PUBLIC ROADS

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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

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THE PACIFIC HIGHWAY, WASHINGTON—A FEDERAL AID ROAD

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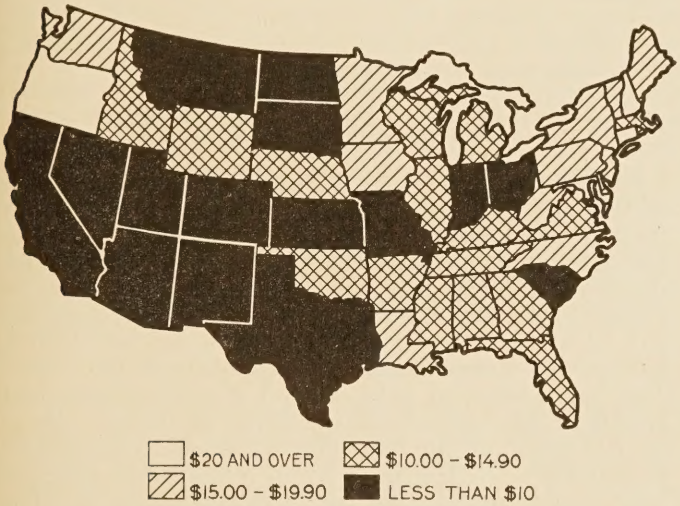
MOTOR VEHICLE FEES AND GASOLINE TAXES

A Review of the Development of Present-Day Policies in Motor Vehicle Taxation

By Henry R. Trumbower, Economist, U. S. Bureau of Public Roads

FROM 1901, the first year in which any State imposed a license tax on automobiles, to the end of 1923 owners of motor vehicles, both trucks and passenger cars, paid into the treasuries of the several States, as nearly as can be determined, $798,314,319. New York, the first State to levy the tax, collected during the first year just $954; in 1923, a little over 20 years later, the motor vehicle license fees of the country amounted to $188,970,992. The amounts collected in each year are set forth in the following tabulation, which also shows the number of vehicles registered and the average revenue per vehicle since 1909. Prior to that year it was impossible to obtain the information in regard to the number of vehicles, and not until 1912 were the registration methods of the various States sufficiently systematized to insure accuracy in the statistics.



Average license fees per motor vehicle, 1923

Total motor vehicle license fees, yearly registrations, and average receipts per vehicle, 1901–1923

Year	Number of vehicles registered	Total gross receipts [1]	
		Amount	Average per vehicle
1901	----	$954	----
1902	----	1,082	----
1903	----	26,865	----
1904	----	33,411	----
1905	----	62,500	----
1906	----	192,706	----
1907	----	334,916	----
1908	----	484,277	----
1909	294,000	938,860	$3.20
1910	472,700	2,227,434	4.70
1911	677,000	3,967,475	5.85
1912	1,010,399	5,638,878	5.60
1913	1,258,062	8,192,253	6.50
1914	1,711,339	12,382,031	7.20
1915	2,445,666	18,245,711	7.45
1916	3,512,996	25,865,369	7.35
1917	4,983,340	37,501,233	7.55
1918	6,146,617	51,477,419	8.35
1919	7,566,446	64,697,255	8.55
1920	9,231,941	102,546,212	11.10
1921	10,463,295	122,478,654	11.70
1922	12,238,375	152,047,823	12.50
1923	15,092,177	188,970,992	12.50
Total	----	798,314,310	----

[1] These receipts do not include any gasoline taxes.

In 1909, according to the best information obtainable, about 294,000 automobiles were registered; 14 years later the registration reached 15,092,177. According to these figures the average license tax collected from each motor vehicle in 1909 was $3.20 and this average had risen by 1923 to $12.50. The yearly increase in the average per vehicle is evidence of the steady advance in the charges and fees for motor vehicle licenses which characterized the period. How this advance occurred is shown by the following table, which presents a classification of the States for each year beginning with 1913 according to the average revenues received per car:

Classification of States according to average motor vehicle revenues per vehicle

Average revenues per vehicle	Number of States in each class [1]										
	1913	1914[2]	1915	1916	1917	1918	1919	1920	1921	1922	1923
$4.90 and less	21	17	13	14	14	6	7	2	1	----	1
$5–$9.90	15	17	20	21	22	27	24	17	15	15	15
$10–$14.90	9	11	12	11	10	9	10	18	21	17	16
$15–$19.90	4	3	3	3	3	6	7	10	11	14	13
$20–$24.90	----	----	----	----	----	1	1	2	1	1	3
$25–$29.90	----	----	----	----	----	----	----	----	----	2	1
$30–$34.90	----	----	1	----	----	----	----	----	----	----	----
Total	49	48	49	49	49	49	49	49	49	49	49

[1] Includes District of Columbia.
[2] On account of the Supreme Court declaring the licensing law unconstitutional, no revenues were reported for Michigan.

As the table shows, there were 21 of the States, or 42.8 per cent, which in 1913 received average revenues per vehicle less than $5; and 36, or 73.5 per cent, had average annual receipts less than $10. From this situation in 1913 there was a steady progression by amendment and revision of the State laws involving increases in the rates of fees and classifications and reclassifications of motor vehicles, each measure tending to raise the average yield per vehicle until by 1923 the only jurisdiction in which the average fee remained less than $5 was the District of Columbia. By 1920 it is observed that over 60 per cent of the States charged fees and license taxes which yielded an average of $10 and more per vehicle, and by 1923, 33 or 67 per cent, were in this class. In the same year over a third of the States had in effect scales of license fees which resulted in average revenues per vehicle of $15 and over and four of these States charged license fees which brought the average annual revenues up to over $20 per vehicle.

Another reason for the increase in the average revenues per vehicle was the special classification of the motor truck by which many of the States established still higher rates for this type of motor vehicle. Special classifications and charges covering automobiles for hire tended to bring about advances in the average revenues.

WIDE VARIATION IN LICENSE FEES OF VARIOUS STATES

The wide variation in the amount of the fees collected by the States is illustrated by the following tabulation, from which it appears that the average fees per motor vehicle, based on gross registration receipts, range all the way from $26.36, the amount collected by New Hampshire, to $5.73, the average in Arizona. The average fee of $4.78 received by the District of Columbia is the only one below $5. Of the 15 States whose average receipts per motor vehicle range between $5 and $10, only 3, Ohio, South Carolina, and Indiana, are east of the Mississippi River. There appears to be a tendency for the Eastern States to charge a higher scale of license fees, though there are specific exceptions to this statement. Oregon, for example, an extreme Western State, collected $24.52 as the average license tax in 1923. As pointed out in the article entitled "The Incidence of the Highway Tax Burden" (PUBLIC ROADS, vol 5, No. 4, June, 1924), the scale of motor vehicle fees is to a certain extent dependent upon the highway expenditures of the particular State and the policy which the State is following in financing its program of highway expenditure.

Average fees per motor vehicle based on gross registration receipts, 1923

New Hampshire	$26. 36	Alabama	$12. 17
Oregon	24. 52	Tennessee	11. 82
Connecticut	23. 82	Nebraska	11. 72
Maryland	20. 90	Wisconsin	10. 84
Vermont	17. 79	Oklahoma	10. 48
New Jersey	17. 76	Wyoming	10. 40
Delaware	17. 22	Mississippi	10. 33
Rhode Island	16. 86	Illinois	10. 00
West Virginia	16. 52	Montana	9. 88
New York	16. 49	Nevada	9. 80
Minnesota	16. 33	California	9. 64
Louisiana	16. 04	New Mexico	9. 21
Iowa	15. 46	Kansas	9. 15
Maine	15. 29	Ohio	9. 04
Pennsylvania	15. 18	South Dakota	8. 59
North Carolina	15. 10	Missouri	8. 43
Washington	15. 10	Texas	7. 91
Idaho	14. 65	Utah	7. 23
Virginia	14. 62	South Carolina	7. 08
Massachusetts	14. 53	North Dakota	6. 96
Michigan	14. 37	Indiana	6. 33
Kentucky	13. 50	Colorado	5. 96
Florida	12. 92	Arizona	5. 73
Arkansas	12. 67	District of Columbia	4. 78
Georgia	12. 40		

An investigation of the specific license fees charged by the various States shows that, for the purpose of levying such a tax, motor vehicles are divided into several classes. The primary classification is fourfold, namely, passenger cars, commercial cars or motor trucks, trailers, and motor cycles. This classification is based upon the type of vehicle. Many States make a further differentiation and make special provision in the scale of fees for passenger cars and motor trucks used for hire or classed as common carriers. Vehicles belonging to and used by automobile dealers are also in most instances put in a special class and taxed at a rate different from, and usually higher than, the rates applied to similar cars used by others than dealers. A number of States also derive motor vehicle revenues from licenses issued to drivers of cars, and the drivers are again divided into "operators not for hire" and "operators for hire."

On January 1, 1924, 11 different methods of levying fees upon passenger cars were in effect in the various States. These ranged from the simple flat rate with no attempt at classification to complicated formulas for determining what should be paid for the privilege of operating motor vehicles of the various types. To show how this development of motor vehicle license tax systems proceeded from simple systems to the various systems now in effect there is presented below in tabular form a statement setting forth the different licensing systems in effect in the years 1908, 1912, 1914, 1921, and 1924:

Methods of licensing passenger automobiles by the various States by periods

Basis of license fee	Number of States				
	1908 [1]	1912 [2]	1914 [3]	1921 [4]	1924 [5]
Flat rate	27	22	19	3	1
Horsepower	3	14	27	27	19
Weight of vehicle				5	7
Gross weight (vehicle and load)				3	6
Cost or value of vehicle				2	2
Piston displacement				1	1
Horsepower plus gross weight				3	4
Horsepower plus weight, unloaded				1	4
Horsepower plus cost				1	
Weight plus cost				1	2
Weight plus horsepower plus cost				1	1
Flat rate plus weight					1
No license law	18	12	2		
Total	48	48	48	48	48

[1] Automobilist's Legal Adviser: Nichols.
[2] Motor Car Laws of all States in the Union: Dame-Handy.
[3] Good Roads Year Book, 1914.
[4] Engineering News-Record; Sept. 1, 1921.
[5] Report, Motor Vehicle Conference Committee, 1924.

In 1908 there were still 18 States which had no registration and licensing laws, and of the 30 States which then licensed automobiles 27 had in effect flat-rate schedules and 3 charged fees which were determined by the horsepower of the car. By 1912 there were 36 States which made a charge for automobile licenses, and 14 of these based the amount of the fee upon a horsepower classification; 22 still charged flat rates. Two years later, in 1914, all but 2 of the States had adopted motor vehicle license laws; 19 of them charging flat rates and the remainder a variable fee based on horsepower. In the next seven years great changes were made, mainly by the substitution of another method for the flat-rate fee. In 1921 only 3 States continued charging flat license fees; 27 had in effect horsepower schedules and the remainder had introduced other bases to determine what was to be paid for a license. In the next three years the same trend continued and at the beginning of 1924 only 1 State was charging a flat rate and the remainder were following other methods, the horsepower type of schedule still remaining the most popular.

FROM POLICE POWER TO HIGHWAY REVENUE

As long as the emphasis in licensing automobiles was placed upon the State's police power a flat charge of a certain amount upon the registration of a car was deemed sufficient. The fee in most cases was nominal and was not regarded as a revenue-producing measure. When, however, the licensing of motor vehicles and the collection of registration fees began to be related to the problem of highway construction and maintenance the revenue aspect was brought into prominence, and as the rate was advanced classification systems were introduced which would take into account two factors. One of these factors was the extent of the road damage assumed to be caused by different types of cars. It was felt generally that heavy cars were more destructive in their use of the road than lighter cars, and a classification according to horsepower appeared to be a simple way of obtaining greater revenues from the larger and heavier machines. The other theory which to a certain extent was evident in the introduction of classification systems was the "ability-to-pay" principle which crops out in all taxation discussions. Aside from the question of highway use and road damage, the opinion was frequently expressed in State legislatures that the owner of the larger car was in all probability better able to pay the higher license fees than the owner of the light and small car. This was an additional argument for changing from the flat-rate system to the horsepower basis for determining license fees.

The introduction of a tax on gasoline by many of the States as a means of producing revenues for highway purposes has also had some effect upon the extent to which these States have gone in working out classification schemes in connection with the levying of license fees. The economic aspects of the gasoline tax will be discussed in another place, but it should be brought out at this time that the only State which now has a flat license fee, California, changed from the horsepower basis of classification to the flat rate when the gasoline tax went into effect on the theory that the greater portion of the revenues which the State was entitled to collect to compensate for the use of the highways would be produced by the gasoline tax. At the present time California charges $3 as the annual license fee for a gasoline or steam propelled passenger vehicle, irrespective of its size, horsepower, weight, or capacity.

THE BASES OF LICENSE FEES

The horsepower basis of license fees is a classification which can be easily applied. The schedules are usually simple and leave no doubt in the mind of the taxpayer as to the correctness of the fee. The schedule is applied in several ways. Some States classify automobiles according to horsepower and charge a specific fee for vehicles coming into the different groups. North Carolina, for example, charges a license fee of $12.50 for all passenger cars of 24 horsepower or less, $20 for cars from 25 to 30 horsepower, $30 for cars from 30 to 35 horsepower, and $40 for all cars of 35 horsepower and over. This schedule follows the grouping principle. Another type of horsepower schedule is found in New Jersey, where owners are charged a license fee of 40 cents per horsepower for cars of 29 horsepower or less and 50 cents for cars of horsepower greater than 29. This is a more flexible schedule which attempts to obviate the sudden increases in fees that are bound to occur where the fees are raised appreciably at the end of a group classification. It is intended to bring about more uniform charges.

Classification of automobiles according to the weight of the vehicle is another basis of determining license fees, which in 1923 was followed by seven States. South Dakota, for example, charges a license fee of $13 for automobiles of less than 2,000 pounds, $17 for cars from 2,000 to 3,000 pounds, $20 for cars from 3,000 to 4,000 pounds, and $35 for cars of 4,000 pounds and over. Other States charge a certain amount per unit of weight. New York, for instance, charges 50 cents per 100 pounds for cars weighing 3,500 pounds and less and 75 cents per 100 pounds for cars weighing over 3,500 pounds. This modification is made for the same reason that some of the States classifying according to horsepower charge definite rates per horsepower.

Six of the States classify automobiles for licensing purposes according to the gross weight including vehicle and load. Delaware's schedule of fees, according to which a charge of $2 is made for each 500 pounds of gross weight, is an example of this method. The gross weight is ascertained by adding to the weight of the car an estimated weight of 125 pounds for each person applied to the rated passenger capacity.

There are only two States, Colorado and Oklahoma, which use the value or cost of the passenger car as the basis for licensing charges. The application of such a principle is obviously somewhat complicated and can lead to certain dissatisfaction. Colorado charges one-half of 1 per cent of the manufacturer's price of the vehicle and allows a 30 per cent reduction after the fifth year of use and 50 per cent reduction after the eighth year of use. The Oklahoma scale is $10 for the first $500 value and 75 cents per $100 value in excess of $500. The use-of-the-road factor is in these cases evidently subordinated to considerations of the owner's ability to pay. The taxation principle is more closely adhered to than the principle of privilege.

Only one State, Connecticut, bases its schedules of license fees upon the displacement of the engine pistons, the charge being 8 cents per cubic inch. This is in fact another species of classification and charging according to horsepower.

Four States have in force and effect schedules of license fees based upon a combination of horsepower and gross weight and four States use a combination of horsepower and the weight of the vehicle only. The West Virginia schedule is an example of the former class, the rate being 30 cents per horsepower plus 30 cents for each 100 pounds gross weight (passengers estimated at 125 pounds each). Maine, on the other hand, charges 25 cents per horsepower and 25 cents per 100 pounds of the weight of the vehicle.

There are two States which base their license fees upon a combination of weight and value. Iowa, for example, has a schedule which provides for a charge of 1 per cent of the value plus 40 cents per 100 pounds. The executive council of the State has to fix every year the basic value and weight for computing fees. This combination is another example of the effort made by the legislature to give recognition to both the taxation and the privilege principles.

One State, North Dakota, employs a three-fold basis for license fees—value, net weight, and horsepower. For the first registration the fee is computed on one-half of 1 per cent of the value, 20 cents per 100 pounds, and 10 cents per horsepower. A 10 per cent reduction is made for the second registration, 25 per cent reduction for the third registration, and 40 per cent reduction for all other registrations. A $5 minimum fee is provided for in all cases.

DEVELOPMENT OF SPECIAL FEES FOR MOTOR TRUCKS

Specific license fees for motor trucks, generally spoken of as commercial cars, were not provided for in the early days when legislatures passed their first motor vehicle licensing acts because the motor truck had not yet made its appearance. The change in the type of fees applied to motor trucks is shown in the following tabulation, where the bases for determining the license fees for motor trucks are set forth for the years 1914, 1921, and 1924:

Methods of licensing motor trucks or commercial cars by the various States

Basis of license fee	Number of States[1]		
	1914	1921	1924
Capacity	2	25	25
Horsepower	17	2	
Net weight		2	2
Gross weight	1	7	10
Value		1	
Tire width		1	1
Weight of chassis		1	
Flat rate per vehicle	25	2	
Horsepower plus gross weight		2	2
Horsepower plus net weight		2	1
Horsepower plus capacity		1	2
Horsepower plus flat rate	1		
Weight plus horsepower plus value plus capacity		1	
Net weight plus capacity		1	
Value plus capacity			1
Flat rate plus capacity			1
Flat rate plus net weight			1
Value plus net weight plus horsepower			1
Horsepower plus weight plus capacity			1
No license law	2		
Total	48	48	48

[1] Sources same as those for passenger cars.

In 1914, 46 States charged fees for the licensing of motor vehicles and only 11 of these (Indiana, Maine, Maryland, Massachusetts, Oregon, Rhode Island, Connecticut, New Hampshire, New Jersey, New York, and Pennsylvania) made any special provision for motor trucks. The remainder of the States applied to motor trucks the same schedule of fees which was paid by passenger cars. Most of these charged flat rates or rates based upon the horsepower of the vehicle.

