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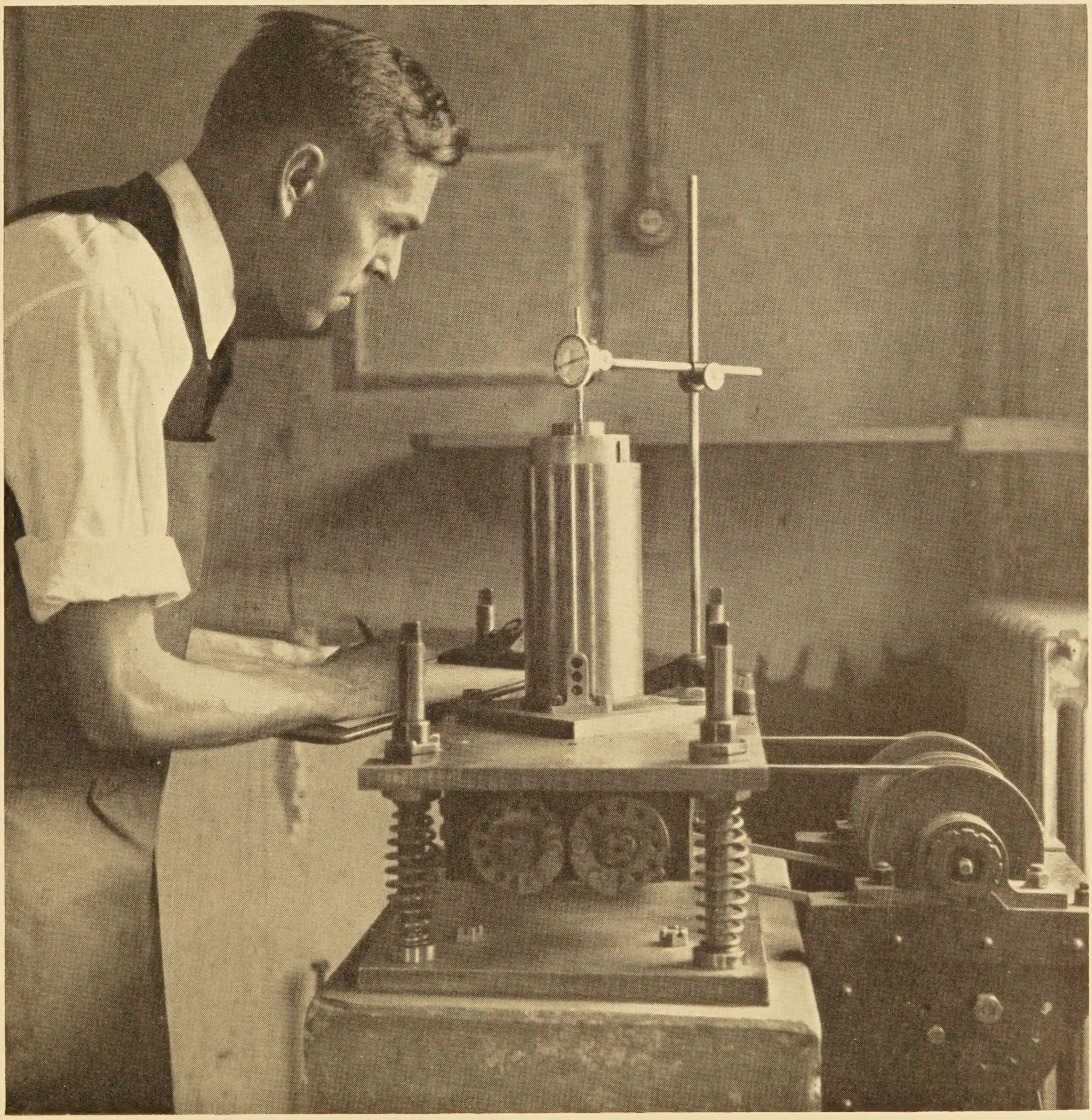

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PUBLIC ROADS ▸▸▸ *A Journal of Highway Research*

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D. M. BEACH, *Editor*

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The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions.

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PRELIMINARY RESULTS OF ROAD-USE STUDIES

BY DIVISION OF CONTROL, BUREAU OF PUBLIC ROADS

Reported by ROBERT H. PADDOCK and ROE P. RODGERS, Associate Highway Engineer Economists

MOTOR VEHICLES annually travel approximately 250 billion vehicle-miles over the streets and highways of the United States. The benefits derived from such travel may be considered one measure of the returns received on the large capital investment in highway facilities. To finance the facilities necessary for the effective handling of such a great volume of travel, a large portion of the needed revenues is collected from vehicles owners largely on the basis of motor-vehicle use. However, highways also furnish other benefits than those received directly by motorists, and highway-user revenues are supplemented to a limited extent by revenues from other sources.

In planning highway programs an important problem is determination of where highway-user revenues should be spent to benefit the greatest number of motorists and to provide for the most essential needs on all classes of roads and streets. It is evident that a properly considered highway program should be intended, insofar as possible, to provide facilities for various classes of motorists so that the maximum benefits to the public will be realized.

Determinations of the type and extent of highway use as obtained from road-use studies will assist in formulating such a program. These studies, which are integral parts of the current State-wide highway planning surveys under way in 46 States, will provide factual bases for answering important questions concerning the nature of highway traffic. They will make possible an understanding of the relationships between highway expenditures and the travel of those who pay a large share of the transportation bill. The studies will also show the variations between the motoring habits of rural and urban residents and between the traffic of different types of motor vehicles.

The data presented in this summary are presented without the complementary material which will be available from other phases of the planning surveys, and which are essential in formulating integrated highway-development programs. However, a study of road-use data will assist in an understanding of highway-transportation problems.

ANALYSIS MADE OF INTERVIEWS FROM 17 REPRESENTATIVE STATES

Road-use information was obtained by means of a large number of personal interviews with motor-vehicle owners and drivers. These interviews were carefully selected to insure a proper representation of each geographical division of a State, of each group of governmental jurisdictions within similar population ranges, of various occupations, and of vehicles according to types and ages in operation. Information obtained from vehicle owners by survey interviewers made it possible to determine the extent of the owners' travel during the preceding year, and the routes of such travel for each trip. Experience has demonstrated that the year's driving of an individual can be accounted for reliably because of the numerous habitual trips, frequent local recreational trips, and unusual long trips that can be easily recalled.

By summarizing the data and expanding to the total State registration for each vehicle type—taking into account all known factors affecting the amount and kind of driving—information is obtained from which it is possible to estimate—

1. The total amount of travel on the various highway systems in a given area or in the State, and
2. The amount of travel performed on the various highway systems in the State by vehicle owners residing in the several governmental jurisdictions.

The two special analyses presented in this report are largely based upon preliminary road-use data obtained in the 17 States of Colorado, Florida, Iowa, Louisiana, Michigan, Minnesota, Missouri, Montana, New York, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Utah, Washington, and Wisconsin. Interviews covering a total of 198,809 passenger cars and 71,941 trucks were taken in these States during different periods, most of them during 1936, but some at an earlier date. All figures were adjusted to the year 1936 in proportion to the motor-vehicle registrations for the particular years under consideration. The 17-State sample was then expanded to obtain figures representing the entire United States by applying road-use data for a particular State to those surrounding or similar States for which data were not yet available.

Factors taken into consideration in these calculations included motor-vehicle registrations, the distribution of population by population groups (see table 1), motor-vehicle ownership per capita for various population groups, and existing mileages of the several highway systems in each State. A number of additional corrective factors were omitted in this preliminary analysis, but it is believed that the results are reliable.

The 17 States which formed the basis for this analysis represent:

45.4 percent of the estimated population of the United States in 1936.
47.8 percent of motor-vehicle registrations in the United States in 1936.
41.0 percent of the State primary road mileage in the United States in 1936.

Results of road-use studies indicate that these States were responsible for:

46.3 percent of estimated travel on all roads and streets in 1936.
44.9 percent of estimated travel on State-administered highways in 1936.

The close agreement of these figures indicates that for the purpose of this study, the 17 States were representative of the country as a whole.

That the estimate of total annual travel amounting to almost 250 billion vehicle-miles for all passenger cars, trucks, and busses in the United States is reasonable, can be demonstrated by comparison with the total

TABLE 1.—*Approximate distribution of population and of motor-vehicle registration in the United States in 1936 by population groups of residence*

Population group	Population [1]		Motor-vehicle registration [2]	
	Number	*Percent*	*Number*	*Percent*
Unincorporated areas	44, 636, 770	36. 4	8, 617, 876	30. 6
Incorporated places having a population of—				
1,000 or less	4, 362, 746	3. 6	1, 491, 044	5. 3
1,001 to 2,500	4, 820, 707	3. 9	1, 544, 370	5. 5
2,501 to 10,000	10, 614, 746	8. 6	3, 061, 979	10. 9
10,001 to 25,000	9, 097, 200	7. 4	2, 444, 929	8. 7
25,001 to 100,000	12, 917, 141	10. 5	3, 419, 713	12. 1
100,001 or more	36, 325, 736	29. 6	7, 585, 639	26. 9
Total	122, 775, 046	100. 0	28, 165, 550	100. 0

[1] Population data from 1930 census. Total midyear population for 1936 estimated by United States Census Bureau at 128,429,000.
[2] Includes passenger cars, trucks, and busses.

quantity of gasoline consumed in street and highway travel. The total estimated travel of 249,778,990,000 vehicle-miles in 1936, divided by the 17,855,454,000 gallons of gasoline used on highways in 1936, gives an average of 14 miles per gallon for all types of motor vehicles. This result is in close agreement with other estimates of average gasoline consumption per vehicle made in recent years. Both this figure and the estimated average annual travel of 8,870 miles for all types of motor vehicles also compare favorably with similar values determined from other highway planning survey data in a number of States.

OVER HALF OF ALL TRAVEL PERFORMED ON PRIMARY STATE HIGHWAYS

The highway systems over which total travel was distributed are classified as (1) primary rural highways and transcity connections, (2) secondary highways and local rural roads, and (3) city streets. Primary rural highways under State control consisted of 339,000 miles which, with the urban extensions and connecting links through municipalities of 20,000 miles, totaled 359,000 miles in the United States in 1936.

The secondary and local rural road classification includes 178,000 miles of rural highways under State control other than primary State highways, as well as an estimated 2,440,000 miles of county and township roads or a total for this classification of 2,618,000 miles for the United States.

City street mileage comprised 215,000 miles, of which 20,000 miles was urban extensions and connecting links of the primary systems and 195,000 miles was the estimated total of other streets in all incorporated places in 1936.

In determining the distribution of travel to these various systems all travel on streets of incorporated places incurred in going to or coming from rural portions of the primary highway system was summarized separately and for this particular presentation has been credited to the primary system. Similarly, travel on city streets incurred in going to or coming from rural portions of the secondary system was credited to the secondary system. Purely local city travel originating inside a municipality and not extending beyond the city limits was credited to the local street classification, even though some of that travel occurred on the urban extensions or connecting links of the primary system within the city.

Table 2 shows the distribution of estimated annual motor-vehicle travel in the United States in 1936 on the various highway systems, as performed by motor-vehicle owners resident in different population groups.

Table 3 shows for each population group of residence or vehicle ownership the percentage of total annual travel performed on each of the highway systems. The composition of the total annual motor-vehicle travel occurring on each highway system according to the various population groups in which the travel originated appears in table 4.

Average annual travel figures for each highway system by motor-vehicle owners resident in each population group appear in table 5.

TABLE 2.—*Estimated motor-vehicle travel on various highway systems in the United States in 1936* [1]

Travel by motor-vehicle owners resident in—	Total travel on—			
	Primary rural highways and transcity connections	Secondary highways and local rural roads	City streets	All systems
	Million vehicle-miles	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*
Unincorporated areas	40, 846. 6	19, 453. 7	3, 333. 0	63, 633. 3
Incorporated places having a population of—				
1,000 or less	9, 869. 0	2, 942. 7	760. 4	13, 572. 1
1,001 to 2,500	10, 368. 9	2, 063. 6	1, 826. 8	14, 259. 3
2,501 to 10,000	19, 800. 8	2, 909. 3	6, 284. 5	28, 994. 6
10,001 to 25,000	15, 127. 6	1, 906. 8	6, 869. 8	23, 904. 2
25,001 to 100,000	18, 632. 8	2, 044. 5	12, 710. 2	33, 387. 5
100,001 or more	26, 328. 0	2, 113. 4	43, 586. 5	72, 027. 9
Total	140, 973. 7	33, 434. 0	75, 371. 2	249, 778. 9

[1] Based on preliminary data from road-use surveys in 17 representative States.

TABLE 3.—*Percentage of estimated motor-vehicle travel on the various highway systems in the United States in 1936*

Travel by motor-vehicle owners resident in—	Total travel on—			
	Primary rural highways and transcity connections	Secondary highways and local rural roads	City streets	All systems
	Percent	*Percent*	*Percent*	*Percent*
Unincorporated areas	64. 2	30. 6	5. 2	100. 0
Incorporated places having a population of—				
1,000 or less	72. 7	21. 7	5. 6	100. 0
1,001 to 2,500	72. 7	14. 5	12. 8	100. 0
2,501 to 10,000	68. 3	10. 0	21. 7	100. 0
10,001 to 25,000	63. 3	8. 0	28. 7	100. 0
25,001 to 100,000	55. 8	6. 2	38. 0	100. 0
100,001 or more	36. 6	2. 9	60. 5	100. 0
Total	56. 4	13. 4	30. 2	100. 0

TABLE 4.—*Percentage of estimated motor-vehicle travel on each highway system by population groups of residence in which travel originated in the United States in 1936*

Travel by motor-vehicle owners resident in—	Total travel on—			
	Primary rural highways and transcity connections	Secondary highways and local rural roads	City streets	All systems
	Percent	*Percent*	*Percent*	*Percent*
Unincorporated areas	29. 0	58. 2	4. 4	25. 5
Incorporated places having a population of—				
1,000 or less	7. 0	8. 8	1. 0	5. 4
1,001 to 2,500	7. 4	6. 2	2. 4	5. 7
2,501 to 10,000	14. 0	8. 7	8. 3	11. 6
10,001 to 25,000	10. 7	5. 7	9. 1	9. 6
25,001 to 100,000	13. 2	6. 1	16. 9	13. 4
100,001 or more	18. 7	6. 3	57. 9	28. 8
Total	100. 0	100. 0	100. 0	100. 0

The data presented in tables 2 and 3 indicate that of the nearly 250 billion vehicle-miles traveled in 1936 by passenger cars, trucks, and busses in the United States, 56.4 percent was travel on the primary rural highways and transcity connections, 13.4 percent on the secondary highways and local rural roads, and 30.2 percent on city streets. These figures may be more easily visualized by reference to table 5, which shows that the average motor vehicle traveled 8,870 miles during 1936, and that the division of this travel among the three classes of highways was 5,000, 1,190, and 2,680 miles, respectively.

TABLE 5.—*Estimated average travel per motor vehicle on the various highway systems of the United States in 1936*

Travel by motor-vehicle owners resident in—	Average travel on—			
	Primary rural highways and transcity connections	Secondary highways and local rural roads	City streets	All systems
	Vehicle-miles	*Vehicle-miles*	*Vehicle-miles*	*Vehicle-miles*
Unincorporated areas	4,740	2,250	390	7,380
Incorporated places having a population of—				
1,000 or less	6,620	1,970	510	9,100
1,001 to 2,500	6,710	1,340	1,180	9,230
2,501 to 10,000	6,470	950	2,050	9,470
10,001 to 25,000	6,190	780	2,810	9,780
25,001 to 100,000	5,450	600	3,710	9,760
100,001 or more	3,470	280	5,740	9,490
Total	5,000	1,190	2,680	8,870

Because the total average annual travel for motor vehicles registered in each population group was relatively uniform with the exception of those owned in unincorporated areas (table 5), the percentage of total annual travel on all highways and streets corresponded very closely to the percentage distribution of vehicle registrations within each population group. This fact is apparent from comparison of the figures in the last columns of tables 1 and 4.

