per capita. Of this amount $3.70 was destined for highway purposes, or 16.1 cents of every dollar collected from the public.

The States of the Mountain division raised $61,367,959 in 1921 for highway purposes, which represents a per capita burden of $18.40. Seven per cent of the highway income, $4,305,524, was derived from motor-vehicle fees and gasoline taxes. The bond sales amounted to $19,908,036, or 32.4 per cent of the total highway income, a per capita obligation of $6. The Federal Government contributed toward highway improvements $9,731,542, which constituted 15.8 per cent of all highway income. General property taxes and revenues derived from other sources amounted to $27,422,857, constituting 44.8 per cent of the total highway income, a per capita burden of $8.20. Exclusive of motor-vehicle fees and gasoline taxes, these States received $162,761,525 in taxes and payments of all kinds from the public, or $48.90 per capita. Of this amount, $8.20 was used for highway purposes. Of every dollar collected from the public 16.8 cents were credited to the highway funds.

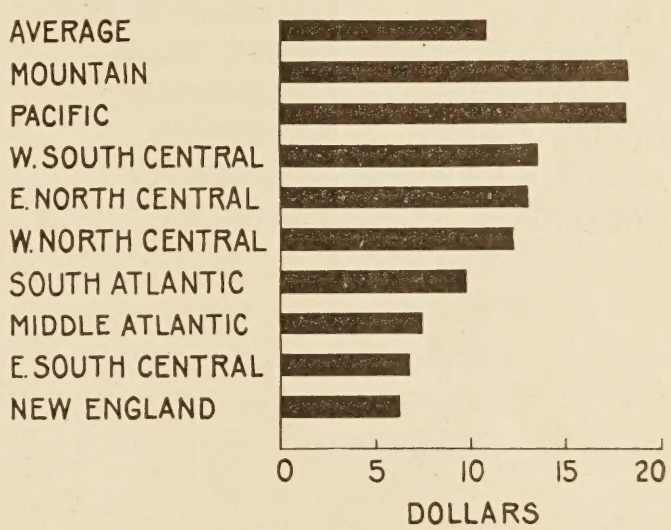
The total highway income in the Pacific division was $102,084,938 in 1921, amounting to $18.30 per capita. The motor-vehicle license fees and gasoline taxes were $11,877,984, or 11.6 per cent of the total. The revenues derived from bond sales were $41,840,910, or 41 per cent of the total highway income, a per capita obligation of $7.50. The Federal-aid receipts were $5,253,105, which constituted 5.1 per cent of the total highway income. The revenues derived from general property taxes and from other sources were $43,112,939, or 42.3 per cent of the total highway income, amounting to $7.75 per capita. In these States the total taxes, fees, etc., collected exclusive of motor-vehicle revenues were $333,040,929, or $59.20 per capita. Of this total amount collected from the public, $7.75 was devoted to highways and 13.1 cents out of every dollar collected were used for highway purposes.

WIDE VARIATIONS IN HIGHWAY INCOME OF GEOGRAPHIC GROUPS

As the per capita allocations present a good many variations in the several groups of States, it may be of interest to compare the several items by groups.

Total highway income

Divisions	Amount	Per capita
New England	$46, 455, 284	$6. 25
Middle Atlantic	168, 305, 433	7. 50
East North Central	281, 139, 024	13. 10
West North Central	153, 642, 716	12. 25
South Atlantic	137, 657, 698	9. 85
East South Central	60, 280, 684	6. 80
West South Central	138, 504, 160	13. 50
Mountain	61, 367, 959	18. 40
Pacific	102, 084, 938	18. 30
Total	1, 149, 437, 896	10. 90



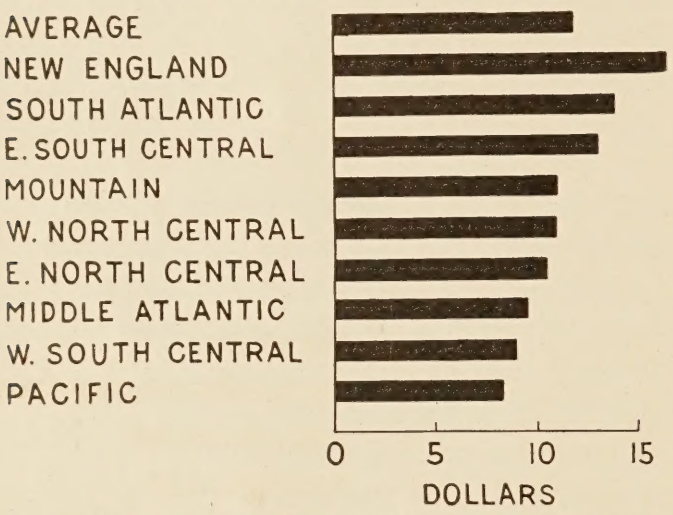
Total highway income per capita, 1921, by geographic divisions

The average per capita income for the whole country for rural highway purposes was $10.90. In four of the divisions, New England, Middle Atlantic, South Atlantic, and East South Central, the per capita highway income was less than the average for the country, and in the remaining divisions it was above the average. The per capita income of $6.25 in New England was the lowest found in any group and the $18.40 of the Mountain States was the highest, although the Pacific States, with $18.30, were a close second. In both of these groups it will be noted the per capita highway income was almost three times as large as in New England. This wide variation is explained by the fact that in these Western States the total income exceeded by very substantial amounts the total highway income of the New England States, while at the same time the population in the New England area was far in excess of the population of the

two western groups. In the Mountain States, where the per capita highway income was $18.40, the density of population based upon the 1920 census was only 3.9 persons per square mile. In the New England States, where the total highway income averaged only $6.25 per capita, the density of population was 120 persons per square mile, and in the Middle Atlantic States, with a population density of 222 persons per square mile, the per capita highway income was $7.50. In general it may be said that the per capita highway income tends to vary inversely with the density of population.

MOTOR-VEHICLE FEES AVERAGE NEARLY $12 PER VEHICLE

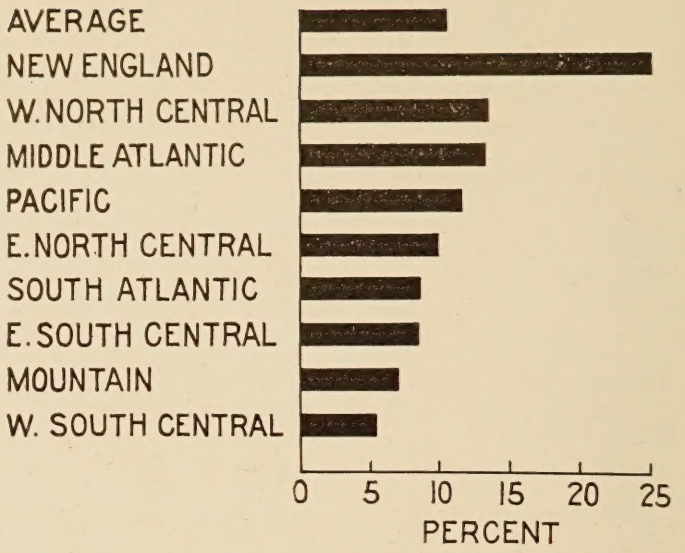
The motor-vehicle revenues consisted almost wholly of the fees charged for licenses issued for the operation of automobiles, motor trucks, and motor vehicles. Gasoline taxes are also included, but in 1921 these taxes amounted to only a small sum. The collection of these revenues exacted from motor-vehicle owners and users may be summarized as follows. The average amount paid by the owners is also shown.



Average highway income derived from motor vehicles, per motor vehicle, 1921, by geographic divisions

Division	Amount of motor-vehicle revenues credited to highway income, 1921	Number of motor vehicles	Average revenue per motor vehicle
New England	$11,629,091	706,312	$16.40
Middle Atlantic	168,305,433	1,774,614	9.55
East North Central	27,432,261	2,602,617	10.50
West North Central	20,574,538	1,871,157	10.95
South Atlantic	11,860,998	859,908	13.80
East South Central	5,108,387	391,232	13.05
West South Central	7,496,965	834,209	8.95
Mountain	4,305,524	399,160	11.00
Pacific	11,877,984	984,171	8.30
Total	122,626,166	10,423,380	11.80

In this year the owners and operators of motor vehicles contributed $122,626,166, which was included as a part of the total highway income for the country. Averaging this amount over the 10,423,380 motor vehicles which were registered results in an average payment of $11.80 per motor vehicle. In the New England States the average was the highest, $16.40. This was wholly due to the higher scale of license fees charged because there was no gasoline tax in effect in that year in any of these States. In the Pacific States the highway burden placed upon the user of the road, $8.30, was the lowest. The variations are almost wholly due to the differences in the scale of license fees.

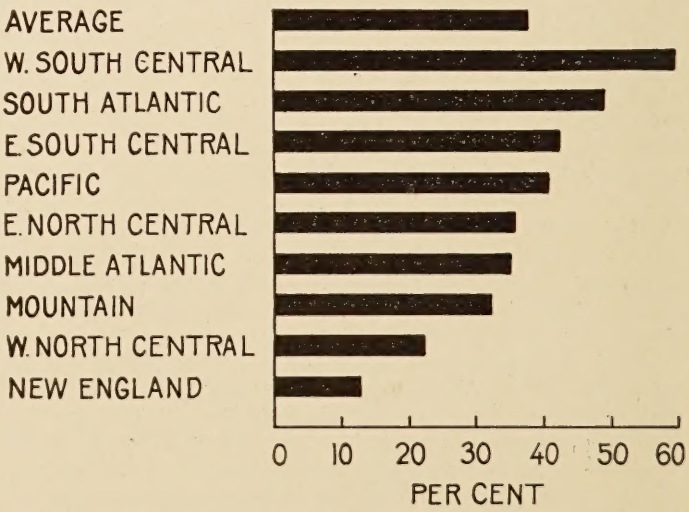


Ratio of motor-vehicle fees and gasoline taxes to total highway income, 1921, by geographic divisions

The ratio which the motor-vehicle revenues bore to the total highway incomes in the several sections of the country is shown below:

Division	Ratio of motor-vehicle fees and gasoline taxes to total highway income, 1921	Division	Ratio of motor-vehicle fees and gasoline taxes to total highway income, 1921
	Per cent		*Per cent*
New England	25.1	West South Central	5.4
Middle Atlantic	13.3	Mountain	7.0
East North Central	9.8	Pacific	11.6
West North Central	13.4		
South Atlantic	8.6	Average	10.6
East South Central	8.5		

For the country as a whole the motor vehicles contributed 10.6 per cent of the total highway income. The range was from 5.4 per cent in the West South Central States to 25.1 per cent in the New England States. Outside of the New England States the highest ratio of motor-vehicle revenues to total highway income was 13.4 per cent in the West North Central States.



Ratio of revenues derived from bond sales to total highway income, 1921, by geographic divisions

THIRTY-EIGHT PER CENT OF INCOME FROM BONDS

That part of the total highway income which was derived from the sale of bonds varies widely in the different States and geographical divisions. The ratio of the amounts of money thus raised for highway purposes to the total highway income is set forth in the following tabulation:

Division	Revenues derived from sale of bonds, 1921	
	Amount	Per cent of total highway income
New England	$5,889,745	12.7
Middle Atlantic	59,543,258	35.4
East North Central	101,550,318	36.1
West North Central	34,291,178	22.3
South Atlantic	67,406,730	49.0
East South Central	25,551,347	42.5
West South Central	82,127,751	59.3
Mountain	19,908,036	32.4
Pacific	41,840,910	41.0
Total	438,109,273	38.1

For the country as a whole $438,109,273, or 38.1 per cent, of the total highway income was obtained from bond issues. In the West South Central States the largest proportion of highway income, 59.3 per cent, was represented by State and local indebtedness. In the New England States the smallest part of the year's highway funds, 12.7 per cent, was raised in this manner. In all of the groups of States, with the exception of the New England States, the West North Central States, and the Mountain States, over a third of money devoted to highway work was obtained through bond issues. In only one of the divisions, the West South Central States, did the income from bonds amount to more than half of the year's total highway income.

The per capita obligations incurred through these bond issues for highway purposes vary in these several groups as shown in the following statement:

Division	Per capita highway bond issues, 1921	Division	Per capita highway bond issues, 1921
New England	$0.80	West South Central	$8.00
Middle Atlantic	2.68	Mountain	6.00
East North Central	4.70	Pacific	7.50
West North Central	2.75		
South Atlantic	4.80	Average	4.10
East South Central	2.90		

In the New England States because of the large population and the relatively small amount of bonds issued the per capita obligation of 80 cents was lower than in any other section. The highest per capita obligation was found in the West South Central States, where the income from bond issues amounted to $8 per capita.