Those States which attempted to place motor trucks in a separate class and charge fees different from those assessed against passenger cars did so on two directly opposite theories. Seven of them (Indiana, Maine, Maryland, Massachusetts, New York, Oregon, and Rhode Island), although they were charging for passenger cars fees based upon horsepower, deliberately put motor trucks into a separate class and charged them flat fees which in several instances were less than the regular rates applied to passenger cars of similar horsepower. Maryland, for example, charged \$5 for passenger cars of 10 horsepower and less, \$10 for cars of 11–20 horsepower, \$15 for cars of 21–30 horsepower, \$20 for cars of 31–40 horsepower, and \$25 for cars of over 40 horsepower, whereas all motor trucks were charged only \$3. Likewise Massachusetts charged a license fee of only \$5 for motor trucks of all sizes and capacities and at the same time had in effect a scale of fees ranging from \$5 to \$25 depending upon horsepower for passenger automobiles. This deviation in favor of the motor truck can be explained in two ways. First, the passenger car at that time was still regarded by many as a luxury and therefore capable of being heavily taxed, while the motor truck, it was held, was useful and, therefore, should be relieved of any undue burden. The effect of the motor truck upon the highways was not considered because its use was still rather limited. A second reason which may have been in the minds of those who felt that motor trucks should not pay as high a fee as passenger automobiles was that the motor trucks which were in use at that time were largely engaged in intracity operation; few were seen on the rural highways. These more or less nominal fees were charged rather on the police-power theory than on the theory that revenues should be derived from them for highway purposes.

Four States established special scales of fees for motor trucks. Connecticut and New Hampshire graded the fees according to the capacity of the truck, Pennsylvania charged according to gross weight, and New Jersey applied the regular fees based upon horsepower plus a fee of \$10 on trucks weighing over 4,000 pounds. These States were the first to come to the conclusion that motor trucks on account of their weight damaged the highways more than passenger cars and should therefore be charged higher fees. By 1921 the States had developed 13 different methods of charging license fees for motor trucks and 1924 showed a number of modifications of these methods, all of which are intended to give the States revenues in proportion to the use which the trucks make of the highways and the wear and tear caused by them. Twenty-five of the States now classify the trucks according to carrying capacity alone and 10 base their schedules of fees on the gross weight of the truck and rated carrying capacity. In essence the theory underlying all of the various systems of classification is that the larger and the heavier the truck the higher should be the license fee. A number of States provide for differentials in fees based upon the fact as to whether pneumatic or solid tires are used. It is being recognized that if the license fee is to bear any relationship to the road damage caused by the truck the type of tires used must be taken into consideration.

VARIATION IN MOTOR TRUCK FEES GREATER THAN IN PASSENGER CAR FEES

The variation in the fees for a motor truck of any particular capacity in the various States is much greater than it is in the case of passenger automobiles. To show these differentials a comparison of license fees has been made for several different sizes of trucks, indicating the fees of the various States for 1914, 1921, and 1924. Three types of trucks are used in making these comparisons, involving the following assumptions: 1½-ton truck, solid tires, 23 horsepower, price \$2,700, 4,900 pounds unloaded; 3½-ton truck, solid tires, 31 horsepower, price \$4,800, 8,800 pounds unloaded; 5-ton truck, solid tires, 34 horsepower, price \$5,800, 10,700 pounds unloaded. The averages of fees charged by all States for these assumed vehicles in the three years 1914, 1921, and 1924 are as follows:

Average license fees for 1½-ton, 3½-ton, and 5-ton trucks

Capacity of truck	1914	1921	1924
1½ tons	\$6.43	\$27.55	\$31.15
3½ tons	8.36	64.05	85.75
5 tons	8.80	96.52	139.39

In 1914 motor truck fees were low in nearly all States, most of them, as already mentioned, applying to such vehicles the regular fee charged for passenger cars. By 1924 the average fees paid for a 1½-ton truck were 485 per cent of the 1914 fees; the fees of a 3½-ton truck were over 1,000 per cent of the 1914 fees; and a 5-ton truck fee had increased nearly 1,600 per cent. This greater increase in the fees paid by the larger trucks is wholly due to the fact that motor trucks had in the interim been classified in such a manner that the larger and the heavier types of trucks were placed into groups or classes to which were applied the higher fees.

The number of States charging various average fees for these three types of motor trucks in the three years are shown in the following table:

Number of States charging various average license fees for three sizes of motor trucks, 1914, 1921, and 1924

Average fees	1½-ton			3½-ton			5-ton		
	1914	1921	1924	1914	1921	1924	1914	1921	1924
Less than $10	33	4		29	2		29	2	
$10-$19	12	7	8	12	3		11	3	
$20-$29	1	17	20	4	3	2	4	2	1
$30-$39		9	8	1	4	3	2	1	
$40-$49		7	4		6	7		3	4
$50-$59		3	5		6	4		5	6
$60-$69		1	1		5	4		3	2
$70-$79			1		2	5		4	4
$80-$89					3	3		3	3
$90-$99			1		4	2		1	
$100-$109					8	8		3	2
$110-$119						1		1	1
$120-$129					1	2		2	3
$130-$139						1			
$140-$149						3		3	4
$150-$159								4	7
$160-$169									
$170-$179						1		1	
$180-$189								2	3
$190-$199									
$200-$209					1	1		4	3
$210-$219									
$220-$229						1			
$230-$239									1
$240-$249									
$250-$259									
$260-$269									
$270-$279									
$280-$289									
$290-$299									
$300-$309								1	3
$310-$319									
$320-$329									
$330-$339									
$340-$349									
$350-$359									
$360-$369									
$370-$379									
$380-$389									
$390-$399									
$400-$409									1
Total	46	48	48	46	48	48	46	48	48

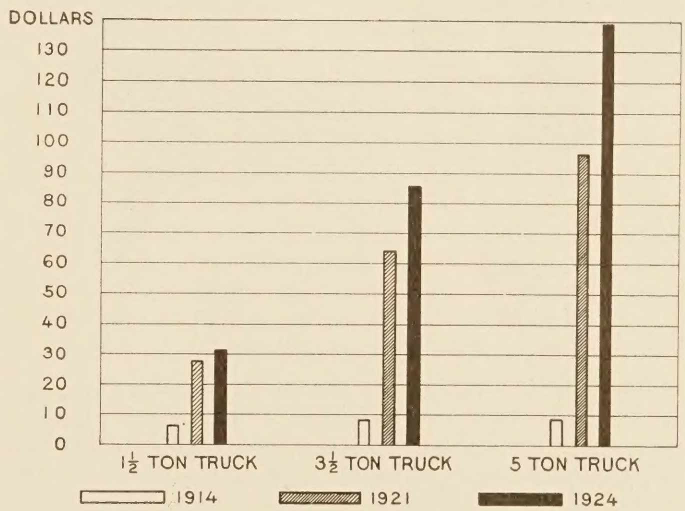
The highest license fee charged for any truck in 1914 was $34 for a 5-ton truck; two States charged that fee. In that year a majority of the States charged less than $10. While the fees had been advanced very much by 1921 the fees for 1924 were still higher. In 1924 only eight States charged less than $20, and that was for the 1½-ton truck. The tabulation shows how great the variation is—a 5-ton truck can be licensed in one State for from $20 to $29; in another State it has to pay between $400 and $409. In about half the States the fee for a 5-ton truck is less than $120; in the rest of the States it ranges from $120 to $409. It is evident that there is a tendency to fix fees at constantly higher levels for the motor trucks and particularly those of large capacities.

The differentials in the rates of passenger automobiles are much less. The lowest rate for a five-passenger car of 25 horsepower in 1924 is $3 and the highest fee charged by any of the States on a similar car is $46.20, which is unusually high. In 25 States in which complete information could be obtained the average license fee for passenger automobiles in 1923 was $10.78 and $18.23 for motor trucks.

There is no indication of a uniform differential between the average fees charged for passenger cars and for motor trucks. Only about half of the States have compiled their motor vehicle registration data in such manner that a segregation can be made of the revenues collected from passenger cars and from motor trucks. The following tabulation shows the States making this division and the average fees collected in 1923 from each class of motor vehicles, also the percentage relation which the motor truck fees bear to the passenger car fees:

Comparison of averages fees for passenger cars and motor trucks, 1923

State	Average passenger car fees	Average motor truck fees	Ratio of motor truck fees to passenger car fees
			Per cent
Arkansas	$12.00	$17.00	142
California	8.59	18.70	218
Colorado	5.12	11.57	226
Connecticut	15.47	32.82	212
Delaware	11.65	20.57	176
Georgia	14.12	16.86	119
Illinois	8.39	14.91	178
Indiana	5.20	10.84	208
Louisiana	15.52	16.30	105
Massachusetts	10.58	15.21	144
Michigan	12.38	17.03	137
Minnesota	15.55	19.67	126
Montana	9.24	11.12	120
Nebraska	10.60	18.70	177
Nevada	8.75	15.00	171
New Jersey	9.29	27.02	291
New Mexico	8.68	12.00	138
New York	12.14	26.45	218
Rhode Island	12.00	19.76	164
South Carolina	6.29	13.27	211
Vermont	13.66	24.85	183
Virginia	12.89	15.61	121
Washington	12.47	22.72	182
Wisconsin	10.00	18.11	181
Wyoming	8.90	19.66	221
Average	10.78	18.23	169

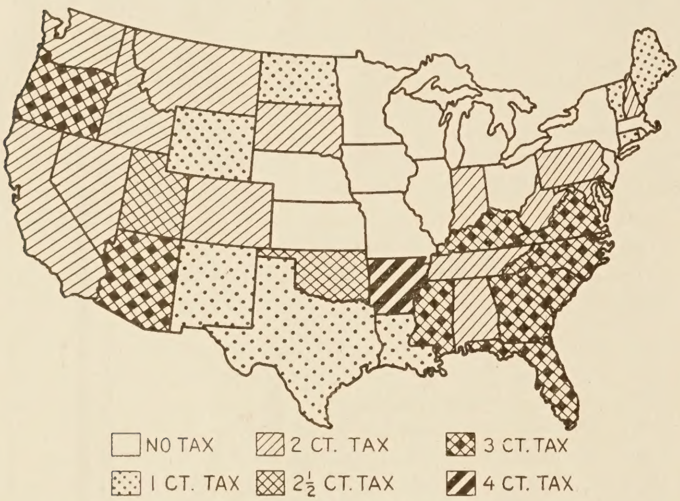


Average license fees for 1½, 3½, and 5 ton trucks, 1914, 1921, and 1924

In these States the average passenger-car fees range from $15.55 in Minnesota to $5.12 in Colorado; the motor truck fees from $32.82 in Connecticut to $10.84 in Indiana. The rates for the two classes of vehicles show the greatest difference in New Jersey, where the average motor-truck fee is 191 per cent higher than the average passenger-car fee. The smallest differential appears in Louisiana, where the average motor-truck fee is only 5 per cent above the average fee received from passenger cars. In only eight of the States are the average motor-truck fees more than double the fees of passenger cars. The average motor-truck fees are 69 per cent above the average fees charged for passenger cars in these States. If we apply the 1924 scales of license fees existing in the 48 States to an average car of 25 horsepower we get an average fee of $15.38.

USE OF MOTOR-VEHICLE REVENUE BY STATES AND COUNTIES

Although all but two of the States were collecting fees from the licensing of motor vehicles in 1914 only 19 of them[1] turned over the funds obtained from this source to their respective State highway departments for construction and maintenance purposes. In one of these States—Maryland—the law provided that one-fifth of the revenue collected should be used within the city of Baltimore and the balance for the maintenance of State roads. The motor-vehicle laws of nine States[2] provided that the revenues derived from motor vehicles should be paid to the counties at stated times for use on the highways maintained by them. In a few cases it was provided that the registration and administration expenses should be first deducted before turning over the funds to the counties. In every case except one the money which the counties received was the money paid in fees by the residents of the counties. The Georgia law employed as the basis of apportionment the provision that the funds be apportioned among the counties in accordance with the road mileage of the respective counties. In those States where the counties received practically all of the motor-vehicle fees there were at the time no State highway departments which could assume control and supervision of the expenditure of funds for highway purposes. Road construction and maintenance had always been matters which were left largely to local authorities. From time to time funds were appropriated by the legislature and turned over to local bodies in the shape of aid for certain extraordinary highway construction expenditures. This was usually done where expensive bridges were built on highways which carried long-distance traffic and where highways were built which were regarded as trunk roads and which partook of the character of State roads because of the nature of the traffic.



Rates of gasoline tax levied, July, 1924

Ten States[3] followed the practice of dividing these funds between the State and the counties; in most cases the money accruing to the State was turned over to its highway department and the money turned over to the counties was to be used by them for local road work. In Arkansas the money was equally divided between the State and the counties; the State's portion of these license revenues was given to the State highway department and the share going to the counties was transferred to the school funds of the several counties. At the same time the Ohio law provided that one-third of the license fees should be turned over to the counties to be used for highway purposes and two-thirds be retained by the State and placed in the general fund.

Six[4] States kept all the motor-vehicle revenues in the general fund, making no apportionment and no direct provision for highway use. Alabama divided these license revenues between the general fund of the State and the general funds of the local governmental units. In Texas a fee of 50 cents was charged for the registration of a motor vehicle, and funds resulting therefrom were retained by the county clerks, who were the licensing officers specified by law.

In 1923 of the $188,613,074 collected by the States as motor-vehicle license revenues ($357,918 collected by the District of Columbia not included) $153,226,636, or 81 per cent, was used for highways by and under the direction and supervision of State highway departments. In only 13 States were any substantial amounts apportioned among the counties. The laws in some of the States provided for the motor-vehicle registration and licensing expenses to be paid out of these specific revenues; in other States the costs connected with this work are charged to the general funds. The 19 per cent which was not used by the State highway departments includes in addition to the funds turned over to local units the expenses of registering cars and the issuing of licenses and other administrative expenses of similar character.

At this time every State has come to recognize the relationship between the licensing of automobiles and the procuring of funds for highway purposes. Among those States where the fees have been low in the past steps are taken to augment the highway funds through higher registration fees.

THE GASOLINE TAX AS A PRODUCER OF HIGHWAY REVENUES

At about the time when most of the States had succeeded in abolishing the old turnpikes and toll roads by purchasing them at agreed prices or through condemnation proceedings and had declared them "free" highways a movement started which in essence was an extension of the toll principle to all the highways of a State brought about through the enactment of laws providing for a tax upon the sale of gasoline. In 1919 two States—Oregon and Colorado—passed a gasoline tax law; this year, 1924, there are 35 States and the District of Columbia which are collecting this kind of tax. Seventy-three per cent of the States, in other words, have in effect a gasoline tax; and these States have a rural road mileage of 1,954,886 miles comprising 66.5 per cent of the total rural highway mileage of the country.

[1] Arizona, Connecticut, Georgia, Illinois, Kentucky, Maine, Maryland, Massachusetts, Michigan, Missouri, New Jersey, New Mexico, New York, Oklahoma, Pennsylvania, Rhode Island, Utah, Vermont, and Virginia.

[2] Florida, Indiana, Kansas, Nebraska, Nevada, New Hampshire, North Dakota, Oregon, and Wyoming.

[3] Arkansas, California, Colorado, Idaho, Iowa, Montana, North Carolina, Ohio, South Dakota, and Wisconsin.

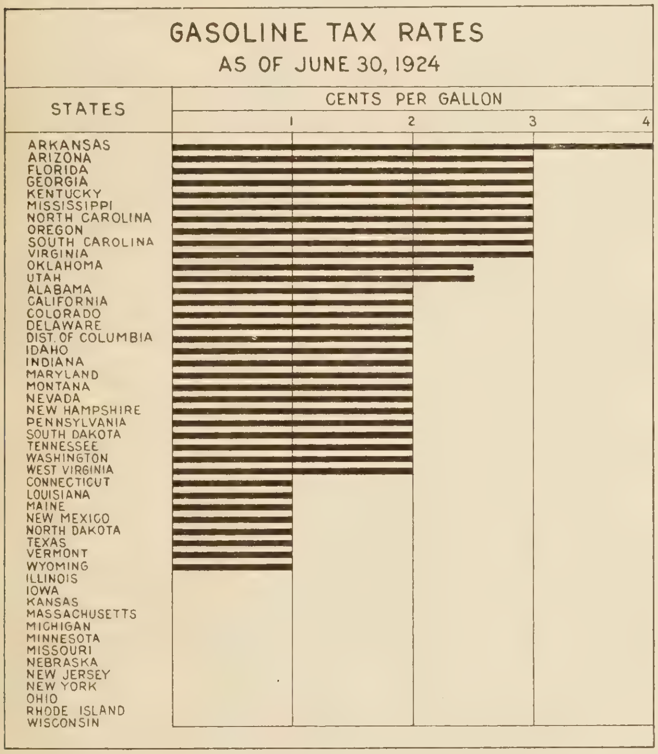
[4] Delaware, Minnesota, South Carolina, Tennessee, Washington, and West Virginia.

The rates charged by these States range from 1 cent to 4 cents per gallon. The tendency has been for more States to enact gasoline tax laws and for States having the law to increase the rate of the tax. In the following tabulation is presented a list of the States levying this tax and the present rates:

States levying gasoline taxes classified according to rate [1]

1-cent tax	2-cent tax	2½-cent tax	3-cent tax	4-cent tax
Connecticut.	Alabama.	Oklahoma.	Arizona.	Arkansas.
Louisiana.	California.	Utah.	Florida.	
Maine.	Colorado.		Georgia.	
New Mexico.	Delaware.		Kentucky.	
North Dakota.	Idaho.		Mississippi.	
Texas.	Indiana.		North Carolina.	
Vermont.	Maryland.		Oregon.	
Wyoming.	Montana.		South Carolina.	
	Nevada.		Virginia.	
	New Hampshire.			
	Pennsylvania.			
	South Dakota.			
	Tennessee.			
	Washington.			
	West Virginia.			

[1] Massachusetts passed a 2-cent tax law; it is held in abeyance and referred to the people for approval at the November, 1924, election. District of Columbia charges a 2-cent tax under act of Congress.



Of the 35 States, 15 levy a 2-cent tax, 8 a 1-cent tax, 9 a 3-cent tax, 2 a 2½-cent tax, and 1 State is charging a tax of 4 cents a gallon. The States which are not collecting this form of tax are all in the east north central and west north central sections, with the exception of Massachusetts, Rhode Island, New York, and New Jersey. It is evident that there is a solid South and a solid West in favor of this type of tax. During the year 1923 these States received $36,813,939 in gasoline taxes.

LESS THAN 60 PER CENT OF GASOLINE TAXES EXPENDED UNDER STATE SUPERVISION

The disposition of the revenues derived from the gasoline tax differs from that of the motor vehicle license fees. In 1923 about 81 per cent of the motor vehicle license revenue was applicable to highway work by or under the supervision of State highway departments, whereas only 58.5 per cent of the total gross receipts accruing from the gasoline tax was disposed of in this manner. In the following table the disposition of the gasoline tax receipts of the States collecting this tax is compared with the disposition which these same States made of the motor vehicle license fees in 1923. In each case the percentage for use by the State highway departments is given.