MAJOR USE OF PRIMARY HIGHWAYS WAS BY CITY CAR OWNERS

There was considerable difference, however, in the relative use of the various highway systems by vehicles registered in the several population groups. These differences are indicated in tables 3 and 5. Vehicles owned in unincorporated areas performed 64.2 percent and 30.6 percent of their travel in 1936 on the primary highways and the secondary and local rural roads, respectively, and used city streets for only 5.2 percent of their total travel.

The use of the various highway systems by vehicles owned in the smaller incorporated places was somewhat similar to that for rural-owned vehicles. However, it is interesting to note the extent of the change in use of other highway systems with increase in the size of the place of vehicle ownership. Vehicles owned in the group of smallest incorporated places used the primary highways and the secondary and local rural roads for 72.7 percent and 21.7 percent, respectively, of their total annual driving, while vehicles owned in cities having populations over 100,000 used these same systems to the extent of 36.6 percent and 2.9 percent, respectively. Vehicles owned in the smallest incorporated places were used on city streets for only 5.6 percent of their total annual travel, but those owned in the largest cities performed 60.5 percent of their annual travel on streets of incorporated places. (See table 3.)

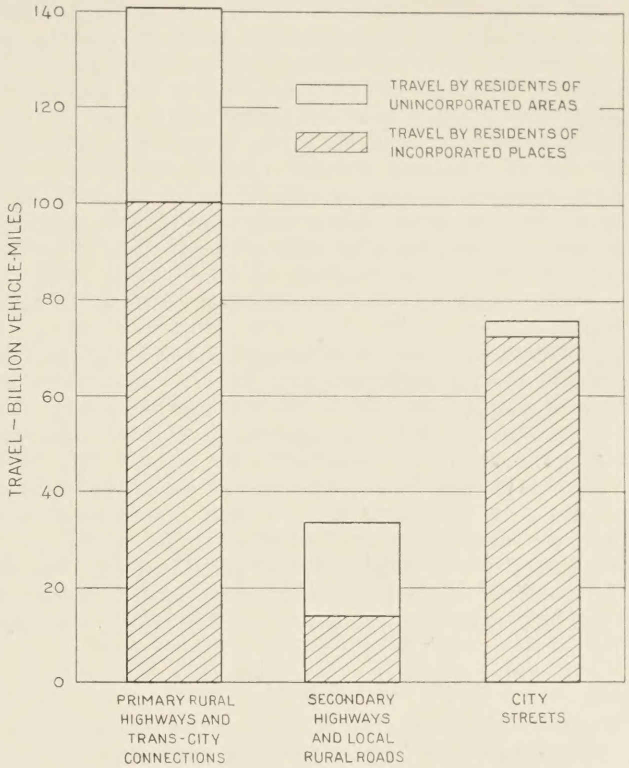

FIGURE 1.—DISTRIBUTION OF ESTIMATED ANNUAL MOTOR-VEHICLE TRAVEL IN THE UNITED STATES IN 1936 BY RESIDENTS OF UNINCORPORATED AREAS AND INCORPORATED PLACES.

This increase in the use of city streets by vehicles owned in the larger incorporated places was, of course, accompanied by a corresponding decrease in the use of other highway systems. It should be noted, however (table 3), that even for vehicles owned in the largest cities the primary rural highways and transcity connections were used for over one-third of the total annual travel. This use was sufficiently high to account for 18.7 percent (table 4) of the annual travel by all motor vehicles on the primary highway system.

As shown in table 4 and figure 1, the largest proportion of travel on the primary highway system was that of town and city residents. Motorists living in incorporated places accounted for 71 percent of the total travel on this system.

The importance of the primary highways to the city motorist is apparent. Though his use of the rural highway system decreased (see table 3) as the size of the place in which the motorist lived increased, the percentage of his travel on such highways was considerable. Only for vehicle owners resident in cities over 100,000 population did their travel on primary rural highways fall below 50 percent of their total travel.

Considering only residents of cities having populations of more than 10,000, table 2 shows that they accounted for more than 60 billion vehicle-miles of the 140,973,700,000 vehicle-miles traveled on primary highways in 1936. Residents of unincorporated areas accounted for only slightly more than 40 billion vehicle-miles of the primary highway travel, or less than that provided by vehicle owners from cities having more than 25,000 population.

In considering travel by residents of incorporated places having 10,000 population or less, it is significant that the percentage of their travel on primary highways as shown in table 3 was greater than that of any other group, even the residents of unincorporated areas. Practically all such incorporated places are located on or within a very short distance from primary roads. Highway development in this country has been such that generally it has been expected that all but the very smallest places would be given consideration in the location of primary routes. Vehicle owners living within these cities are located close to primary highways; they are much closer than many rural residents who live on township or county roads; and they are generally closer than residents of the larger cities who frequently must travel a considerable distance to reach primary routes.

It is apparent from this discussion and from the data shown in the accompanying tables that the major use of the primary highways is by city motor-vehicle owners, and that in spite of their large use of local city streets, the use of primary highways by all city-owned vehicles is greater than their use of all other highway facilities. It therefore follows that the provision of adequate rural highway facilities today is of major importance to the city motorist and that the required improvements in those facilities are largely occasioned by the city motorists' demands on the primary system.

TRIP-LENGTH DATA OBTAINED IN 11 STATES

Table 4 shows that only 4.4 percent of the total travel on city streets was contributed by motorists living in unincorporated areas, and that most of the remaining 95.6 percent of travel performed by residents of incorporated places represented the operations of residents in the larger cities. Of all travel on city streets, 57.9 percent was performed by residents of cities having populations of over 100,000, and drivers living in cities with over 10,000 inhabitants accounted for 83.9 percent of the total travel on local city streets.

Concerning motor-vehicle use on all streets and highways, approximately one-fourth was by residents of unincorporated areas, while twice that amount, or 51.8 percent of all travel, represents the driving of those living in cities having over 10,000 inhabitants. The largest percentage of vehicle travel accounted for by residents of any one group of governmental units as shown in table 4 was that originating in cities having populations over 100,000. Residents of these cities contributed 28.8 percent of all travel on all roads and streets.

These data on vehicle travel have also been expressed in terms of average 24-hour traffic volumes for each class of road and street. Table 6 shows that for the

TABLE 6.—*Approximate mileage of each highway system and average 24-hour traffic volume on each highway system in the United States in 1936*

Highway system	Approximate mileage	Estimated total annual motor-vehicle travel	Average 24-hour traffic volume
	Miles	*Million vehicle-miles*	*Vehicles*
Primary rural highways and transcity connections	359,000	140,973.7	1,076
Secondary highways and local rural roads	[1] 2,618,000	33,434.0	35
City streets	[2] 215,000	75,371.2	960
All systems	[3] 3,172,000	249,778.9	216

[1] Based on latest available estimates.
[2] Estimate includes 20,000 miles of transcity connections which are also included with primary system mileage, because exclusively local city travel includes travel over such connections.
[3] Excludes duplication of 20,000 miles of trans-city connections.

country as a whole, primary rural highways and their transcity connections carried an average daily volume of 1,076 vehicles, which was slightly higher than the 960 vehicles computed as the average for city streets. These volumes were about 30 times greater than the average daily volume on secondary and local rural roads combined. Average 24-hour traffic volume for the more than 3 million miles of roads and streets in the United States was estimated at 216 vehicles.

Another special study of considerable value was also made from road-use data concerning the radii of operation of motor vehicles. It was sought by this investigation to determine the length of vehicle trips that extend beyond the limits of cities; that is, of trips that are either partly or wholly on rural roads. Thus all trips by residents of unincorporated areas were included; but for motorists living in incorporated places, only those trips were counted that extended beyond the limits of the town or city in which the driver resided.

This special study was made in the 11 States of Florida, Kansas, Louisiana, Minnesota, New Hampshire, Pennsylvania, South Dakota, Utah, Vermont, Washington, and Wisconsin. In 1936 there were 4,862,541 passenger cars and 880,432 trucks registered in these 11 States, or a combined registration of 5,742,973. These figures are presented in table 7, together with information concerning the number of interviews taken in each State. The number of interviews totaled 129,407, and consisted of 94,167 for passenger cars and 35,240 for trucks. Trip-length information was not expanded to represent data for the entire country, but only to represent total registrations in each of these States.

For purposes of this analysis, all trips have been classified as one-way trips. If a motor-vehicle owner left his home and drove to some other point 10 miles distant, requiring a total travel of 20 miles from point of starting until return to that point, such a trip could be classified as two one-way trips of 10 miles each. The one-way trip classification has been used for all tabulations in this discussion.

TABLE 7.—*1936 motor-vehicle registrations and number of road use interviews used for basis of analysis of total number of one-way trips outside city limits in 11 States*

State	1936 registration			Number of interviews		
	Passenger cars	Trucks	Total	Passenger cars	Trucks	Total
Florida	321,467	63,885	385,352	7,015	3,010	10,025
Kansas	490,793	[1] 87,113	577,906	8,663	2,813	11,476
Louisiana	228,361	73,628	301,989	3,891	1,623	5,514
Minnesota	668,915	114,448	783,363	13,059	5,649	18,708
New Hampshire	97,361	[1] 24,875	122,236	1,936	914	2,850
Pennsylvania	1,615,955	235,834	1,851,789	23,783	10,567	34,350
South Dakota	158,192	28,216	186,408	3,608	1,533	5,141
Utah	96,768	19,397	116,165	2,148	1,097	3,245
Vermont	75,195	8,845	84,040	1,472	850	2,322
Washington	419,493	79,538	499,031	14,027	1,313	15,340
Wisconsin	690,041	144,653	834,694	14,565	5,871	20,436
Total	4,862,541	880,432	5,742,973	94,167	35,240	129,407

[1] Includes busses.

PASSENGER-CAR AND TRUCK TRIPS PREDOMINATELY OF SHORT LENGTH

Tables 8 and 9 contain analyses of the length of one-way trips partially or wholly traveled on roads in unincorporated areas. The numbers of these trips within designated length classifications are shown graphically in figure 2 for passenger cars and trucks combined.

The short length of travel of a large part of motor-

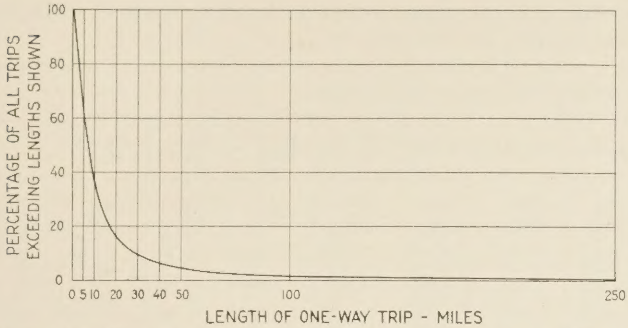

Figure 2.—Percentage of all Passenger-Car and Truck Trips Exceeding Various Lengths.

vehicle operation is readily apparent. For passenger cars, trips of less than 5 miles constituted 38.4 percent of the number of all one-way trips traveled partly or wholly on highways in unincorporated areas. Trips of over 5 but less than 10 miles comprised 26.5 percent of the total. Of all the one-way trips tabulated, therefore, 64.9 percent of the total number were less than 10 miles long. Trips less than 20 miles long accounted for 85 percent of all passenger-car trips. Accordingly, only 15 percent of all trips extending beyond city limits or traveled entirely on rural roads were greater than 20 miles long. Passenger cars went over 100 miles from their starting point on only 1.5 percent of all their trips.

Analysis of truck movements gave fairly similar results, 34 percent of all trips being less than 5 miles long, 59.5 percent less than 10 miles, and 80.3 percent less than 20 miles. Trips over 100 miles were 2.0 percent of the total number of all trips, and truck trips above 50 miles and less than 250 miles long constituted 6.2 percent of the total number as compared with 4 percent for passenger cars.

Considering passenger cars and trucks combined, 37.5 percent of the number of all one-way trips involving travel on roads in unincorporated areas extended less than 5 miles from the point of origin. The fact that the many short trips made wholly within incorporated areas have been omitted from these trip-length data emphasizes still further the preponderant use of motor vehicles for short trips.

Tables 10 and 11 show the States of destination of one-way trips over 100 miles long made by passenger cars and by trucks registered in the 11 States. These data are summarized in table 12 to show the percentage of such trips having destinations in the State of origin,

Table 8.—*Frequency distribution of the length of all one-way trips made by passenger cars that extended outside city limits in 11 States* [1]