FEDERAL AID AMOUNTS TO 7 PER CENT OF TOTAL HIGHWAY INCOME

To the total highway income of 1921 the Federal Government contributed $79,333,226, or 6.9 per cent. In the following tabulation are shown the proportions which these Federal funds bore to the total highway incomes of the several groups of States:

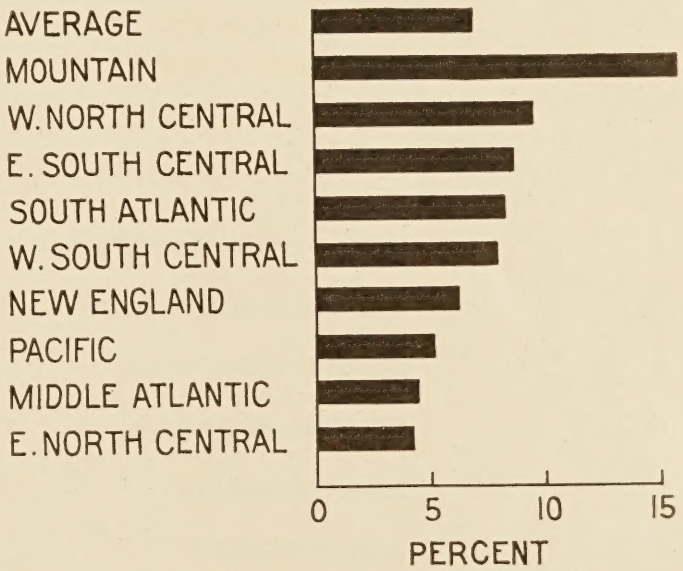
Division	Federal aid, 1921, per cent of total highway income	Division	Federal aid, 1921, per cent of total highway income
New England	6.2	West South Central	7.9
Middle Atlantic	4.4	Mountain	15.8
East North Central	4.2	Pacific	5.1
West North Central	9.5		
South Atlantic	8.2	Average	6.9
East South Central	8.7		

The variations in the ratios of Federal aid funds to the total highway income of these several groups of States depend upon the magnitude of the highway-construction programs and upon the amount of forest-road construction by the Federal Government in each of the States, and also upon the apportionments according to the provisions of the Federal law.

PROPERTY TAXES 44 PER CENT OF THE TOTAL INCOME

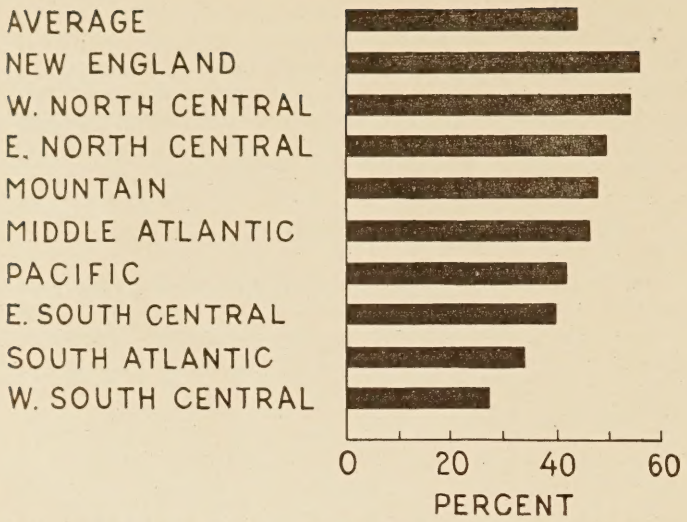
That part of the total highway income derived from general property and from other sources, chiefly taxes, amounted to $509,369,231, or 44.4 per cent of the total highway income. Its relation to the rest of the highway income in various groups of States is indicated in the following table:

Division	General property taxes and other sources of revenue for highway purposes, 1921	
	Amount	Per cent of total highway income
New England	$26,031,762	56.0
Middle Atlantic	78,980,242	46.9
East North Central	140,268,558	49.9
West North Central	84,140,831	54.8
South Atlantic	47,122,844	34.2
East South Central	24,339,475	40.3
West South Central	37,723,723	27.4
Mountain	27,422,857	44.8
Pacific	43,112,939	42.3
Total	509,369,231	44.4



Ratio of revenues derived from Federal aid and forest road funds to total highway income, 1921, by geographic divisions

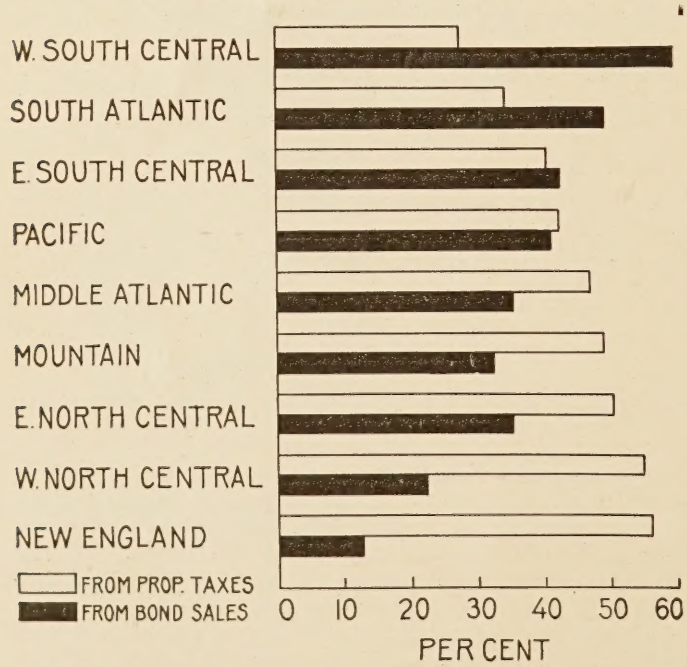
The largest amount of revenues raised from taxes is found in the East North Central States, where the direct contribution of taxpayers amounted to $140,268,558, just half of the total highway income. In the New England States the percentage of total highway income derived from taxes was the highest and in the West South Central States it was the lowest. The percentage variation in this case is the inverse of the percentage of highway income raised through bond issues as seen in the tabulation on page 6.



Ratio of revenues derived from property taxes to total highway income, 1921, by geographic divisions

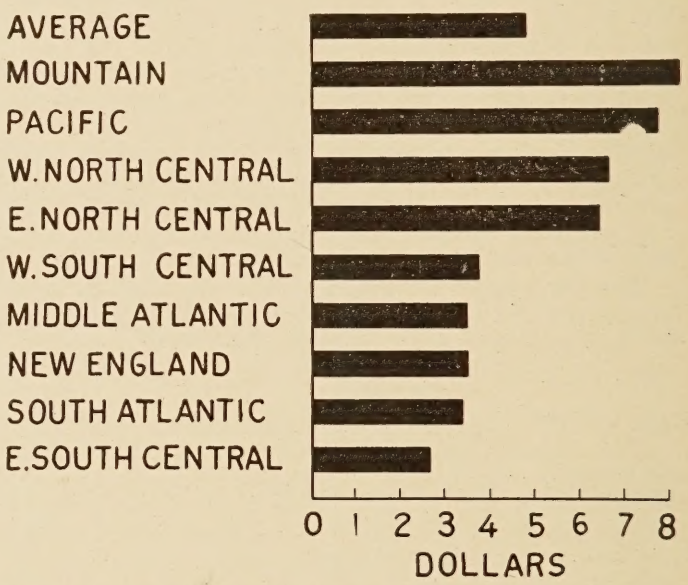
Division	Proportion of total highway income from general property taxes and bond issues	
	General property taxes	Bond issues
	Per cent	*Per cent*
New England	56.0	12.7
West North Central	54.8	22.3
East North Central	49.9	36.1
Mountain	44.8	32.4
Middle Atlantic	46.9	35.4
Pacific	42.3	41.0
East South Central	40.3	42.5
South Atlantic	34.2	49.0
West South Central	27.4	59.3

It will be observed that those groups of States which showed the highest percentages of the total highway income derived from taxes showed the lowest percentages of highway revenues derived from bond issues.



Comparison of highway income from general property taxes and bond sales, 1921, by geographic divisions

In the New England States 56 per cent of the total income was derived from taxes and only 12.7 per cent from the proceeds of bond issues. At the other extreme are found the West South Central States, which raised 59.3 per cent of their highway income through bond issues and only 27.4 per cent through general property taxes and other taxes. The fact that the West South Central States raised a larger percentage of their highway income through taxes than the New England States raised through bond issues, although the percentage of income raised through taxes of the New England States and the percentage raised by bond issues in the West South Central States are very nearly the same, is explained by the fact that the New England States raise a larger percentage of their highway income by taxation of motor vehicles. The New England States derived 25.1 per cent of their highway revenues from motor-vehicle fees, while the West South Central States derived but 5.4 per cent in this manner. It can be said in considering the sources of highway income in these different groups of States that the ratio of revenues derived from taxes varies inversely with the ratio derived from bond sales.



Per capita burden of highway income derived from general property taxes, 1921, by geographic divisions

PER CAPITA TAX BURDEN FOR HIGHWAYS LESS THAN FIVE DOLLARS

The burden which the collection of these taxes for highway purposes placed upon individuals is indicated in the following tabulation:

Division.	Per capita highway income derived from taxes	Division	Per capita highway income derived from taxes
New England	$3.52	West South Central	$3.70
Middle Atlantic	3.52	Mountain	8.20
East North Central	6.50	Pacific	7.75
West North Central	6.70		
South Atlantic	3.40	Average	4.82
East South Central	2.70		

The direct payments made by the public for rural highway construction and improvements aside from the revenues derived from other sources vary considerably

in the different sections of the country. In the East South Central States the direct payments of taxpayers amount to only $2.70 per capita; that is the lowest per capita payment. The highest per capita payment is found in the Mountain States, where the contribution from taxpayers is $8.20. It is of interest to note that the per capita burden of tax payments for highway purposes are exactly the same for the New England States and for the Middle Atlantic States. There is also a close coincidence in the per capita payments in both the East and the West North Central groups. For the country as a whole the per capita tax burden was $4.82.

In order to determine how much of a burden the taxes collected for highway purposes really are it is of interest to compare the per capita burden of the total taxes paid by the public and the per capita taxes which are collected for highway purposes. In the following tabulation this relationship is clearly set forth:

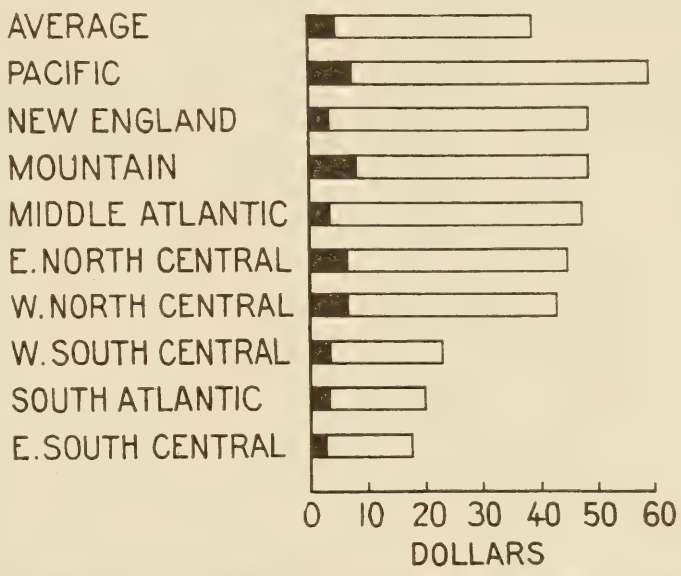
Division	Total taxes, fees, etc., per capita, 1921	Highway taxes, per capita	
		Amount	Per cent of total taxes
New England	$49.00	$3.52	7.2
Middle Atlantic	47.30	3.52	7.5
East North Central	45.20	6.50	14.4
West North Central	43.00	6.70	15.5
South Atlantic	20.10	3.40	16.8
East South Central	17.55	2.70	15.3
West South Central	23.00	3.70	16.1
Mountain	48.90	8.20	16.8
Pacific	59.20	7.75	13.1
Average	38.80	4.82	12.4

In comparing the relation which the per capita tax payments for highway purposes bears to the total tax payments, we note that the country can be divided roughly into two sections. In the New England and Middle Atlantic States the ratios are 7.2 and 7.5 per cent, respectively. In this northeastern section slightly over 7 per cent of the taxes collected accrue to the highway funds of the States. The per capita total taxes and the per capita highway taxes are quite uniform. In the rest of the country the ratio of per capita highway taxes to the per capita total taxes varies from 13.1 to 16.8 per cent, showing again that the relative burden of direct payments for highway purposes is quite uniform, although the per capita amounts differ considerably for the various sections.