Percentage of motor vehicle license fees and gasoline taxes applicable to highway work under the supervision of the State highway departments, 1923

State	Motor vehicle fees	Gasoline taxes	State	Motor vehicle fees	Gasoline taxes
	Per cent	*Per cent*		*Per cent*	*Per cent*
Alabama	78	0	New Mexico	95	95
Arizona	100	25	North Carolina	99	99
Arkansas	30	24	North Dakota	99	0
California	46	50	Oklahoma	90	100
Colorado	48	47	Oregon	72	97
Connecticut	100	100	Pennsylvania	100	0
Delaware	100	100	South Carolina	80	27
Florida	71	70	South Dakota	93	91
Georgia	97	16	Tennessee	99	99
Idaho	25	100	Texas	44	75
Indiana	95	86	Utah	100	26
Kentucky	100	100	Vermont	92	100
Louisiana	100	100	Virginia	100	67
Maine	89	99	Washington	96	100
Maryland	90	100	West Virginia	100	100
Mississippi	54	40	Wyoming	100	100
Montana	10	17			
Nevada	94	52	Average	81	58.5
New Hampshire	93	99			

Taking these States as a whole it is evident that the State highway departments expend or control the expenditure of a much larger portion of the motor vehicle license funds than they do of the gasoline tax funds. In the case of the gaoline tax there is a much greater tendency for the State to share these newly discovered revenues with the counties and to divert them for other purposes than in the case of the motor vehicle license fees. There are now 17 States which provide in their gasoline tax laws that the full proceeds of this tax shall be used by the respective State highway departments or under their supervision. These States are Arkansas,[5] Connecticut, Delaware, Idaho, Kentucky, Louisiana, Maryland, New Hampshire, North Carolina, Oregon, South Dakota, Tennessee, Utah, Vermont, Washington, West Virginia, and Wyoming. In some of the States the costs of collecting the tax are deducted from the receipts and the net proceeds are made available for State highway purposes; in other States the total gross receipts are transferred to the highway funds, in which cases the collection costs are met out of other funds. In any event they are usually small in amount and the work is done in many instances by the regular State officials and employees, making it unnecessary to incur any extra expenses.

Ten of the States (California, Colorado, Florida, Indiana, Maine, Mississippi, Nevada, Oklahoma, Pennsylvania, and Virginia) make a division of the gasoline tax revenues between the respective State highway departments and the county highway organizations. In some of the States there is an equal division of the tax in a few States two-thirds of the tax goes to the State and one-third to the counties; in others the division is made on the basis of 60 per cent to the counties and 40 per cent to the State. In one State three-fourths of the tax is turned over to the counties and one-fourth is retained by the State; in another State the reverse of this division obtains.

[5] Effective Jan. 1, 1924.

One State—North Dakota—places the whole proceeds of the tax in the general fund of the State, no part of it being devoted directly to highway purposes. Alabama makes a disposition of the gasoline tax revenues by putting one-half into the general fund of the State and by letting the counties use the other half for highway purposes. In Texas, three-fourths of the tax is used by the State highway department and the other one-fourth is credited to the State school funds. South Carolina, Montana, and Georgia make a threefold division of the proceeds—to the State highway department, the county highway organizations, and the State general fund. South Carolina makes an equal apportionment among these three claimants; Montana credits the State highway funds with 20 per cent and the county highway funds and the State general funds with 40 per cent each. In Geogia one-third of the gasoline tax goes to the State highway fund and one-third to the county and one-third is credited to a special State fund to meet the State's obligations in connection with bonds which the State issued for the construction of a railroad.

In Arizona the gasoline tax of 3 cents is collected by the Secretary of State and apportioned by him as follows: 50 per cent of the tax from each county directly to the county in which it is collected and 50 per cent to the State treasurer. The revenue is then used as follows: 25 per cent for State road work and 75 per cent for county road work. In New Mexico $15,000 of the tax collected is credited to the State fish hatchery fund and the balance to the State road funds.

It is noted that in a number of cases a portion of the gasoline tax receipts is credited to the general fund of the State. This is done in some instances because the State has issued highway bonds, and this gasoline tax money is intended to take care of those obligations.

AVERAGE ANNUAL GAS CONSUMPTION IN EIGHT STATES 450 GALLONS

On account of the fact that so many changes in the tax rate took place in these States during the year 1923, it is impossible to ascertain the annual gasoline consumption per vehicle except for those States where the rate remained the same throughout the whole year. In the following table the gross receipts, number of motor vehicles registered, the receipts per motor vehicle, and the average consumption per vehicle are set forth for the eight States in which the same rate prevailed throughout the year:

Gross receipts derived from gasoline taxes and average receipts and gasoline consumption per vehicle, 1923

State	Gross receipts	Number of motor vehicles	Gross receipts per vehicle	Gasoline consumption per vehicle [1]
				Gallons
Connecticut	$880, 222. 70	181, 748	$4. 84	484
Kentucky	680, 435. 30	198,377	3. 43	343
Louisiana	754, 437. 85	136, 622	5. 52	552
Maryland	688, 304. 02	169, 351	4. 06	406
Mississippi	467, 855. 53	104, 286	4. 49	449
New Mexico	165, 000. 00	32, 032	5. 15	515
North Dakota	461, 081, 71	109, 266	4, 22	422
Washington	1, 225, 149. 66	258, 264	4. 74	474
Total	5, 322, 486. 77	1, 189, 946	4. 50	450

[1] The tax rate in all of these States was 1 per cent per gallon.

At a rate of 1 cent per gallon this tax yielded in these eight States $4.50 per motor vehicle, indicating that the annual consumption was, on the average, 450 gallons. Using this average as a basis for computation, it is easy to estimate the average revenues per vehicle which can be derived where higher rates per gallon are collected.

If we assume 6,000 miles as the average annual mileage per vehicle (this is an average of 13.3 miles per gallon of gasoline) we arrive at the following toll charges per vehicle-mile for the use of the highways:

Gasoline tax	Toll per vehicle-mile
Cents per gallon	*Cents*
1	0. 075
2	. 150
3	. 225
4	. 300
5	. 375

According to these estimates a 1-cent gasoline tax means that the motor-vehicle operator would be called upon to pay a toll charge of 10 cents for a trip from Washington to Philadelphia. The trip over the Lincoln Highway from New York to San Francisco would be taxed $2.50.

It is interesting to compare these tax rates with the toll charges which motorists formerly had to pay on toll roads and turnpikes. On six different turnpikes in Virginia and Maryland tolls amounting to $5.05 were charged for a total distance of 187.5 miles [6] which is equivalent to 2.7 cents a mile. If a State attempted to charge this same rate for the use of the public highways by automobiles it would have to establish a gasoline tax at 36 cents per gallon, assuming the same consumption per mile as in the foregoing analysis. Compared with these former toll road charges it will be seen that the gasoline taxes now levied are extremely moderate.

THE APPLICATION OF THE GASOLINE TAX

The States have not gone very far in laying down precise definitions of the products to be taxed in the statutes passed thus far. The intent of the legislation generally is to tax all fuels which are used in the operation of motor vehicles propelled by internal-combustion engines. In some States the law names gasoline and no other kind of fuel, in others kerosene is included, and in some it is specifically exempted from the provisions of the tax. Some of the laws contain elaborate provisions exempting motor fuels which are used in farm tractors, motor boats, and airplanes, the purpose being to tax only the fuel used by vehicles which are operated over the public highways. Such an application of the law is in accordance with the toll-road principle. In certain States all the gasoline sold within the State is subject to the tax irrespective of the use to which it is put. Under such conditions the clothes-cleaning establishment using a certain amount of gasoline, as well as the motor boat operator and the aviator, have to make their contribution to the maintenance of the highway in proportion to the amount of gasoline they consume. Where exemptions are made based upon the use to which gasoline is put it is the general practice to compel the payment of the tax when the purchase is made and allow the purchaser to file a claim for a refund based upon an affidavit that the gasoline was not used as fuel for a highway vehicle.

[6] American Automobile Blue Book, vol. 3, 1919.

License fees and gasoline taxes per vehicle-mile based on averag travel of 6,000 miles, 1923

State	Average license fee per vehicle-mile	Average gasoline tax per vehicle-mile[1]	Combined taxes per vehicle-mile
	Cents	*Cents*	*Cents*
Alabama	0.203	0.149	0.352
Arizona	.095	.160	.255
Arkansas	.211	.179	.390
California	.160	.038	.198
Colorado	.099	.075	.174
Connecticut	.397	.081	.478
Delaware	.287	.049	.336
District of Columbia	.080		.080
Florida	.215	.180	.395
Georgia	.207	.144	.351
Idaho	.244	.106	.350
Illinois	.167		.167
Indiana	.105	.083	.188
Iowa	.258		.258
Kansas	.152		.152
Kentucky	.225	.057	.282
Louisiana	.267	.092	.359
Maine	.255	.044	.299
Maryland	.348	.068	.416
Massachusetts	.242		.242
Michigan	.239		.239
Minnesota	.272		.272
Mississippi	.172	.075	.247
Missouri	.140		.140
Montana	.165	.100	.265
Nebraska	.195		.195
Nevada	.163	.123	.286
New Hampshire	.439	.046	.485
New Jersey	.296		.296
New Mexico	.153	.086	.239
New York	.274		.274
North Carolina	.252	.196	.448
North Dakota	.116	.070	.186
Ohio	.151		.151
Oklahoma	.175	.033	.208
Oregon	.408	.196	.604
Pennsylvania	.253	.088	.341
Rhode Island	.281		.281
South Carolina	.118	.198	.316
South Dakota	.143	.079	.222
Tennessee	.197	.078	.275
Texas	.132	.029	.161
Utah	.120	.113	.233
Vermont	.296	.053	.349
Virginia	.244	.118	.362
Washington	.252	.079	.331
West Virginia	.276	.039	.315
Wisconsin	.181		.181
Wyoming	.173	.059	.232
Average	.208	.041	.249

Toll per vehicle-mile on 187.5 miles of turnpike in Maryland and Virginia, 2.7 cents.

[1] A number of the figures in this column are based on collections of gasoline taxes for less than one year. (See PUBLIC ROADS, vol. 5, No. 2, April, 1924, p. 17.)

The cost of collecting the tax is very small. Few taxes are collected at so moderate a cost. In most States collection is exacted from the wholesale distributor and precaution is taken through periodic reports that the tax is not collected twice. According to the apparent trend it will not be long before all States will be employing the gasoline tax to secure revenues for highway purposes. Three States—Wisconsin, Michigan, and Iowa—in addition to the 35 which now use the tax, have pushed gasoline tax bills through the legislatures, but in each case they were vetoed by the governors. In each case the veto was based on the ground that the tax was a sales tax and for that reason undesirable, or on some fault in the proposed method of distributing the revenue.

In only a few States where the gasoline tax has been introduced has a revision of the motor vehicle license fees been made, relieving the motor vehicle operator in any way of a part of those charges. California reduced the license fees to a flat rate of $3 for all types of motor vehicles. In Maryland, when the gasoline tax was raised from 1 cent to 2 cents a gallon, the legislature took the definite position that additional revenues were not demanded through the imposition of the larger gasoline tax and the highway authorities were requested to make a readjustment in the motor-vehicle fees to offset the increased gasoline tax. A reduction in fees was made which it was estimated would about equal the average amount each class of motor vehicle would have to pay in additional gasoline taxes.

It would appear so far as can now be learned from an analysis of the development of the gasoline tax that it is going to be a permanent method of raising a part of the funds necessary for highway purposes. It is distinctly a tax for highway service, and, considering the character of the service rendered in return, none of the rates now charged is excessive. Even when the gasoline tax is coupled with the license fee for the motor vehicle the combined taxes considered as toll for the use of the roads are extremely moderate. Compared with the turnpike charges referred to above, for example, the charges per mile for license fees and gasoline taxes, assuming an average annual mileage of 6,000 miles, seem rather insignificant.

Classification of States according to combined motor vehicle taxes per vehicle-mile in relation to increase in motor vehicle registrations, 1923

Combined motor vehicle taxes per vehicle-mile: Over 0.4 cent	0.3 to 0.4 cent	0.2 to 0.3 cent	0.1 to 0.2 cent	Less than 0.1 cent	Increase in motor vehicle registration, 1923	
					Per cent	
Connecticut					19	Average, 26.
Maryland					[1] 24	
New Hampshire.					23	
North Carolina.					35	
Oregon					24	
	Alabama				40	Average, 28.
	Arkansas				34	
	Delaware				22	
	Florida				31	
	Georgia				21	
	Idaho				16	
	Louisiana				34	
	Pennsylvania				26	
	South Carolina				34	
	Vermont				20	
	Virginia				30	
	Washington				23	
	West Virginia				40	
		Arizona			29	Average, 22.
		Iowa			14	
		Kentucky			29	
		Maine			17	
		Massachusetts			25	
		Michigan			26	
		Minnesota			18	
		Mississippi			34	
		Montana			18	
		Nevada			30	
		New Jersey			26	
		New Mexico			26	
		New York			20	
		Oklahoma			23	
		Rhode Island			16	
		South Dakota			5	
		Tennessee			28	
		Utah			21	
		Wyoming			30	
			California		28	Average, 23.
			Colorado		16	
			Illinois		24	
			Indiana		24	
			Kansas		15	
			Missouri		21	
			Nebraska		11	
			North Dakota		10	
			Ohio		25	
			Texas		31	
			Wisconsin		20	
				District of Columbia.	42	

[1] Nonresident registrations included in both years in making this computation.

(Continued on page 24)

IMPACT TESTS ON HIGHWAY BRIDGES

Progress Report of Cooperative Research Conducted at Ames, Iowa

IMPACT stresses in highway bridges subjected to motor-truck loads are given in the progress report of the highway bridge impact tests recently made to the cooperating agencies, the Iowa State Highway Commission, the Engineering Experiment Station of Iowa State College, and the United States Bureau of Public Roads, by Almon H. Fuller, consulting bridge engineer of the Iowa commission.

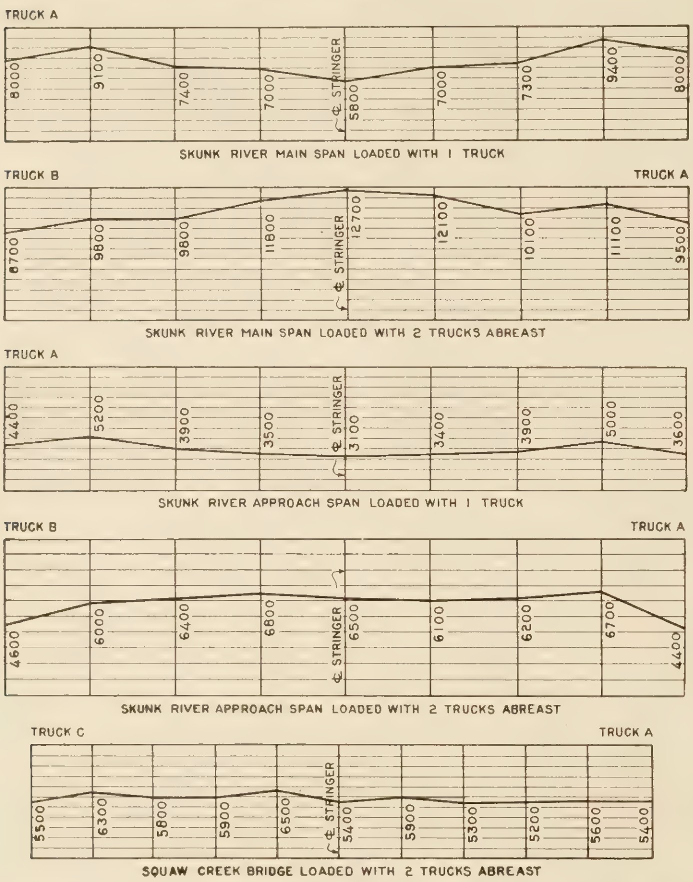


FIG. 1.—Distribution of stresses in stringers, maximum stress in each stringer due to various positions of loads

The tests were begun in 1922 and a preliminary report of the work of that year was published as Bulletin No. 63 by the Engineering Experiment Station. The recent report covers the continuation of the work in 1923. The greater part of the season's work was done on the 8-panel, 150-foot main span, and the 32-foot approach span over the Skunk River on the Lincoln Highway near Ames, Iowa, the same structures which were used in the 1922 work. A few days' work was done on each of the two other structures, one a 70-foot through plate girder bridge with an 8-inch concrete floor supported on steel stringers, located on the Lincoln Highway over Squaw Creek in the city of Ames. The other was a 5-panel, 40-foot, riveted steel, pony truss bridge with 8-inch reinforced concrete slab resting directly on floor beams, located near Roland, Iowa.

The 1923 work included observations of static load and impact stresses on all the bridges. Three conditions of impact were observed—one with the trucks operated over the clean bridge floor, one in which the trucks were driven over a 1 by 2 inch obstruction, and one in which they were driven over a 2 by 4 inch obstruction.

Probable percentages to be added to static load stresses to allow for impact are given as follows:

For stringers: Clean floor, 12 per cent; 1-inch obstruction, 40 per cent; 2-inch obstruction, 80 per cent.

For floor beams: Clean floor, 10 per cent; 1-inch obstruction, 40 per cent; 2-inch obstruction, 57 per cent.

For hip verticals: Clean floor, 25 per cent; 1-inch obstruction, 90 per cent; 2-inch obstruction, 150 per cent.

Similar percentages for main truss members are also given in the detailed tables accompanying the report. They are omitted above not because the results do not command confidence but because they are few in number and because the unit stresses are so small that they are not representative of fully loaded structures.

DISTRIBUTION OF STATIC STRESS IN STRINGERS

An extension of the static readings which were necessary as a base for determining the impact percentages gave the data for the distribution of stresses in stringers due to loads at rest. In the 1922 work the static readings were made with the trucks at rest. In 1923 they were made with the trucks operating at very slow speed. The hardly noticeable impact thus introduced was less important than the certainty that the correct position of the load was assured.

The maximum stresses in each stringer of three of the bridges under one and two trucks respectively are given in Figure 1. The stresses shown in the diagram are the maxima resulting from various positions of the truck across the width of the slab. Where two trucks were used they were placed abreast.

Two 3½-ton trucks loaded with gravel were used, the total loads averaging approximately 14 tons. As each truck was unloaded once on account of accident there were four distinct truck loads, designated A, B, C, and D. The axle weights for the four loads were as follows.

	Front axle load	Rear axle load	Total load
	Pounds	*Pounds*	*Pounds*
Truck A	5,910	23,410	29,320
Truck B	5,830	21,710	27,540
Truck C	5,800	22,200	28,000
Truck D	5,740	22,780	28,520

The distribution of static stress in the stringers under one truck is much the same as reported for the 1922 work in Bulletin No. 63 of the Engineering Experiment Station, Iowa State College. The 1923 work commands greater confidence because readings were taken on both flanges of every stringer. This was not done in all instances in 1922.