State	Length of one-way trips from point of origin in miles											Total all trips
	Less than 5	5 to 9.9	10 to 19.9	20 to 29.9	30 to 39.9	40 to 49.9	50 to 99.9	100 to 249.9	250 to 499.9	500 to 999.9	1,000 and over	
TOTAL NUMBER OF TRIPS												
	1,000 trips	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*
Florida	45, 189	40, 584	31, 803	11, 069	4, 055	1, 373	3, 776	1, 497	400	85	76	139, 907
Kansas	124, 109	69, 011	54, 600	17, 267	6, 526	2, 282	6, 634	2, 591	458	154	89	283, 721
Louisiana	43, 984	25, 005	18, 019	6, 970	2, 986	1, 335	3, 842	946	182	35	10	103, 314
Minnesota	97, 533	62, 426	51, 591	16, 477	6, 477	3, 680	8, 224	5, 045	556	89	45	252, 143
New Hampshire	10, 782	12, 941	10, 975	3, 046	1, 393	900	1, 536	326	27	8	4	41, 938
Pennsylvania	296, 153	214, 362	154, 277	47, 626	21, 246	9, 180	19, 254	8, 016	763	221	91	771, 189
South Dakota	16, 704	11, 760	11, 880	4, 894	1, 631	1, 233	1, 950	734	180	41	24	51, 031
Utah	17, 019	9, 198	6, 838	2, 626	1, 653	908	1, 053	477	134	60	41	40, 007
Vermont	14, 763	10, 650	6, 178	2, 079	718	562	757	223	28	1	1	35, 960
Washington	73, 201	42, 913	33, 562	11, 020	5, 700	2, 208	4, 882	2, 062	359	49	59	176, 015
Wisconsin	95, 622	77, 445	58, 499	20, 691	9, 538	4, 123	9, 324	3, 826	541	82	49	279, 740
Total	835, 059	576, 295	438, 222	143, 765	61, 923	27, 784	61, 232	25, 743	3, 628	825	489	2, 174, 965
PERCENTAGE OF TOTAL NUMBER OF TRIPS												
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Florida	32. 3	29. 0	22. 7	7. 9	2. 9	1. 0	2. 7	1. 1	0. 3	0. 1	(2)	100
Kansas	43. 8	24. 3	19. 2	6. 1	2. 3	. 8	2. 3	. 9	. 2	. 1	(2)	100
Louisiana	42. 6	24. 2	17. 4	6. 8	2 9	1. 3	3. 7	. 9	. 2	(2)	(2)	100
Minnesota	38. 7	24. 8	20. 4	6. 5	2. 6	1. 5	3. 2	2. 0	. 2	. 1	(2)	100
New Hampshire	25. 7	30. 9	26. 1	7. 3	3. 3	2. 2	3. 6	. 8	. 1	(2)	(2)	100
Pennsylvania	38. 4	27. 8	20. 0	6. 2	2. 7	1. 2	2. 5	1. 0	. 1	. 1	(2)	100
South Dakota	32. 7	23. 0	23. 3	9. 6	3. 2	2. 4	3. 8	1. 4	. 4	. 1	. 1	100
Utah	42. 6	23. 0	17. 1	6. 5	4. 1	2. 3	2. 6	1. 2	. 3	. 2	. 1	100
Vermont	41. 0	29. 6	17. 2	5. 8	2. 0	1. 6	2. 1	. 6	. 1	(2)	(2)	100
Washington	41. 6	24. 4	19. 0	6. 3	3. 2	1. 3	2. 8	1. 1	. 2	. 1	(2)	100
Wisconsin	34. 2	27. 7	20. 9	7. 4	3. 4	1. 5	3. 3	1. 4	. 2	(2)	(2)	100
Total	38. 4	26. 5	20. 1	6. 6	2. 8	1. 3	2. 8	1. 2	. 2	. 1	(2)	100
CUMULATIVE PERCENTAGE OF TOTAL NUMBER OF TRIPS												
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Florida	32. 3	61. 3	84. 0	91. 9	94. 8	95. 8	98. 5	99. 6	99. 9	100. 0	100	----------
Kansas	43. 8	68. 1	87. 3	93. 4	95. 7	96. 5	98. 8	99. 7	99. 9	100. 0	100	----------
Louisiana	42. 6	66. 8	84. 2	91. 0	93. 9	95. 2	98. 9	99. 8	100. 0	100. 0	100	----------
Minnesota	38. 7	63. 5	83. 9	90. 4	93. 0	94. 5	97. 7	99. 7	99. 9	100. 0	100	----------
New Hampshire	25. 7	56. 6	82. 7	90. 0	93. 3	95. 5	99. 1	99. 9	100. 0	100. 0	100	----------
Pennsylvania	38. 4	66. 2	86. 2	92. 4	95. 1	96. 3	98. 8	99. 8	99. 9	100. 0	100	----------
South Dakota	32. 7	55. 7	79. 0	88. 6	91. 8	94. 2	98. 0	99. 4	99. 8	99. 9	100	----------
Utah	42. 6	65. 6	82. 7	89. 2	93. 3	95. 6	98. 2	99. 4	99. 7	99. 9	100	----------
Vermont	41. 0	70. 6	87. 8	93. 6	95. 6	97. 2	99. 3	99. 9	100. 0	100. 0	100	----------
Washington	41. 6	66. 0	85. 0	91. 3	94. 5	95. 8	98. 6	99. 7	99. 9	100. 0	100	----------
Wisconsin	34. 2	61. 9	82. 8	90. 2	93. 6	95. 1	98. 4	99. 8	100. 0	100. 0	100	----------
Total	38. 4	64. 9	85. 0	91. 6	94. 4	95. 7	98. 5	99. 7	99. 9	100. 0	100	----------

[1] Based on analysis of 42,407,204 one-way trips performed by 94,167 passenger cars in these States.
[2] Less than 0.1 percent.

TABLE 9.—*Frequency distribution of the length of all one-way trips made by trucks that extended outside city limits in 11 States* [1]

TOTAL NUMBER OF TRIPS

State	Length of one-way trips from point of origin in miles											Total all trips
	Less than 5	5 to 9.9	10 to 19.9	20 to 29.9	30 to 39.9	40 to 49.9	50 to 99.9	100 to 249.9	250 to 499.9	500 to 999.9	1,000 and over	
	1,000 trips	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*	*1,000 trips*
Florida	11, 145	11, 433	8, 504	3, 616	1, 456	514	1, 358	842	179	19	14	39, 080
Kansas	17, 622	12, 722	10, 389	3, 777	1, 540	741	1, 946	792	111	23	16	49. 679
Louisiana	14, 769	11, 787	12, 645	4, 803	2, 539	962	3, 909	1, 325	97	8	(2)	52, 844
Minnesota	20, 591	20, 750	14, 942	5, 534	2, 169	1, 302	3, 767	2, 511	206	11	3	71, 786
New Hampshire	2, 708	3, 504	2, 584	863	414	195	602	75	3	(2)	(2)	10, 948
Pennsylvania	53, 717	33, 446	24, 704	7. 291	3, 789	1. 897	4, 077	1, 130	59	20	(2)	130, 130
South Dakota	2, 824	2. 528	3, 104	1, 239	516	542	1, 181	505	77	6	2	12, 524
Utah	4, 579	1, 960	1. 616	659	395	247	462	314	45	5	2	10, 284
Vermont	3, 159	2, 817	1. 969	564	247	197	258	51	33	2	(2)	9, 297
Washington	17, 515	9, 438	9, 724	4. 734	2, 768	905	1, 966	755	72	6	8	47, 892
Wisconsin	36, 323	28, 531	23, 340	8, 775	4, 197	2, 759	4, 382	1, 611	152	10	(2)	110, 080
Total	184, 952	138, 916	113, 521	41, 855	20, 030	10, 262	23, 908	9, 911	1, 034	110	45	544, 544

PERCENTAGE OF TOTAL NUMBER OF TRIPS

State	Less than 5	5 to 9.9	10 to 19.9	20 to 29.9	30 to 39.9	40 to 49.9	50 to 99.9	100 to 249.9	250 to 499.9	500 to 999.9	1,000 and over	Total all trips
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Florida	28. 5	29. 2	21. 8	9. 3	3. 7	1. 3	3. 5	2. 1	0. 5	0. 1	(3)	100
Kansas	35. 5	25. 6	20. 9	7. 6	3. 1	1. 5	3. 9	1. 6	. 2	. 1	(3)	100
Louisiana	27. 9	22. 3	23. 9	9. 1	4. 8	1. 9	7. 4	2. 5	. 2	(3)	(3)	100
Minnesota	28. 7	28. 9	20. 8	7. 7	3. 0	1. 8	5. 2	3. 5	. 3	. 1	(3)	100
New Hampshire	24. 7	32. 0	23. 6	7. 9	3. 8	1. 8	5. 5	. 7	(3)	(3)	(3)	100
Pennsylvania	41. 3	25. 7	19. 0	5. 6	2. 9	1. 4	3. 1	. 9	. 1	(3)	(3)	100
South Dakota	22. 5	20. 2	24. 8	9. 9	4. 1	4. 3	9. 4	4. 0	. 6	. 1	. 1	100
Utah	44. 5	19. 1	15. 7	6. 4	3. 8	2. 4	4. 5	3. 1	. 4	. 1	(3)	100
Vermont	34. 0	30. 3	21. 2	6. 0	2. 7	2. 1	2. 8	. 5	. 4	(3)	(3)	100
Washington	36. 6	19. 7	20. 3	9. 9	5. 7	1. 9	4. 1	1. 6	. 2	(3)	(3)	100
Wisconsin	33. 0	25. 9	21. 2	8. 0	3. 8	2. 5	4. 0	1. 5	. 1	(3)	(3)	100
Total	34. 0	25. 5	20. 8	7. 7	3. 7	1. 9	4. 4	1. 8	. 2	(3)	(3)	100

CUMULATIVE PERCENTAGE OF TOTAL NUMBER OF TRIPS

State	Less than 5	5 to 9.9	10 to 19.9	20 to 29.9	30 to 39.9	40 to 49.9	50 to 99.9	100 to 249.9	250 to 499.9	500 to 999.9	1,000 and over	Total all trips
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Florida	28. 5	57. 7	79. 5	88. 8	92. 5	93. 8	97. 3	99. 4	99. 9	100. 0	100	----------
Kansas	35. 5	61. 1	82. 0	89. 6	92. 7	94. 2	98. 1	99. 7	99. 9	100. 0	100	----------
Louisiana	27. 9	50. 2	74. 1	83. 2	88. 0	89. 9	97. 3	99. 8	100. 0	100. 0	100	----------
Minnesota	28. 7	57. 6	78. 4	86. 1	89. 1	90. 9	96. 1	99. 6	99. 9	100. 0	100	----------
New Hampshire	24. 7	56. 7	80. 3	88. 2	92. 0	93. 8	99. 3	100. 0	100. 0	100. 0	100	----------
Pennsylvania	41. 3	67. 0	86. 0	91. 6	94. 5	95. 9	99. 0	99. 0	100. 0	100. 0	100	----------
South Dakota	22. 5	42. 9	67. 5	77. 4	81. 5	85. 8	95. 2	99. 2	99. 8	99. 9	100	----------
Utah	44. 5	63. 6	79. 3	85. 7	89. 5	91. 9	96. 4	99. 5	99. 9	100. 0	100	----------
Vermont	34. 0	64. 3	85. 5	91. 5	94. 2	96. 3	99. 1	99. 6	100. 0	100. 0	100	----------
Washington	36. 6	56. 3	76. 6	86. 5	92. 2	94. 1	98. 2	99. 8	100. 0	100. 0	100	----------
Wisconsin	33. 0	58. 9	80. 1	88. 1	91. 9	94. 4	98. 4	99. 9	100. 0	100. 0	100	----------
Total	34. 0	59. 5	80. 3	88. 0	91. 7	93. 6	98. 0	99. 8	100. 0	100. 0	100	----------

1 Based on analysis of 22,268,882 one-way trips performed by 35,240 trucks in these States.
2 Less than 500 trips.
3 Less than 0.1 percent.

TABLE 10.—*Estimated total number of annual one-way trips over 100 miles long traveled by passenger cars registered in 11 States of origin, and classified by State of destination of individual trips*

State of destination	State of origin										
	Florida	Kansas	Louisiana	Minnesota	New Hampshire	Pennsylvania	South Dakota	Utah	Vermont	Washington	Wisconsin
Alabama	38, 172	418	33, 422	----------	----------	960	1, 498	90	----------	80	102
Arizona	----------	764	72	546	----------	108	430	3, 474	----------	1, 272	172
Arkansas	1, 368	38, 180	43, 030	726	----------	594	86	----------	----------	46	496
California	870	16, 122	1, 556	8, 994	84	3, 516	5, 710	33, 084	----------	39, 830	5, 716
Colorado	1, 032	144, 456	130	1, 434	----------	994	5, 902	21, 856	----------	1, 090	1, 088
Connecticut	1, 060	----------	130	----------	9, 044	18, 178	----------	----------	----------	----------	596
Delaware	168	----------	----------	----------	280	124, 146	86	----------	7, 424	----------	----------
Florida	1, 746, 624	2, 048	8, 518	2, 156	1, 514	30, 266	456	----------	----------	160	5, 838
Georgia	137, 300	688	6, 096	110	----------	3, 986	----------	----------	86	220	628
Idaho	----------	1, 204	----------	216	----------	----------	1, 620	115, 152	86	123, 418	260
Illinois	4, 496	23, 858	2, 060	59, 168	288	29, 806	7, 314	434	----------	2, 040	536, 088
Indiana	4, 590	3, 582	292	2, 398	----------	12, 360	1, 442	90	----------	494	34, 820
Iowa	610	20, 996	344	119, 550	126	1, 906	73, 950	90	----------	466	67, 972
Kansas	296	1, 827, 206	330	842	----------	950	3, 090	260	----------	312	990
Kentucky	6, 094	2, 462	726	436	----------	6, 564	198	120	----------	126	2, 916
Louisiana	7, 826	4, 026	873, 324	612	84	904	----------	150	----------	----------	926
Maine	1, 140	278	----------	110	47, 766	10, 444	----------	----------	9, 366	----------	286
Maryland	1, 500	----------	324	152	420	381, 698	602	----------	----------	----------	994
Massachusetts	2, 570	690	----------	536	124, 144	36, 346	----------	150	79, 258	96	1, 918
Michigan	3, 814	9, 594	584	56, 724	428	46, 672	1, 444	758	----------	3, 376	158, 378
Minnesota	424	14, 926	----------	5, 106, 158	----------	742	101, 304	76	----------	1, 528	322, 160
Mississippi	6, 482	1, 504	88, 934	196	----------	----------		----------	----------	62	632
Missouri	1, 156	505, 022	990	5, 554	84	2, 610	2, 502	400	116	684	8, 436
Montana	----------	1, 570	----------	5, 232	----------	360	3, 292	21, 496	----------	32, 826	1, 222
Nebraska	134	98, 148	----------	6, 592	----------	916	24, 628	544	----------	392	4, 402
Nevada	136	424	----------	----------	----------	----------	----------	31, 824	----------	844	----------
New Hampshire	538	----------	----------	----------	100, 766	7, 056	----------	----------	22, 576	----------	----------
New Jersey	2, 044	98	----------	----------	856	1, 100, 928	----------	----------	1, 560	----------	528
New Mexico	----------	8, 696	924	76	----------	----------	100	256	----------	164	206

TABLE 10.—*Estimated total number of annual one-way trips over 100 miles long traveled by passengercars registered in 11 States of origin, and classified by State of destination of individual trips*—Continued

State of destination	State of origin										
	Florida	Kansas	Louisiana	Minnesota	New Hampshire	Pennsylvania	South Dakota	Utah	Vermont	Washington	Wisconsin
New York	12, 708	4, 458	1, 606	2, 296	14, 820	1, 368, 620	2, 526	902	28, 172	1, 620	9, 522
North Carolina	23, 894	274	2, 396		84	14, 120			116	160	2, 662
North Dakota	68	562	126	89, 242		244	20, 480			1, 066	4, 032
Ohio	6, 056	4, 124	396	1, 786	534	837, 310	186	492	232	204	8, 896
Oklahoma	584	284, 538	1, 812	1, 214		1, 578	258	152		382	424
Oregon	100	2, 042	256	640		114	952	4, 188		343, 286	586
Pennyslvania	4, 482	1, 076	162	720	560	4, 419, 820			1, 284	160	2, 256
Rhode Island	202	70	72		12, 698	4, 126			3, 032		
South Carolina	8, 336	98	200	660		2, 620			116		68
South Dakota		3, 048		62, 812		228	698, 396			904	11, 084
Tennessee	13, 486	1, 872	6, 868	1, 048	224	4, 620	184	90			1, 650
Texas	2, 894	41, 380	93, 052	2, 308	84	1, 682	796	570		774	2, 268
Utah		962		196			272	314, 246		2, 356	462
Vermont	340				34, 402	5, 206			73, 884		
Virginia	2, 980	380	304		252	94, 218	86			46	472
Washington	220	2, 196		2, 158		142	2, 450	3, 302		1, 882, 136	558
West Virginia	618	352	162	286		159, 020					124
Wisconsin	976	1, 906	388	157, 866		3, 694	5, 870	90		416	3, 277, 310
Wyoming	168	9, 136	130	1, 748	84	490	10, 748	148, 118		4, 876	1, 534
District of Columbia	5, 042	1, 718	528	1, 096	880	294, 168		210	402	296	1, 510
Canada	2, 594	2, 944	848	31, 142	15, 532	55, 096	2, 336	8, 960	26, 328	76, 274	13, 678
Mexico	220	2, 610	1, 756	1, 284		366	794	428		3, 618	748
Total	2, 056, 412	3, 092, 706	1, 172, 848	5, 737, 020	366, 038	9, 090, 492	981, 988	712, 052	254, 038	2, 528, 100	4, 497, 614

TABLE 11.—*Estimated total number of annual one-way trips over 100 miles long traveled by trucks registered in 11 States of origin, and classified by State of destination of individual trips*