The highway income of the country is, of course, called forth by the highway expenditures. The magnitude of these expenditures makes necessary the collection of funds sufficient to meet the demands made by highway construction and maintenance and to meet the payments of principal and interest on past bond issues. There are three variables which determine the burdens of these expenditures for individuals, namely, the amount of money spent per mile of road, the miles of roads constructed and maintained, and the population which has to make the financial contributions. In order to make comparisons which recognize each of these three variables it is important to determine what the expenditures have been per person per mile of road. If we take per capita expenditures alone, we can, it is true, make comparisons as to what the outlays for highway purposes have been in different sections and what the individual burden has been. This does not, however, tell the whole story. A relatively high per capita expenditure may mean any of a number of conditions or a combination of such conditions; it may mean that the per capita expenditure is relatively high because of the small population in a State or in a group of States; it may be relatively high because of a very large road mileage upon which improvements have been made; it may be high because high type roads have been constructed although the road mileage may be relatively small in amount; or it may be due to a combination of these three factors.

AVERAGE EXPENDITURE PER PERSON 1 CENT FOR 200 MILES OF ROAD

In 1921 the total highway expenditures for all rural highway purposes were $1,036,587,772. In the following tabulation the resulting per capita expenditure in each of the sections is shown in relation to the total mileage of road in the corresponding sections with the purpose of bringing out the per capita expense per mile of road:



Comparison of per capita highway taxes with total per capita taxes, State and local, by geographic divisions

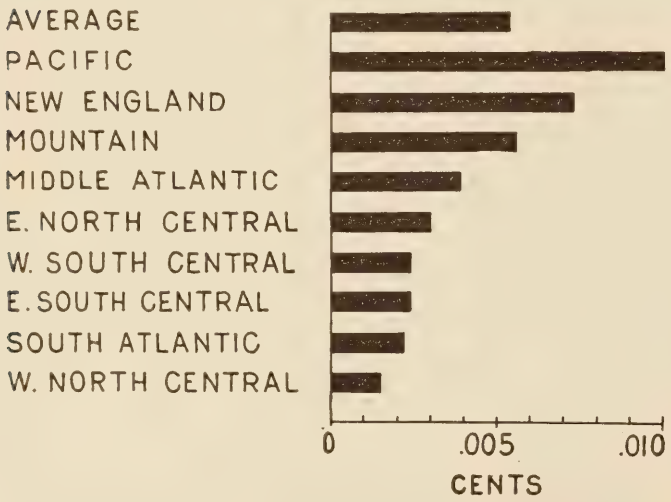
Division	Mileage of rural highway	Highway expenditures per capita	Highway expenditures per person per mile of road
			Cents
New England	83,296	$6.10	0.0073
Middle Atlantic	186,935	7.20	.0039
East North Central	412,753	12.40	.0030
West North Central	759,820	11.80	.0015
South Atlantic	365,567	7.70	.0022
East South Central	242,745	5.75	.0024
West South Central	416,617	10.20	.0024
Mountain	306,382	17.15	.0056
Pacific	167,180	16.90	.0101
Total	2,941,294	[1] 9.80	[1] .0054

[1] Average.

The highway expenditures per person per mile, while they averaged 0.0054 cent, ranged from 0.0015 cent in the West North Central States to 0.0101 cent per person per mile in the Pacific States. A more direct comparison can be made by arranging the several groups in order from the lowest to the highest.

Division	Expenditures per person per mile	Percentage relationship
West North Central	0.0015	100
South Atlantic	.0022	147
East South Central	.0024	160
West South Central	.0024	160
East North Central	.0030	200
Middle Atlantic	.0039	260
Mountain	.0056	370
New England	.0073	480
Pacific	.0101	670

An examination of these expenditures per person per mile reveals the relative significance of expenditures for highway improvements. This is seen, for example, in comparing the West North Central group with the East North Central group. The per capita highway expenditures of the West North Central division were $11.80 and for the East North Central



Highway expenditures per person per mile of road, 1921, by geographic divisions

group $12.40. But when the comparison is based upon the expenditures per person per mile of road a wholly different result is obtained. On this basis the highway expenditures per person per mile in the East North Central States were 100 per cent above those of the West North Central States. The highest expenditure per person per mile of road was found in the Pacific States, where it amounted to 0.0101 cent, or 670 per cent of that in the West North Central States.

STATE HIGHWAY DEPARTMENTS RESPONSIBLE FOR ONLY 40 PER CENT OF STATE EXPENDITURE

The rural highway income which has been analyzed thus far is the income of the whole country used for construction and maintenance of all rural roads, State, county, and local. Only a part of this income is spent by State highway departments and by the direction or under the supervision of such departments. The total highway expenditures for 1921 were $1,036,587,772; of this amount only $413,241,662, or 39.8 per cent, was spent by or under the supervision of State highway departments. The remaining 60.2 per cent of the expenditure was made by counties, townships, and highway districts. The ratios of expenditures made by State highway departments to the total highway expenditures in the several groups of States are set forth in the following table:

Division	Total highway expenditure (1921)	Highway expenditures by or under State highway departments	
		Amount	Per cent of total
New England	$45,361,397	$26,757,690	59.0
Middle Atlantic	160,470,634	101,477,088	63.5
East North Central	267,988,153	68,512,054	25.6
West North Central	148,865,686	47,143,661	31.7
South Atlantic	106,656,946	51,181,157	48.0
East South Central	51,236,234	16,620,731	32.4
West South Central	103,820,179	33,951,911	32.7
Mountain	58,157,949	28,001,863	48.2
Pacific	94,030,614	39,595,509	42.0
Total	1,036,587,772	413,241,664	39.8

It is obvious from this table that outside of the New England and Middle Atlantic States the major part of the highway expenditure is made by counties and local units. In the East North Central States, in which section or group of States the highway expenditures were greater than in any other group, the expenditures made by or under the supervision of the State highway departments were approximately only 25 per cent of the total highway expenditures. In the Middle Atlantic States the money expended by State departments was 63.5 per cent of the total, the largest in any group. By applying these percentages to the per capita taxes paid for highway improvements in the different groups of States we are able to ascertain the per capita burden which these State expenditures entail.

Group	Total highway income derived from taxes per capita	Highway expenditures made by State highway departments, per cent of total	Highway income derived from taxes and used by State highway departments, per capita
New England	$3.52	59.0	$2.08
Middle Atlantic	3.52	63.5	2.24
East North Central	6.50	25.6	1.66
West North Central	6.70	31.7	2.12
South Atlantic	3.40	48.0	1.63
East South Central	2.70	32.4	.88
West South Central	3.70	32.7	1.21
Mountain	8.20	48.2	3.95
Pacific	7.75	42.0	3.25
Average	4.82	39.8	1.94

The per capita burden of the total highway income derived from taxes was $4.82 for the country as a whole. It is of significance to note that only $1.94 of this per capita tax was used by State highway departments. In the East South Central States less than a dollar per capita of the taxes collected for highway purposes was turned over to State departments for expenditure.

HIGHWAY INCOME QUADRUPLED SINCE 1914

It is impossible to obtain complete data covering either the amount of money expended for highway purposes or the income devoted to such purposes year by year. Surveys, however, were made by the Bureau of Public Roads for the years 1904 and 1914, and it is possible to compare the figures for these years with those for 1921. It is a matter of common knowledge that the development of highway work was very great during the period between 1904 and 1921. In 1904 the

total highway income of States, counties, and local districts was $79,623,594; in 1914 it had increased to $240,263,766, and in 1921 it had risen to $1,119,437,896. It should be borne in mind that these amounts include the total highway funds irrespective of their source. They include tax funds, motor-vehicle revenues, proceeds of bond issues, and Federal-aid contributions. In the following tabulation the highway income is shown by groups of States for the years 1904, 1914, and 1921. For purposes of comparison the amounts for the various sections in 1904 and 1921 are shown as percentages of the 1914 amounts.

Division	Total highway income					
	1904		1914		1921	
	Amount	Per cent	Amount	Per cent	Amount	Per cent
New England	$7,385,753	48	$15,435,744	100	$46,455,284	301
Middle Atlantic	13,854,590	34	40,864,831	100	168,305,433	412
East North Central	19,613,190	35	56,445,180	100	281,139,024	500
West North Central	10,482,195	32	33,120,011	100	153,642,716	462
South Atlantic	7,308,145	30	24,428,952	100	137,657,698	565
East South Central	7,022,385	55	12,754,577	100	60,280,684	572
West South Central	7,260,146	47	15,333,027	100	138,504,160	905
Mountain	2,309,349	25	9,454,277	100	61,367,959	650
Pacific	4,389,841	13	32,427,167	100	102,084,938	315
Total	79,623,594	33	240,263,766	100	1,119,437,896	465

In 1914 the income for highway purposes was practically three times the amount devoted to those purposes in 1904, and in 1921 it was over four times as large as in 1914. The demand for highway construction and improvement in 1904 had not yet been stimulated by the use of the automobile. By 1914 the motor vehicle had become an important factor, and by 1921 it had become the all-important factor both on account of the extension of the use of the motor vehicle and the large increase in the number in service. It is to be noted that the greatest increases in highway funds between 1904 and 1914 were in the Mountain and Pacific States. In the other groups of States the increases were more or less uniform.

While the highway income for 1921 averaged 465 per cent of the 1914 income, the Western States again exceeded all the others in their increases. In the Mountain States the highway income for 1921 was 650 per cent of the amount reported for that purpose in 1914, and in the West South Central division it was 905 per cent. In the other States the 1921 income figures ranged from 301 per cent of the 1914 figures in the New England States to 565 per cent in the South Atlantic States.

INCREASE IN ROAD INCOME PARTLY DUE TO REDUCED PURCHASING POWER OF THE DOLLAR

In making these comparisons of highway income we must not lose sight of the fact that between 1914 and 1921 there was also a marked advance in the general price level. The large increase of money expended and income received for highway purposes from 1914 to 1921 was caused not only by the more extensive program of construction and maintenance but by the decrease in the purchasing power of the dollar. The Bureau of Labor index numbers indicate that over that period there was an increase of 50 per cent in wholesale prices. It is believed that highway construction costs taking into account labor and materials were subject to at least as great an increase. In other words, if there had been no change in the price level the income necessary to meet the highway expenditures of 1921 would have been about $746,000,000 or an increase of approximately 320 per cent over that of 1914.

In 1914 there were 1,711,339 motor-vehicle registrations as compared with 10,463,295 in 1921, an increase of 610 per cent. This large increase in the use of the automobile no doubt provided the incentive for the increased highway expenditures which made necessary the larger highway revenues.

In the following table is shown a comparison of the total per capita highway incomes for these years for which the data are available:

Division	Per Capita highway income					
	1904		1914		1921	
	Amount[1]	Per cent	Amount[2]	Per cent	Amount[3]	Per cent.
New England	$1.32	56	$2.35	100	$6.25	266
Middle Atlantic	.90	42	2.12	100	7.50	354
East North Central	1.23	40	3.09	100	13.10	424
West North Central	1.01	32	3.14	100	12.25	390
South Atlantic	.72	35	2.06	100	9.85	480
East South Central	.93	61	1.52	100	6.80	448
West South Central	1.11	63	1.75	100	13.50	770
Mountain	1.38	38	3.60	100	18.40	510
Pacific	1.82	23	7.75	100	18.30	236
All States	1.05	40	2.61	100	10.90	418

[1] Based on 1900 population. [2] Based on 1910 population. [3] Based on 1920 population

It will be noted that the percentages in this table differ somewhat from those with respect to total highway incomes. This is largely brought about by changes in the population figures. In 1904 the per capita highway income was $1.05; in 1914 it had risen to $2.61; and in 1921 it was $10.90, which was 418 per cent of the 1914 figure. The per capita income was the largest in the Mountain and in the Pacific divisions. The largest increase over 1914 was in the West South Central States, where the per capita income in 1914 was only $1.75, and in 1921 $13.50, an increase of 770 per cent. The greatest increase in per capita income between 1904 and 1921 was in the South Atlantic States where in 1904, it was only 72 cents and in 1921 $9.85, an increase of 1,415 per cent.