On a few of the stringers strain gauge readings were taken at various points on vertical sections as a means of locating the neutral axis. In each case the neutral axis was found to be above the center of the web, indicating a certain amount of T-beam action of the concrete floor. Besides observing the stresses they were computed under the assumption (1) that the load was supported entirely by the steel stringers as simple beams, and (2) that there was perfect T-beam action between the steel and the concrete.

Comparison of the observed and computed stresses shows that the observed stresses in all instances are so far below the stresses computed on the assumption that all load was carried by the stringers as simple beams as to leave no doubt that the T-beam action of the concrete floor or the restraining effect of end connections or both relieve the simple steel stringer of a considerable portion of the normal stress.

In two out of three cases the observed stresses were so near the ones computed on the assumption of perfect T-beam action and simple beams as to indicate that an excellent bond existed between the concrete floor and the steel stringers. The fact that the observed stresses while comparatively close to the computed ones, were always lower suggests a certain amount of restraint at the ends or partially fixed beams.

The observed position of the neutral axis of stringers in the Skunk River approach span (about 5 inches above the center of the web) compares so favorably with the computed position, assuming T-beam action, as to suggest that a complete bond existed. The observed position in stringers of the west panel of the main Skunk River span (about 1 inch above the center of the web) is sufficiently below the computed position (about 4 inches above the center of the web) to suggest that the bond was impaired on one or more of the stringers. As the neutral axis was determined experimentally for only one stringer, a more definite statement is not justified.

No strain gauge readings were taken on stringers of the Squaw Creek Bridge to determine the position of the neutral axis. The close comparison of observed computed stresses on the basis of perfect T-beam action, and the ratio of modulii of elasticity of 10 (from determinations on Skunk River approach span) suggest excellent bond.

COMPARISON OF OBSERVED AND COMPUTED STRESSES IN OTHER MEMBERS

Static load stresses were computed at all points at which they were observed and for identical loads. Close comparisons are not expected for three reasons:

1. Observed stresses were not taken at a sufficient number of points in the cross section of each member to represent the average distribution.

2. A high degree of precision can not be expected in observed stresses. It is believed that all of the averages are within 500 pounds per square inch and that many of them are within 200 pounds.

3. A high degree of precision in the computed stresses can not be expected because of the effect of the continuous steel and concrete floor. The results give strong indication that the floor relieves the lower chords of a considerable portion of their tension, raises the plane of bottom tension, and thereby reduces the effective depth of the truss and increases the compression in the upper chords. It is also likely that the web members are affected by the shear in the floor and that the general distributing power and continuity of the floor still further affects the stresses throughout the structure.

Tables 1, 2, and 3 show comparisons of observed and computed stresses in trusses, girders, and floor beams. The computations were made by the "ordinary" method and by "special" methods in which the effect of the floor was considered. A few irregularities exist which are not readily explained. When it is remembered, however, that comparatively little emphasis was placed on truss work in 1923, these comparisons seem reassuring rather than disturbing. The small intensity of the stresses suggests that greater loads are a necessity for satisfactory work on trusses.

TABLE 1.—*Comparison of observed and computed stresses on Skunk River Bridge*

[All trucks headed west]

Member	Load	Position of load	Observed unit stresses	Computed unit stresses: Ordinary method	Computed unit stresses: Special method
			Pounds	*Pounds*	*Pounds*
Diagonal U1′–L2′	A	2 feet S. of N. curb	1,800	2,070	-------
	A and B	2 feet S. of N. curb	2,500	3,570	-------
Diagonal U1–L2	C and D	2 feet N. of S. curb	2,500	3,230	-------
	C and D	C–2 feet N. of S. curb	2,300	2,500	-------
		D–2 feet S. of N. curb	2,500	3,110	-------
Diagonal U2′–L3′	A	2 feet S. of N. curb	-------	-------	-------
	A and B	2 feet S. of N. curb	4,500 −1,800	7,220 −1,870	-------
Diagonal U3–L4	A and B	2 feet S. of N. curb	3,000 −1,400	4,720 −1,860	-------
Diagonal U3–L4	A and B	2 feet S. of N. curb	2,500 −2,000	4,000 −2,960	-------
Diagonal U4–L3′	A and B	2 feet S. of N. curb	2,500 −1,700	2,250 −2,860	-------
Diagonal U4–L3	A and B	2 feet S. of N. curb	2,900 −2,200	2,880 −2,430	-------
End post L0–U1	C and D	2 feet N. of S. curb	1,400	1,600	-------
	C and D	D–2 feet N. of S. curb	-------	-------	-------
		C–2 feet S. of N. curb	1,000	1,220	-------
Hip vertical U1–L1	A and B	A–2 feet N. of S. curb	-------	-------	-------
		B–2 feet S. of N. curb	3,450	3,540	-------
Hip vertical U1–L1	C	1 foot N. of S. curb	3,000	2,790	-------
	C	2 feet N. of S. curb	3,000	2,630	-------
Post U2′L–2′	A and B	2 feet S. of N. curb	1,700 −1,500	2,180 −1,230	-------
Floor beam L1	A and B	A–2 feet S. of N. curb	-------	-------	6,600
		B–2 feet N. of S. curb	7,000	9,270	-------

Figures preceded by a minus sign are the reverse stresses in the members.

TABLE 2.—*Comparison of observed and computed stresses on Roland 40-foot pony truss bridge*

[All trucks headed north]

Member	Load	Position of load: Rear wheels of A	Position of load: Rear wheels of C	Observed unit stresses	Computed unit stresses: Ordinary method	Computed unit stresses: Special method
				Pounds	*Pounds*	*Pounds*
L0–L1–L1–L2	A and C	L1	L1	1,820	6,230	2,280
L2–L2′	A and C	Midspan	Midspan	2,720	5,600	2,720
	C		Midspan	1,810	3,990	1,835
L0–U1	A and C	L1	L1	4,510	4,970	-------
U1–U2	A and C	L2	L2	4,620	5,680	6,270
U2–U2′	A and C	Midspan	Midspan	4,720	4,410	5,240
	C		Midspan	3,350	3,060	3,530
U1–L1	A and C	L1	L1	2,400	3,600	-------
U1–L2	A and C	L2	L2	5,620	8,750	-------
U2–L2	A and C	L2	L2	2,610	2,760	-------
	A and C	L3	L2	1,520	1,190	-------
U2′–L2	A and C	L2	L2	1,550	2,760	-------
Floor beam L1	A and C	L1	L1	5,710	16,650	8,800

TABLE 3.—*Comparison of observed and computed stresses on Squaw Creek through girder bridge*

[All trucks headed west]

Member	Load	Position of load		Observed unit stresses	Computed unit stresses	
		Truck A	Truck C		Ordinary method	Special method
				Pounds	*Pounds*	*Pounds*
Top flange, north girder.	A and C	2 feet S. of N. curb.	11.5 feet S. of N. curb.	3,000	3,000	3,270
	A and C	2 feet S. of N. curb.	2 feet S. of N. curb.	3,000	3,510	3,800
Bottom flange, north girder.	A and C	2 feet S. of N. curb.	11.5 feet S. of N. curb.	2,500	3,000	2,300
	A and C	2 feet S. of N. curb.	2 feet S. of N. curb.	2,250	3,510	2,680
Floor beam J_3.	A and C	9.5 feet S. of N. curb.	17 feet S. of N. curb.	4,270	8,770	6,160

MEASUREMENT OF IMPACT STRESSES

For the measurement of impact stresses the instruments used in the previous year's work which proved to be best adapted were retained. One new instrument, a six-element electrical, remote-reading and recording instrument developed by the United States Bureau of Standards was used for a few days. This instrument, a photogragh of which is shown in Figure 2, is decribed in United States Bureau of Standards Bulletin 247 under the title of "A New Electrical Telemeter" by Burton McCollum and O. S. Peters.

All the instruments were calibrated in the labratory for static loads on steel rods in tension or on flanges of I-beams in bending or both. All of them were also calibrated for impact on a special impact machine, shown with a number of instruments attached in Figure 3. It consists essentially of a "hammer" weighing approximately 2,060 pounds supported so that it may be raised through known distances and allowed to drop freely upon the head of a 1-inch rod in tension. The range of motion and the deformation in various portions of the mechanism were read by means of a number of Ames dials.

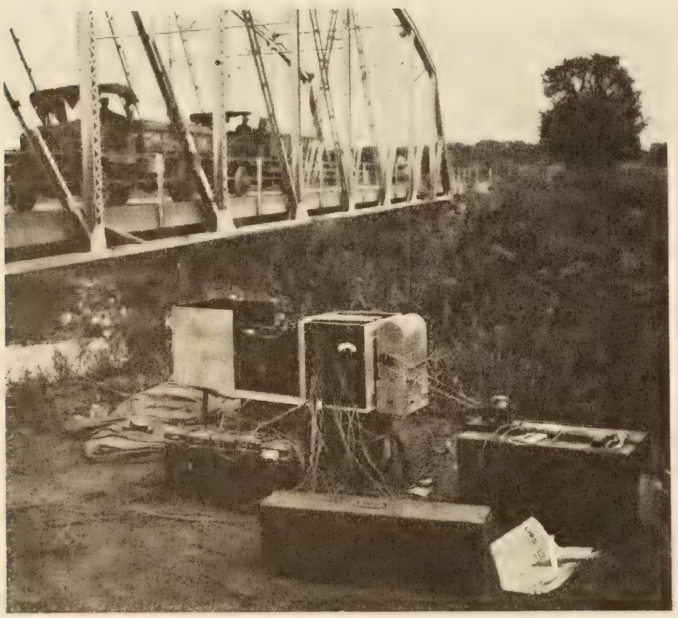


FIG. 2.—Bureau of Standards instrument and Skunk River bridge

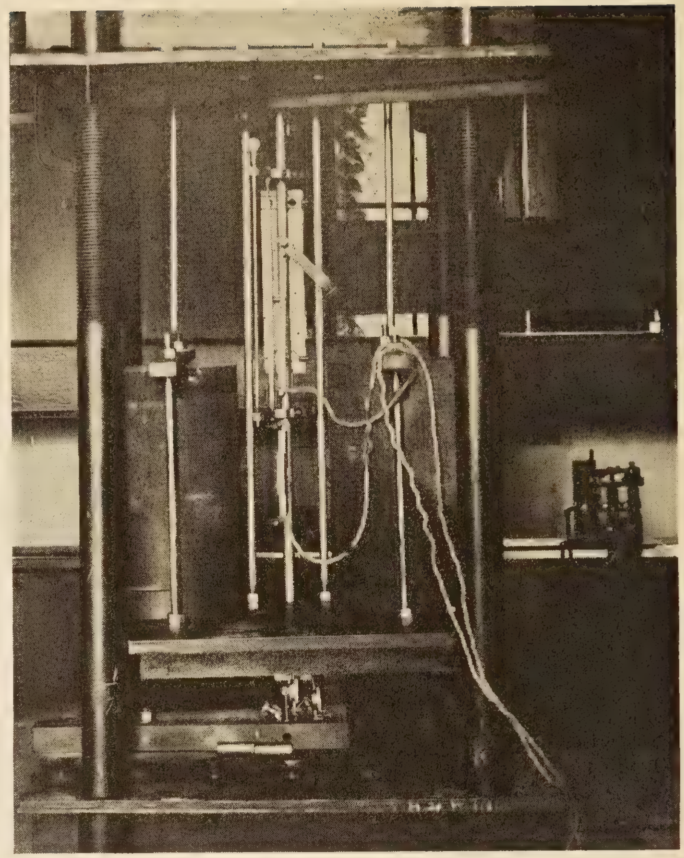


FIG. 3.—Calibration of instruments under impact

The Turneaure instrument, used in 1922 and described in Bulletin 63 of the Iowa Engineering Experiment Station, was observed to lag for small impacts and to overthrow for large ones, but its readings for intermediate impacts compared reasonably closely with those of the other instruments.

As suggested in the report of the previous year's work, the dials of the West instrument [1] were choked or damped with a view to increasing the accuracy of the instrument for high impacts. The behavior in the calibrating machine and in comparison with the other instruments on the bridges gave assurance that this could be done, but considerable care, including frequent calibration, was needed to secure consistent and correct results. The few days' use of the Bureau of Standards instrument indicated that it will surpass all of the other instruments in the number of readings that can be made with it in a given time, in ease of identification and readiness of interpretation. In general, the readings of the various instruments checked reasonably well and there is considerable confidence in the season's results.

As in 1922 the impact was delivered by solid-tired trucks with wheel loads as given on page 10. The trucks were operated at full speed (from 10 to 14 miles per hour). Observations were made of the impact set up by truck operation over the clean bridge floor and over 1 by 2 inch and 2 by 4 inch obstructions.

Table 4 gives a summary of the impact observations on various members of the several bridges. The results are given in unit stresses and in impact percentages. The values have been chosen not by

[1] For description See Bul. 63, Iowa Engineering Experiment Station.

mathematical average but by inspection, in which greater weight has been given to the runs made under the more satisfactory and more nearly typical conditions.

TABLE 4.—*Summary of impact percentages and impact unit stresses, Skunk River, Squaw Creek, and Roland bridges*

[Truck speed 10-14 miles per hour]

Member	14-ton truck: No obstruction, Stress	Per cent	1 by 2 inch obstruction, Stress	Per cent	2 by 4 inch obstruction, Stress	Per cent
	Pounds		*Pounds*		*Pounds*	
Stringers, approach span, Skunk River bridge	4,400	22	5,400	43	9,300	140
	4,100	16	4,700	32	8,000	120
Stringers, main span, Skunk River bridge	11,000	35	12,200	57	15,000	95
	10,000	20	11,200	40	13,400	70
Top chords and end post, Roland bridge	4,500	40	7,000	100	13,000	350
	4,000	25	6,000	70	9,800	180
Lower chords, Roland bridge	2,900	43	3,600	70	4,300	110
	2,600	30	2,900	43	3,900	78
First diagonals, Skunk River bridge	2,500	60	4,600	150	9,000	350
	2,300	40	4,000	120	7,500	250
Hip verticals, Skunk River bridge	[2] 4,100	[2] 17	[2] 7,500	87	[2] 11,500	175
	[3] 2,000	22	[3] 4,000	137	[3] 6,700	275

Member	Two 14-ton trucks: No obstruction, Stress	Per cent	1 by 2 inch obstruction, Stress	Per cent	2 by 4 inch obstruction, Stress	Per cent
	Pounds		*Pounds*		*Pounds*	
Stringers, approach span, Skunk River bridge	5,800	17	7,400	40	10,500	100
	5,600	12	6,700	32	8,800	75
Stringers, main span, Skunk River bridge	10,600	17	14,000	43	16,000	85
	10,000	10	12,000	34	14,500	67
Stringers, Squaw Creek bridge	6,700	21	10,400	95	15,000	180
	6,100	14	9,800	82	13,000	120
Floor beam, Skunk River bridge	8,300	10	10,500	50	11,500	68
	7,800	10	9,500	45	10,200	55
Floor beam, Squaw Creek bridge	5,000	15	6,500	50	9,000	92
	4,500	10	6,000	40	7,500	77
Floor beam, Roland bridge	6,700	17	8,000	45	14,000	150
	6,400	10	7,500	30	12,000	100
Top chords and end post, Roland bridge	5,900	29	7,400	50	10,000	115
	5,300	20	6,700	35	8,800	78
End post, Skunk River bridge	1,200	45			2,000	80
	1,000	30			1,500	30
End post, Skunk River bridge [1]	1,500	45			2,200	45
	1,200	30			2,000	30
Lower chords, Roland bridge	3,400	28	3,900	50	6,000	130
	2,900	20	3,400	33	4,500	67
North girder, west span, Squaw Creek bridge	3,000	25	3,200	30	4,500	65
	2,800	20	3,000	25	4,000	50
Do.[1]	3,000	30	3,300	35	5,000	80
	2,800	25	3,000	30	4,500	60
First diagonals, Skunk River bridge	3,500	70			7,500	200
	3,000	50			7,000	150
Do.[1]	3,350	38	6,600	140	7,000	140
	3,000	30	4,900	75	6,000	100
First diagonals, Roland bridge	7,300	48	9,700	73	12,000	140
	6,800	30	7,000	40	10,000	100
Remaining diagonals, Skunk River bridge	4,200	25	4,600	40	6,800	100
	3,800	20	4,100	30	5,800	72
Remaining diagonals, Roland bridge	2,500	58	3,400	100	4,600	185
	2,100	35	2,800	60	3,500	110
	−4,000	−75	−4,200	−91	−5,000	−125
	−3,200	−33	−3,600	−60	−4,300	−75
Hip verticals, Skunk River bridge	[2] 6,200	30	[2] 11,000	105	[2] 13,000	150
	[3] 2,400	23	[3] 3,800	85	[3] 4,800	112
Hip verticals, Roland bridge	[2] 4,100	20	[2] 5,200	40	[2] 8,500	130
	[3] 1,700	30	[3] 2,600	100	[3] 5,000	300
Post U2′-L2′, Skunk River bridge	[2] 2,200	50	[2] 3,600	45	[2] 10,500	200
	[3] 1,500	25	[3] 1,500	30	[3] 2,200	100
	[2] −2,000	−25	[2] −2,100	−45	[2] −4,000	−150
	[3] −1,800	−15	[3] −1,900	−30	−3,500	−100

[1] Two trucks in tandem, all others abreast.
[2] Average stresses in inside flanges.
[3] Average stresses in outsde flanges.

Minus signs indicate reverse stresses in members.

[Upper figures are the averages of the two high stresses in each group of runs. Lower figures are the general averages]

FUTURE WORK

Ultimately the work on this problem should lead to the acquisition of data which will give in terms of impact the effect of various tires, conditions of tires, chains, etc. The immediate problem, obviously, is not to continue until all of these possibilities have been investigated for all types of floors, but so to standardize the conditions already used as to serve as a means of interpreting other conditions.

This standardization may consist in establishing a relation between the impact stress and the simultaneous force of the blow of the truck wheels on the bridge floor. After this has been done the work of the United States Bureau of Public Roads, in which by the compression of copper cylinders, use of accelerometers, etc., the force of impact blows has been determined, may be used to estimate the impact stresses in a bridge to which such impacts are delivered.

The report proposes a definite program for the continuance of the tests over a two-year period, and suggests, among other things, the construction of a special test span apart from a traveled highway on which the effect of various loads, such as a crowd of people, of livestock, a number of heavy trucks, etc., may be tested without inconvenience to the public.

THE ORGANIZATION OF THE ADVISORY BOARD ON HIGHWAY RESEARCH

The Advisory Board on Highway Research of the National Research Council announces that 40 State highway commissions have already responded to the invitation to name representatives to serve on the board. Through the State representation the highway commissions and the Advisory Board will have a medium whereby research problems may be thoroughly studied. Through this medium problems will be brought to the attention of the State departments, and the solutions will be made known.