State of destination	State of origin										
	Florida	Kansas	Louisiana	Minnesota	New Hampshire	Pennsylvania	South Dakota	Utah	Vermont	Washington	Wisconsin
Alabama	38, 538		70	23							
Arizona								2, 990			
Arkansas		2, 134	34, 250								
California		52			44	40		5, 242		8, 296	176
Colorado		13, 748					10, 704	7, 958			
Connecticut					3, 576	1, 318			2, 078		
Delaware						14, 238					
Florida	930, 621					190					
Georgia	49, 568			44		544					
Idaho				50			68	59, 912		52, 786	
Illinois	220	2, 504		12, 609		2, 294	924			110	361, 321
Indiana	121	776		5, 827		86	34				2, 866
Iowa		2, 512		97, 133			43, 992				36, 182
Kansas		581, 866					460			110	
Kentucky	137	652				4, 224					176
Louisiana	126		1, 266, 240								
Maine					11, 850				72		
Maryland	5, 321					71, 294					176
Massachusetts					38, 142	4, 114			12, 604		
Michigan	133	15, 566		378		764				204	75, 605
Minnesota		154		2, 489, 410			28, 570				201, 889
Mississippi	250		30, 856								
Missouri		233, 474	136	38, 565		132	306				176
Montana							8, 020	598		17, 472	
Nebraska		26, 368		2, 556			19, 652			110	176
Nevada								11, 122			
New Hampshire					13, 990				9, 426		
New Jersey	45				220	34, 420			4, 830		
New Mexico		716	66								
New York	2, 504			56	2, 156	371, 576			36, 822		176
North Carolina	4, 251		60			394					
North Dakota		60		54, 566			5, 018				176
Ohio	180	60		277		154, 188					1, 078
Oklahoma		55, 618	60								
Oregon						40		32		80, 058	
Pennsylvania	2, 077					497, 144			4, 026		
Rhode Island					6, 600	54			86		
South Carolina	3, 599										
South Dakota		60		7, 689			463, 604			110	176
Tennessee	4, 921		546			32					
Texas	148	5, 690	95, 366					96			
Utah					2, 260			235, 788			
Vermont						228			11, 862		
Virginia	2, 070	60				6, 246					176
Washington							936			676, 740	
West Virginia	47					32, 678					
Wisconsin				20, 907							1, 092, 571
Wyoming		364					7, 752	43, 918		110	
District of Columbia	8, 913					13, 622					
Canada				516	132	332			3, 654	3, 132	
Mexico								64		228	
Total	1, 053, 790	942, 434	1, 427, 650	2, 730, 606	78, 970	1, 210, 192	590, 040	367, 720	85, 460	839, 466	1, 773, 096

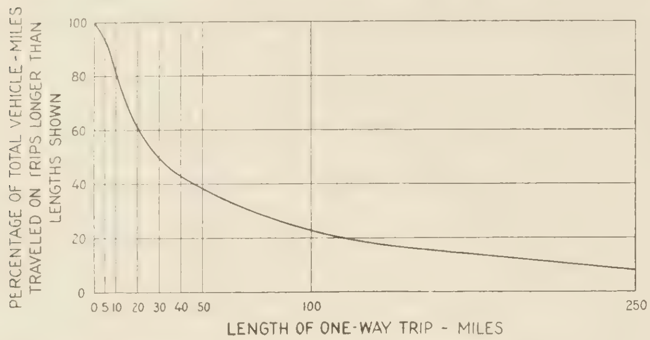

FIGURE 3.—PERCENTAGE OF TOTAL VEHICLE-MILES BY PASSENGER CARS AND TRUCKS TRAVELED ON TRIPS EXCEEDING VARIOUS LENGTHS.

adjoining States, and other States, providing another indication of the dispersion of motor-vehicle travel. It should be noted that even on these longer trips a very high percentage of the destinations was in the State of origin or in an adjoining State.

TABLE 12.—*Destination of motor-vehicle travel in 11 States on one-way trips over 100 miles long*

PASSENGER CARS

State of origin	Destination of trips in— State of origin	Adjoining States	Other States	Total
	Percent	*Percent*	*Percent*	*Percent*
Florida	84.9	8.5	6.6	100
Kansas	55.5	37.4	7.1	100
Louisiana	74.5	19.2	6.3	100
Minnesota	89.0	8.0	3.0	100
New Hampshire	27.5	60.6	11.9	100
Pennsylvania	48.6	43.7	7.7	100
South Dakota	71.1	23.9	5.0	100
Utah	44.1	45.0	10.9	100
Vermont	29.1	61.5	9.4	100
Washington	74.4	21.5	4.1	100
Wisconsin	72.9	24.1	3.0	100
TRUCKS				
Florida	88.3	8.4	3.3	100
Kansas	61.7	35.0	3.3	100
Louisiana	88.7	11.2	.1	100
Minnesota	91.2	6.6	2.2	100
New Hampshire	17.7	63.5	18.8	100
Pennsylvania	41.1	56.1	2.8	100
South Dakota	78.6	19.2	2.2	100
Utah	64.1	34.2	1.7	100
Vermont	13.9	73.1	13.0	100
Washington	80.6	16.2	3.2	100
Wisconsin	61.6	38.1	.3	100
PASSENGER CARS AND TRUCKS				
Florida	86.0	8.5	5.5	100
Kansas	56.9	37.1	6.0	100
Louisiana	81.7	15.1	3.2	100
Minnesota	89.7	7.6	2.7	100
New Hampshire	25.8	61.6	12.6	100
Pennsylvania	47.7	45.1	7.2	100
South Dakota	73.9	22.1	4.0	100
Utah	50.1	41.8	8.1	100
Vermont	25.3	64.5	10.2	100
Washington	75.7	20.4	3.9	100
Wisconsin	71.9	25.4	2.7	100

In addition to the distribution of the number of trips in various mileage ranges, the total vehicle-miles involved in these trips have also been computed and are presented in table 13 and figure 3. Here another aspect of motor-vehicle use is shown. For passenger cars, while trips of less than 5 miles constituted 38.4 percent of the total number of trips, they accounted for but 6.6 percent of the total vehicle-miles of travel partly or wholly on rural roads. Trips of less than 20 miles, accounting for 85.0 percent of all trips, involved but 40.9 percent of the total vehicle-miles of travel. Trips classified in mileage groups from 20 miles upward were responsible for a much larger percentage of travel than of total trips. In the higher mileage brackets, trips in the range from 50 to 249.9 miles were only 4.0 percent of the total number of trips, but they accounted for 28.6 percent of vehicle-miles traveled outside city limits.

These characteristics were similar but less pronounced for trucks. Thirty-four percent of the total number of one-way truck trips was classified as extending less than 5 miles, accounting for but 4.9 percent of the total vehicle-miles of travel; and trips of less than 20 miles, or 80.3 percent of all trips, constituted 33.9 percent of the mileage traveled wholly or partially on rural roads.

TABLE 13.—*Number of trips and vehicle-miles traveled by vehicles which went outside city limits in 11 States*

PASSENGER CARS

Length of one-way trip from point of origin (miles)	Number of trips		Travel	
	1,000 trips	*Percent*	*Million vehicle-miles*	*Percent*
0 to 4.9	835,059	38.4	2,087.6	6.6
5.0 to 9.9	576,295	26.5	4,322.2	13.6
10.0 to 19.9	438,222	20.1	6,573.3	20.7
20.0 to 29.9	143,765	6.6	3,594.1	11.3
30.0 to 39.9	61,923	2.8	2,167.3	6.8
40.0 to 49.9	27,784	1.3	1,250.3	3.9
50.0 to 99.9	61,232	2.8	4,592.4	14.4
100.0 to 249.9	25,743	1.2	4,505.0	14.2
250.0 to 499.9	3,628	.2	1,360.5	4.3
500.0 to 999.9	825	.1	618.8	1.9
1,000.0 and over	489	(1)	733.5	2.3
Total	2,174,965	100.0	31,805.0	100.0
TRUCKS				
0 to 4.9	184,952	34.0	462.4	4.9
5.0 to 9.9	138,916	25.5	1,041.9	11.0
10.0 to 19.9	113,521	20.8	1,702.8	18.0
20.0 to 29.9	41,855	7.7	1,046.4	11.0
30.0 to 39.9	20,030	3.7	701.0	7.4
40.0 to 49.9	10,262	1.9	461.8	4.9
50.0 to 99.9	23,908	4.4	1,793.1	18.8
100.0 to 249.9	9,911	1.8	1,734.4	18.3
250.0 to 499.9	1,034	.2	387.8	4.1
500.0 to 999.9	110	(1)	82.5	.9
1,000.0 and over	45	(1)	67.5	.7
Total	544,544	100.0	9,481.6	100.0
PASSENGER CARS AND TRUCKS				
0 to 4.9	1,020,011	37.5	2,550.0	6.2
5.0 to 9.9	715,211	26.3	5,364.1	13.1
10.0 to 19.9	551,743	20.3	8,276.1	20.1
20.0 to 29.9	185,620	6.8	4,640.5	11.2
30.0 to 39.9	81,953	3.0	2,868.3	6.9
40.0 to 49.9	38,046	1.4	1,712.1	4.1
50.0 to 99.9	85,140	3.1	6,385.5	15.5
100.0 to 249.9	35,654	1.3	6,239.4	15.1
250.0 to 499.9	4,662	.2	1,748.3	4.2
500.0 to 999.9	935	.1	701.3	1.7
1,000.0 and over	534	(1)	801.0	1.9
Total	2,719,509	100.0	41,286.6	100.0

1 Less than 0.1 percent.

AVERAGE TRIP LENGTH ONLY 15.2 MILES

One-way truck trips less than 50 miles long constituted 93.6 percent of all truck trips outside city limits and accounted for 57.2 percent of all truck travel performed wholly or partially on rural roads. Trips less than 100 miles long accounted for 98.0 percent of such truck trips and 76.0 percent of all truck travel on rural roads. Corresponding figures for trips less than 250 miles were 99.8 percent of the number of trips and 94.3 percent of travel. It may be noted, however, that for distances over 250 miles, the passenger car was used relatively more than the truck. Thus, passenger-car and truck trips of 250 miles or more were 0.3 and 0.2 percent, respectively, of total number of trips, while the travel generated was 8.5 percent of total passenger-car vehicle-miles, and but 5.7 percent of all vehicle-miles of travel by trucks performed wholly or partially on rural roads.

Computations have also been made in this study of the mean and median lengths of trips involving the use of roads in unincorporated areas by residents of various governmental jurisdictions. Results are given in table 14. For the purpose of this particular presentation, unincorporated areas and incorporated places with a population of 2,500 or less have been grouped together, because motor-vehicle owners resident in these two classifications were considered to have travel characteristics sufficiently similar to warrant their combination. For motorists of these smaller cities, rural roads, either primary or purely local, are approximately as easily accessible as such roads are to strictly rural motorists.

Figure 4 shows that for both passenger cars and trucks the mean and median lengths of one-way trips that extended outside city limits were greatest for the largest place of residence of the owners. Thus the mean length of trips made by passenger cars owned by residents of unincorporated areas and places of 2,500 or less inhabitants was 10.6 miles, while for residents of cities having in excess of 100,000 persons the mean length was 37.1 miles. Corresponding values for median trip lengths were 5.9 and 16.3 miles. Figures for trip lengths for trucks were somewhat higher for all places of origin except the largest cities.

The mean one-way trip length for combined passenger-car and truck travel for all governmental jurisdictions was 15.2 miles, and the median trip, 7.4 miles.

The relative effect of the size of cities on highway use is also strikingly illustrated in tables 15 and 16 and figure 5, which show the average number of trips made outside cities by motor-vehicle owners of cities of various sizes. As in previous tables, a single round trip starting inside the city and going to some place outside the city limits was considered as two one-way trips for purposes of mileage classification. Thus, the average passenger-car owner resident in cities having from 2,501 to 10,000 population went outside the city of residence for 75 round trips less than 10 miles long, or as it has been expressed in table 15, for 150 one-way trips less than 5 miles long.

Trips which extended for one-way distances of 50 miles or more were made approximately the same number of times during the year by the average passenger-car operators resident in all sizes of cities. However, the average number of trips extending beyond city limits in the shorter trip-length ranges decreased rapidly with increased size of the city of residence. For example, table 15 shows that residents of cities having populations of over 100,000 made about one-half as many trips in the 20.0- to 29.9-mile trip-length range,

TABLE 14.—*Length of trips traveled outside city limits by vehicles registered in the various population groups in 11 States*

State	Length of trips traveled by vehicles registered in [1]—													
	Unincorporated areas and incorporated places having a population of 2,500 or less		Incorporated places having a population of—								All incorporated places having a population of more than 2,500		All places	
			2,501 to 10,000		10,001 to 25,000		25,001 to 100,000		More than 100,000					
	Mean [2]	Median [3]	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
	Miles	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*
PASSENGER CARS														
Florida	11.4	6.3	20.2	9.9	29.7	14.6	30.5	14.9	22.8	10.0	23.5	11.3	16.1	8.1
Kansas	9.6	5.0	23.2	11.6	29.7	15.6	34.6	16.0	41.0	18.5	29.6	14.6	13.3	6.3
Louisiana	9.9	5.5	17.9	7.8	22.1	11.2	26.6	13.5	74.2	57.5	28.3	12.6	14.2	6.5
Minnesota	11.4	6.1	24.9	11.6	27.4	12.3	...	...	54.3	19.7	34.7	15.1	16.4	7.3
New Hampshire	13.0	8.3	13.7	8.6	20.1	11.1	27.2	16.7	...	...	18.5	9.9	15.5	8.9
Pennsylvania	9.8	5.9	13.3	7.1	15.1	8.4	19.7	9.4	30.8	13.6	17.5	8.5	13.5	7.1
South Dakota	15.9	8.6	25.2	8.3	34.2	10.0	60.9	26.9	...	...	30.9	9.9	18.7	8.7
Utah	10.8	4.8	18.0	8.2	38.3	15.4	38.8	18.9	52.9	24.0	34.2	14.3	17.4	6.6
Vermont	9.3	5.7	20.2	9.5	24.5	11.4	...	...	...	...	21.6	9.8	11.7	6.5
Washington	11.5	5.8	20.2	8.1	30.6	13.8	26.2	14.7	40.8	20.0	30.6	14.1	14.6	6.7
Wisconsin	10.9	6.4	24.5	12.6	27.9	13.9	33.2	8.4	48.2	25.8	31.2	15.9	15.9	7.9
Average	10.6	5.9	17.2	8.3	20.5	9.9	24.4	11.7	37.1	16.3	22.9	10.0	14.6	7.2
TRUCKS														
Florida	15.3	7.7	18.1	9.5	32.3	15.7	21.8	13.2	20.6	9.5	25.8	10.1	19.4	8.7
Kansas	10.9	6.2	19.9	10.1	29.5	13.3	47.0	30.0	54.4	29.1	31.7	14.8	17.0	7.8
Louisiana	12.0	7.4	28.7	21.3	42.6	30.6	57.6	36.8	52.0	27.1	44.8	26.8	21.5	9.9
Minnesota	15.1	7.5	26.6	11.7	38.1	20.2	...	...	36.1	11.8	33.8	13.2	21.1	8.7
New Hampshire	12.1	8.2	11.4	7.4	24.6	13.7	32.9	19.3	...	...	20.6	10.0	16.1	8.9
Pennsylvania	11.9	6.5	10.6	5.0	12.6	6.8	18.1	8.4	19.9	9.4	14.2	6.9	13.0	6.7
South Dakota	21.7	10.5	37.3	17.6	64.8	44.7	66.9	45.3	...	...	52.5	28.0	28.7	12.9
Utah	16.0	5.2	14.4	5.4	20.3	12.0	41.8	22.5	58.4	20.0	28.8	9.7	19.9	6.4
Vermont	11.9	7.7	14.9	6.3	45.0	13.5	...	...	...	...	21.2	7.4	14.2	7.6
Washington	12.6	6.5	18.3	9.7	32.5	21.3	24.8	15.4	45.4	31.3	31.6	19.2	17.5	8.4
Wisconsin	11.6	6.9	21.2	11.6	31.0	16.1	33.0	16.5	35.9	19.0	29.2	15.0	16.5	8.3
Average	12.8	7.0	17.6	8.6	24.8	11.2	29.7	13.7	35.6	15.3	26.0	11.1	17.4	8.1
PASSENGER CARS AND TRUCKS														
Average	11.1	6.1	17.3	8.4	21.3	10.0	25.1	12.0	36.7	16.0	23.6	10.2	15.2	7.4

[1] This is the one-way distance of all trips. A trip from Washington, D. C., to Baltimore, Md., and return would be considered as 2 trips of 40 miles each.
[2] The mean shows the arithmetical average length of all trips.
[3] The median indicates the length of that trip below and above which equal numbers of trips occur.