THE USE OF BONDS BY COUNTIES AND STATES

Up to this point the analysis has been confined to a determination of the sources of income in the various groups of States, including the income of State highway departments and counties and local districts. The data compiled by the Bureau of Public Roads show that for 1921 the counties, townships, and districts had an income of $743,493,212 for highway purposes as compared with an income of $405,944,684 which were the funds under the control of State highway departments. The total revenues raised through the sale of bonds has already been set forth. In this connection, however, it is important to ascertain the extent to which bond issues were used to raise funds by the States and by the counties and local subdivisions.

The data show that counties, townships, and districts derived $322,613,529, or 43.5 per cent, of their total highway income from the sale of bonds in 1921. This relation is shown for the various groups in the tabulation following.

Division	Total highway income of counties, townships, and districts	Income derived from bond sales	
		Amount	Per cent of total
New England	$19,441,981	$3,504,650	18.0
Middle Atlantic	58,768,442	14,414,467	24.5
East North Central	221,080,834	91,392,840	41.3
West North Central	107,313,301	28,104,534	26.4
South Atlantic	76,590,092	39,189,230	51.2
East South Central	46,329,099	24,464,597	53.0
West South Central	117,492,554	81,443,272	69.0
Mountain	30,675,600	14,338,388	46.7
Pacific	65,801,309	25,761,551	38.6
Total	743,493,212	322,613,529	43.5

For purposes of comparison the following table shows the percentage of the State highway income derived from bond sales:

Division	Total funds under control State highway departments	State highway income derived from bond sales	
		Amount	Per cent of total
New England	$27,013,303	$2,385,095	8.8
Middle Atlantic	109,536,991	45,128,791	41.3
East North Central	60,058,190	10,157,478	16.9
West North Central	46,329,415	7,708,079	17.0
South Atlantic	61,067,606	27,112,708	44.5
East South Central	13,951,585		
West South Central	21,011,606	684,479	3.3
Mountain	30,692,359	5,569,648	18.2
Pacific	36,283,629	16,079,359	44.1
Total	405,944,684	114,825,637	28.1

In several of the sections, it will be noted, a very substantial part of the county and local income was derived from bond issues. In the West South Central States 69 per cent of the local highway funds were procured in this manner. In this section and in the South Atlantic States and in the East South Central States the proceeds derived from bond sales amounted to over 50 per cent of the local highway revenues. In the New England States, on the other hand, the bond sales amounted to only 18.05 per cent of the total local highway income, and this was the smallest percentage for the country.

It will be seen that the proportion of the income available to the State highway departments which was derived from bond sales was only 28.1 per cent as compared with 43.5 per cent in the case of the counties and local units. The South Atlantic, the Pacific, and the Middle Atlantic States derived from 41 to 44.5 per cent of the State highway revenues from bonds; in the other groups the percentage was considerably less; and it is worthy of especial note that none of the East South Central States raised any of their State funds by bond issues. In a number of the States the failure to employ this source of income is due to prohibitory clauses in their constitutions.

What the future trend will be as to the relativity between the different sources of highway income is hard to foretell. It has already been noted that there has been a large increase in both the absolute and relative amount of funds derived from motor-vehicle license fees and gasoline taxes. The present indications are that the revenues derived from these sources will increase, especially because so many States have recently enacted gasoline tax laws and because some of the States which have been collecting gasoline taxes contemplate increasing the rates charged. If we assume that there will be no increase in highway expenditures, the additional funds derived from motor-vehicle revenues may result in a decrease in the amount collected as taxes or a decrease in the amount raised by bond issues or in both.

PENNSYLVANIA HIGHWAY TRANSPORT SURVEY

INVESTIGATION SIMILAR TO CONNECTICUT STUDY UNDER WAY

STATE HIGHWAY DEPARTMENT AND FEDERAL BUREAU COOPERATING

A HIGHWAY transportation survey similar in its purposes and general methods to the survey conducted in Connecticut and described in the March issue of PUBLIC ROADS is well under way in Pennsylvania. The survey, which is being conducted by the United States Bureau of Public Roads in cooperation with the Pennsylvania Department of Highways, was begun in November, 1923, and will be continued through October, 1924.

The adjustment of the State highway system to the economic needs of the traffic is a practical problem of the first importance in every State. It is a fundamental principle of economic highway design that no road should be improved to a degree in excess of its earning capacity. The return to the public in the form of economic transportation is the sole measure of the worth of the improvement. Where an effort is made to conform to this principle, the first question asked by the designing engineer is: What will be the volume of traffic when the road is improved? A mere census of the traffic before the road is improved will not answer this question. Is it possible by consideration of the density of the population on the territory adjacent to the road, combined with a study of the volume and character of the production of the territory, its wealth and the number of motor vehicles owned in the tributary area, to develop a basis for such a forecast? This is one of the subjects which will receive the attention of the cooperating agencies in the Pennsylvania survey.

Other practical facts sought in the survey are:

The maximum loading and maximum size of vehicles and the frequency of critical loads as an index of pavement width and design requirements.

The effect of congestion at intersections and "bottle necks" upon the rate of traffic flow.

The extent to which the improvement of old roads or the opening of new traffic routes is economically justified.

The type and volume of traffic using the various highways of the State as an index to the allocation of highway construction and maintenance funds.

The relation between traffic loads and density and the costs of highway construction and maintenance.

The amount and frequency of motor truck overloading, the distribution of load to the front and rear axles of the vehicles, the depth and width of tires.

The cost of various types of improvements, such as relocations, grade reductions, elimination of grade crossings and elimination of traffic "bottle necks" with the estimated saving in transportation costs resulting from such improvements.

The earning value of the State highway system in comparison with the present worth of the system using the replacement value minus depreciation as the basis of computing present worth.

The classification of Pennsylvania highways as industrial, high, medium or low-type traffic routes based on (1) total passenger car and motor truck density and (2) motor truck capacities. Design is influenced by present and anticipated capacity usage. Routes having a large proportion of trucks of small capacity using the highway will not require the same construction as where heavy capacities prevail.

BASIC ECONOMIC DATA SOUGHT

Besides these facts, each of which has immediate value in connection with the design and administration of the State highways, it is hoped to develop a large amount of basic economic data, such as the tonnage shipped by motor truck, marketing methods, and the relation of highway transportation to other methods of transportation. Other information of this character sought by the survey includes the following:

1. The mileage zones of motor-truck haulage and the relation of the type of commodity hauled to such zones.

2. The net tonnage of freight transported by regular and irregular trucking operators.

3. The situs of ownership of passenger cars and motor trucks operating over the State highway system.

4. The value of the net tonnage hauled over the system by motor truck.

5. The origin and destination of the commodities transported over the highway system and the character of origin and destination; i. e., whether the movement is between farm and railroad, from farm to city merchant, etc.

6. The relation of motor-truck transportation to other methods of transportation, particularly as to competition, rates, operating schedules, and delivery time in the short, middle-distance, and long-haul zones.

7. The data concerning haulage practices of truck operators and the tonnage transported by motor truck between various cities and areas which are of value to governmental agencies charged with the regulation and control of highway transportation.

8. The usage of passenger cars for business and nonbusiness purposes.

In order to secure the desired information, four divisions have been formed with headquarters in Philadelphia, Wilkes-Barre, Franklin, and Pittsburgh. The operating personnel in each of these divisions is headed by a division supervisor, who reports directly to the field manager or his assistant at Harrisburg. All costs of the survey are shared equally by the Pennsylvania department and the Federal bureau.

TRAFFIC OBSERVED AT 312 STATIONS

Three hundred and twelve observation stations have been established, 85 per cent of them on primary roads and 15 per cent on secondary roads. At 78 of these stations the information secured includes complete weight data; the others, known as recording stations, have no weighing facilities. Pit scales have been installed at 18 of the most important weighing stations. The other 60 are equipped with portable Berry scales.

In each division the personnel is divided into parties, which, according to the stations to which they are regularly assigned, are known as pit scale parties, Berry scale parties, recording, and night parties. Thus, in the Philadelphia division, there are 2 pit scale parties, 1 Berry scale party, 3 recording parties, and 1 night party. In the Wilkes-Barre and Franklin divisions there are 2 recording parties, 1 Berry scale party and 1 night party; and in the Pittsburgh division there are 2 Berry scale parties, 2 recording parties, 1 pit scale party, and 1 night party.

Each recording party has 26 stations at which it operates each month, working every day at a different station. A pit scale party remains at each station a week and completes its cycle in 6 weeks, there being 18 stations and 3 parties. Each Berry scale party operates 12 stations, and by remaining at each station 2 days completes its cycle in about a month. In addition to these parties, which are occupied mainly in collecting the motor–truck data, a single passenger car party moves from station to station and division to division to obtain the prescribed information with reference to passenger-car traffic, and the night party in each division, operating at key stations on selected routes, secures the information with regard to the night traffic which will be used to extend the day observations to a 24-hour basis.

The arrangement of the stations is such that the weight data secured at the 78 weighing stations can be applied to the traffic observed at the 234 recording stations, and the schedules of the various parties are so devised that there is no duplication of the records.

HIGHWAY FREIGHT TRAINS A FEATURE OF NIGHT TRAFFIC BETWEEN PHILADELPHIA AND NEW YORK

The observations of the night parties are especially important in the Philadelphia division because of the heavy night movement of trucks between Philadelphia and New York. Sixty per cent of the movement between these cities takes place at night, much of it in convoys under the charge of a truck master. As many as nine trucks have been counted in these highway freight trains.

Several items of information are being obtained in this survey which have not been secured in any previous survey. For example, the information in regard to origin and destination of truck shipments embraces not only the terminal points but the character of these points, so that it will be possible to describe the exact character of each movement as a farm-to-railroad shipment, residence-to-residene, manufacturer-to-jobber, etc. The observations with respect to the situs of motor-vehicle ownership also constitute a new class of information; and the passenger bus data, including origin, destination, capacity, number of passengers and frequency of trips will be more complete than any similar information previously secured.

VOLUME CHANGE A MEASURE OF ALKALI ACTION

EFFECT ON CONCRETE MEASURED BY CHANGES IN LENGTH

By DALTON G. MILLER, Senior Drainage Engineer, U. S. Bureau of Public Roads

EDITOR'S NOTE.—The May issue of PUBLIC ROADS contained reports of investigations by the Bureau of Public Roads to determine the effect of alkaline mixing water on the strength of concrete, and to develop protective treatments with tars and paraffin. While the experiments upon which the following report is based have for their principal purpose the improvement of the quality of farm drain tile, the results of the studies may be applied also to concrete pipe culverts. The particular relation described has no direct bearing upon design, but should have useful application in the laboratory.

The experiments described were conducted at the drain tile laboratory, University Farm, St. Paul, Minn., by the Department of Agriculture of the University of Minnesota, the Department of Drainage and Waters of Minnesota, and the division of agricultural engineering of the United States Bureau of Public Roads.

THE SO-CALLED alkali problem in connection with the use of concrete drain tile in Minnesota was early resolved into a question of the effect of sulphates of magnesium and sodium, and as the action on concrete of each of these salts is accompanied by a very decided increase in volume it was decided to use in the laboratory both the actual increase and the rate of increase as indicated by length changes, as a basis for comparing the behavior of different specimens in the same solution as well as the effect of different solutions on similar specimens.

The increase in volume caused by immersion in magnesium sulphate solution is here plainly illustrated. The three swollen cylinders have been immersed in a 1 per cent solution for 38 weeks. The other two from the same lot have been kept in distilled water for the same length of time. All cylinders are 1:3 mix, normal consistency, standard Ottawa sand

Heretofore it has been the practice in work of this general nature to depend upon the appearance of the specimens, supplemented by compression or tension tests to determine the effect of the chemical action. It is obvious that the mere appearance of a specimen is not entirely satisfactory as a criterion, and while compression and tension tests are of course fundamental, and consequently must finally form the basis for any conclusions, yet such tests are subject to certain limitations in studies that have to do with the deterioration of concrete, since the life of a specimen is of course ended when once it is broken. In ordinary laboratory work on concrete the testing of a few specimens more or less is not of great moment; but where the specimens are kept in solutions for long periods and where it is necessary to renew the solutions at short intervals, it becomes essential to reduce—so far as possible without impairing the value of the work—the number of specimens tested.