The board, which is now quartered in the new building of the National Research Council at B and Twenty-first Streets, Washington, D. C., is a branch of the Division of Engineering and Industrial Research. It is headed by Charles M. Upham, as director.

The standing committees through which the work of research is conducted are as follows:

Committee on economic theory of highway improvement. T. R. Agg, chairman.
Committee on structural design of roads. A. T. Goldbeck, chairman.
Committee on character and use of road materials. H. S. Mattimore, chairman.
Committee on highway bridges.
Committee on highway finance. H. R. Trumbower, chairman.
Committee on maintenance. W. H. Root, chairman.
Special investigation on reinforced concrete roadway. C. A. Hogentogler, chairman.
Committee on special assignments.

The following representatives have been appointed by the several State highway commissions:

Alabama, J. H. Scruggs.
Arizona, B. J. McNelly.
Arkansas, F. A. Gerig.
Connecticut, Geo. E. Hamlin.
Delaware, W. W. Mack.
Georgia, Searcy B. Slack.
Idaho, H. W. Gregory.
Indiana, C. Gray.
Iowa, R. W. Crum.
Kansas, C. H. Scholer.
Maine, L. D. Barrows.
Maryland, Harry D. Williar, jr.
Michigan, G. C. Dillman.
Mississippi, Geo. B. Denham.
Missouri, F. V. Reagel.
Nebraska, C. M. Duff.
Nevada, H. M. Loy.
New Hampshire, Wallace F. Purrington.
New Jersey, G. Roland Moore.
New Mexico, I. E. Burke.
New York, Wm. L. Blaum.
North Carolina, C. N. Conner.
North Dakota, W. G. Black.
Ohio, A. S. Rea.
Oklahoma, Frank Herrmann.
Pennsylvania, Wm. H. Connell.
Rhode Island, G. H. Henderson.
South Carolina, Charles H. Moorefield.
Tennessee, O. H. Hansard.
Utah, E. S. Borgquist.
Vermont, Thurman W. Dix.
Virginia, Wm. R. Glidden.
Washington, E. R. Hoffman.
West Virginia, R. B. Dayton.
Wisconsin, ———.
Wyoming, W. B. Norris.

THE EFFECT OF HAUL ON THE COST OF EARTHWORK

A Study by the Bureau of Public Roads of This Element of the Cost of Excavation

By J. L. HARRISON, Highway Engineer, U. S. Bureau of Public Roads

THE most reliable statistics available indicate that the annual expenditure for highway construction is now approximately $600,000,000. Of this amount from $150,000,000 to $200,000,000 is expended on Federal-aid roads, concerning which accurate and complete data may be had. An analysis of these data discloses the fact that approximately 25 per cent of this money is spent for grading. There is no definite information as to the proportionate cost of this element on other roads but it is probably as great as on the Federal-aid roads. If this assumption is accepted, the general magnitude of the field on which this study bears—that is, the magnitude of its direct financial aspects—may be properly presented by the general statement that from $100,000,000 to $150,000,000 is being expended annually in the movement cf subgrade materials as an incident to highway construction. Any information which will improve efficiency in this field has, therefore, unusual possibilities of producing tangible savings of importance, an item which should receive careful consideration prior to beginning any investigational work.

The Federal-aid road data indicate that the unit prices at which contractors accept excavation vary between rather wide limits. Omitting from the present discussion those States in which the problem is complicated by special considerations, such as removing old pavements, extra long free haul, unusually rocky land, etc., there still remain important differences in the average unit prices bid on excavation, as the following table shows:

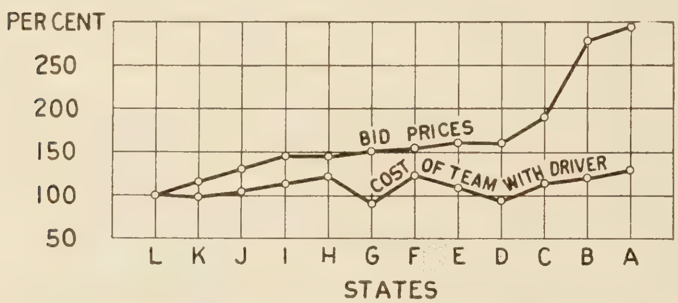


FIG. 1.—Variation in bid prices for earthwork in 12 Mississippi Valley States, compared with cost of team with driver

Average unit bid prices for excavation in Mississippi Valley States, 1923

State	Quantity under contract	Average cost of excavation per cubic yard	Per cent of lowest State average cost	Average hourly cost of team with driver	Free haul limit
	Cubic yards	*Cents*	*Per cent*	*Cents*	*Feet*
A	555, 589	59	295	75	1, 000
B	878, 516	56	280	69	None.
C	1, 253, 813	38	190	65	700
D	241, 604	32	160	53	500
E	2, 408, 704	32	160	62	1, 000
F	3, 196, 918	31	155	70	500
G	1, 849, 790	30	150	51	1, 000
H	2, 939, 685	29	145	69	500
I	3, 922, 329	29	145	65	500
J	1, 019, 805	26	130	59	500
K	3, 435, 439	23	115	56	400
L	4, 467, 174	20	100	57	200

It has been common practice to assume that such differences in cost of excavation as are revealed by this table are due in a large measure to variations in the cost of labor and teams. These are, of course, important factors in the cost at which grading work can be accomplished but it may be reasonably assumed that if these were the only important factors grading prices would vary in substantial harmony with them. Figure 1 shows the variations in bid prices as given in the fourth column of the table and also the variations in average hourly cost of a team with driver as given in the same table. This graph plainly indicates that other factors than the cost of teams and drivers are paramount in determining variations in unit bid prices.

Among other factors the equipment used and the soil conditions encountered suggest themselves as possibly having enough influence on cost to offer an explanation of the differences not accounted for by variations in the cost of team time. As bearing on the problem in hand, these can, however, be set aside, as the States shown in the above table have been selected from the Mississippi Valley where fresnoes, wheelscrapers, and elevator graders are the common earthmoving equipment and where soil conditions, while by no means uniform, are, on the whole, favorable to their use.

In this study it has not been considered necessary to differentiate sharply between the several kinds of material, such as sand, loam, and clay, as they usually occur in the Mississippi Valley, and which are generally classed as common excavation. It is true that in a given time and for a given distance a normal fresno or wheeler outfit would probably move a somewhat different quantity of one material than of another, but these differences do not appear to be sufficient to have any controlling effect on the questions here involved. Nor should the location of the material—that is, whether it is in one State or another—have any bearing on the quantity which can be moved a given distance in a given time by such an outfit. Neither small variations in the character of the material nor its location with reference to State lines should, therefore, enter as important factors in establishing average bid prices, especially when the quantities considered are large and contain all these materials as they do when they result from averaging a considerable number of jobs in each State.

The depreciation, wear and tear, and breakage of equipment are large elements in the cost of moving earth. So also are loss and depreciation of stock. They are of small importance here because there is no reason for supposing that mules or equipment depreciate faster in Dakota than in Texas, and even if it could be shown that some difference in rate of depreciation does exist it is not at all likely that this difference would be great enough to have any large influence on bid prices.

LENGTH OF HAUL A CONTROLLING FACTOR IN THE COST OF EARTHWORK

Besides these factors, there is in all excavation work the factor of length of haul. This study has brought out clearly the strong influence of length of haul on the cost of excavation. Other factors such as the character of the soil, grades, and prevailing weather conditions, over which the designer of the road has practically no control, may operate to increase or decrease the cost of the earthwork; but the length of haul appears in general to have a more marked influence than any of these and it is an element which can be definitely controlled in advance by the designing engineer. That an increase in the length of haul which doubles the time required per trip in moving earth from the excavation to the fill will double the cost of moving it may be accepted as a foregone conclusion. While the study confirms the accepted practice in regard to the kind of equipment best adapted to hauls of various lengths, it appears to be well established that adaptation of equipment will not enable designing engineers or contractors to disregard distance as a primary consideration in the cost of moving subgrade materials. By showing that positive and material savings can be effected by reducing the average haul it indicates that engineers may reconsider with profit certain of the practices which are accepted as fundamental in grade location, especially the practice of balancing cuts and fills by long end or longitudinal hauls. Consideration must, of course, be given to the use of excavation in embankments where the cost of overhaul is less than the cost of wasting plus the cost of borrow.

TEAM TIME AS A BASIS FOR STUDYING COSTS

Whenever an effort is made to determine the money cost of moving a yard of earth an astonishing number of variables appear. In the first place, the amount of earth that can be moved in any given time varies with the distance it is moved. The amount which can be moved per unit of time also varies somewhat with such conditions as grade, weather, temperature, etc., but whatever affects the output per unit of time affects the unit cost.

Moreover the money cost of team time varies not only from job to job but from week to week on the same job. Hay and grain, the principal items in the cost of maintaining stock, fluctuate in price over a wide range, and other elements which enter into the cost of delivering an hour of team time on any job are equally inconstant. Therefore, to approach the problem of determining why unit bid prices are higher in some States than in others by an analysis of unit costs in dollars seemed unwise as the number of fluctuating elements left no apparent basis for even a day-today comparison of results and made the possibility of any valuable comparison as between different jobs very difficult of attainment.

For these reasons, instead of using the cost in money as a basis for comparative studies, an effort was made to develop the time-distance basis. The theory that underlies this basis of comparison is that an average mule team pulling any given variety of earth-moving equipment ought to travel as fast in the Dakotas, Kansas, or Iowa as it will travel in Texas or Louisiana if working in the same sort of material. It was recognized that high temperature in the South or low temperature in the North would probably affect the rate of travel, but it was, of course, apparent that these influences could be avoided by using a little care in the selection of the season for making field studies.

In this connection it might be observed that when a time-distance basis is adopted in the study of earthwork the problem is reduced to one of obtaining information as to how long it normally takes to move a unit of excavation a given distance, or, to reverse the statement, how many units of excavation can be moved over any distance in a unit of time. The relationship as between different jobs and between regions is then expressed in units of team time, standard equipment and a uniform hook up being assumed. In the application of the data secured to estimating either by engineers or by contractors, the value of team time at any point can be determined readily enough by an examination of local rates of pay, feed costs, etc., having at all times in mind the fact that team time, as here used, includes the driver and all animals used in operating a unit of equipment.

The selection of this basis for comparison makes it a simple matter to study such elements as material, grade, temperature, white versus colored drivers, etc., for, given a standard hook up and ample time, it is possible to study these or any other factors by segregating the data which diverges from the normal only as to one factor and accumulating it until significant averages can be obtained. The results which have been secured by the use of this basis for study justify the imprsesion that it will offer a ready solution for many grading problems which have in the past seemed more or less intangible.

THE FIELD WORK

The first step in making these studies has been to examine going construction projects with a view toward selecting for extensive study those where the amount of cut is large enough to enable the engineers to obtain appropriate data and where the equipment is standard. Jobs where the work is light have so far been avoided because, under such conditions, the outfits are apt to be so spread out that the collection of data is difficult. Jobs where the equipment is not standard or which include two or more types of equipment in the same group have also been avoided, as, under such circumstances, it is difficult to determine quantities with accuracy. In short, the first work has been to get data concerning main features, leaving special conditions for later studies. When the project is determined upon the established practice is to select and carefully cross-section a cut. When work in this cut is begun a record is kept of the number of hours that are required in moving the material and the distance it is moved, together with other pertinent data. As often as desired while the work is in progress, new cross sections are taken and quantities calculated. Time studies are made daily to show the average time required to make a round trip including loading and unloading, the average distance the earth is moved being determined with such care as is possible where a working outfit must be studied without being disturbed.

INFORMATION DEVELOPED BY THE STUDY

Figures 2 and 3 show the relation between length of haul and time required per trip by No. 2 wheel scrapers and 4-foot fresno scrapers, respectively. They represent the average relation as found in Kansas, Missouri, Oklahoma, and Texas, in which the performance is similar.

The graphs appear as straight lines, indicating, for the studies made, that the average rate at which teams travel does not change materially with the distance the load is moved. As extended, they cross the horizontal axis some distance to the right of the zero point. This distance represents the average time required for loading, unloading, and turning, together with the minor delays incident to operations of this nature. If the distance is short, material can sometimes be moved by fresno from the ditches to the embankment within the time here set down as the average for loading, unloading, and turning. As this fact has only a limited bearing on the matters discussed in the article, it is merely noted here for subsequent amplification and discussion.

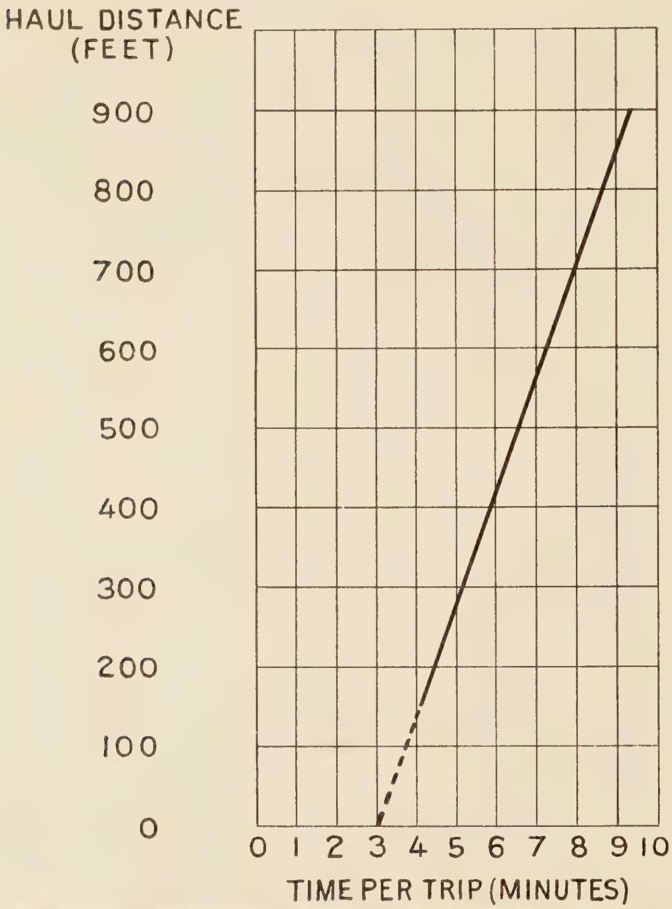


FIG. 2.—Relation between length of haul by No. 2 wheel scraper and time per trip

Translating the general time-distance graphs into mathematical formulæ we have, for fresnoes,

$$t=1.2+0.0101D$$

in which,

t=time per load in minutes and
D=distance load is moved in feet

The factor 0.0101 is governed by the rate at which teams have been found to move under average conditions. The constant 1.2 is the time consumed in loading, unloading, and turning.

For wheelers the formula similarly developed is

$$t=3+0.0071D$$

Repeated measurements made in the field indicate that the average load for normally operated fresnoes ranges from slightly over one-third cubic yard on short hauls to slightly under one-third cubic yard on long hauls. The load of the ordinary wheel scraper is found in practice to vary in about the same manner with an average of 0.4 cubic yard per trip. The studies on the standard $1\frac{1}{2}$ cubic yard wagon operated in connection with an elevator grader are not as complete as for wheelers and fresnoes, but they indicate that wagons operated with elevator graders average about $1\frac{1}{4}$ cubic yards per trip. Reducing the above formulæ to a 1-cubic yard basis in the light of these data, we have, then, these general formulæ:

For wheel scrapers, $T=2\frac{1}{2}\ (3+0.0071D)$
For fresnoes, $T=3\ (1.2+0.0101D)$
in which, T = time required to handle 1 cubic yard of material

In a further analysis of the time-distance curves it may be noted that the graphs for the fresno and wheel scraper are, in a general way, directly comparable. A fresno outfit, as operated by the usual small contractor, includes the foreman (usually the subcontractor himself), the plow team with driver and plow holder, and six to eight three-mule fresno teams with drivers. The drivers customarily load and dump as well as drive. A wheel scraper outfit of this size has a foreman (generally the subcontractor), a plow team with driver and holder, a two to three-mule snatch team and driver, a loader, a man on the dump and from 6 to 10 two-mule wheelers. The items of supervision and plowing are so nearly the same, whether wheelers or fresnoes are used, that consideration of them may be omitted. As a rough generality the commercial value of teamster's time is about the same as that of a two-mule team. The fact that a wheeler outfit uses a snatch team with

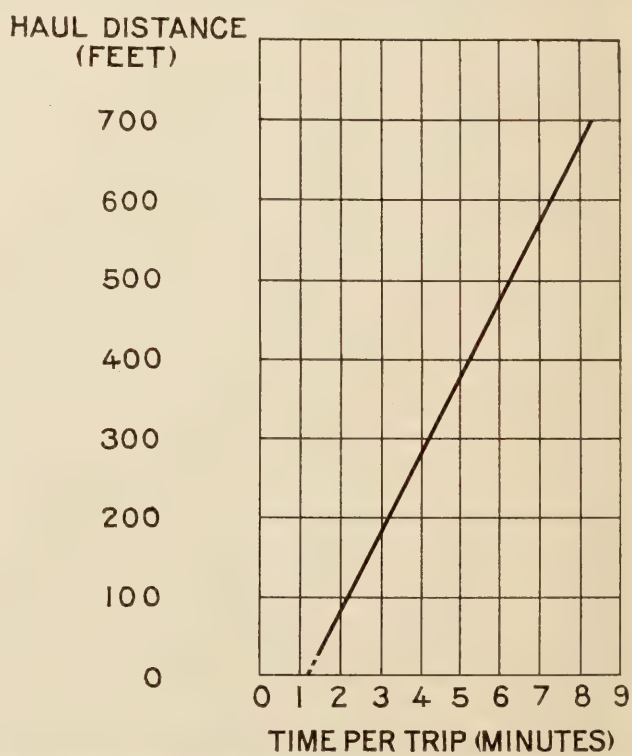


FIG. 3.—Relation between length of haul by 4-foot fresno scraper and time per trip

driver, a loader, and a man at the dump (none of these being customarily used with a fresno outfit), which, in a general way, is equivalent to eight mules, makes up for the extra mule on the fresno. From this standpoint the cost per unit of time of operating a fresno is so nearly the same as the cost of operating a wheel scraper that equality may be assumed. It therefore results that the point of equal operating cost may be obtained by equating the two formulæ:

$$3\ (1.2+0.0101D)=2\tfrac{1}{2}\ (3+0.10071D)$$
$$\text{or } D=310 \text{ feet}$$

The importance of this deduction lies in the fact that it shows that wheelers can not be successfully operated in competition with fresnoes except at hauls exceeding 300 to 350 feet, and therefore that lower bid prices can not be secured by resorting to the use of this type of equipment. While both on the basis of mathematical development and observed field practice it appears that fresnoes should be laid aside and wheelers used at this haul distance, contractors claim that fresno hauls as long as this are hard on the stock and so must be used sparingly. The field observations confirm this claim. Moreover, from the graph for fresno work it is a simple matter to show that the teams are under full load almost twice as many minutes per hour on a 300-foot haul as they are on a 100-foot haul. It therefore appears that the statement that a 300-foot fresno haul ought not to be attempted over any extended period is sound.