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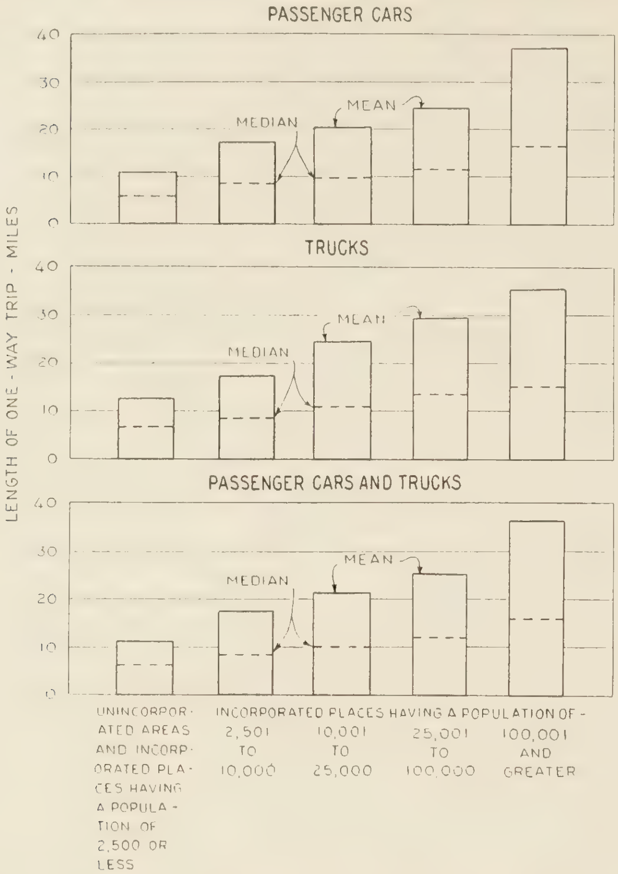

FIGURE 4.—MEAN AND MEDIAN LENGTHS OF ONE-WAY TRIPS THAT WENT OUTSIDE OF CITY LIMITS BY VEHICLES REGISTERED IN VARIOUS POPULATION GROUPS.

TABLE 15.—*Average number of one-way trips of various lengths traveled outside city limits by passenger cars registered in various population groups*

Length of one-way trip in miles from point of origin	Average number of one-way trips traveled by passenger cars registered in cities having populations of—			
	2,501 to 10,000	10,001 to 25,000	25,001 to 100,000	More than 100,000
0 to 4.9	150	84	40	14
5.0 to 9.9	126	84	56	28
10.0 to 19.9	96	92	60	34
20.0 to 29.9	38	32	30	16
30.0 to 39.9	18	18	14	10
40.0 to 49.9	8	10	6	4
50.0 and over	26	28	28	22
Total	462	348	234	128

TABLE 16.—*Percentage of trips of various lengths traveled outside city limits by passenger cars registered in various population groups*

Length of one-way trip in miles from point of origin	Percentage of trips traveled by passenger cars registered in cities having populations of—			
	2,501 to 10,000	10,001 to 25,000	25,001 to 100,000	More than 100,000
0 to 4.9	32.5	24.1	17.1	10.9
5.0 to 9.9	27.3	24.1	23.9	21.9
10.0 to 19.9	20.8	26.4	25.6	26.6
20.0 to 29.9	8.2	9.2	12.8	12.5
30.0 to 39.9	3.9	5.2	6.0	7.8
40.0 to 49.9	1.7	2.9	2.6	3.1
50.0 and over	5.6	8.1	12.0	17.2
Total	100.0	100.0	100.0	100.0

one-third the number in the 10.0- to 19.9-mile range, and one-tenth as many trips in the 0 to 4.9-mile range, as did residents of cities having populations of 2,501 to 10,000.

This smaller number of short trips by vehicles owned in the larger cities is to be expected because of the greater area covered by the larger cities. Since the analysis involved only those trips that extended beyond city limits, a large number of the shorter trips made by residents of large cities did not extend beyond the city limits and are not included in those trips shown here. It is probable that vehicle owners resident in the larger cities make as many, or possibly more, individual trips per year as do residents of the smaller cities. Many of these trips, however, are confined within the rather extensive city limits.

DATA EXPLAIN TRAFFIC CONGESTION NEAR LARGE CITIES

These data should not be considered as evidence that the vehicle owner in smaller cities makes more trips per year than does the owner resident in the larger cities. Rather, the data are an indication that the rural highway is of greater interest to the vehicle owner of large cities for long trips than for short ones, and that the rural highways serve vehicle owners resident in the smaller cities for local travel purposes to a much greater extent proportionally than they do residents of large cities. That is, for those trips extending to rural portions of the highway system there is proportionally a greater interest in longer trips by the residents of a large city than by the residents of small places. Table 16 illustrates this point. Passenger-car owners resident in cities of 2,501 to 10,000 population made 32.5 percent of their trips involving rural highways within the 0 to 4.9-mile trip-length range, while the residents of cities of over 100,000 population made only 10.9 percent of their out-of-city trips within that travel range. The percentages for trips of 50 miles or more one way were 5.6 and 17.2 percent, respectively.

These trip-length data indicate that much of the dense traffic often resulting in congestion on rural portions of highways near city limits is composed of a multitude of cars making short trips originating within the city. Heavily traveled sections of highway extend greater distances from the limits of large cities than from smaller cities because of the greater concentration of vehicles in the city and also because of the higher percentage of longer trips.

Facts derived from road-use data provide important guidance in outlining future highway policies, in regard to both physical and financial plans. The extent and location of the improvements made on the primary highway system are of considerable importance to all residents of the State. Except for those who live in the largest cities, all motorists in the State use the primary highway system more than any other class of roads. The condition of this sytem, therefore, is of comparable interest to all motorists except those residing in the largest cities. The latter do the greatest part of their traveling on city streets. On the other hand, it is significant that these motorists, resident in large cities, because of their large numbers, are responsible for a considerable amount of the total travel on primary highways. Therefore, their interest in such roads, although comparatively less per motorist than for other residents of the State, is still very large in the aggregate.

(*Continued on page 62*)

A NEW VIBRATORY MACHINE FOR DETERMINING THE COMPACTIBILITY OF AGGREGATES

BY THE DIVISION OF TESTS, BUREAU OF PUBLIC ROADS

Reported by J. T. PAULS, Senior Highway Engineer, and J. F. GOODE, Junior Highway Engineer

THE IMPORTANCE of compaction in highway construction has long been recognized. Recent laboratory and field investigations have repeatedly emphasized the value of thorough consolidation in both the base and surfacing courses. Thorough compaction is known to produce the following desirable results:

1. It increases interlocking of the aggregate particles, which is the primary factor in developing a high degree of stability.
2. It retards the entrance of moisture, thus preventing excessive loss of stability under adverse service conditions.
3. It reduces the flow of air and water through bituminous mixtures and is therefore an effective means of lessening damage from weathering and film stripping.

In order to obtain consistently a high degree of consolidation during construction, it is essential to know in advance the limits of compactibility of the materials used. Such tests as have been employed to determine the attainable density of materials, among which are dry rodding, shaking, and various molding tests involving tamping and direct compression, do not always give consistent results. Furthermore, as will be shown in this report, they fail to show the maximum compactibility limits of many aggregates.

The Bureau has been using for some time a small vibrator [1] called the voids determinator for the determination of voids in sheet asphalt aggregates. This vibrator, however, does not give consistent results for mixtures containing high percentages of dust; and, since the testing cylinder has a capacity of only 25 cubic centimeters, it is not suitable for testing aggregates containing large fragments. Accordingly, a new machine has been developed that produces more consistent results and higher densities, and which appears to be equally satisfactory for all gradations of aggregates commonly used in both base and surface construction.

APPARATUS CONSISTS ESSENTIALLY OF A VIBRATING TABLE

The general appearance of the newly developed test apparatus is shown in the cover illustration. The principle of its operation is more clearly brought out in figure 1.

The machine consists essentially of a floating table that is made to move vertically in periodic motion by rotating eccentric masses rigidly connected to its lower surface. The table is a steel plate 13 by 24 inches in size and ¾ inch thick. It is supported at each corner by a helical spring through which there is a vertical guidepost on which the table slides.

On the lower surface of the table, mounted parallel to the long axis of the plate, are two shafts running in ball bearings and geared to rotate at the same speed but in opposite directions. Four steel blocks of equal size and weight are symmetrically mounted at the ends of the two shafts, one at each end of each shaft. The size of these blocks and the speed at which they are rotated determine the magnitude of the unbalanced force. Since the two shafts rotate in opposite directions only vertical accelerations are imparted to the system.

The weight shafts are rotated at speeds of 4,300, 2,500, or 1,500 revolutions per minute by a 3-horsepower electric motor with a 3-speed, V-belt drive.

By trial it was found that the best compaction was obtained with a total eccentric weight of 1,100 grams located 1$\frac{1}{16}$ inches off center and rotating at 4,300 revolutions per minute. For these particular conditions the maximum centrifugal force developed by each of the four eccentric masses is theoretically about 338 pounds. In the extreme upper and lower positions these forces add to give a theoretical total vertical resultant of about 1,350 pounds while at the midpoint between these positions the forces developed by the weights on one shaft exactly balance those of the other shaft and the total horizontal resultant is 0 pound.

At a frequency of 4,300 cycles per minute a powerful vibration is developed in the entire mass.

The assembly for holding the aggregate to be tested is bolted to the top of the vibrating plate or table. It is shown in section in figure 2. Its essential parts are a base plate and bottom plunger bolted to the table, a cylinder fitting over the bottom plunger and resting on a rubber support, and a top plunger which rests on the test material in the cylinder.

A micrometer dial mounted on a suitable base is used in conjunction with a series of calibrated gage blocks to measure the thickness of the compacted specimen without removing it from the cylinder.

The top plunger imposes a dead load of 1.75 pounds per square inch on the sample to be compacted. This dead load generally provides sufficient confinement to flatten the top of the specimen and to prevent segregation of the particle sizes. Both the top and bottom plungers have just sufficient clearance within the cylinder to allow free vertical movement during vibration, and each is fitted with three bronze guide strips to maintain it in a position parallel to the axis of the cylinder. The loss of fine aggregate is held to a minimum by the insertion of close-fitting pasteboard gaskets or pads above and below the test specimen. A suitable correction is made in the measured height of the specimen to allow for the final thickness of the pads.

EQUIPMENT ADAPTABLE FOR TESTING DIFFERENT AGGREGATES

In making a test, the first step is to obtain an initial or zero reading with the micrometer dial on the combined height of the two plungers with the two pasteboard pads compressed between the plungers by vibration for a short period. For this zero reading a steel spacer gage of the approximate thickness of a compacted specimen is inserted under the dial so that its ¾- or

[1] Research on Bituminous Paving Mixtures, by W. J. Emmons. PUBLIC ROADS, vol. 7, No. 10, December 1926.

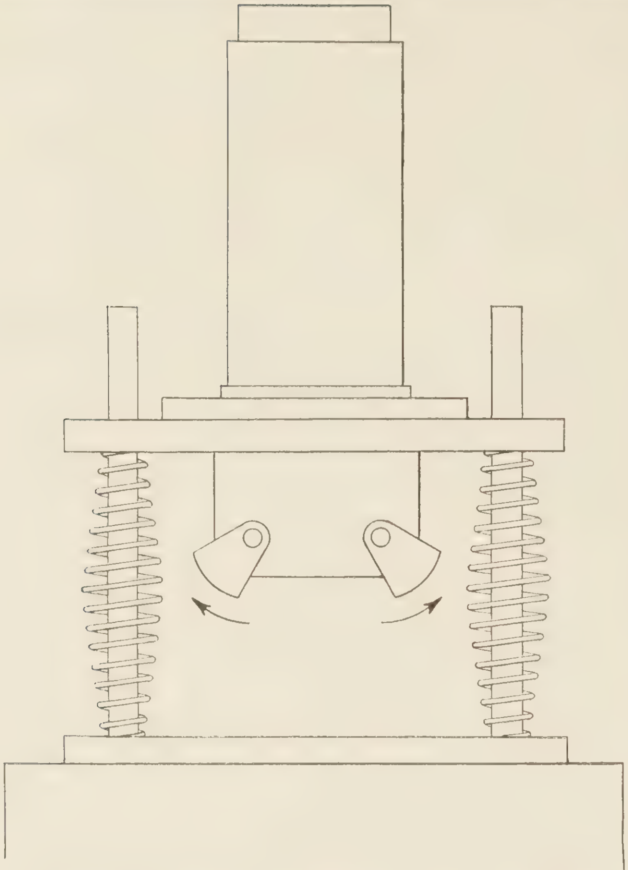

FIGURE 1.—ESSENTIAL ELEMENTS OF THE VIBRATORY COMPACTOR.

1-inch range of travel will not be exceeded when the specimen is in place.

For tests in the 4-inch cylinder, which is the one used for aggregates up to about 1-inch maximum size, sufficient aggregate is used to produce a compacted specimen approximately 1½ to 1¾ inches high. This requires about 750 grams of aggregate.

If desired, a much smaller cylinder may be used when testing fine aggregates such as soil, sand, rock dust, or sheet asphalt aggregate, and the depth of the compacted specimen may be reduced to 1 inch or less and its weight to as little as 75 grams. For very large aggregates, a larger cylinder should be used and the thickness of the compacted specimen should be increased so that it is at least one-half to three-fourths inch more than the nominal diameter of the largest individual aggregate particle. The weight of the top plunger should be such that the dead load is approximately 1 pound per square inch per inch of depth of the compacted specimen.

It is essential that the loose aggregate be placed in the cylinder without segregation. When the aggregate to be tested has a large percentage retained on the No. 10 sieve it has been found that the addition of about 50 to 70 cubic centimeters of kerosene to 750 grams of aggregate aids greatly in preventing segregation and does not interfere with compaction. The most satisfactory amount of kerosene seems to be that which will just fill the voids in the compacted aggregate.

Materials such as fine soil, sand, clay, etc., are not particularly subject to segregation and, because of the greater difficulty with which air is forced out of them when wet, do not always compact as well with kerosene as without. They are therefore tested dry.