In the Minnesota investigations all experimental pieces are kept in solutions in earthenware jars, and

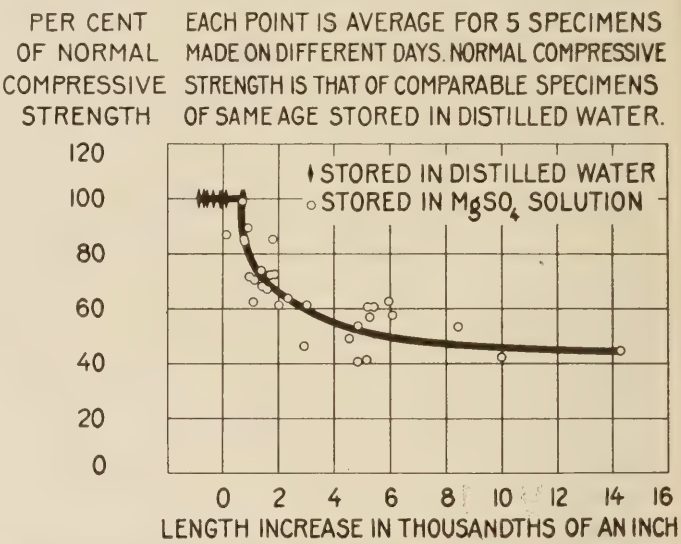


FIG. 1.—Relation between length changes and compressive strength of 2 by 4 inch Portland cement mortar and concrete cylinders immersed in solutions of magnesium sulphate

the solutions are changed weekly. In order to insure consistent results it has been found that this change must be made at frequent intervals. In fact the ideal arrangement would be to use a constantly changing solution, as this would most nearly represent field conditions. Two by four inch cylinders have been used in the work, as this size reduced to a minimum the volume of concrete in all jars. Moreover, the 2 inch diameter roughly approximates the thickness of the wall of the average size of tile used in the larger drains in Minnesota.

The cylinders are made in batches of nine, each series consisting of five batches made on different days. In each end of three cylinders of each batch a 1-inch brass screw is set in neat cement. Changes in length are determined by measurements between screw heads. The laboratory standard concrete specimen is mixed 1:3 by volume, normal consistency, with the aggregate graded to produce a fineness modulus of 4.67, the largest pebbles used passing a three-eighths inch screen.

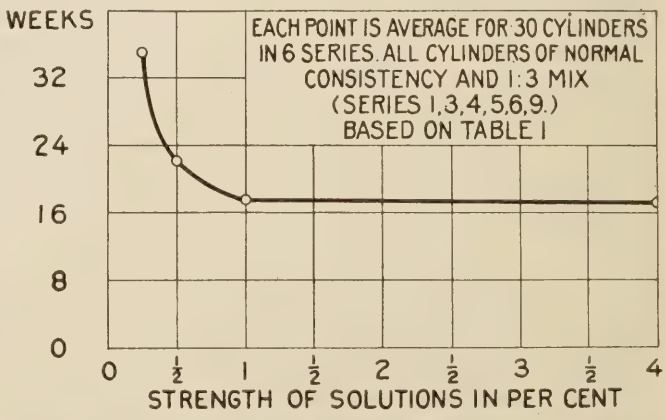


FIG. 2.—Time required for 2 by 4 inch Portland cement mortar and concrete cylinders in magnesium sulphate solutions of different strength to increase 0.010 inch

The cylinders are cured one day in the moist closet and 20 days in distilled water, after which they are placed in the solutions. Ten or fifteen cylinders have ordinarily been stored in each jar, the present practice being to start a series with 15 cylinders to a jar. In all cases the quantity of solution in a jar is 10 liters (2.6 gallons). About 10,000 cylinders have been made to date and this number is being constantly increased.

INCREASE IN LENGTH INDICATES LOSS IN STRENGTH

The results of some of the earlier work in the laboratory are shown in Tables 1 and 2 and by the curves in Figures 1, 2, and 3. Figure 1 is based on tests of some 200 cylinders. The points from which this curve was developed represent length changes of cylinders with screws and compression tests of blank-end cylinders from the same batches; consequently the relation between length change and strength ratio is not exact. Also the ends of many of the cylinders in the solutions become quite soft and crumble badly at the edges, rendering compression results more erratic than usual even after capping with plaster of Paris. It is evident, however, that any appreciable increase in length is indicative of loss of strength, as those cylinders stored in distilled water generally show no tendency to expand, but, on the contrary, in many cases slightly contract. Study of Figure 1 indicates that an increase in length of 0.10 inch in a 4-inch specimen means a loss in strength of 50 per cent or slightly more.

One of the interesting phases of the work so far has been that of the relative effects of solutions of different strengths on the cylinders. It has been found that the destructive effect of a 4 per cent solution is not much greater than that of a 1 per cent solution, although for solutions below 1 per cent the action is approximately proportional to the strength of the solution. Because

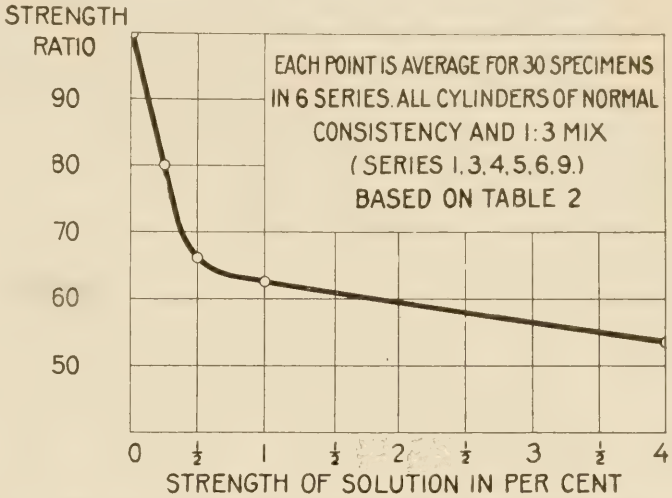


FIG. 3.—Strength ratio of 2 by 4 inch Portland cement mortar and concrete cylinders after immersion in magnesium sulphate solutions for periods averaging 15 weeks

(Continued on page 17)

TABLE 1.—*Time required for 2 by 4 inch Portland cement mortar and concrete cylinders immersed in magnesium sulphate solutions to increase in length 0.010 inch* [1]

Series	Fineness moduli	Compressive strength		Absorption at 21 days	Strength of solutions				Remarks
		7 days	28 days		One-fourth per cent	One-half per cent	1 per cent	4 per cent	
					Time required to increase 0.010 inch				
		Lbs. per sq. in.	*Lbs. per sq. in.*	*Per cent*	*Weeks*	*Weeks*	*Weeks*	*Weeks*	
1	3.00	1,850	2,840	7.1	25.6	15.0	12.9	15.8	Standard Ottawa sand.
3	3.00	1,370	2,180	11.8	32.1	14.5	10.8	10.4	Minnesota sand, screened 20–30.
4	3.00	1,640	2,470	9.3	21.9	12.5	10.8	10.6	Minnesota sand, screened 20–30, shale removed.
5	3.10	1,310	3,150	8.6	34.2	22.7	15.6	15.1	Minnesota sand, pit run.
6	4.67	2,700	4,250	6.2	44.5	35.4	23.8	19.8	Minnesota sand and pebbles passing three-eighths inch screen.
9	4.67	3,340	4,900	5.3	50.0	32.1	30.5	30.5	Minnesota sand, same as series 6, except shale removed.
Average	3.57	2,035	3,300	8.1	34.8	22.0	17.4	17.0	

[1] Each result is average for five cylinders of normal consistency and 1: 3 mix made and measured on different days.

TABLE 2.—*Effect of different strength of solutions of magnesium sulphate on compressive strength of 2 by 4 inch Portland cement mortar and concrete cylinders of normal consistency and 1:3 mix* [1]

Series	Age	Strength of solutions									
		0 per cent	One-fourth per cent	One-half per cent	1 per cent	4 per cent	0 per cent	One-fourth per cent	One-half per cent	1 per cent	4 per cent
		Breaking strength					Strength ratios				
	Weeks	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*					
1	17	3,871	2,820	2,425	1,730	1,900	100.0	72.9	62.6	44.7	49.0
3	12	2,450	2,120	1,555	1,490	1,010	100.0	86.6	63.4	60.9	41.2
4	12	2,680	1,830	1,240	1,530	1,090	100.0	68.3	46.3	57.1	40.7
5	16	4,140	2,910	2,550	2,515	2,235	100.0	70.3	61.5	60.7	53.9
6	16	4,095	4,060	3,660	3,481	2,970	100.0	99.1	89.4	85.0	72.6
9	17	5,995	5,095	4,435	4,020	3,720	100.0	85.0	74.0	67.1	62.1
Average	15							80.4	66.2	62.6	53.3

[1] Each result is average for five cylinders made on different days.

OBSERVATIONS ON THE OPERATION OF MATERIAL TESTING LABORATORIES

By F. H. JACKSON, Senior Assistant Testing Engineer and C. E. PROUDLEY, Junior Assistant Testing Engineer, United States Bureau of Public Roads

DURING the last two construction seasons the writers, representing the United States Bureau of Public Roads, have visited a number of laboratories engaged in the testing of materials used in the construction of Federal-aid roads. The visits were made with the purpose of ascertaining to what extent these laboratories were following approved methods of testing as recommended by the Committee on Tests and Investigations of the American Association of State Highway Officials and approved by the Bureau of Public Roads. Fifty-five laboratories located in 45 States were inspected during the two seasons.

Since the passage of the Federal aid road act in 1916 the Bureau of Public Roads has required that all materials used in Federal-aid roads be tested for conformity with specifications. Prior to 1916 very few of the States were provided with proper facilities for carrying on this work, and it was necessary for the bureau at first to do a considerable amount of testing in its own laboratory. Within the last three or four years, however, it has been possible for a number of the States to install their own testing laboratories. Others have found it possible to enter into cooperative agreements with universities or technical schools, and still others have been able to obtain the services of existing commercial testing laboratories. During the 1923 season the bureau records show that there were 28 State and 24 university and 35 commercial laboratories engaged wholly or in part in the routine testing of Federal-aid road materials.

In the organization of the newer laboratories it has not always been possible to secure experienced men as operators, nor has it always been possible to install adequate equipment. These unsatisfactory conditions have resulted in some cases in the reporting of erroneous test results, which are naturally accepted at their face value by engineers in charge of construction. Thus they may lead to the acceptance of defective material or the rejection of acceptable material. It is obvious that the value of testing in general hinges on the accuracy with which the tests are made, and for this reason the Bureau of Public Roads is directly interested in assisting road materials laboratories in following standard methods. It may be of interest to highway and testing engineers to call attention briefly to some of the points observed in connection with the inspections made thus far.

THE LABORATORY FACILITIES

All enterprises are subject to a period of growth at the beginning of which they will be found frequently in a rather unsatisfactory state. Road materials testing laboratories are not exceptional in this respect, and the bureau's survey showed that in the character and amount of space and equipment available not less than 20 per cent of them were totally unsatisfactory for their purpose and only about 30 per cent were in what might be termed "first-class condition." We are considering at present only such factors as floor space, light, ventilation, convenience, and kind of equipment, whether standard or otherwise, in good or bad repair, and whether it was adequate to meet the requirements of tests as specified.

It may be said in passing that highway materials laboratories seem to be set up in any place obtainable provided the space is not needed for other purposes. Basements seem to be a favorite selection, but top floors or attic floors are nearly as popular. Such locations may be made quite comfortable, but with much difficulty. In one instance, it was observed that the basement was so damp as to prohibit the storage of cement there for more than a few hours. In another case steam pipes, although asbestos covered, increased the temperature in winter until it became almost unbearable except when ventilating fans were in operation. This same condition is also found on top floors under the roof when the sun beats down upon it.

The problem of obtaining adequate light presents itself to a large majority of laboratories. Electric lights are usually available, but there are some operations which should be done in good daylight in order to obtain best results. A frequent mistake, observed in laboratories occupying remodeled office buildings, was that of attempting to make the light from a few windows cover more than the space for which they were intended.

This brings up the point of personal efficiency which is a big item in testing as well as any other kind of work. Excessive moisture or heat will rapidly lower the vitality of an operator and should he be engaged in a series of comparative tests which depend on uniform manipulation, a likely source of trouble is easily recognized. Either insufficient or glaring light is tiresome to the eyes and the probable error in reading instruments and performing other close work increases accordingly.

Much may be done toward increasing efficiency in a laboratory by judiciously arranging the equipment. Of course, there is a limit to the amount of material which can be made to occupy a given space, but it is true of several laboratories that more careful planning would have greatly facilitated the work. Besides the inconvenience of operating in crowded quarters there is a decided disadvantage in not being able to inspect, clean, and repair machinery in the proper manner. With one exception, and that a small laboratory, it was observed that the congested equipment was in more or less poor condition.

The rock-testing equipment, it was found, usually received less care and attention than any other kind of apparatus. Sieves and screens came next, and last but of equal importance the water storage for cement mortar specimens was too often slighted. The principal result of negligence of rock-testing apparatus is the accumulation of dust and corrosion. Sieves uncared for become clogged with sand particles, or if improperly cleaned the wires are damaged to such an extent that the sieves soon become unfit for use. Occasionally sieves were seen which had corroded from contact with air in a chemical laboratory until they had become totally unfit for use for sand or cement testing.