The data which have been secured in regard to wagons operated in connection with elevator graders have reasonably established the fact that wagons move at about the same speed as wheel scrapers. From the limited number of studies on this type of equipment it has not yet been possible, however, to derive a mathematical statement which can be equated with the formula given for the fresno and the wheeler in order thereby to develop the haul distance below which this style should be laid aside. However, enough data have been collected to warrant the statement that while an elevator grader outfit of the usual pattern handles the longer hauls as cheaply as the wheel scraper, it has not been possible to show that it is effective in so reducing costs that it is comparable with the fresno on hauls much if any below 300 feet.

RESULTS OF THE STUDY

The net result of these studies, so far as they bear on the specific problem under discussion, has been, then, to show that there appears to be no means of handling earth which eliminates the factor of distance moved as a dominant element in cost. At certain hauls a wheeler will move earth cheaper than a fresno and for the longer hauls—over 300 feet—it appears probable that the elevator grader moves earth somewhat more cheaply than either of the other forms of equipment. But no form of equipment has been found in common use which enables contractors to disregard distance as a primary consideration in the cost of moving subgrade materials. The time-distance graphs make this fact very clear. In terms of fresno operation, where the movement can be kept within 75 feet, the time required may be kept within two minutes per load, while, if the movement be 300 feet, it will require slightly over four minutes. But a grading operation that takes four minutes of team time costs the contractor twice as much as an operation requiring two minutes of team time.

It is not necessary to expand this statement to great length to justify the conclusion that grading costs may be reduced by a general modification in design which will reduce the haul distance. The State designated as L in the table consistently shows unit bid prices for excavation which are relatively low. In the light of the conclusion above reached, it is interesting to observe that two elements in the L subgrade design contribute to this, viz, the cross section and the low free-haul limit of 200 feet. This cross section, shown in Figure 4, somewhat generalized in order to make its variable elements clear, differs from that in general use in other parts of the country in that it permits considerable side balancing of quantities instead of depending on a balance by end or longitudinal haul. This is accomplished by widening, sometimes accompanied by deepening the ditches so that a large percentage of the material needed for fills can be secured from alongside. In coupling a practice of this sort with a low free-haul limit engineers find it desirable to reduce cuts to a minimum. The research work done at the Iowa State College seems to have established the fact that rolling grades are of little disadvantage to the users of highways, a proper maximum being ob-

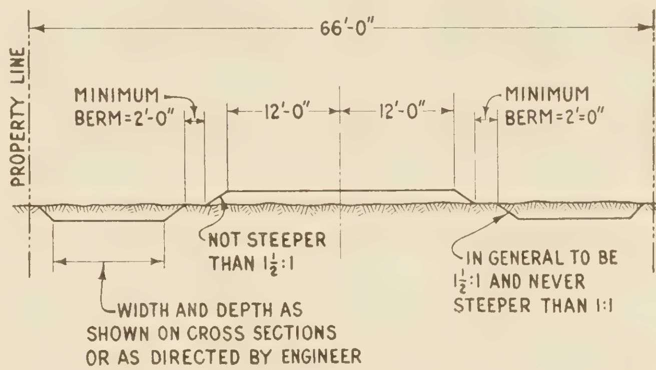


FIG. 4.—Generalized cross section used by State L

served. It appears, then, to be a natural conclusion from the foregoing that at least on projects with average excavation quantities lower bid prices may be secured through such adjustments of design as may be necessary in order to secure short hauls.

The time-distance graphs indicate that the current practice of balancing cuts and fills by long end or longitudinal haul is expensive. Many States have so-called free-haul limits of 500 feet or more with design practices established in accordance therewith. In those cases where the free haul is as low as 500 feet but is calculated from center of mass to center of mass, the actual maximum haul will not infrequently run over 1,000 feet. Of course, the amount of material moved 1,000 feet is not large but it requires almost exactly twice as long to deliver it this distance by wheeler as it does to deliver it a distance of 300 feet. At a delivery distance of 300 feet the cost of wheeler work and fresno work is practically the same. A fresno longitudinal haul of 300 feet, in turn, takes about twice the time generally required for side borrow work. The effect of design based upon long free-haul limits on bid prices when compared in this way with short-haul work, is apparent.

RHYTHMIC CORRUGATIONS IN GRAVEL ROADS

A Study of the Nature of "Chatter Bumps" and Their Relation to Traffic

By GEORGE E. LADD, Economic Geologist, United States Bureau of Public Roads.

WHAT is the nature of the rhythmic corrugations which occur in gravel roads in all parts of the country and which are a source of inconvenience if not an actual menace to traffic? How do they originate? Do they migrate or are they stationary? What is their relation to traffic? What relation have they to the kind of gravel used or the method of construction? What are the best maintenance methods with which to combat them? These and other similar questions have been investigated by the United States Bureau of Public Roads in the States of Maine,[1] New Hampshire, Vermont, Massachusetts, Connecticut, New Jersey, Michigan, and Wisconsin. Detailed studies of gravel-road construction jobs were made in four States with the object of keeping them under observation in the future. Gravels were sampled and tested, methods and costs of construction and maintenance were studied, and notes were made bearing on the traffic limitations of gravel roads.

Corrugations resulting from impact on a road which is frequently sprinkled

NATURE AND ORIGIN OF THE CORRUGATIONS

Gravel-road corrugations are analogous in form to those occurring in bituminous roads, excepting, that the former develop more uniformly and extensively. If not removed by maintenance they develop until each corrugation crosses the whole course of traffic and each series of them develops along the road until the next series is overtaken. The distance from crest to crest averages about 31 inches, and crests are rarely found either less than 25 inches or more than 35 inches apart. Any considerable variation from the average appears to be confined to the area where one series as it develops along the road overtakes another. The maximum height from bottom of trough to top of crest is 1½ inches. Any greater height than this was found in the field study to be associated with the beginning of pitting and raveling. These figures appear to be true of corrugations regardless of the nature of material in which they occur or the methods by which they develop. People traveling by automobile over roads so corrugated, not taking into consideration the speed at which they are passing over them, almost invariably estimate the distance from center to center of crest at 8 to 12 inches. A large number of highway engineers who have never given the problem special attention fall into the same error. The facts, however, as stated, were determined by observation on hundreds of miles of corrugated gravel roads in various States.

Inquiry among road builders as to the cause of gravel road corrugations resulted in the discovery of an amazing variety of explanations, some of which were very ingenious. The majority of replies erroneously attributed these corrugations to maintenance methods, particularly the use of the drag. The most ingenious explanation was offered by a man working on a corrugated road on the coast of New Jersey. He affirmed with positiveness that they are caused by the action of waves on an adjacent beach, transmitted to the road by earth vibration. As a matter of fact, these rhythmic corrugations develop in two ways, or through a combination of the two. They originate in vertical oscillations of rapidly moving automobiles, produced by obstacles, rough places in the road, or sharp depressions, and to this extent might in individual cases have their origin in an exaggerated case of poor dragging. They are, however, too widespread and too independent of dragging to justify in any general way their being attributed to this factor as a cause. Methods of their development which, it is repeated, may in some cases be combined, are as follows:

First method.—They are formed by the kick-back of surface materials arising from the spin of one or both

Typical corrugation, showing spacing and depth

of the rear wheels of automobiles as they descend after a bounce over some obstacle or depression. In the State of Maine, where gravel roads are maintained by keeping a loose surface brushed over the road by means of scrapers, drags, and planers, corrugations were observed from their incipiency over a very extensive area. It was noted frequently that where cars bounded over obstacles or rough places in the road, a set of corrugations was started by the action of one

[1] The investigation was made during the summer of 1921 by the writer, leading a party consisting of F. D. Hurwitz, E. F. Strickler, and two temporary assistants.

rear wheel only. As the wheel descends with accelerated rotation it momentarily kicks back a portion of the loose material of the road surface. Spring action causes a second and third like phenomenon. As many as five of these mounds have been seen in sequence. By repetitions of this action elliptical mounds of loose material are formed the longer axes of which are at right-angles to the axis of the road. As traffic continues the action is transferred to the other rear wheel and a parallel set of these mounds is formed. The weaving in and out of cars rapidly connects the pairs of little mounds into a ridge and these ridges in time become continuous across the entire road. The shifting of cars about the center of the road evidently carries corrugations across it, so that they are picked up by traffic going in the opposite direction and they ultimately form a continuous series of crests and troughs extending from border to border. The writer has never seen two independent series on opposite sides of the road, where ridges do not coincide. It would appear, therefore, that they develop across the road faster than a series can multiply and advance along the road.

An interesting fact about their occurence is that they are never found on steep hillsides. They may occur on the lower slopes or on broad tops, but they are not found either on the ascending or descending steep slopes. This tends to verify the explanation of their origin, which has been given. Going up the steep hill wheels of cars cling more closely to the road and on the descending side the cars coast. In neither case is there opportunity for the driving wheels to throw back surface materials in the manner indicated.

Corrugations of this type are never well bonded and compact. After weeks of heavy traffic they may be scraped away by the hand.

Second method.—Whenever the clay bond in a gravel road is sufficient in quantity and has sufficient moisture to give the aggregate a certain plasticity, and especially where the gravel particles are well rounded, series of corrugations develop which correspond in measurements to those described above. Their origin, however, is different from that of corrugations of the class decribed above, in that they result from the squeezing of a plastic mass, and are produced in a way similar to the development of waves in improperly mixed bituminous roads. Such corrugations have been observed in northern States where glacial gravels are used, but there they are rather a result of a much too high original bond or the scraping of ditch dirt on the road. This type of corrugations may be best observed in New Jersey, especially on the Shore Road in and near Long Branch. Here the roads are built of highly waterworn gravel of small sized particles so rounded and polished that a clay binder, as low even as 10 per cent by weight, makes possible a plastic condition of the whole, especially when sufficient moisture is added. The mositure on certain roads in question is furnished by daily sprinkling, in others by rainfall or by capillarity. Similar phenomena have been noted in roads built of cinders.

Rhythmic corrugations of this type result from impact, and, unlike the case of the first type discussed, the front and rear wheels of automobiles are equally active in their development.

DO THEY MIGRATE OR CHANGE POSITION?

Before the investigation was begun it was assumed that corrugations would slowly advance in the direction of traffic. Those, however, originating by the first method discussed appear to remain fixed where they originate. They are kept down in height by the action of wheels passing over them, and more especially by the limit of bound of cars, but they seem to move neither forward nor backward. At a number of places where they developed early in July reference stakes were driven on one side of the road, and they were kept under observation until late in the fall. No evidence of migration was noted. If corrugations move at all it would seem that they would at least swing on an axis located near the center of the road. This is exactly what happens with the impact type which originate in the more or less plastic varieties of gravel road. Many cases of this swinging on an axis were observed and photographed. This phenomenon is conspicuous where corrugations 6 or 8 feet in length cross the center of the narrow roads of a semiplastic nature. The writer has seen these swinging movements progress from a position at right angles to the road to one departing but a few degrees from the axis of the road.

In New Jersey an arrangement of corrugations was found which for a time was very puzzling. They were "herringbone" corrugations. They approached the center of the road from both sides at an angle of about 60 degrees with its axis, making a series of V-shaped markings centering along the middle of the road. That these corrugations were originally at right-angles to the axis of the road is evidenced by the fact that where the road is crossed by a concrete walk, a fixed obstacle, traffic had developed normal corrugations in its immediate vicinity on the take-off side but not on the approach side. At a distance of 12 or 15 feet away, however, they became angular and assumed the positions described. In seeking a solution of this phenomenon the writer found conditions as follows: The road is 60 feet in width with a very low crown. It is built of gravel consisting of very highly rounded and polished pebbles and sand and about 10 per cent of clay-silt bond. The road is sprinkled with water throughout the summer season to prevent dust. During the summer it is subject to traffic which rises on holidays to more than 10,000 cars a day. It is close to the shore and overlooks the surf, but automobile passengers are prevented from seeing the beach itself because of a broad boardwalk on the shore side. Considering the fact that here is a great bathing resort, and that the average automobilist enjoys the sight of surf bathing, it was assumed that when traffic was not so excessive as to confine cars to double rows in both directions, that there would be a drift of travel toward the shore side, traffic going north as near to the boardwalk as possible, and on the other side, going south, as near to the center of the road as possible, in both cases to obtain the best possible view. Such a drift of traffic on this road would account for the extraordinary swing of the corrugations observed. Whether or not this theory gives the correct explanation of the behavior of corrugations on this road, it at least accords with the facts and is a possible explanation.

THEIR RELATION TO TRAFFIC

Gravel roads subject to a traffic of not more than 200 or 300 cars per day remain practically free from corrugations if occassionally dragged. As soon, however, as traffic reaches 400 to 450 cars per day, corrugations develop very rapidly. In the State of Maine, where tourist traffic is large during the summer months, and its rate of increase is well known, the State highway officials can predict almost to a day when corrugations will begin to develop on certain roads. The traffic limitations of gravel roads in general are determined by the intensity of maintenance required and by its cost. Sufficient data have not yet been gathered on this subject. A highway engineer's handbook, referring to the subject of gravel roads, states that they are not fit for traffic exceeding 100 cars a day, but in Maine, Connecticut, New Hampshire, and other States they are successfully serving a traffic of from 700 to several thousand cars per day. In Wisconsin and Michigan gravel roads are maintained with comparatively smooth surface, so that automobile travel is comfortable and satisfactory on roads serving from 1,800 to 3,200 cars per day, with a maintenance cost ranging from $280 to $320 per year, or from $600 to $700 per year when the roads are also treated with dust preventives.

Maintenance costs on gravel roads in various States have been reported to the writer as ranging from $1,000 to $3,000 per year. No satisfactory analyses of such costs have been made and it is presumed that a considerable portion of them really belong to improvement and reconstruction.

THE RELATION OF RHYTHMIC CORRUGATIONS TO KINDS OF GRAVEL, MIX, AND METHODS OF CONSTRUCTION

The fact that these corrugations are so general and occur in all sections of the United States makes it evident that nearly all gravel roads, if they serve sufficient traffic, are subject to the development of this nuisance and menace, although the methods of construction and kinds of gravel vary widely. The situation, however, is not hopeless. Several highway officials have expressed the opinion that less corrugation trouble is found where the gravel is angular than where it is composed of highly rounded particles. It is also claimed that where the road is constructed of gravel more uniform in size than pit run, and especially where all particles over 1 inch in size are excluded, that corrugations are slower in developing and more easily eliminated by maintenance methods. In northern New Hampshire some roads are built of so-called gravel which has resulted from the decomposition of granite rocks and is full of angular quartz. The roads built of this material are said to give better service so far as corrugations are concerned than those built in the same State of glacial gravels, or those resulting from disintegration of schistose rock. It is claimed in Wisconsin that the best service given by gravel roads, so far as corrugations are concerned, is found where pit-run gravel is passed through a crusher and only the material which ranges in size from 1 inch down is used. Highway engineers, notably some in Wisconsin and Oregon, object to any clay binder in the gravel and prefer only the fines produced by crushing and such as result from surface wear.

During the writer's investigations in the State of Maine it was noted that roads with a relatively high percentage of clay-silt binder were comparatively free from corrugations. On one road on which rhythmic corrugations were well developed, a patch near the center of the road, about 70 feet long and varying from 2 to 4 feet in width, was uncrossed by corrugations and had a hard, smooth surface. Examination showed that this patch had about 5 per cent more clay-silt bond than the surrounding road.

On the gravel road between Waterville and Bangor, Me., corrugations develop rapidly during the summer traffic, and are kept down only by constant maintenance for almost its entire length. Comfortable travel on this road was made possible only by continuous use of drags and planers. One short section of the road, however, was practically free from corrugations throughout the summer. This section was built of a softer gravel which was high in clay-silt bond. Unfortunately, however, while this section of road gives satisfaction during the summer months, it is said to be nearly impassible in the spring. Thus it may be that an all-year gravel road that will not require intensive maintenance can not be built in States subject to heavy freezing and wet seasons.

This problem remains for future solution and must be worked out by a combination of field observations and laboratory tests. In this connection it may be stated that the present standard tests of gravel are unsatisfactory in that they do not include determination of the nature and qualities of natural binder originally in the gravel. The so-called cementing value test has to do only with the products of abrasion of individual gravel particles. While it is important to determine this factor, there must also be a determination, in addition to the facts brought out by mechanical analyses as to the quantity of clay-silt binder, of the cementing value of this fine material.

THE EFFECT OF DUST PREVENTIVES AND SURFACE BINDERS

A preliminary study has been made of problems of surface-treated gravel roads. Matters of methods, costs, and service have been studied to some extent in certain States. Surface binders in a general way prevent development of corrugations, and where these do occur on binder-treated roads it has been demonstrated that they result from excessive quantities of bituminous material. This statement does not refer to dust-prevention treatment, and is perhaps not true of lignin-treated roads. Some States use both tar and oil binders, some will use only oil, and others only tar. One State at least uses lignin almost exclusively. Dust preventives have been shown to fulfill the primary requirement. Their effect on corrugations, however, is not yet clear. It is not unlikely that they delay the development of rhythmic corrugations of the first type discussed above. It is clear, however, that they do not prevent their development. They successfully lay dust for long periods in spite of heavy traffic, and they lengthen the life of a road by retarding loss of surface material.

MAINTENANCE METHODS

The maintenance required by a gravel road depends, of course, largely upon the amount of traffic to which it is subjected. If this does not exceed 200 or 300 cars per day, occasional dragging, especially after rains, will keep the surface in good condition. As traffic increases, however, surface maintenance must be practically continuous, and even then dragging or scraping will not keep a road free from corrugations. The planer, a simple machine familiar to all highway engineers, is employed in addition to the drag and road scraper.

(Continued on page 22)

OILED EARTH ROADS ON LONG ISLAND

By A. T. GOLDBECK, Chief of Division of Tests, U. S. Bureau of Public Roads

A typical oiled earth road on Long Island

ONE of the very objectionable features of an untreated sand-clay or top-soil road is the dust created by traffic when the road surface is dry. Another objection is the expense of constant dragging to keep the surface in a smooth condition. Under some conditions the rate of wear of such roads amounts to as much as an inch a year and additional material must be placed on the surface to replace that worn away. On Long Island these objectionable features seem to have been overcome by the use of oil applied to the surface in a particular manner.