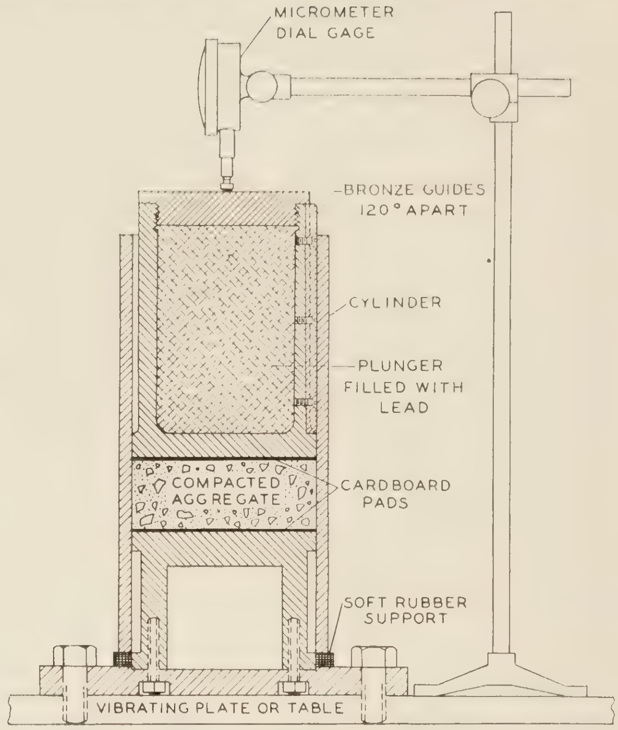

FIGURE 2.—CYLINDER AND PLUNGER ASSEMBLY WITH MEASURING DEVICE.

For determining whether or not to use kerosene it has been found that in general the following conditions will govern:

1. For aggregates having less than 35 percent passing the No. 10 sieve, use kerosene.
2. For aggregates having more than 50 percent passing the No. 10 sieve, test dry.
3. For aggregates having more than 35 percent and less than 50 percent passing the No. 10 sieve, test both with and without kerosene and report the higher density value obtained.

VIBRATION FOR 20 MINUTES ADOPTED AS STANDARD PROCEDURE

All aggregates should be oven-dried before testing, since very small amounts of water or other liquid, as distinguished from the relatively large amount of kerosene added in testing coarse materials, have a marked bulking effect which interferes with the obtaining of accurate test results. Drying is also necessary in order to obtain the true sample weights for use in calculating the density after vibration. Lumps or clods of clay in the aggregate impair the accuracy of the test and should be thoroughly broken down before placing the sample in the cylinder for compaction.

After the material is placed in the cylinder, with a pasteboard pad underneath and another on top, the upper plunger is inserted and the assembly is vibrated for a period of 20 minutes. The final reading is taken with the dial, and from this reading and the initial reading the over-all volume of the material in the cylinder is calculated. This volume, the dry weight, and the apparent specific gravity of the aggregate are used in calculating the density. In this report density is expressed as the percentage of aggregate volume per unit of total volume.

The method of determining this percentage is illustrated with a typical example:

Apparent specific gravity [2] of aggregate	2. 67
Weight of aggregate sample, grams	736
Volume of vibrator-compacted sample, cubic centimeters	313. 9
Unit weight of compacted sample (grams per cubic centimeter) 736/313.9	2. 35
Density of compacted sample, (percent) $\frac{2.35}{2.67}\times 100$	88. 0

The densities of a number of aggregates were determined for various periods of vibration up to a maximum of 60 minutes. The results of these tests are shown in figure 3. The asphaltic concrete aggregate, the sheet asphalt aggregate, and the fine sand showed practically no increase in density after 20 minutes of vibration. The sand-clay and the sand-clay-gravel each showed an apparent increase of 1.1 percent in density for the time increment from 20 to 60 minutes, and the micaceous soil showed an increase of 1.4 percent. It was found, however, that loss of dust, which became quite noticeable late in the test because of wear on the gaskets, accounted for most of the reduction in volume and consequent apparent increase in density after the initial 20 minutes of vibration. Vibration for a period of 20 minutes has, therefore, been adopted as regular procedure for the test.

The results of compaction tests on three different types of aggregate are shown in table 1 and demonstrate the ability of the apparatus to produce results that check. The maximum variation in results for these tests was slightly under 0.5 percent. However, for routine testing by various operators, this degree of accuracy probably could not be expected.

TABLE 1.—*Consistency of check tests using the vibratory compacting machine*

Type of aggregate	Density (aggregate volume per unit of total volume)				
	Test No. 1	Test No. 2	Test No. 3	Test No. 4	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Sand-clay	79. 4	79. 6	79. 6	79. 6	79. 6
Sand-clay-gravel	86. 7	86. 9	86. 7	87. 1	86. 9
Sheet asphalt (sand and dust)	76. 8	76. 6			76. 7

In the following tables and discussion, the results of a number of compaction tests using the vibratory machine and several other methods of compaction are shown. Table 2 shows the comparative effects of vibration and direct compression on the grading of the aggregate and demonstrates that little or no change in grading was produced by the vibratory method of compaction, whereas direct compression resulted in sufficient crushing to alter materially the grading of the aggregate samples.

[2] Standard Definitions of Terms Relating to Specific Gravity, A. S. T. M. Designation E12-27.

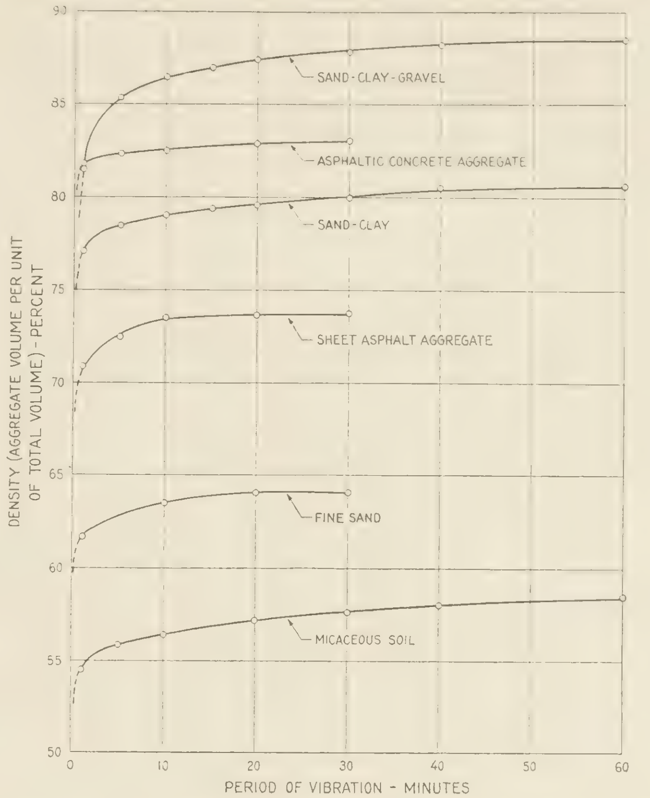

FIGURE 3.—DENSITIES OF VARIOUS TYPES OF AGGREGATES AND THEIR RATES OF CONSOLIDATION.

HIGHER DENSITIES OBTAINED BY VIBRATORY METHOD THAN BY OTHER METHODS

A comparison of densities obtained by several methods of compaction on various types of aggregates is shown in table 3. In the upper section of the table dealing with the aggregates for base courses, the densities obtained from circular-track test sections built and compacted under the most favorable laboratory conditions agree closely with those obtained by the vibratory

TABLE 2.—*Effect of compaction by compression and vibration on breakage of various aggregates*

Type of aggregate	Method of compaction	Grading, total aggregate passing—							
		1-inch sieve	3/4-inch sieve	3/8-inch sieve	No. 4 sieve	No. 10 sieve	No. 40 sieve	No. 100 sieve	No. 200 sieve
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Graded, fine—high dust content	None				100. 0	99. 7	82. 5		15. 5
Do	Vibration				100. 0	99. 7	82. 2		14. 7
Graded, fine—low dust content	None				100. 0	99. 4	82. 3		2. 4
Do	Vibration				100. 0	99. 8	82. 8		2. 8
Do	None					100. 0	75. 2	18. 9	2. 2
Do	Compression, 3,000 lb./sq. in					100. 0	76. 9	25. 6	7. 5
Graded, coarse—medium dust content	None	100	92. 5	75. 8	66. 8	63. 7	48. 6		9. 4
Do	Vibration	100	92. 5	75. 8	66. 6	63. 3	48. 3		9. 4
Graded, coarse—low dust content	None	100	98. 3	76. 7	55. 9	50. 0	38. 5	11. 4	1. 8
Do	Compression, 3,000 lb./sq. in	100	98. 2	82. 0	61. 6	52. 0	39. 8	14. 4	4. 1
Graded, coarse—high dust content	None	100	90. 8	77. 0	66. 3	47. 2	31. 7		17. 3
Do	Compression, 3,000 lb./sq. in	100	92. 5	80. 2	69. 8	53. 2	36. 0		21. 0

test. The other methods of compaction shown, with few exceptions, gave considerably lower densities. Direct compression appears to be quite effective for the fine-grained materials, but, as previously shown, the crushing of the aggregate in this test renders the results somewhat unsatisfactory.

TABLE 3.—*Comparison of aggregate densities obtained by various methods of compaction*

BASE COURSE MATERIALS [1]

Character of material tested: Type	Plasticity index	Passing No. 200 sieve	Density (aggregate volume per unit of total volume): Samples cut from road or test track	Aggregates compacted in laboratory: Vibratory method	Aggregates compacted in laboratory: Compression 3,000 lb./sq. in.	Aggregates compacted in laboratory: Voids determinator
			Percent	*Percent*	*Percent*	*Percent*
Micaceous soil	0	62	53.4	57.3		
Micaceous soil with 3 percent cement	0	63	57.8	57.5		
Micaceous soil with 11 percent cement	0	65	57.0	57.0		
Sand-clay	0	25	74.8	80.6	75.3	80.2
Do	5	26	80.8	80.8	81.4	76.5
Do	6	20	81.2	81.4	78.8	75.6
Do	9	27	79.5	79.6	81.4	75.1
Do	13	29	78.1	78.5	82.4	73.1
Do	18	29	76.2	76.3	82.2	71.1
Sand-clay-gravel	0	17	82.8	89.7		
Do	0	1	77.8	86.9	76.7	
Do	5	15	87.0	88.0		
Do	6	16	89.3	89.9	82.9	
Do	7	22	87.3	87.5	83.2	
Do	8	12	89.1	89.9	84.2	
Do	9	25	83.9	86.7	84.1	
Do	11	17	86.2	87.1		
Do	16	16	84.0	87.2		
HOT, PLANT-MIX SURFACING MATERIALS [2]						
Sheet asphalt, D. C.		14.9	70.7	76.5		71.4
Sheet asphalt, Ohio		12.7	69.3	75.0		
Fine bituminous concrete, Ohio		4.7	82.0	85.9		
Do		6.0	77.9	80.5		
Medium bituminous concrete, Ohio		4.1	76.4	80.6		
Do		6.7	81.3	88.1		
Coarse bituminous concrete, Ohio		3.3	80.7	86.9		
Do		4.2	81.6	89.2		

[1] Samples taken from circular track test sections.
[2] Field samples from pavements. Laboratory compaction tests made on extracted aggregates.

The densities obtained by means of the new vibratory machine are in general much higher than those obtained by the voids determinator.[3] The new apparatus has the further advantage of permitting the testing of large-size aggregates. The voids determinator used in previous work of the Bureau is not suitable for testing materials larger than those passing the No. 10 sieve.

The lower section of table 3 shows a comparison between the aggregate densities of asphaltic pavements of the hot-mix type and the densities obtained by vibrating the extracted aggregates from these pavements. The data shown indicate that construction operations and traffic may not generally produce as high densities in hot-mix pavements as are produced by vibrating the dry aggregates. The highly viscous binders apparently resist the free adjustment of the aggregate particles to form their densest possible arrangement. This resistance is known to be considerably less for the liquid binders than for the highly viscous ones. Mixtures containing the liquid materials often attain densities closely agreeing with the vibratory test results, which accounts for the fact that such mixtures cannot safely be made as rich in bituminous material as hot paving mixtures of comparable aggregate grading.

To attain consistently during construction a satisfactory degree of compaction for any particular material it is necessary to know in advance its compactibility limit, to have an idea of how closely this limit may be approached by practical construction methods, and how closely it needs to be approached to insure satisfactory behavior provided the materials are otherwise satisfactory. Tests have been made on a large number of materials. The few typical results given in table 4 illustrate the relations between field densities and compactibility limits, as determined by the vibratory machine.

For the plastic sand-clay and sand-clay-gravel materials that have been found by various tests to be suitable for base-course construction, the compaction obtained during construction appears to be the deciding factor influencing service behavior. The importance of consolidation is particularly well illustrated in the behavior of the plastic sand-clay-gravel referred to in the footnote of table 4. This material, which is representative of a group of materials that showed similar behavior, was placed in the test section as a base course with insufficient moisture to permit compaction to the density obtained in the vibratory test. It failed in service as soon as unfavorable sub-base moisture conditions were imposed. It was later scarified and recompacted with a higher moisture content. It was then easily compacted to essentially the same density as was obtained in the vibratory test and gave excellent service under very adverse moisture conditions.

TABLE 4.—*Relation of density of soil-type bases to service behavior for base course materials*

Character of material tested: Type	Plasticity index	Grading, total aggregate passing—: No. 10 sieve	Grading, total aggregate passing—: No. 40 sieve	Grading, total aggregate passing—: No. 200 sieve	Density (aggregate volume per unit of total volume): Vibratory compaction	Density (aggregate volume per unit of total volume): Field compaction	Behavior in test sections
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	
Micaceous soil	0	98	76	62	57.3	53.4	Unsatisfactory.
Micaceous soil with 3 percent cement.	0	98	77	63	57.5	57.8	Satisfactory.
Micaceous soil with 11 percent cement.	0	98	78	65	57.0	57.0	Do.
Sand-clay	0	100	71	25	80.6	74.8	Do.
Do	6	100	51	20	81.4	81.2	Do.
Do	9	100	68	27	79.6	79.5	Fairly satisfactory.
Sand-clay-gravel	0	54	34	17	89.7	82.8	Satisfactory.
Do. (Same material)[1]	5	48	31	15	88.0	83.2	Unsatisfactory.
Do. (Same material)[1]	5	48	31	15	88.0	87.0	Satisfactory.

[1] When this material was placed in the roadway it had so low a moisture content that it did not compact to a satisfactory density. It failed early in service but when remixed and relaid with the correct moisture content, it compacted to within 1 percent of the density obtained by vibration and gave satisfactory service.

VIBRATORY METHOD USEFUL IN BLENDING AGGREGATES TO OBTAIN DENSE MIXTURE

In highway base- and surface-course construction it is frequently necessary to blend two or more aggregates to provide a material suitable for the intended use. The vibratory compactor provides a means by which the best combination of two or more available aggregates may be determined. The application of this test to the design of aggregate blends and bituminous mixtures will be discussed in connection with figures 4, 5, 6, and 7.

Figures 4 and 5 illustrate two methods of using the vibratory compactor to obtain the densest combination

[3] Research on Bituminous Paving Mixtures, by W. J. Emmons. Public Roads, vol. 7, No. 10, December 1926.

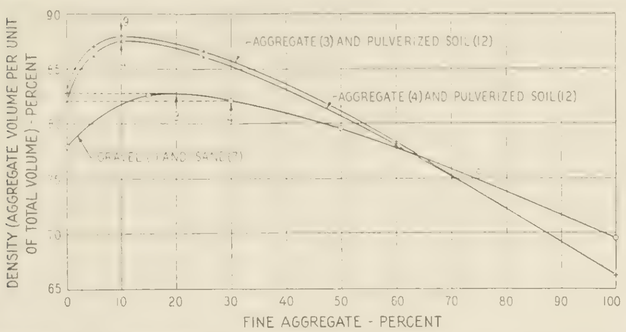

FIGURE 4.—BLENDING CURVES FOR CRUSHED GRAVEL, SAND, AND PULVERIZED SOIL. AGGREGATE NUMBERS CORRESPOND TO THOSE IN TABLE 5.