MUCH FAULTY STORAGE OF CEMENT SPECIMENS

In many cases it was noted that certain details of the specifications of the American Society for Testing Materials for storage of cement specimens were not being followed. This applies particularly to the temperature of the clean water in the storage tanks. It is realized by everyone that to maintain the temperature at 70° F. at all times is difficult, perhaps practically impossible in some places. Nevertheless the specifications should be adhered to as closely as possible because variations from them present a likely source of error in results. Contrast the condition found in one laboratory where a large but shallow pan of water containing briquets is placed on the laboratory table with a small Bunsen flame under it to keep it from freezing and that of another laboratory which has a constant-temperature moist room in which are kept the storage tanks. A simple and rather effective arrangement to overcome this difficulty is to have a continuous flow of water from a supply into which is inserted an electrical heating element. By regulating the flow of water the temperature may be maintained at approximately 70° F. and at the same time the running water keeps the tanks clean. The laboratory of the Bureau of Public Roads has recently installed such a system, the details of which will be gladly furnished upon application.

One other obvious fault with the equipment of a number of laboratories was the lack of essential apparatus or the use of makeshifts of very doubtful efficiency. A surprising number of instances were found in which a moist closet consisting of wet cloths laid over fresh specimens was considered quite satisfactory. Rubber gloves, although advised by standard specifications, were thought to be superfluous. In one instance the quality of rock was determined with absolutely no equipment other than a hammer and United States Department of Agriculture Bulletin 348. Such are the results of inadequate funds, congested quarters, improper interpretation of specifications, and frequently lack of confidence of administrators in the testing engineers.

Briefly then we can say that more thought for the welfare of laboratory operators, more careful arrangement of apparatus, and a wiser selection of equipment would undoubtedly increase the efficiency of the average road materials laboratory many times over.

It may be of interest to review briefly some of the peculiarities observed in methods of testing. In all cases the methods of testing actually employed were compared with the methods recommended by the committee on tests and investigations of the American Association of State Highway Officials as approved for Federal-aid work by the Bureau of Public Roads.[1] Wherever possible, operators were observed while actually engaged in routine testing. Additional information was obtained by conversation with the operators and by general observation. As a result numerous variations from standard methods were noted which may be of interest in showing in a general way just how closely the standards are being followed by the men who do the work.

COMMON MISTAKES IN TESTING CEMENT

Although all Portland cement is supposed to be tested under the specification of the American Society for Testing Materials, which has remained practically unchanged since 1916, more variations in methods were noted in testing this material than any other. They ranged all the way from distinct violations of specification requirements, caused either by inexperience or prejudice, to minor variations in technique due to the personal equation of the operator, or to differences of opinion regarding the proper interpretation of the specifications. As would be expected, errors in testing were more serious in the newer laboratories than in those which had become well established. In some of the older commercial laboratories, however, operators were found who were apparently testing cement more nearly in accordance with methods in vogue in the early nineties than in accordance with present standards. It was more difficult to convince some of these men that their methods were incorrect than the young, inexperienced operators. Although errors in conducting practically all of the tests of Portland cement were observed, by far the greatest departure from standard methods occurred in connection with the preparation and storage of briquets for the standard tension test.

One or two illustrations will serve to call attention to conditions which, although fortunately not common, actually did exist at the time of inspection. In one case an operator was observed mixing a standard mortar in an ordinary iron pan with a trowel, and storing the briquets under a moist cloth for the night. In more than one instance operators were in the habit of ramming the standard mortar into the mold with the handle of a trowel. One man when questioned regarding this practice replied that it was the only way he could get the cement to pass the specifications. In still another case an operator was attempting to determine the normal consistency of a neat cement paste by mixing with the bare hands on a soft wooden surface. Quite a large number of testers were found to be disregarding altogether the specific requirement in the American Society for Testing Materials standards that the molds must be filled without ramming. This was particularly noticeable among the older men, some of whom evidently believed that they could get more consistent results by putting a lot of work into this operation. To sum up, it seemed to be a matter of general observation that, whereas the methods of testing cement employed by the newer organizations were usually such as to yield results lower than normal, the work of most of the commercial and some of the older State and university laboratories would have, as a rule, the opposite effect. Taken as a whole, conditions would certainly justify a vigorous campaign of education among cement testing laboratories on the part of those interested, and would seem to justify to a certain extent the contention of the cement manufacturers that unreliable test data are being turned out in some cases.

VARIATIONS IN TESTING OF AGGREGATES LESS SERIOUS

Variations from standard methods of testing concrete aggregates were not so common nor so serious as in the case of cement. In some instances operators did not seem to have a definite idea of the effect of maximum size of aggregate on the accuracy of the mechanical analysis. In other cases, the effect of size of sample on the efficiency of a mechanical shaker was no appreciated. For instance, one operator was found who was expecting the mechanical shaker to sieve accurately a 1,000-gram sample of sand in 10 minutes. With

[1] See U. S. Dept. Agr. Bull. 1216.

regard to the mortar-strength test for sand a rather serious error was discovered in quite a few cases. This was the tendency on the part of some operators to gage the sand mortar with the same amount of water in all cases, regardless of the character or grading of the sand being tested. Anyone familiar with tests of this nature knows to what such a practice might lead. Elutriation tests of fine aggregates were apparently being conducted in a satisfactory manner except that there appeared to be no agreement in regard to the size of sample to be used. The color test for organic matter was being carried out correctly as far as could be observed. In the abrasion test of gravel aggregates, however, a condition was noted to which attention should be called. This was the practice of some laboratories of making this test indiscriminately on uncrushed or crushed gravel, or a combination of the two. Experience has shown that wide variations in results are obtained when no attention is paid to the amount of crushed fragments in a test charge.

TESTING OF ROCK AND CONCRETE

Apparently the only rock test made to any great extent is the standard Deval abrasion test. The principal variations in methods of conducting this test were found in the preparation of the sample. In some cases great care was taken to secure pieces of uniform size and shape, while in others the sample was merely broken up by hand until the requisite number of pieces had been secured. Lack of attention to details of this nature undoubtedly explains some of the discrepancies in the results of tests which are continually appearing, and which unfortunately often lead the highway engineer to the conclusion that the tests themselves are basically wrong. Although many of the laboratories visited were equipped to make complete rock tests, many instances were encountered where routine tests other than abrasion were seldom if ever made, due principally to the difficulty experienced in the manufacture and use of rock drills. Wherever such tests were made, however, they seemed to be in accordance with standard practice.

Numerous variations were noted in methods of testing concrete in the laboratory. This was probably due largely to the fact that until recently there has been no uniform practice by which laboratories could be guided. The recent tentative specifications of the American Society for Testing Materials, however, have made it possible for all laboratories to follow methods sufficiently uniform to secure comparable results. One detail in connection with the crushing strength tests for concrete which has been overlooked by a number of laboratories should be mentioned. This is the matter of the proper capping of test specimens. The present practice requires that specimens be capped with either neat Portland cement or a mixture of Portland cement and plaster of Paris. The majority of the laboratories inspected, however, were still using the old plaster capping, which has been found to give considerably lower results especially on long-time specimens.

The writers do not wish to be understood as saying all laboratories visited were conducting tests of materials incorrectly. Most of the older State and university testing laboratories, as well as some of the commercial laboratories were found entirely satisfactory insofar as actual methods of testing were concerned. The one outstanding exception to this rule was the matter of cement testing which, as has been pointed out, was found to be in a most unsatisfactory state. It is safe to say, however, that in the majority of the laboratories inspected, incorrect methods of testing of a more or less serious nature were being followed. The writers may be pardoned therefore for emphasizing again the necessity for some action which will lead to an improvement along this line, especially as there is every reason to believe that the conditions noted are representative of the country as a whole.

PERSONNEL STANDARDS NEED REVISION UPWARD

One of the most difficult of laboratory problems is that of personnel. This is especially true of the operators comparatively far down in the salary scale, because it is this class which is most subject to change and therefore most uncertain. Certain observations and comments upon the character of personnel employed in the testing of road materials as evidenced by this inspection follow:

In the majority of cases the laboratory head or supervisor was found to be a competent engineer capable of appreciating the importance of his work and its relation to the other branches of the highway department. In some of the newer State laboratories, however, the men in charge were found to be greatly handicapped by lack of experience. This is probably due to the fact that when new State highway laboratories are established it is the usual custom to put an engineer already in the organization in charge instead of an experienced testing engineer. Such a practice works out satisfactorily in the end provided a man is chosen who has had enough laboratory training to enable him to see the situation from the point of view of the testing engineer as well as of that of the highway engineer.

Among the university laboratories a tendency was noted for the man in charge to give too little time to the actual supervision of the work of the operators, a condition which is usually brought about by requiring him to devote the major portion of his time to teaching. This practice should be discouraged. In a modern highway testing laboratory there is certainly enough for the testing engineer to do without requiring him to spend most of his time in the class room. The constant overlapping of highway and university work is one of the principal arguments against the use of university laboratories for the routine testing of materials.

The assistants employed in routine testing of materials, that is, the actual operators, fall into two general classes: Permanent operators; and temporary assistants, usually students. In those State laboratories where it had been found possible to build up a permanent organization the operators appeared to be as reliable and dependable as could be expected in view of the low scale of pay which obtained in most cases. In these organizations it is the usual custom to work on research problems during the winter months when routine work is at a minimum, and in this way keep a permanent force busy throughout the year. This is, of course, an ideal arrangement and is the goal towards which every road material testing laboratory should aim, since it not only makes it possible to build up a permanent organization but utilizes the facilities of the laboratory to the fullest extent.

The employment of students to conduct routine tests, which is the practice in some of the university

laboratories, should be discouraged. In the first place, they do not, as a rule, remain long enough in the laboratory to become proficient in testing work. In the second place, their interest in the work of the laboratory is secondary to their university work, and being temporary employees they have not the incentive to continued effort which characterizes a permanent man, anxious to advance. Of course, there were exceptions, but as a rule, it may be said that more actual errors in testing were observed on the part of students than any other class of operators.

With regard to the general question of laboratory personnel the writers take exception very strenuously to the belief that anyone can make routine tests. If there is one job in connection with highway work which requires preliminary training and experience it is that of the routine operator in the testing laboratory. The disposition of thousands of dollars worth of materials often depends upon the results of a single test, and yet frequently we find a 16 or 17 year old youth doing the work for a salary which is less than that of the typist who transcribes his report.

THE RELATION BETWEEN THE LABORATORY AND THE JOB

State highway testing laboratories as at present organized may be roughly divided into two general classes: Those which are a coordinate branch of the highway department, the head of the laboratory having complete supervision over the testing and inspection of all materials; and those which make tests only when required by the construction division, the chief having no jurisdiction over the ultimate disposition of materials. In the first case, the laboratory is usually part of a general Bureau of Inspections and Tests whose activities extend into the field in the form of materials inspection at the point of production or on the job. Such bureaus also frequently maintain a staff of prospectors who, working in cooperation with State geologists, are constantly developing new sources of supply. Such organizations are ideal but so far are found in only a handful of States. Examples of materials organizations developed along the above lines are those of the Pennsylvania, Illinois, New Jersey, Iowa, Minnesota, North Carolina, Washington, and Utah State Highway Departments. That the highway executives of these States believe the development of the materials testing side of highway engineering pays is evidenced by the size and importance of the materials testing organizations in these States. It is suggested that any State highway official who may be contemplating the expansion of the department of material inspection and tests, would do well to study the methods used in some of these State highway departments.

State highway laboratories of the second class are more numerous. In some cases they are doing good work; in most cases they are doing work which is as good as could be expected with the funds available. They are all handicapped by the absence of that intimate contact with the job which is so essential if the testing department is to function to its fullest extent. The writers believe that the testing or "materials" engineer rather than the highway engineer is the logical person to assume responsibility for the quality of the materials of construction. In the first place, he is in a better position to interpret intelligently the results of laboratory tests because he realizes the limitations to which the tests are subject. He is therefore better qualified to determine what tolerances should be allowed in specific cases. In the second place, he is interested solely in materials, whereas to the highway engineer, materials are but one of his many troubles. The testing engineer should, on the other hand, be in constant touch with actual construction, not only so that he may see how the materials he has tested are working out in practice but also in order that he may learn the point of view of the construction engineer. In other words he should be actually a "materials" engineer, a man equally familiar with both the methods of testing materials and their use in highway construction.