The writer inspected a number of these roads on the southern part of the island, extending from Bay Shore to East Hampton. The soil in general is of a sandy nature and the roads which have been treated are quite typical of sand-clay and top-soil construction. It was stated that the best results are obtained when the material is of such a nature that it is well bonded together. It must be capable of supporting heavy truck loads under ordinary weather conditions without appreciable indentation under the wheels. If the soil is practically pure sand it will be necessary first to bond the surface with a clay or loam admixture, and similarly if the soil is clay it should be treated by the addition of an admixture of sand. In Table 1 analyses of soil samples taken from untreated roads compared with typical sand-clay mixtures will give an idea of the nature of the surfaces treated.

TABLE 1.—*Analyses of samples taken from road surface before oiling, compared with typical sand-clay mixtures*

	Sample No. 1	Sample No. 2	Characteristics of typical sand-clay surfaces		
			Class A, hard	Class B, medium	Class C, soft
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Retained on 20-mesh	3.1	3.4			
Passing 20, retained on 60-mesh	38.2	53.9			
Passing 60, retained on 100-mesh	6.3	8.5	45–60	30–45	20–30
Passing 100, retained on 200-mesh	3.7	3.5			
Total sand	51.3	69.3	65–80	60–70	55–80
Silt	30.5	20.1	0–15	10–20	10–20
Clay	18.2	10.6	9–18	15–25	10–25
Total	100.0	100.0			
Total sand (retained on 60-mesh)	41.3	57.3			
Coarse material (over 10-mesh)	2.8	0.5			

It will be noted that sample No. 1 is not of as high quality as desired even for a class C sand-clay road, while sample No. 2 should make a first class sand-clay surfacing. These analyses will serve to show the characteristics of typical roads which have been oil-treated on Long Island and will be useful for comparison with sand-clay or top-soil roads in other localities where oiling is contemplated.

METHOD OF TREATMENT

The road surface is first graded to a low crown with a road machine. The oil is then applied cold with a pressure distributor at the rate of one-third to four-tenths gallon per square yard. It is then covered uniformly with sand broadcasted with shovels from piles along the side of the road. Only half of the road is treated at one time and this is immediately covered. As soon as the covering is completed traffic is allowed on the surface and treatment is then given to the other side of the road. Within about two weeks the traffic irons down the surface and gives it the appearance of sheet asphalt. Dragging is sometimes resorted to several days after oiling to aid in obtaining a smooth surface.

During the first year the common practice is to apply two treatments of oil. The following year sometimes one treatment is given and sometimes no treatment is necessary. Whenever the condition of the surface becomes uneven, blading is resorted to and the surface is brought back into shape. Every four or five years it becomes necessary to completely scarify and harrow the surface in order to bring it into first-class condition. Scarifying is done to a depth of 6 or 8 inches and the underlying soil is mixed to a considerable extent with the treated surface. The scarifying is not difficult, since even at the end of five years the oiled surface remains in a somewhat plastic condition. After scarifying and harrowing a road machine is used for shaping the surface, and traffic is allowed to consolidate it. A fresh treatment of oil and cover material is then given in the manner followed on a new road.

Broadcasting sand covering immediately following the application of oil

The oil used on the roads inspected has the following characteristics:

Specific gravity, 25° C./25° C	0. 9587
Flash point (° C.)	58
Specific viscosity, Engler (25° C.)	109
Loss, 163° C., five hours (per cent)	24. 39
Characteristics of residue, viscous liquid, slow flow.	
Consistency of residue float test, 50° C. (seconds)	72
Total bitumen (soluble in carbon disulphide) (per cent)	99. 9
Organic matter insoluble (per cent)	. 0
Inorganic matter insoluble (per cent)	. 1
Per cent of total bitumen insoluble in 86° B. naptha	13. 5

Appearance of surface a few days after treatment. Traffic soon irons out the unevenness

NATURE OF THE ROAD SURFACE

When viewed from a moving automobile the surface looks not unlike sheet asphalt or in some cases like bitulithic when the original material contains large particles. The roadway is very readily cut with a knife and the samples thus obtained seem very much softer than sheet asphalt. A heavy touring car creates slight cuts in it and the tire markings are readily imprinted in the surface when the car moves slowly. In spite of the plastic nature of the surface, however, it does not seem to wave or shove and the shallow grooves formed by vehicles do not become deep, probably because of ironing out by traffic. The low crown on these roads is advantageous as it undoubtedly encourages traffic to use the entire width of the roadway. Surfaces six years old have retained their plastic condition and it is probable that they can be maintained indefinitely with retreatments at proper intervals. Such surfaces might have an oiled depth, owing to the building-up process of scarifying and retreatment of 3 to 6 inches, although the average depth probably was not over 1½ or 2 inches on many of the roads inspected. The depth of treatment naturally depends on the length of time the roads have been under treatment.

TABLE 2.—*Analysis of samples of Long Island oil-treated surface*

	Sample No. 3	Sample No. 4
	Per cent	*Per cent*
Bitumen extracted	8. 3	7. 2
Passing ¼-inch screen, retained on 10-mesh sieve	10. 5	9. 0
Passing 10-mesh sieve, retained on 20-mesh sieve	9. 0	9. 0
Passing 20-mesh sieve, retained on 30-mesh sieve	17. 0	19. 5
Passing 30-mesh sieve, retained on 40-mesh sieve	14. 9	15. 5
Passing 40-mesh sieve, retained on 50-mesh sieve	17. 1	13. 5
Passing 50-mesh sieve, retained on 80-mesh sieve	11. 5	9. 5
Passing 80-mesh sieve, retained on 100-mesh sieve	3. 0	2. 5
Passing 100-mesh sieve, retained on 200-mesh sieve	3. 5	3. 5
Passing 200-mesh sieve	5. 2	10. 8

NOTE.—Sample No. 3—Bayport, L. I., road 3 years old, three applications amounting to 1 gallon per square yard.
Sample No. 4—Sample taken from road surface just after scarifying and before retreating.

Some of the roads carry a very heavy touring traffic. It is stated that in some cases the number of vehicles runs up to about 5,000 and 6,000 per day during the summer season. Several heavy trucks were also noted on sections of these roads.

It seems that this treatment offers an ideal solution of the dust problem on sand-clay and top-soil roads. Macadam, gravel, and shell roads have likewise been treated successfully by this method. The cost of maintenance is only slightly more than the average cost of maintenance of the ordinary earth road in Iowa and is less than the cost of maintaining gravel roads. The riding surface presented is superior to that of either of these types and is entirely free from dust. Wherever sand-clay or top-soil roads are used, oil treatments made in the manner described undoubtedly merit a thorough trial to determine whether or not they are advantageous under local conditions. It is stated that between 1,300 and 1,500 miles of roads on Long Island have now been oiled.

(Continued from page 20)

Planers are of different types. Those used in some States have a single cutting blade, while those used in other States have several shorter blades so arranged as not only to cut down corrugations but to distribute and rearrange the surface materials. Apparently, the ideal machine for eliminating corrugations has not been devised. The planer certainly does not always entirely remove them, some of the bases of ridges being left, so that traffic may in 24 hours after the planing of the road reproduce the corrugations in original form and position. Even resurfacing with 1½ or 2 inches of gravel following planing of the road will not prevent the immediate recurrence of corrugations which have not been entirely eliminated by planing and dragging. In Wisconsin some gravel roads subject to heavy traffic are scarified once or twice during the summer months and left to be recompacted by traffic.

ROAD MATERIAL TESTS AND INSPECTION NEWS

Testing and materials engineers, chemists, and others engaged in the testing and inspection of road materials and in highway research are invited to submit articles for publication in this department of PUBLIC ROADS

WE JUDGE from the favorable comments we have received that this department of PUBLIC ROADS fills a real need of the testing engineer. It was our idea when the department was established that engineers engaged in the special field of materials testing would welcome it as a medium for the interchange of information of mutual interest in regard to their work. Acting on that idea we extended an invitation in the March issue to all testing and materials engineers and chemists to submit articles for publication. Perhaps the fact that in seven months we have not received a single contribution from anyone other than the engineers of the Bureau of Public Roads is due to the pressure of other work rather than to any lack of interest on the part of the testing engineers and chemists, but we would honestly like to see some evidence to support that view of the matter now that the busy season is past.

As an illustration of the kind of subject we would like to see discussed in this department there is the so-called strength-ratio test for concrete sand. Testing engineers are now apparently almost unanimous in the belief that this test is not a satisfactory measure of the quality of fine aggregate for concrete road construction. In view of the importance of a test for quality of fine aggregate, however, it is perfectly reasonable to assume that many laboratories have either attempted to improve the tensile-strength-ratio test or have worked on substitutes for it. The findings of the various laboratories as a result of research along this line would be of great general interest to other laboratories, even though the work done might not be considered of sufficient importance to warrant the preparation and publication of a formal article. This is just a sample of the kind of material which would be acceptable for publication in this department.

So let us repeat—Contributions are welcome. Full credit will be given for every article published. Just address them to A. T. Goldbeck, Chief, Division of Tests, U. S. Bureau of Public Roads, Washington, D. C.

FIELD INVESTIGATION OF SUBGRADE SOILS

For a number of years the bureau has been endeavoring to establish and standardize tests for determining the physical characteristics of subgrade soils in an effort to give the highway engineer definite information relative to the materials upon which he must build the highway. Up to the present date a number of tests have been developed and standardized which enable us to distinguish very readily between various types of subgrade soils from the laboratory point of view. We are now confronted, however, with the very natural question as to whether the conclusions derived from data obtained in the laboratory will hold for the soils as they exist under field conditions. In an effort to answer this question the investigations were carried into the field this spring, observation stations being established in Ohio, Iowa, and Minnesota.

As a result certain very interesting points have come up, some of the most important of which are as follows: What effect has temperature upon the capillary moisture of subgrade soils? What effect has condensation and evaporation upon the moisture content and supporting power of subgrade soils? Are subgrade failures resulting from so-called "frost boils" in the North and "mud boils" in the South attributable to the same basic cause? To what extent can drainage be relied upon to eliminate subgrade failures?

At the present time a report on the work accomplished in the field this spring is being prepared and it is expected will be available for public distribution in the near future.

THE ABRASION TEST FOR GRAVEL

The attention of the bureau has recently been called to the fact that the method for making an abrasion test for gravel, specified on page 7, U. S. Department of Agriculture Bulletin 1216, does not specify that rounded fragments only shall be used in making up a test charge. Experiments have shown that a test charge consisting of approximately 50 per cent rounded and 50 per cent crushed fragments may possibly show a percentage of wear as much as 100 per cent higher than the corresponding test sample in which all the fragments are rounded. The bureau suggests therefore that in making the abrasion test of gravel the various road material laboratories take this fact into consideration and govern their interpretation of the test results accordingly.

PORTLAND CEMENT CHECK SAMPLES DISTRIBUTED

On July 24 the bureau sent out the fifth of a series of check samples of Portland cement. This sample was sent to approximately 60 cooperating laboratories, all of which perform tests on materials used in Federal aid road construction. The bureau considers that this work is very important and urges that laboratories invited to cooperate make tests on check samples just as soon as received and not wait until the routine work has slacked up.

PORTLAND CEMENT INSPECTION

The U. S. Bureau of Standards has recently prepared in mimeographed form a summary of their practice in regard to the inspection of Portland cement. This summary goes into great detail with reference to the various steps which should be taken by the inspectors, precautions to be observed, and dangers to be guarded against. Copies of forms used by the Bureau of Standards in connection with sampling Portland cement are included. The Bureau of Standards is prepared to distribute a limited number of copies of this circular, which is entitled "Inspection of Portland Cement," by J. R. Dwyer and Roy N. Young. Requests for copies should be made direct to the Bureau of Standards.

MID-YEAR MOTOR VEHICLE REGISTRATION 15,552,077

BY G. G. CLARK, HIGHWAY ECONOMIST, U. S. BUREAU OF PUBLIC ROADS

RETURNS from the 48 States and the District of Columbia show a total registration of 15,552,077 passenger cars, taxicabs, busses, and motor trucks to July 1 of the registration year 1924. This is an increase of 2,549,650 over the registration figures of July 1, 1923, and an increase of 459,900 over the total registration for the calendar year 1923.

By geographic divisions the registration and corresponding increases and ratios of population to number of vehicles are as follows:

Geographic divisions	Vehicles	Increases over July 1, 1923	Population 1920 census	Persons per vehicle
		Per cent		
New England	1,003,023	21	7,409,909	7.3
Middle Atlantic	2,754,541	19	22,261,144	8.1
East North Central	3,966,715	19	21,475,543	5.4
West North Central	2,374,938	11	12,544,249	5.3
South Atlantic	1,427,101	23	13,990,272	9.8
East South Central	652,084	32	8,893,307	13.6
West South Central	1,237,525	21	10,242,224	8.3
Mountain	524,855	18	3,336,101	6.4
Pacific	1,611,295	25	5,566,871	3.4
Total	15,552,077	20	105,710,620	6.6

The percentage of gain in registration during the 12 months, July 1, 1923, to July 1, 1924, was largest in the East South Central States. In this group in which the gain was 32 per cent, 13.6 persons were found for each vehicle registered. The smallest percentage of gain, 11 per cent, was found in the West North Central States where one motor vehicle was registered for 5.3 persons.

A total of $199,472,682.17 was collected from the owners and operators of these vehicles for licenses and permits. Of this amount $163,011,584.29, or 82 per cent was made available for highway expenditure by or under the supervision of the respective State highway departments; the remainder was used to cover the cost of registration, to finance debts incurred for highway construction which are not payable by the highway departments, and in some States a portion was distributed to the counties.

No radical changes have been made during this period in the license fee as the total receipts from this source follow the same percentage as the rate of increase in the number of vehicles registered.

The percentage of fees made available for highway work by or under the supervision of the respective State highway departments shows a slight increase over the percentage made available during previous periods.

Full details of the registration and license fees collected by States are printed in the table on the cover of this issue. Whenever possible, passenger cars, motor trucks, taxicabs, busses, and cars for hire have been segregated in this table. However, a number of States do not make distinction between these vehicles for registration purposes and a much larger number of States do not segregate the fees received from each class. Therefore it is impossible at this time to separate in such States either the vehicles or the fees paid.

Motor-cycle registration totaling 126,850 shows a decrease of 14,671 from July 1, 1923. This decrease is in keeping with the general decrease of registration of these vehicles for several years.

GASOLINE TAXES

The tax imposed on gasoline used as motor-vehicle fuel has proved to be a source of revenue which is increasing at a rapid rate. The gross returns for July 1, 1924, when compared with similar figures for July 1, 1923, show an increase of 273 per cent.

On July 1, 1924, 35 States and the District of Columbia were collecting a tax on gasoline. During the registration year to July 1 the sum of $32,430,410.37 was collected from this source, the returns ranging from 1 cent per gallon in 8 States, 2 cents per gallon in 15 States and the District of Columbia, 2½ cents per gallon in 2 States, 3 cents per gallon in 9 States, and 4 cents per gallon in one State. Of the total collected, $20,065,581.29, or about 62 per cent, was made available for expenditure by or under the supervision of the respective State highway departments.

The total amount collected from this source for the previous registration year to July 1, 1923, was $8,669,174.03 collected in 27 States. Fifty-seven per cent of this amount was made available for road work by or under the supervision of the State highway departments. In several States parts of the proceeds of the gasoline tax are diverted to other purposes than State-supervised highway construction or maintenance and in one State the entire amount collected is diverted to other purposes.

(Continued from page 9)

That the combined license fees and gasoline taxes are not excessive in the opinion of motorists is evidenced by the fact that there is no falling off in the rate of increase in motor vehicle registration as the combined taxes are increased. Grouping the States into classes according to the amount of the combined taxes collected per vehicle-mile brings out the interesting fact that the groups in which the vehicle-mile tax was greatest reported the greatest percentage increase in motor vehicle registration. As shown by the table on page 9, the five States which collected more than 0.4 cent in combined taxes reported an average increase of 26 per cent in their motor vehicle registration. The 13 States with combined taxes ranging from 0.3 to 0.4 cent reported registration increases averaging 28 per cent. These are the two highest tax classes, and it is very interesting to note that the States in the two lower classes, with taxes from 0.2 to 0.3 cent and from 0.1 to 0.2 cent, showed average registration increases which were respectively only 22 and 23 per cent.