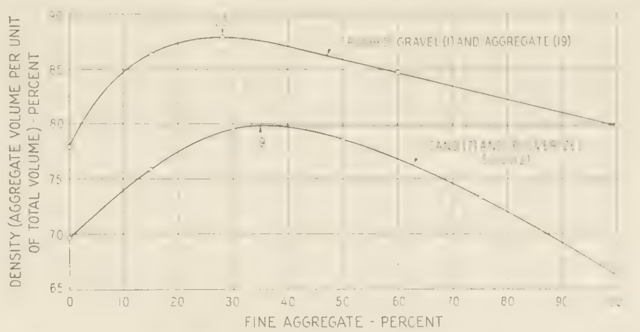

FIGURE 5.—BLENDING CURVES FOR CRUSHED GRAVEL, SAND, AND PULVERIZED SOIL. AGGREGATE NUMBERS CORRESPOND TO THOSE IN TABLE 5.

of three different aggregates for use as a base-course material. For this type of construction the combination of the available materials that gives the densest mixture is generally the most desirable. The three aggregates used in producing the blending curves of figures 4 and 5 were crushed gravel (1-inch maximum size), fine sand, and a pulverized soil. The densities and the gradings of the individual constituents and the various blends are shown in table 5.

In the first method illustrated in figure 4, an initial series of blends was made of the gravel and sand and the densest blend of these two materials was determined. This blend, designated as aggregate 3 in table 5, was then blended in various proportions with the pulverized soil, the densest blend in this series being presumably the densest possible blend of the three materials. This blend, designated aggregate 9 in table 5, had a density of 87.9 percent aggregate solids and the following composition: Gravel 72 percent, sand 18 percent, and pulverized soil 10 percent.

A less dense blend of the gravel and sand, selected at random and designated aggregate 4 in table 5, was also blended with the pulverized soil as shown in figure 4. The highest density obtained by blending with aggregate 4 was lower than that obtained with aggregate 3, indicating that the procedure of selecting the densest combination of the coarse materials for blending with the fines was the correct method.

In the second method, illustrated in figure 5, the order of the tests was reversed. The initial series of blends was made with the sand and pulverized soil. The densest blend of these, designated aggregate 19 in table 5, was then blended with the gravel. The two methods gave identical final results both as to maximum density and proportions of the three constituents, the density at the high point of the second curve being again 87.9 percent and the proportions of material being: Gravel 72 percent, sand 18 percent, and soil 10 percent.

It is of interest to note that the grading of the densest blend of these three materials, which were selected more

TABLE 5.—*Densities and gradings of blended aggregates, sand-clay-gravel base-course type*

Identification	Composition of aggregate: Coarse: Type	Coarse: Amount	Fine: Type	Fine: Amount	Density (aggregate volume per unit of total volume)	Grading, total aggregate passing—: ¾-inch sieve	⅜-inch sieve	No. 4 sieve	No. 10 sieve	No. 40 sieve	No. 200 sieve
		Percent		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	Crushed gravel	100	Sand	0	77.9	82.0	48.5	24.9	0.8	0.3	0
2	do	85	do	15	82.6	84.7	56.2	36.2	15.7	12.0	.6
3	do	80	do	20	82.8	85.6	58.8	39.9	20.6	15.9	.9
4	do	70	do	30	82.1	87.4	64.0	47.4	30.6	23.8	1.3
5	do	50	do	50	79.6	91.0	74.3	62.5	50.4	39.4	2.2
6	do	25	do	75	75.6	95.5	87.1	81.2	75.2	59.0	3.2
7	do	0	do	100	69.6				100.0	78.5	4.3
3	Aggregate No. 3	100	Pulverized soil	0	82.8	85.6	58.8	39.9	20.6	15.9	.9
8	do	95	do	5	87.0	86.3	60.9	42.9	24.6	20.1	5.1
9	do	90	do	10	87.9	87.0	62.9	45.9	28.5	24.3	9.2
10	do	75	do	25	86.6	89.2	69.1	54.9	40.5	36.9	22.1
11	do	40	do	60	78.3	94.2	83.5	76.0	68.2	66.4	51.7
12	do	0	do	100	66.2					100.0	85.6
4	Aggregate No. 4	100	do	0	82.1	87.4	64.0	47.4	30.6	23.8	1.3
13	do	95	do	5	86.2	88.0	65.8	50.0	34.1	27.6	5.5
14	do	90	do	10	87.6	88.7	67.6	52.7	37.5	31.4	9.7
15	do	75	do	25	86.1	90.6	73.0	60.6	48.0	42.9	22.4
16	do	40	do	60	78.1	95.0	85.6	79.0	72.2	69.5	51.9
12	do	0	do	100	66.2					100.0	85.6
7	Sand	100	do	0	69.6				100.0	78.5	4.3
17	do	85	do	15	75.8				100.0	81.7	16.5
18	do	70	do	30	79.5				100.0	85.0	28.7
19	do	65	do	35	79.8				100.0	86.0	32.7
20	do	50	do	50	78.6				100.0	89.3	45.0
21	do	25	do	75	73.3				100.0	94.6	65.3
12	do	0	do	100	66.2					100.0	85.6
1	Crushed gravel	100	Aggregate No. 19	0	77.9	82.0	48.5	24.9	.8	.3	0
22	do	85	do	15	86.3	84.7	56.2	36.2	15.7	13.2	4.9
23	do	72	do	28	87.9	87.0	62.9	45.9	28.5	24.3	9.2
24	do	40	do	60	84.7	92.8	79.4	70.0	60.3	51.7	19.6
19	do	0	do	100	79.8				100.0	86.0	32.7

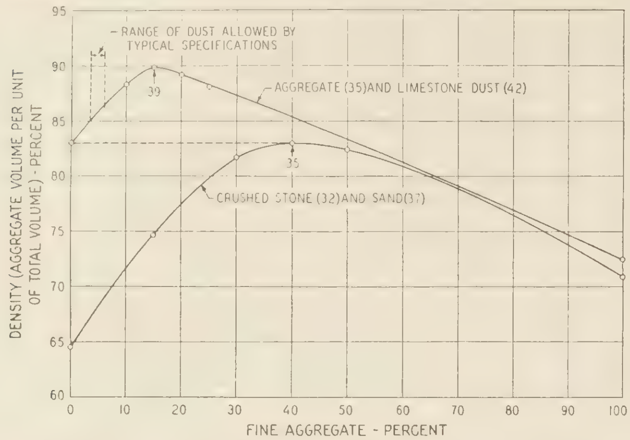

FIGURE 6.—BLENDING CURVES FOR BITUMINOUS CONCRETE. AGGREGATE NUMBERS CORRESPOND TO THOSE IN TABLE 7.

or less at random, conformed to the grading requirements now recommended for base-course construction. This relationship is shown in table 6.

In figure 6 is shown the application of method 1 in blending crushed stone, sand, and limestone dust for a typical bituminous concrete aggregate. The densities and gradings of the various blends are shown in the lower section of table 7. As shown in figure 6 a maximum density of 89.8 percent solids was obtained, using

TABLE 6.—*Comparison of grading obtained by blending sand, clay, and gravel for maximum density, with recommended grading requirements for base-course construction*

	Grading, total aggregate passing—						
	1-inch sieve	¾-inch sieve	⅜-inch sieve	No. 4 sieve	No. 10 sieve	No. 40 sieve	No. 200 sieve
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Maximum-density blend	100	87.0	62.9	45.9	28.5	24.3	9.2
A. A. S. H. O. specification for type B, sand-clay-gravel base	100	70–100	50–80	35–65	25–50	15–30	5–15

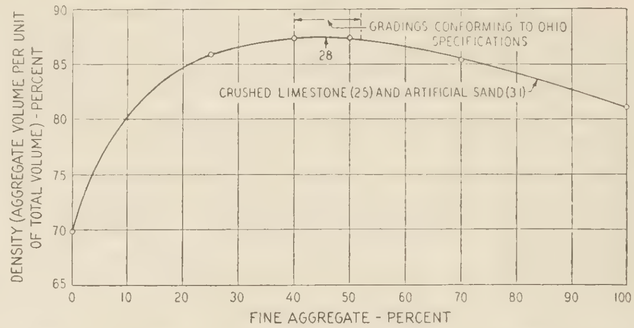

FIGURE 7.—BLENDING CURVE FOR CRUSHED LIMESTONE AND ARTIFICIAL LIMESTONE SAND. AGGREGATE NUMBERS CORRESPOND TO THOSE IN TABLE 7.

15 percent of limestone dust with the densest blend of the stone and sand (aggregate 35, table 7).

VIBRATOR ENABLES DESIGN OF MIXTURES WITHOUT OVERFILLING VOIDS

Here is an example where too dense an aggregate for practical use in bituminous concrete was obtained since the voids remaining would only permit the use of about 10 percent by volume or approximately 5 percent by weight of asphalt. To produce a practical aggregate it would be necessary to reduce its density. This would best be accomplished by reducing the dust content since the densest possible combination of the coarse fractions is always desirable. Reduction of the dust content to range between 3½ and 6 percent would reduce the density to between 85 and 86.5 percent solids, thus permitting the use of approximately 6 to 7 percent asphalt by weight and bringing the design into line with established practice.

Figure 7 shows a blending curve for bituminous concrete aggregate composed of crushed stone and artificial limestone sand without dust. This type of aggregate is used extensively in Ohio. The densities and gradings of the constituents and blends are shown in the upper section of table 7. This type differs from the previous

TABLE 7.—*Densities and gradings of blended aggregates of the type used in bituminous concrete*

Identification	Composition of aggregate: Coarse — Type	Coarse — Amount	Fine — Type	Fine — Amount	Density (aggregate volume per unit of total volume)	Grading, total aggregate passing— ¾-inch sieve	⅜-inch sieve	No. 4 sieve	No. 10 sieve	No. 40 sieve	No. 200 sieve
WITHOUT MINERAL FILLER											
		Percent		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
25	Crushed stone	100	Artificial sand	0	69.8	100	90.0	5.0	0	0	0
26	do	75	do	25	85.9	100	92.5	28.8	23.3	9.3	.9
27	do	60	do	40	87.3	100	94.0	43.0	37.3	14.8	1.4
28	do	54	do	46	87.5	100	94.6	48.7	42.9	17.0	1.6
29	do	50	do	50	87.4	100	95.0	52.5	46.6	18.5	1.8
30	do	30	do	70	85.4	100	97.0	71.5	65.2	25.9	2.5
31	do	0	do	100	81.1			100.0	93.2	37.0	3.5
WITH MINERAL FILLER											
32	Crushed stone	100	Sand	0	64.5	100	0	0	0	0	0
33	do	85	do	15	74.7	100	15.0	15.0	11.7	4.5	.3
34	do	70	do	30	81.7	100	30.0	30.0	23.4	9.0	.6
35	do	60	do	40	83.0	100	40.0	40.0	31.2	12.0	.8
36	do	50	do	50	82.4	100	50.0	50.0	39.0	15.1	1.0
37	do	0	do	100	70.8			100.0	78.0	30.1	2.0
35	Aggregate No. 35	100	Limestone dust	0	83.0	100	40.0	40.0	31.2	12.0	.8
38	do	90	do	10	88.3	100	46.0	46.0	38.1	20.8	10.4
39	do	85	do	15	89.8	100	49.0	49.0	41.5	25.2	15.2
40	do	80	do	20	89.2	100	52.0	52.0	45.0	29.6	19.9
41	do	75	do	25	88.1	100	55.0	55.0	48.4	34.0	24.7
42	do	0	do	100	72.4					100.0	96.4

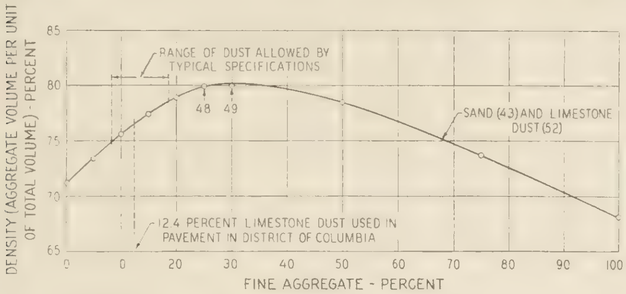

Figure 8.—Blending Curve for Sheet Asphalt Sand and Commercial Limestone Dust. Aggregate Numbers Correspond to Those in Table 8.

example in that the densest combination of the two aggregate constituents provides sufficient void space for the bituminous material. It is therefore desirable to use the densest blend, this being easily found by means of the vibratory compactor.

The aggregate void space in the densest blend shown in figure 7 would permit the use of about 6 percent asphalt, which conforms approximately to the design used successfully in Ohio with the same type of aggregate.

The results of vibratory compaction tests on blends of fine sand and limestone dust to give a dense aggregate for sheet asphalt are shown in figure 8. The densities and gradings of the two constituents and the blends are given in table 8. A maximum density of 79.9 percent solids was obtained with the blends consisting of 70 percent fine sand and 30 percent dust and 75 percent sand and 25 percent dust. Again the 20 percent voids in this blend provide insufficient space for the proper amount of asphalt and the high dust content would produce an aggregate that would be difficult to mix and handle.

Table 8.—*Densities and gradings of blended aggregates of the type used in sheet asphalt*

Sample identification	Composition of aggregate		Density (aggregate volume per unit of total volume)	Grading, total aggregate passing—			
	Sand	Limestone dust		No. 10 sieve	No. 40 sieve	No. 80 sieve	No. 200 sieve
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
43	100	0	71.2	100	81.3	33.8	3.5
44	95	5	73.4	100	82.2	37.1	8.1
45	90	10	75.6	100	83.2	40.4	12.7
46	85	15	77.4	100	84.2	43.7	17.3
47	80	20	78.9	100	85.1	47.0	21.9
48	75	25	79.9	100	86.0	50.4	26.4
49	70	30	79.9	100	86.9	53.7	31.0
50	50	50	78.5	100	90.7	66.9	49.4
51	25	75	73.7	100	95.3	83.5	72.4
52	0	100	68.1	100	100.0	100.0	95.3

In this type of construction the problem of design utilizing the vibratory compactor might be attacked from either of two angles:

1. The amount of dust could be set on the basis of well-established practice, which would call for considerably less than 25 percent dust, and the asphalt content required to fill the void space could then be determined by vibratory tests on the fixed aggregate blend.

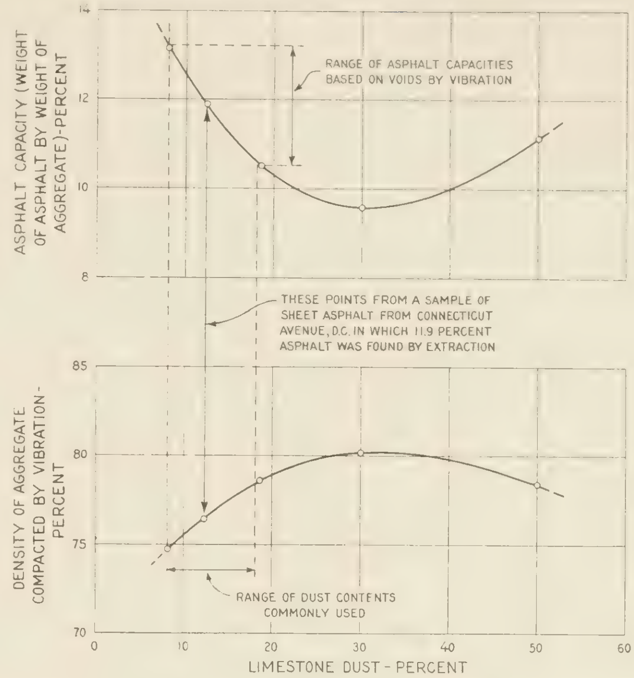

Figure 9.—Variation in Density Obtained by Vibration and Corresponding Asphalt Capacity of Sheet Asphalt Aggregates Containing Various Percentages of Limestone Dust Filler.