For reasons which have been pointed out the writers are not in sympathy with the general idea of using university laboratories for routine control testing of highway materials. Such laboratories may be and are utilized for carrying on research and many of them are doing excellent work along this line at the present time. The routine control testing should, however, be done by a laboratory under the sole jurisdiction of the highway department with a competent materials engineer in charge who is responsible directly to the chief engineer for all materials used.

Many of the State highway departments in the past have depended entirely on commercial laboratories for control testing of such materials as Portland cement, paving brick, bituminous aggregates, etc. There can be no objection whatever to this practice provided the work is done by an established firm with a reputation for thorough inspection. The great expansion in road-building within the last few years has resulted, however, in the organization of many new commercial laboratories, advertised as fully equipped to handle all kinds of road materials inspections. They are being established principally in those States which have the poorest facilities for doing the work themselves. It was possible for the writers to visit a few of these laboratories and though the time at their disposal was not sufficient to make a thorough study possible, enough was learned to indicate that some of the laboratories were far from being satisfactorily equipped or organized for highway materials testing.

(Continued from page 13)

of this the standard strength of solution now used in the laboratory is 1 per cent. Apart from the fact that this concentration is almost as destructive as much higher ones, its use has the added advantage of more nearly approaching ordinary bad field conditions.

As will be noted, the general form of the curve in Figure 2 based on the data of Table 1 is quite similar to that in Figure 3 based on compression test data of Table 2, although the difference between the 1 per cent and 4 per cent points is somewhat greater on the curve in Figure 3 than in Figure 2.

ROAD MATERIAL TESTS AND INSPECTION NEWS

STANDARDIZATION OF THE CRUSHING STRENGTH TEST FOR ROCK

Working in cooperation with the Road Materials Committee of the American Society for Testing Materials, the Bureau of Public Roads has been conducting a series of tests with a view to determining the best size and shape of test specimen for compression tests of rock. Although this test is used quite frequently in connection with the examination of stone for railroad ballast and building construction, and to a lesser degree, in connection with road construction, the method of conducting the test has never been standardized. The data now available are not comparable because many of the older tests were made on cubical specimens of various dimensions, whereas most of the later tests have been made on cylinders either 1 inch or 2 inches in diameter and of various heights. This particular study is a part of a general investigation looking to the standardization of the crushing strength test by the American Society for Testing Materials. The investigation will ultimately include not only a study of the size and shape of the test piece, but also the effect of other factors which influence the test results, such as the rate of application of the load and the character of the bearing surfaces of the test piece.

The first series of tests made in connection with the study of shape and size of test piece has been completed. In this series two samples of granite and a sample of limestone were tested. Cylinders both 1 inch and 2 inches in diameter were prepared, with heights of 1, 1½, and 2 inches for the 1-inch size, and 2, 3, and 4 inches for the 2-inch size. In making the tests, the other two factors which may affect the results were kept constant. The rate of application of the load was approximately 0.1 inch per minute, while the bearing surfaces of all specimens were ground plane with carborundum and water on a grinding lap and tested directly without the use of any capping whatever. The bureau has found that much higher unit stresses are obtained on stone when tested in this manner than when either a cement or plaster cap is used.

The results of these tests are shown in the following table. Each figure represents the average crushing strength obtained from three tests.

Dimensions of cylinder		Crushing strength		
Diameter	Height	No. 1 granite	No. 2 granite	Limestone
Inches	*Inches*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
1	1	32,000	23,500	6,000
1	1½	31,500	20,500	5,500
1	2	32,500	22,500	5,000
2	2	35,500	29,500	9,000
2	3	33,000	26,000	8,500
2	4	31,000	29,000	8,000

A rather interesting feature of the tests on the granite is that the lowest crushing strength, as a rule, was obtained with specimens, the height of which was one and one-half times their diameter. Tests made by other members of the committee seem to substantiate the values here shown. Tests on the limestone, however, show very little variation in result due to height of cylinder, although the values obtained from the cylinders 2 inches in diameter are somewhat higher than those obtained on cylinders 1 inch in diameter. This, it will be noted, is also true of the two samples of granite tested.

PROPORTIONING CONCRETE FOR TESTING PURPOSES

It is advisable to proportion materials for laboratory concrete specimens by weight. This insures uniformity not so easily obtained volumetrically due to variations in compaction.

In the laboratory of the Bureau of Public Roads, the materials for a concrete specimen are measured as follows:

The weight per cubic foot of the coarse aggregate and fine aggregate is determined according to the method described in United States Department of Agriculture Bulletin 949. A volume of 5,000 cubic centimeters of coarse aggregate furnishes enough concrete for one 6 by 12 inch cylinder.

By proportion

$$\frac{62.37}{W_a}=\frac{V_w}{W}$$

or

$$W=\frac{V_w\times W_a}{62.37}$$

in which

W = weight in grams of volume of aggregate required.

V_w = weight in grams of water equivalent to volume of aggregate required.

W_a = weight in pounds of a cubic foot of aggregate.

62.37 = weight in pounds of a cubic foot of water.

Example—

Required: 1 : 2½ : 5 mix of concrete in 6 inch by 12 inch cylinder.

Data given: Weight of cement per cubic foot, 94 pounds; weight of sand per cubic foot, 110 pounds; weight of gravel per cubic foot, 104 pounds.

Computations: 1 : 2½ : 5 mix.
1000 : 2500 : 5000.

$$\text{Cement}\quad\frac{1000\times 94}{62.37}=1{,}507\text{ grams.}$$

$$\text{Sand}\quad\frac{2500\times 11}{62.37}=4{,}410\text{ grams.}$$

$$\text{Gravel}\quad\frac{5000\times 104}{62.37}=8{,}340\text{ grams.}$$

Proportions by weight: 1,507 : 4,410 : 8,340.

STATIC LOAD TESTS ON PAVEMENT SLABS

The Bureau of Public Roads is about to conduct static-load tests on two series of pavement slabs which were previously used to study the effect of impact. The slabs are 7 feet square and vary considerably in their construction. Bituminous concrete bases and tops, concrete bases and one-course concrete pave-

ments are represented. Thicknesses and mixes are also varied. One series of slabs rests on a dry clay subgrade; the other is supported by a clay subgrade kept constantly moist. The slab corners will be tested under static loads and corresponding values of deflection, stress in the slab, and the amount of load will be taken until failure occurs.

The load will be applied by means of a hydraulic jack resting on the slab and working against a large, cylindrical, steel tank filled with water. The tank is 30 feet long and 6 feet in diameter. It is estimated that it will weigh 30 tons when filled. Mounted horizontally on suitable supports it will be moved on rollers into position over the slabs.

After the slabs now in place have been tested, they will be replaced by new slabs for the purpose of studying the effect of static loads on several of the more modern designs of concrete pavements, also the extent to which various types of longitudinal center joints transfer the load from one side of the pavement to the other.

PORTABLE OUTFIT FOR TESTING AGGREGATES

The Bureau of Public Roads has prepared and distributed to its materials engineers a number of portable testing outfits for use in the field examination of aggregates. Each outfit consists of a set of 8 half-cylindrical sieves and screens, ranging in size of opening from 100-mesh to 1-inch round; a 30-pound spring scale for making mechanical analyses of coarse aggregate and other weight determinations; a 200-gram spring balance for making mechanical analyses of concrete and asphalt sands; a portable stove for drying sand; a geologist's hammer; and bottles for silt and colorimetric determinations on concrete sand, etc. The equipment is contained in a small carrying case 18 inches long and weighs, together with the case, about 15 pounds.

COMPRESSION TEST FOR CONCRETE

A series of tests was made recently by the Bureau of Public Roads in an effort to reduce to a minimum the variation in the characteristics of mortar compression specimens resulting from lack of uniformity in the molding method. The mortar compression test has been coming into greater favor recently for investigational purposes and no doubt would receive general approval as a standard strength test also, if the method were standardized so as to insure uniform results.

In the bureau's tests four operators worked independently but used the same equipment and apparatus. The series of tests included 7 and 28 day specimens of briquettes and 2 by 4 inch cylinders of 1:3 Ottawa sand mortar. Briquettes were made according to standard specifications. Cylinders were made according to A. S. T. M. Tentative Standard Specifications C9–16T. Three sets of cylinders were made, using three styles of tampers, the suggested A. S. T. M. form, a one-fourth-inch bullet-pointed rod and a five-eighths-inch rod with a rounded end. Twenty-five strokes of the tamper were used in each case. Each operator repeated the series on 3 different days.

Comparing the work of different operators there was less variation in the strength of compression specimens made with the five-eighths-inch rod, than in the specimens made with either of the other styles of tampers; but the one-fourth-inch rod gave results nearly as consistent.

An operator could duplicate his own results most easily with the A. S. T. M. tamper, the five-eighths-inch rod coming next in favor. More uniform results were obtained by the operators in the tension test, probably because most cement operators have had more experience with this test.

Variation between individual breaks of sets was practically the same in all cases except those molded with the one-fourth-inch rod, in which case the percentage variation was considerably higher.

THE CUSHIONING QUALITIES OF MOTOR TRUCK TIRES

The results of a large number of tests by the United States Bureau of Public Roads prove that the deflection of motor-truck tires under static load is not a reliable measure of their relative shock-absorbing qualities, especially when the tires compared are not of the same general type. When the tires compared are of the same type—that is, when solid rubber and cushion tires are compared with each other, or when two or more pneumatic tires are compared—the static-load comparison is a fair indication of their relative cushioning properties.

It is not a proper basis of comparison between solid rubber tires and pneumatic tires, probably for the reason that the deflection of the solid rubber tire is dependent largely upon the shape of the tire and the quality of the rubber, and that the resistance to deformation is not proportional to the loads applied, but increases at a greater rate than the increment of loading. The deflection of pneumatic tires with respect to the loading is practically uniform and proportional to the loads. The reistance to the loading is only slightly dependent upon the material of the tire, and is mainly dependent upon the compressed air within. Although the rubber composition of some solid tires is apparently softer than a pneumatic tire as a whole, it will be seen that the cushioning properties of the pneumatic tire are much more effective than those of the solid or a cushion tire. The cushioning properties of the pneumatic tire remain in proportion to the load and still function at the end of the blow. This is not true with regard to the action of solid rubber tires. In these the rubber increases in density under increasing loads and deforms in such a manner that the unit intensity of loading at the area of contact is very greatly increased, thus losing in cushioning value and presenting greater resistance to the load or blow as it is brought to rest, with the result that the impact may be very greatly increased.

The cushioning effect of the various tires is clearly shown by the tests made by the bureau. As typical of the relative characteristics of the several types, consider a 3½-ton truck, using different tires, and carrying a load of 4½ tons, the testing speed in all cases being 15 miles per hour. This truck was allowed to strike an obstruction 2 inches high and 4 inches wide lying flat on the pavement. The same truck was also subjected to a drop test in which it was caused to drop 2 inches from one level to another. No change was made in the truck, except that three different types of tires were used. At one rear wheel the sprung weight of this truck was 5,300 pounds, the unsprung weight 1,700 pounds, and the total load was 7,000 pounds. With worn solid tires the impact force as measured was 26,500 pounds; with new solid tires, 18,700 pounds; and with pneumatic tires, 8,000 pounds, when the truck was run over the 2-inch obstruction. When the same truck was operated in the 2-inch drop test, the impact force developed when using worn solid tires was 23,500 pounds; new solid tires, 17,000 pounds; and pneumatic tires, 8,200 pounds. The results show the remarkable cushioning effect of pneumatic tires.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