So long as the taxes levied upon the use of the motor vehicle do not retard the rate of increase in registration it may be safely concluded that the tax is not excessive. The above figures indicate that the motor-vehicle taxes have not been increased in any State to the point at which the law of diminishing returns becomes operative. Oregon, with its combined taxes of more than six-tenths of a cent per vehicle mile, the largest tax found in any State, reported a registration increase in 1923 of 24 per cent, which was a rate of increase equal to or greater than those reported by all but 3 of the 11 States whose combined taxes ranged from 0.1 to 0.2 cents per vehicle-mile.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1924

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

AUGUST 31, 1924

STATES	FISCAL YEARS 1917-1924			FISCAL YEAR 1925									BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS	STATES
	PROJECTS COMPLETED PRIOR TO JULY 1, 1924			PROJECTS COMPLETED SINCE JUNE 30, 1924			*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	$ 4,598,721.63	$ 2,186,247.54	464.1	$ 443,164.31	$ 218,730.40	75.5	$ 15,330,056.61	$ 7,498,954.46	839.3	$ 367,310.86	$ 154,111.71	7.6	$ 1,195,013.89	Alabama
Arizona	8,338,365.41	4,287,683.98	527.8	332,420.20	174,523.00	26.2	1,999,675.90	1,212,683.70	138.6	266,850.29	163,072.20	32.7	1,657,733.22	Arizona
Arkansas	11,094,751.31	4,424,345.63	944.4	122,739.41	50,850.57	4.9	6,162,288.53	2,056,909.25	328.8	2,380,491.34	1,134,998.32	110.7	1,395,296.23	Arkansas
California	12,999,075.03	5,647,148.17	533.7	1,940,703.56	1,047,037.44	58.0	11,926,181.55	6,374,801.05	436.2	1,786,901.93	841,476.45	31.9	3,182,842.89	California
Colorado	8,108,070.31	4,029,898.97	502.6	255,565.11	136,958.23	23.5	5,231,701.65	2,817,961.64	177.9	444,999.28	249,731.34	23.3	2,325,330.82	Colorado
Connecticut	3,062,872.02	1,269,558.60	73.6	199,024.56	98,423.00	4.9	2,851,926.15	936,604.04	47.4	410,228.33	109,200.00	6.7	967,409.36	Connecticut
Delaware	3,056,832.22	1,007,714.93	72.5	462,969.09	197,825.82	13.9	608,205.95	214,911.10	13.9	588,061.54	233,370.00	15.6	85,708.25	Delaware
Florida	961,134.07	461,470.92	48.9				9,190,174.82	4,506,551.34	259.4	398,642.71	171,123.94	10.2	1,147,740.90	Florida
Georgia	17,167,373.32	7,955,805.20	1214.2	479,165.95	238,182.21	40.6	9,303,989.84	4,592,560.37	718.8	2,021,929.52	966,076.73	137.2	697,272.49	Georgia
Idaho	8,181,697.92	4,092,395.52	506.9	197,306.67	113,420.29	18.7	1,761,847.73	1,021,213.39	123.4	851,082.12	547,590.28	48.3	903,092.52	Idaho
Illinois	26,964,706.06	12,279,546.33	804.7	493,620.15	244,171.81	14.6	16,450,654.64	8,174,734.64	558.4	153,358.60	76,679.30	6.1	2,661,359.92	Illinois
Indiana	7,577,444.16	3,655,540.97	225.7	461,440.45	226,266.09	18.2	15,682,278.63	7,651,303.31	510.0	1,001,858.16	481,030.23	30.5	2,298,251.40	Indiana
Iowa	23,195,778.19	9,237,031.86	1682.9	98,400.80	43,700.00	2.6	8,721,632.22	4,054,399.47	641.4	356,429.80	173,200.00	34.3	1,827,805.67	Iowa
Kansas	17,084,136.48	6,043,176.80	502.7	3,276,833.27	1,166,738.82	94.3	15,550,532.64	6,153,206.97	597.5	1,235,074.78	611,580.79	101.6	1,324,585.62	Kansas
Kentucky	10,822,980.31	4,613,947.28	429.4				7,691,317.08	3,713,743.94	329.3	358,008.82	179,004.40	23.6	1,865,043.38	Kentucky
Louisiana	8,498,463.19	3,636,143.36	661.2	113,769.13	54,557.86	7.8	5,657,879.78	2,804,437.19	364.6	152,006.67	76,003.33	12.3	694,300.26	Louisiana
Maine	6,911,058.78	3,299,935.38	230.7	260,943.30	129,792.71	10.0	1,505,435.72	748,285.60	56.6	222,227.50	111,113.74	12.0	800,844.57	Maine
Maryland	6,760,044.42	3,213,321.78	243.2	79,448.49	39,724.24	3.7	2,301,910.45	1,007,450.21	72.9	735,978.43	270,647.31	21.7	117,806.46	Maryland
Massachusetts	10,191,202.02	4,105,727.22	232.9	88,434.91	28,760.00	1.4	5,930,451.96	1,970,232.59	101.8	407,133.25	126,791.38	5.9	1,688,268.81	Massachusetts
Michigan	13,434,135.07	6,060,612.23	494.5				13,928,561.23	6,708,729.87	494.3	45,171.00	22,585.50	1.4	3,087,844.40	Michigan
Minnesota	24,037,561.24	9,885,843.07	2292.0	108,570.20	39,500.00	12.2	9,902,351.38	4,580,829.97	815.6	1,045,190.59	519,800.00	148.1	292,445.96	Minnesota
Mississippi	7,898,193.89	3,828,941.39	655.0	61,901.51	30,950.75	9.6	7,837,647.88	3,910,893.44	480.5	1,007,528.02	497,508.48	47.9	1,262,978.94	Mississippi
Missouri	11,352,027.70	5,245,899.18	803.5	35,842.36	17,921.18	0.1	16,929,374.31	8,087,053.65	721.5	3,956,018.81	1,905,870.60	208.4	2,683,443.39	Missouri
Montana	8,867,279.16	4,384,335.12	791.4	108,869.05	87,529.84	12.4	2,876,282.84	2,107,672.46	268.2	1,063,490.31	604,120.51	120.3	3,782,759.07	Montana
Nebraska	7,876,337.16	3,714,691.59	1440.4	200,802.81	100,401.40	22.6	7,221,153.76	3,510,057.71	733.9	1,014,509.69	506,904.60	112.4	3,618,990.70	Nebraska
Nevada	3,460,245.52	1,853,624.98	225.6	587,270.26	511,310.71	43.3	4,662,427.47	3,903,926.93	397.8	2,547.71	2,222.11		619,236.27	Nevada
New Hampshire	3,076,750.19	1,487,867.58	171.3				1,252,298.78	586,791.62	40.7	233,335.90	112,525.58	8.0	247,779.22	New Hampshire
New Jersey	7,623,795.12	2,661,531.49	148.7	298,751.09	111,360.00	5.6	9,724,981.71	2,795,603.75	73.4	796,997.14	205,677.49	10.7	815,074.27	New Jersey
New Mexico	5,306,286.45	2,758,849.68	714.3	62,583.77	38,142.25	4.3	7,016,229.26	4,589,997.38	709.5	311,857.56	191,792.38	22.0	1,010,560.31	New Mexico
New York	18,862,742.49	8,257,844.44	572.7	391,274.42	153,023.98	12.5	27,028,766.96	10,351,676.72	608.3	7,213,038.00	2,213,920.00	140.7	5,731,682.86	New York
North Carolina	12,567,732.97	5,676,757.66	884.7	38,212.36	16,890.22	7.6	11,116,708.27	4,156,350.61	301.0	1,505,316.48	709,351.48	43.6	1,734,901.03	North Carolina
North Dakota	9,088,973.11	4,418,505.42	1587.9	139,674.74	69,724.43	25.0	3,634,215.34	1,800,155.68	577.7	258,135.37	110,437.00	20.8	1,964,833.47	North Dakota
Ohio	33,122,751.43	11,879,917.99	962.5	742,323.36	294,754.13	19.7	13,028,842.05	4,927,429.79	353.7	2,641,527.60	896,444.89	73.0	2,141,617.20	Ohio
Oklahoma	12,986,865.26	5,888,852.03	497.3	738,661.44	349,064.35	32.5	8,189,798.49	3,966,056.68	355.0	2,282,876.56	991,165.07	114.2	1,342,564.87	Oklahoma
Oregon	12,082,873.17	5,819,093.79	655.6	513,232.52	303,539.04	48.5	2,419,116.36	1,397,424.72	127.1	916,370.40	560,238.86	54.1	425,862.59	Oregon
Pennsylvania	36,825,248.98	14,114,694.79	729.7	415,284.23	176,961.99	9.7	10,286,779.06	5,754,526.25	344.3	4,675,257.92	1,226,136.25	80.9	3,329,296.72	Pennsylvania
Rhode Island	1,774,397.25	779,227.96	46.0	157,932.08	62,600.00	3.1	1,243,889.16	438,306.80	25.2				652,906.24	Rhode Island
South Carolina	9,016,476.73	4,124,045.22	924.4	454,462.14	216,444.36	90.9	5,984,408.28	2,478,502.93	438.1	628,722.95	235,728.45	71.9	632,825.04	South Carolina
South Dakota	8,674,597.86	4,244,636.27	989.8	551,979.03	306,772.84	85.7	7,136,700.83	3,587,283.47	990.4	817,598.02	378,330.33	74.7	201,657.09	South Dakota
Tennessee	6,805,683.35	3,313,936.07	259.6	854,869.74	427,434.87	24.0	12,836,444.00	6,034,273.41	409.3	3,158,756.70	1,364,493.04	129.6	884,499.61	Tennessee
Texas	42,341,998.56	16,190,624.91	3122.8	1,140,024.71	538,466.86	121.5	24,917,869.28	9,900,561.39	1517.1	4,021,240.94	1,515,009.95	266.7	3,579,549.89	Texas
Utah	3,304,423.75	1,895,805.92	219.0	719,066.79	390,456.24	91.2	3,658,519.93	2,411,856.29	212.9	1,161,249.33	800,886.74	74.7	617,467.81	Utah
Vermont	1,922,114.16	942,769.12	74.4				1,794,475.68	863,325.61	45.8	255,272.32	118,784.62	6.5	609,099.65	Vermont
Virginia	10,035,301.48	4,801,782.43	562.5	141,742.05	70,871.02	4.6	9,029,422.39	4,175,782.70	308.7	1,659,955.26	557,301.18	58.0	987,215.67	Virginia
Washington	11,384,615.67	5,290,895.45	457.0				2,951,003.81	1,306,000.00	121.6	1,341,215.00	621,300.00	53.6	668,482.55	Washington
West Virginia	5,489,747.95	2,365,041.53	255.6	898,083.14	402,583.56	24.7	4,428,254.78	1,998,238.67	155.6	528,260.11	232,245.33	18.5	756,022.91	West Virginia
Wisconsin	18,753,903.15	7,441,033.57	1325.3	268,053.95	134,026.97	9.2	4,301,465.28	2,141,404.69	191.6	572,540.18	274,399.01	17.5	3,687,586.76	Wisconsin
Wyoming	6,127,625.61	3,078,098.70	687.6	35,927.39	23,179.25	1.1	4,672,794.58	2,948,235.74	353.9	169,412.59	94,122.00	4.8	543,715.31	Wyoming
Hawaii													365,625.00	Hawaii
TOTALS	$ 549,655,391.27	$ 237,852,399.82	32452.9	$ 18,970,344.39	$ 9,082,572.73	1140.3	$ 393,768,825.00	$ 178,929,788.19	18488.7	$ 57,421,966.39	$ 24,146,102.90	2655.2	$ 75,114,136.36	TOTALS

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $ 56,371,163.31 Federal aid $ 26,175,885.42 Miles 2795.2

MOTOR VEHICLE REGISTRATION AND REVENUES, JULY 1, 1924

State	Grand total motor cars	Private passenger cars	Motor trucks	Taxis, busses, and cars for hire [1]	Motor cycles	Total gross receipts		Amount applicable to highway work by or under supervision of State highway department		Amount of registration fees paid		Total registration to July 1, 1923	Increase July 1, 1924, over July 1, 1923	State
						From registration fees, licenses, and permits	From gasoline tax [2]	From registration fees, licenses, and permits	From gasoline tax	Passenger cars [3]	Motor trucks [3]			
													Per cent	
Alabama	154,234	133,216	18,225	2,793	330	$1,554,979.65	$737,572.58	$1,219,104.05				97,788	57	Alabama.
Arizona	50,409	43,616	6,793		286	313,668.00	334,768.59	313,668.00	$167,384.30			41,630	21	Arizona.
Arkansas	116,700	103,600	13,100		219	2,299,828.31	980,804.36	2,299,828.31	980,804.36			97,147	20	Arkansas.
California	1,184,015	1,017,556	166,459		10,615	5,794,078.41	6,000,000.00	[4] 2,800,000.00	3,000,000.00	$3,225,333.15	$2,163,781.81	933,808	27	California.
Colorado	186,926	173,856	13,070		1,723	1,143,289.99	748,404.48	[4] 500,000.00	374,202.24	925,025.83	161,539.46	159,001	17	Colorado.
Connecticut	188,344	156,621	29,142	2,581	3,299	4,545,130.30	[5] 348,585.35	4,545,130.30	[5] 348,585.35	2,575,771.74	1,008,590.40	152,396	24	Connecticut.
Delaware	31,300	26,000	5,300		271	544,628.00	120,385.22	544,628.00	120,385.22	307,238.00	112,281.00	26,300	19	Delaware.
District of Columbia	72,954	63,405	8,479	1,070	1,431	299,265.00	[6] 83,391.71		[6] 83,391.71			62,777	16	District of Columbia.
Florida	164,112	132,807	28,616	2,689	597	1,515,667.50	1,837,406.34	[4] 1,050,000.00	1,224,338.42			135,896	21	Florida.
Georgia	177,030	154,280	22,650	100	670	2,315,603.55	1,648,252.24	2,252,844.45	549,417.41	1,891,938.20	375,236.40	149,900	19	Georgia
Idaho	62,175	55,803	6,372		519	1,223,097.45	225,532.64	305,774.36	225,532.64	1,018,673.70	176,147.75	55,631	12	Idaho.
Illinois	986,480	862,452	124,028		5,387	10,696,508.51		10,696,508.51		7,708,796.28	2,389,564.47	833,920	18	Illinois.
Indiana	581,899	508,831	72,744	324	3,794	4,813,400.00	2,107,601.08	3,673,812.20	2,064,302.11	3,636,219.00	965,784.00	486,848	20	Indiana.
Iowa	569,415	531,719	37,696		2,336	8,531,030.04		7,823,000.00				517,228	10	Iowa.
Kansas	360,796	327,004	33,792		1,195	[4] 3,835,370.00		[4] 3,642,851.00				332,068	9	Kansas.
Kentucky	203,028	182,599	20,429		568	3,007,968.58	392,020.65	2,971,122.50	392,020.65			167,336	21	Kentucky.
Louisiana	150,000	125,000	25,000		475	2,480,706.00	427,583.54	2,480,706.00	427,583.54	2,001,000.00	431,241.00	110,000	36	Louisiana.
Maine	110,282	91,803	16,004	2,475	1,124	1,663,263.43	165,166.40	1,579,326.30	165,075.75			96,333	15	Maine.
Maryland	178,153	165,636	10,082	2,435	2,827	1,871,171.45	563,944.46	1,201,963.46	550,095.24	1,249,288.49	237,284.45	163,654	9	Maryland
Massachusetts	508,997	433,695	75,302		8,438	6,668,069.00		6,668,069.00		4,555,082.50	1,138,202.50	420,822	21	Massachusetts.
Michigan	764,423	691,707	72,716		3,046	10,950,392.93		5,143,671.24		8,886,436.43	1,286,753.85	624,590	22	Michigan.
Minnesota	462,777	429,308	33,150	319	2,754	8,012,922.65		8,012,922.65		6,953,684.67	839,426.76	405,225	14	Minnesota.
Mississippi	112,099	100,889	11,210		85	1,127,948.46	265,711.00	586,140.74	106,284.40			85,476	32	Mississippi.
Missouri	477,056	430,621	46,435		1,706	3,928,326.02		3,928,326.02				411,525	16	Missouri.
Montana	69,100	61,100	8,000		223	698,755.50	[4] 125,525.40		[4] 25,105.08	579,494.50	92,785.50	63,950	8	Montana.
Nebraska	273,236	246,415	26,821		948	3,336,541.75		2,414,800.00		2,746,374.96	521,256.93	243,347	12	Nebraska.
Nevada	15,961	15,961	(7)		95	167,010.50	46,382.48					12,492	27	Nevada.
New Hampshire	64,373	64,373	(7)		1,431	923,063.21	204,399.65	852,064.96	204,399.65	756,129.82		52,584	22	New Hampshire.
New Jersey	435,894	338,133	[5] 88,096	9,665	6,398	8,079,325.75		7,379,006.68		3,318,670.20	2,523,248.00	360,577	20	New Jersey.
New Mexico	34,951	33,499	108	1,344	182	344,813.41	84,993.90	327,572.74	80,744.21	294,227.19	2,467.63	24,937	40	Mew Mexico.
New York	1,233,362	996,392	203,877	33,093	16,725	20,197,362.41		20,197,362.41		12,808,938.41	5,748,547.00	1,025,718	20	New York.
North Carolina	285,546	260,667	24,879		1,488	3,975,658.37	2,024,421.68	3,578,092.55	1,821,979.51			209,400	36	North Carolina.
North Dakota	104,845	104,845	(7)		425	706,628.85	94,573.94	706,628.85				99,000	6	North Dakota.
Ohio	1,160,000	999,300	160,700		13,590	10,509,916.50		5,254,958.25				965,000	20	Ohio.
Oklahoma	308,906	298,906	10,000		850	2,894,682.63	1,042,700.00		447,000.00			240,000	29	Oklahoma.
Oregon	161,739	149,647	12,092		2,235	4,336,682.54	1,089,472.94	[4] 3,192,510.00	1,045,108.47	3,610,614.50	622,287.29	133,657	21	Oregon.
Pennsylvania	1,085,285	924,274	154,830	6,181	14,367	19,562,394.31	3,524,018.90	19,562,394.31		9,582,379.80	4,607,396.70	922,062	18	Pennsylvania.
Rhode Island	78,413	62,887	14,268	1,258	1,122	1,312,397.85		1,260,183.30		804,363.62	310,564.91	64,457	22	Rhode Island.
South Carolina	137,891	125,215	12,676		382	1,069,751.29	992,726.52	855,801.02	330,848.24	869,506.95	177,419.52	102,127	35	South Carolina.
South Dakota	126,813	117,812	9,001		260	1,952,200.00	447,554.00	1,366,540.00	393,847.00	1,737,720.00	192,980.00	120,021	6	South Dakota.
Tennessee	182,723	164,119	18,604		601	2,391,849.64	724,391.01	1,195,924.82	724,391.01			144,902	26	Tennessee.
Texas	661,919	611,047	47,906	2,966	2,135	9,452,542.45	1,762,720.65	6,536,037.52	1,322,040.49			571,981	16	Texas.
Utah	67,133	58,784	8,349		600	442,920.43	286,172.77	[4] 400,000.00	[4] 275,000.00			50,798	32	Utah.
Vermont	52,614	49,053	3,561		639	1,186,230.61	[5] 48,230.03	[8] 810,000.00	48,230.03	917,210.46	92,196.00	44,613	18	Vermont.
Virginia	225,343	197,052	28,291		1,350	3,371,208.20	[5] 1,132,534.80		755,023.20	2,696,445.34	452,377.41	184,961	22	Virginia.
Washington	265,541	227,015	36,423	2,103	2,457	4,242,122.95	1,290,785.08	[4] 4,000,000.00	1,290,785.08	3,046,155.20	882,648.70	220,667	20	Washington.
West Virginia	154,772	133,572	17,650	3,550	1,094	2,552,544.35	445,032.36	2,552,544.35	445,032.36	1,751,659.88	405,797.98	124,341	25	West Virginia.
Wisconsin	473,913	429,634	44,279		3,348	6,226,933.43		5,926,933.43		5,065,570.50	977,320.00	418,536	13	Wisconsin.
Wyoming	38,200	34,000	4,200		210	402,832.01	76,643.62	402,832.01	76,643.62			35,000	9	Wyoming.
Total	15,552,077	13,645,726	1,831,405	74,946	126,850	199,472,682.17	32,430,410.37	163,011,584.29	20,065,581.29	95,519,949.32	28,895,127.42	13,002,427	20	Total.

[1] Where no data are given these vehicles are not registered as a separate class but are included with passenger cars or motor trucks.
[2] Where no data are given, gasoline tax laws are not in force.
[3] Where no data are given the States do not segregate the fees for these classes of vehicles
[4] Estimated; final figures not available
[5] To May 31 only.
[6] Gas tax law effective May 24, 1924.
[7] Included with passenger cars.
[8] Already appropriated by legislature; more may be available later.