MAY 31, 1924

STATES	FISCAL YEARS 1917-1923			FISCAL YEAR 1924									BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS	STATES
	PROJECTS COMPLETED PRIOR TO JULY 1, 1923			PROJECTS COMPLETED SINCE JUNE 30, 1923			*PROJECTS UNDER CONSTRUCTION			PROJECTS APPROVED FOR CONSTRUCTION				
	TOTAL COST	FEDERAL AID	MILES	TOTAL COST	FEDERAL AID	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES		
Alabama	$ 3,789,011.74	$ 1,794,703.21	367.9	$ 809,709.89	$ 391,544.33	96.2	$ 14,343,932.92	$ 7,111,741.36	828.0	$	$		$ 412,921.54	Alabama
Arizona	6,518,025.52	3,195,689.68	372.1	1,820,339.99	1,091,994.20	155.7	2,419,995.90	1,439,148.62	164.7	282,404.40	172,577.32	32.8	543,287.62	Arizona
Arkansas	8,623,205.72	3,308,572.12	736.2	2,376,036.54	1,074,487.36	201.1	6,206,905.23	1,973,663.06	334.8	1,663,527.73	646,234.70	96.1	800,585.69	Arkansas
California	8,495,547.60	3,538,967.90	340.5	4,503,527.43	2,108,130.27	193.2	11,670,617.36	6,277,613.82	430.2	207,198.09	122,246.87	3.9	2,581,306.36	California
Colorado	6,470,695.56	3,136,238.67	426.6	1,564,560.31	858,240.49	74.1	4,240,501.64	2,300,955.98	161.1	309,349.90	152,128.34	9.5	1,750,935.56	Colorado
Connecticut	2,568,643.95	1,026,148.86	60.7	128,610.43	64,305.21	3.9	3,411,072.42	1,208,614.44	61.4				606,612.59	Connecticut
Delaware	2,196,610.22	621,154.83	45.2	860,222.00	386,560.00	27.3	936,095.90	321,022.50	22.9	76,669.90	31,961.10	0.2	13,206.40	Delaware
Florida	69,466.31	29,700.63	15.6	604,477.52	288,175.17	23.3	8,579,162.96	4,232,785.06	255.5	1,037,874.30	440,221.40	13.7	408,668.22	Florida
Georgia	13,960,499.47	6,363,703.60	925.5	3,141,534.04	1,559,525.28	291.3	8,553,999.69	4,110,539.70	721.5	812,013.98	356,385.91	60.4	76,719.62	Georgia
Idaho	6,890,673.73	3,272,111.01	426.1	1,301,024.19	820,284.51	80.7	1,263,572.26	745,053.76	90.1	751,242.98	422,880.76	53.9	480,683.95	Idaho
Illinois	25,211,526.23	11,414,291.96	743.5	1,596,036.76	786,682.95	56.1	14,427,878.03	7,026,599.48	488.5	2,598,414.58	603,256.08	87.2	401,793.64	Illinois
Indiana	5,513,487.76	2,668,277.55	157.0	1,945,251.03	928,993.26	64.6	15,173,499.83	7,426,710.72	504.3	967,026.91	464,350.92	38.5	984,156.23	Indiana
Iowa	16,040,079.62	6,056,136.48	1,059.4	7,155,698.57	3,180,995.38	623.5	7,282,591.38	3,361,757.08	589.1	1,372,229.60	647,600.00	65.3	11,499.73	Iowa
Kansas	12,216,428.90	4,248,438.34	349.7	4,646,077.17	1,707,714.99	142.2	16,043,026.16	5,993,105.03	563.4	2,572,909.95	1,064,206.84	110.5	204,593.76	Kansas
Kentucky	6,620,289.80	2,799,991.15	285.0	4,202,690.51	1,823,956.13	154.7	7,573,552.00	3,663,928.55	329.3	101,092.14	50,541.07	4.0	631,737.65	Kentucky
Louisiana	7,131,394.90	3,157,128.03	590.4	1,234,851.99	427,311.12	61.1	5,557,561.95	2,674,116.23	370.0				11,585.03	Louisiana
Maine	4,662,854.19	2,242,963.03	159.8	2,248,204.59	1,056,972.35	70.9	1,272,125.92	633,936.15	48.2	804,168.95	399,778.95	34.6	69,868.16	Maine
Maryland	5,309,394.94	2,524,843.54	185.0	1,450,649.48	688,478.24	58.2	1,843,490.49	666,562.25	55.3	820,558.35	60,000.00	25.1	73,120.96	Maryland
Massachusetts	6,841,975.16	2,802,957.88	163.7	3,221,788.48	1,251,509.34	66.5	4,316,018.48	1,555,087.16	77.7	914,833.53	291,788.94	14.4	928,630.46	Massachusetts
Michigan	9,528,041.53	4,343,817.14	363.4	3,621,638.91	1,594,197.90	121.3	13,290,787.70	6,480,284.08	477.3	201,747.97	93,445.50	6.1	1,151,202.65	Michigan
Minnesota	19,828,671.37	8,004,277.87	1,893.4	4,208,889.87	1,891,565.20	398.6	7,511,903.19	3,092,454.43	551.5	385,121.03	134,500.00	52.7	84,714.94	Minnesota
Mississippi	4,746,771.31	2,284,557.86	462.4	2,763,348.19	1,355,346.34	169.9	8,046,353.57	4,015,246.28	505.6	427,290.23	190,310.42	17.9	391,440.45	Mississippi
Missouri	5,272,757.08	2,358,848.60	365.6	5,882,354.23	2,783,592.39	427.5	13,892,214.29	6,732,072.94	576.4	2,788,890.47	1,273,290.95	149.0	2,363,897.37	Missouri
Montana	7,935,186.30	3,896,053.50	711.5	824,817.33	431,454.03	64.0	2,144,062.95	1,530,753.64	229.0	977,724.46	512,114.90	108.5	3,051,557.84	Montana
Nebraska	3,159,814.47	1,449,675.04	475.6	4,597,022.49	2,205,282.17	939.7	6,132,216.62	2,963,295.74	641.0	1,716,789.48	853,214.77	168.0	2,402,322.94	Nebraska
Nevada	3,049,109.29	1,562,111.35	203.6	411,136.23	291,513.63	22.0	4,392,423.46	3,734,897.69	354.0	48,297.53	42,125.10	0.2	312,049.98	Nevada
New Hampshire	2,336,997.00	1,129,004.69	140.5	739,763.19	358,862.89	30.8	710,627.11	330,403.37	24.8	239,231.68	109,995.68	7.2	141,072.36	New Hampshire
New Jersey	5,423,362.96	1,975,783.52	112.1	2,200,432.16	685,747.97	36.6	9,936,391.60	2,625,213.16	64.6	417,573.68	107,667.49	41.5	258,421.93	New Jersey
New Mexico	4,706,909.12	2,433,663.68	617.1	599,377.33	325,186.00	97.2	5,315,301.87	3,423,018.97	604.0	1,547,940.33	1,047,545.43	102.7	174,389.04	New Mexico
New York	9,826,633.82	4,358,659.70	290.6	7,915,755.70	3,364,013.15	250.2	24,370,626.96	9,507,456.47	560.3	5,033,900.00	1,740,295.00	105.5	4,074,617.82	New York
North Carolina	11,770,363.76	5,325,763.37	826.8	797,369.21	350,994.29	57.9	9,136,546.81	3,284,593.17	246.9	2,842,006.65	1,259,959.15	74.9	375,694.86	North Carolina
North Dakota	5,142,157.55	2,492,599.09	792.5	3,946,815.56	1,925,906.33	795.4	2,440,363.59	1,194,816.41	400.2	853,212.51	426,606.69	113.2	1,145,019.35	North Dakota
Ohio	22,840,050.09	7,966,325.17	662.9	9,894,698.45	3,773,542.92	286.9	12,491,044.13	4,730,089.66	347.6	1,561,096.50	499,108.47	42.8	376,293.19	Ohio
Oklahoma	9,795,634.54	4,417,788.46	371.5	3,191,230.72	1,471,063.57	125.9	7,803,091.38	3,774,328.47	351.6	2,566,768.77	1,090,617.34	111.9	29,715.45	Oklahoma
Oregon	10,391,362.48	4,782,736.38	534.1	1,691,510.69	1,036,357.41	121.5	2,800,425.31	1,481,878.83	161.5				28,356.23	Oregon
Pennsylvania	33,090,029.45	12,615,058.79	652.8	3,346,501.08	1,379,436.00	70.8	8,797,632.19	2,816,365.00	151.9	12,645,174.35	3,498,242.50	225.3	926,557.50	Pennsylvania
Rhode Island	1,494,075.35	647,634.96	38.6	290,321.90	131,593.00	7.4	1,087,787.06	411,759.49	22.7	334,265.25	89,147.31	5.6	287,281.37	Rhode Island
South Carolina	6,191,485.41	2,885,754.37	655.1	1,892,361.00	769,071.67	251.3	6,753,180.11	2,673,767.50	514.7	648,631.57	203,553.71	36.4	101,370.58	South Carolina
South Dakota	4,758,907.24	2,320,007.33	534.5	3,915,690.62	1,924,628.94	455.3	5,925,317.64	2,964,990.42	716.5	149,283.79	74,641.88	18.4	225,267.25	South Dakota
Tennessee	3,210,970.94	1,535,762.18	112.5	2,064,853.17	1,019,402.48	87.6	14,010,617.93	6,809,832.84	455.8	2,386,464.89	919,212.07	72.1	111,686.46	Tennessee
Texas	29,172,501.06	11,094,069.77	2259.6	11,846,295.22	4,542,975.45	901.4	25,850,956.09	10,276,130.76	1633.8	3,824,285.38	1,399,550.26	214.1	1,317.00	Texas
Utah	2,175,007.41	1,196,437.68	116.6	1,129,416.34	699,368.24	102.4	3,926,766.16	2,496,027.84	279.5	818,151.77	596,199.59	53.3	280,697.75	Utah
Vermont	1,370,715.63	669,433.75	53.1	551,398.53	273,335.37	21.3	1,257,846.96	603,240.34	37.2	517,413.80	253,242.99	9.7	369,101.28	Vermont
Virginia	6,823,978.36	3,279,029.56	402.5	3,061,720.63	1,447,951.63	155.0	8,504,608.59	3,910,842.83	309.8	1,177,475.06	110,693.00	36.6	395,873.43	Virginia
Washington	10,356,980.82	4,819,105.70	419.8	646,288.24	287,467.07	35.4	3,217,995.26	1,487,800.00	125.1	349,409.83	151,900.00	13.0	27,097.06	Washington
West Virginia	4,100,225.73	1,800,932.41	206.3	1,389,522.22	564,109.12	49.3	4,833,686.80	2,136,265.05	163.8	619,277.45	275,200.22	21.7	179,349.73	West Virginia
Wisconsin	15,504,691.39	5,996,989.24	1077.6	3,249,211.76	1,444,044.33	247.7	2,665,045.55	1,323,212.92	114.9	252,613.91	126,306.06	13.7	2,910,298.13	Wisconsin
Wyoming	4,601,439.36	2,210,774.20	534.8	1,438,619.13	815,095.43	137.8	4,099,496.50	2,576,868.47	301.2	325,739.27	109,591.52	41.3	38,649.25	Wyoming
TOTALS	$ 407,704,641.14	$ 174,044,673.82	23297.2	$ 132,919,640.92	$ 59,623,915.30	9801.5	$ 356,240,287.50	$ 162,110,847.62	16999.6	$ 60,947,241.80	$ 23,114,437.00	2518.4	$ 33,106,126.26	TOTALS.

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $ 53,556,879.31 Federal aid $ 24,333,867.02 Miles 2,441.9

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 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.
Report of the Chief of the Bureau of Public Roads for 1921.
*Report of the Chief of the Bureau of Public Roads for 1922. 5c.
*Report of the Chief of the Bureau of Public Roads for 1923. 5c.

DEPARTMENT BULLETINS

No. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
*136. Highway Bonds. 20c.
220. Road Models.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
*314. Methods for the Examination of Bituminous Road Materials. 10c.
*347. Methods for the Determination of the Physical Properties of Road-Building Rock. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 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.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
*532. The Expansion and Contraction of Concrete and Concrete Roads. 10c.
*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. 10c.
*583. Reports on Experimental Convict Road Camp, Fulton County, Ga. 25c.
*586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916. 10c.
*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. 5c.
*724. Drainage Methods and Foundations for County Roads. 20c.
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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. 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.

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Where do we Go from Here?

WE HAVE MADE SOME PROGRESS along the way toward complete improvement of the highways of this country in the last 10 years. The statistics give us credit for more than 400,000 miles of surfaced road, and nearly all of it has been improved within the decade. Perhaps it is time to ask the doughboy's question, Where do we go from here?

ONE THING IS CERTAIN, and that is that we are going to have better roads in this country. The public demands them. There has been manifest of late some reaction against the expenditure of public funds for roads. There can be no avoiding that expenditure. With more than 15,000,000 motor vehicles now operating on our highways, additional mileage of improved highways and the maintenance of those already improved is a huge work that can neither be laid aside nor neglected. The cost of operating and maintaining these motor vehicles on the highways in their present condition will be greater than the cost of improving and maintaining the roadways so that they will be equal to the traffic demands.

IN OTHER WORDS, with the number of motor vehicles now in operation, the public at large will pay in other ways a sum greater than the cost of improved highways if we do not improve the highways. Unless the States build them the locality must, and the voice of experience proclaims it a very foolish thing for the people of a State to decide not to support an adequate program of State road building, as a means of decreasing taxes, because it is much more likely to increase taxes.