2. The amount of asphalt could be set also on the basis of well-established practice, and the amount of dust to be used could then be adjusted by vibratory compaction tests on a series of blends covering a narrow range of dust contents to produce an aggregate that would hold the fixed amount of asphalt.

Figure 9 illustrates the relation between asphalt capacity as determined by vibratory compaction tests and the dust content of the aggregate.

The use of the compaction test to coordinate content of bituminous materials and capacity for them appears to offer special possibilities in the design of dense surfacing mixtures where overfilling of the voids might seriously impair stability.

SUMMARY

As shown in the preceding discussion the vibratory test appears to offer valuable aid in connection with the following problems of design and construction:

1. Establishment of a definite optimum degree of compaction toward which field compaction may be aimed.

2. Determination of the best combination of two or more available aggregates for base-course or surface construction.

3. Investigation of the capacity for bituminous materials of certain aggregates to insure against overbituminization.

4. Modification of aggregate blends to permit the use of sufficient bituminous material for workability and surface sealing without overfilling the void spaces and destroying stability.

(*Continued from page 54*)

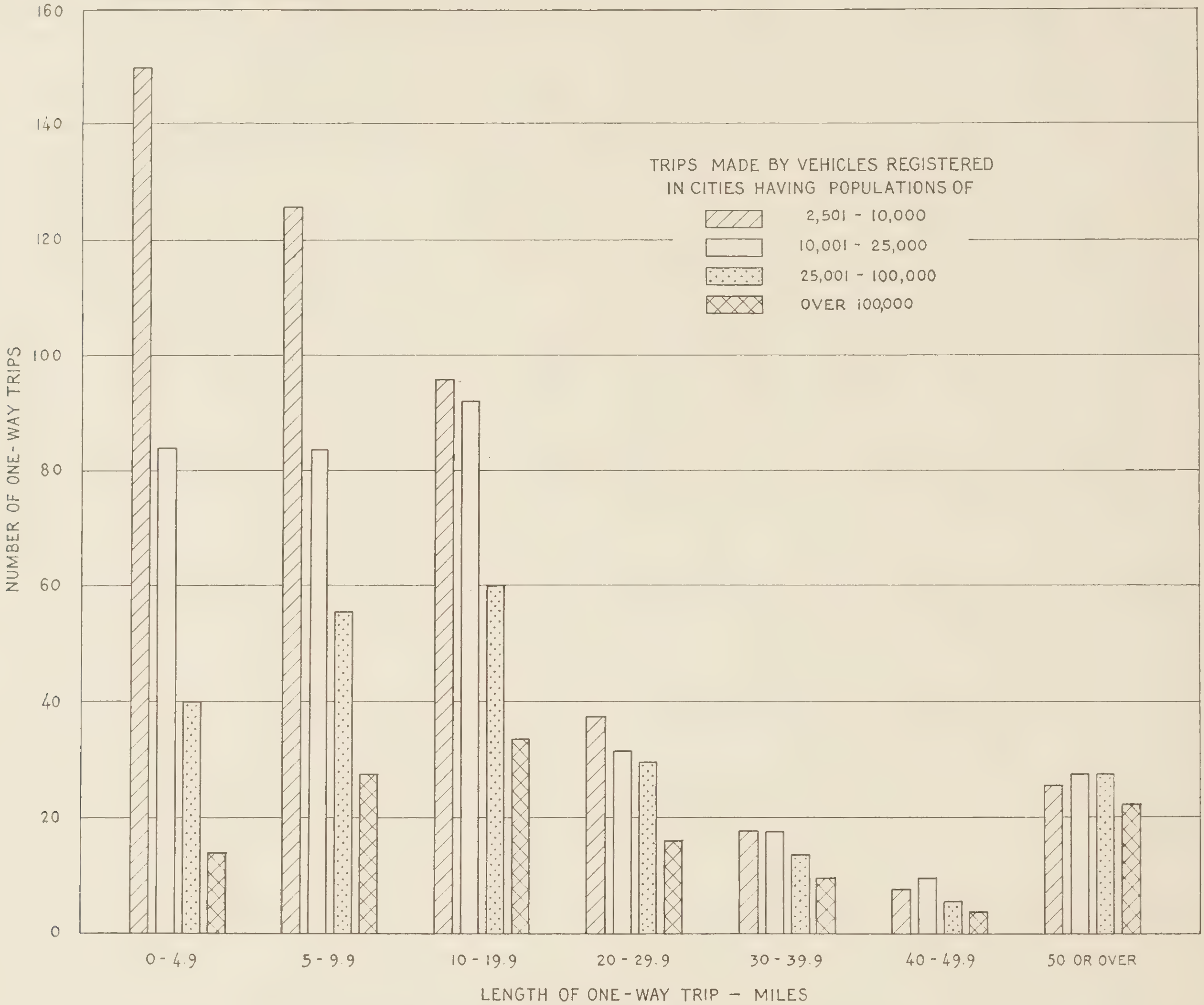

Figure 5.—Number of Trips Made by Vehicles Registered in Various Incorporated Places According to Length of One-Way Trips That Went Outside of City Limits.

The expenditure of motor-vehicle tax revenue on secondary highways and local roads does not create highway user benefits as widespread as those created by primary road expenditures, because these roads are used to a much smaller extent than the primary system or city streets. The use of secondary highways and local roads by residents of unincorporated areas and small towns is comparable with the use of local city streets by city residents.

The preceding data show the extensive use of motor vehicles for local travel and the self-imposed limitations on their use which results in a large percentage of their travel being performed within a surprisingly small area around their place of ownership. Accordingly, those roads radiating from centers of population are very important links in the highway system. It is apparent, then, that appreciable portions of the expenditures of motor-vehicle tax revenue on the primary system, in order to benefit the large cities properly, must be so applied as to alleviate the conditions of congestion and accompanying danger that exist within short distances of population centers.

Data on the use of rural roads and city streets and the extent of such use cannot be used alone to determine adequate plans for a highway program. Road-use data must be supplemented by data regarding the condition of existing roads, by other types of traffic data, and by financial data. For example, road-use information might point to the desirability of improving primary highway conditions in the vicinity of large cities but special traffic studies would be necessary to determine whether improvement at a particular location should consist of a by-pass route to accommodate an existing high percentage of through traffic or whether it should consist of extensions to main city thoroughfares of adequate width and design to accommodate a high percentage of local traffic together with a relatively small amount of through traffic. Studied alone, however, road-use information presents an essential picture of highway operations and a background of travel characteristics which are extremely valuable in projecting comprehensive plans for a highway system to serve the best interests of all motorists.

SUMMARY

These preliminary analyses of road-use data indicate:

1. Use of the rural road facilities by urban motorists decreases with increase in size of the city in which they reside.
2. Motorists residing in incorporated places perform 71 percent of all travel occurring on primary highways.
3. In the case of all motorists except those resident in cities of more than 100,000 population, more than half their annual travel occurs on primary highways.
4. Motor-vehicle use is largely comprised of short trips for passenger cars as well as for trucks.
5. A large amount of rural highway travel is occasioned by the travel of city motor-vehicle owners within short distances of their residences.
6. The proportional amount of such travel by urban residents decreases with increase in the size of the cities in which the vehicle owners reside.
7. Expenditures for rural highway facilities in the vicinity of cities, especially the larger ones, will provide proportionally greater benefits for urban than for rural motor-vehicle owners.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF APRIL 30, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 6,865,382	$ 3,146,870	239.4	$ 7,712,955	$ 3,845,646	282.2	$ 1,307,250	$ 650,570	50.3	$ 3,181,375
Arizona	2,283,575	1,679,245	118.2	1,231,929	874,131	48.7	350,012	223,396	13.8	1,952,195
Arkansas	1,280,707	1,266,330	86.8	3,629,785	3,625,843	228.2	343,467	340,912	15.5	1,761,085
California	10,198,246	5,559,953	240.0	5,154,134	2,804,228	72.9	1,058,749	558,364	8.1	4,717,588
Colorado	2,578,157	1,368,526	99.3	2,734,853	1,456,727	85.0	2,166,750	1,124,009	38.8	2,590,278
Connecticut	934,030	455,835	8.9	1,021,668	504,690	11.9	644,160	321,920	6.5	1,659,871
Delaware	510,437	254,021	14.2	695,941	343,194	9.9	695,890	329,690	20.0	1,418,868
Florida	2,898,007	1,414,222	64.1	2,686,486	1,343,243	53.9	283,900	141,950	6.3	3,817,233
Georgia	5,205,428	2,491,320	260.9	5,259,210	2,629,605	270.7	1,577,150	788,585	89.0	7,032,558
Idaho	2,120,236	1,202,494	200.7	1,378,664	822,939	45.0	917,503	559,414	23.5	1,682,989
Illinois	11,478,998	5,682,378	307.3	8,025,824	4,009,358	170.2	3,263,211	1,631,560	86.2	4,428,536
Indiana	6,077,173	2,948,099	154.6	3,521,276	1,760,638	69.3	3,119,099	1,455,490	56.3	3,403,782
Iowa	7,727,570	3,651,245	263.5	4,465,034	1,843,033	146.0	672,451	226,300	35.9	2,553,356
Kansas	5,172,155	2,570,857	727.9	4,238,567	2,119,283	184.5	3,855,402	1,919,996	207.3	4,266,095
Kentucky	5,556,100	2,747,346	209.2	2,750,562	1,375,281	59.0	2,348,952	1,174,674	59.9	3,294,273
Louisiana	1,516,025	753,365	38.3	11,115,551	2,642,130	42.2	1,380,075	671,501	17.4	3,100,818
Maine	2,860,227	1,388,934	65.0	1,641,459	820,728	33.6	119,110	59,555	2.0	996,965
Maryland	1,085,456	542,728	17.1	2,729,978	1,353,851	45.2	1,486,470	635,000	23.8	1,969,785
Massachusetts	1,877,599	938,724	9.0	3,392,414	1,694,505	24.5	1,451,005	721,555	12.0	2,965,358
Michigan	8,295,221	3,909,644	172.8	4,103,724	2,051,862	125.8	1,169,755	581,180	21.6	3,687,008
Minnesota	4,902,005	2,356,216	304.8	5,796,123	2,875,292	264.1	1,235,614	616,902	61.2	4,673,917
Mississippi	4,975,778	2,122,923	211.1	9,047,642	3,435,536	394.6	414,300	185,150	4.1	3,246,311
Missouri	5,764,313	2,734,844	156.9	3,260,364	1,601,196	76.2	4,309,223	2,063,220	186.7	4,980,107
Montana	1,653,927	929,612	83.6	1,928,464	1,086,932	74.9	1,808,947	1,023,955	92.5	4,835,423
Nebraska	4,119,631	1,984,688	362.0	5,631,473	2,834,730	463.6	2,848,104	1,425,550	296.6	3,004,158
Nevada	1,404,575	1,178,382	168.8	1,799,236	1,552,165	63.6	10,264	8,827	.3	1,643,938
New Hampshire	1,178,535	579,858	23.7	155,856	77,222	2.0	502,882	247,842	11.8	1,457,890
New Jersey	2,637,665	1,309,420	18.3	2,913,986	1,454,438	26.4	357,210	178,605	2.4	2,859,493
New Mexico	2,253,381	1,468,905	242.6	2,300,174	1,396,594	98.7				1,764,412
New York	14,230,225	6,738,841	253.3	11,983,150	5,866,776	192.1	1,233,200	575,600	27.2	5,172,368
North Carolina	6,763,450	3,189,099	259.6	5,992,519	2,992,402	389.6	1,453,190	692,690	69.6	2,893,893
North Dakota	3,437,527	3,233,548	260.9	434,490	243,744	57.5	1,451,312	777,848	167.3	4,405,888
Ohio	8,727,886	4,282,814	103.3	8,079,402	4,030,672	78.9	1,569,600	724,500	20.8	8,603,703
Oklahoma	7,093,181	3,720,600	254.7	1,679,375	890,385	47.7	1,487,800	791,645	46.7	4,475,169
Oregon	3,183,317	1,845,945	110.7	2,246,158	1,370,327	100.7	260,297	157,460	24.1	2,712,800
Pennsylvania	8,575,988	4,201,896	141.8	8,691,991	4,310,954	88.9	2,442,148	1,100,850	20.4	5,740,739
Rhode Island	1,179,290	589,645	16.4	390,482	195,241	3.5	331,030	165,515	3.1	1,373,648
South Carolina	5,361,442	2,369,848	266.5	2,860,644	1,276,376	86.2				2,494,519
South Dakota	2,016,762	1,128,306	246.1	4,650,859	2,571,990	453.7	1,062,780	585,650	68.0	3,750,545
Tennessee	5,741,748	2,825,832	182.2	3,626,389	1,813,916	72.0	1,831,380	915,690	59.5	4,674,044
Texas	14,143,847	6,970,620	898.4	14,871,392	7,322,071	696.6	1,775,072	861,970	116.2	7,873,543
Utah	1,121,537	749,894	107.2	2,406,783	1,710,420	80.8	282,010	208,327	14.0	1,289,982
Vermont	1,295,969	614,434	33.9	722,784	343,793	17.7	200,670	100,095	4.3	621,501
Virginia	6,022,569	3,005,159	211.4	3,155,558	1,574,219	85.8	727,688	363,844	16.4	2,106,061
Washington	4,036,518	2,070,943	99.8	3,044,447	1,593,650	38.4	308,064	159,600	8.0	1,976,533
West Virginia	1,851,632	1,309,939	66.7	1,636,172	819,011	39.1	387,070	193,535	12.4	3,057,039
Wisconsin	5,069,889	2,502,304	176.2	6,694,362	3,272,880	183.3	366,002	173,965	11.2	3,370,316
Wyoming	2,526,025	1,526,619	281.4	1,186,722	729,771	108.4	307,000	141,186	22.0	1,337,327
District of Columbia							76,000	38,000	.4	449,500
Hawaii	809,490	396,078	18.0	859,420	421,240	9.5	484,577	239,928	8.8	1,461,475
Puerto Rico	408,596	199,770	6.4	1,711,401	851,255	39.5	338,549	167,985	3.5	502,865
TOTALS	219,007,427	112,109,118	8,863.9	197,247,832	98,436,113	6,342.7	58,072,344	29,001,555	2,173.7	159,289,123

U. S. GOVERNMENT PRINTING OFFICE: 1939

STATUS OF FEDERAL-AID SECONDARY OR FEEDER ROAD PROJECTS

AS OF APRIL 30, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 234,900	$ 117,450	18.4	$ 834,850	$ 412,050	38.6				$ 833,746
Arizona	453,523	295,507	36.1	110,104	79,348	6.3	$ 187,308	$ 93,916	23.9	401,221
Arkansas	13,126	6,563		371,315	368,899	41.5	268,172	267,120	39.3	476,913
California	1,501,456	846,807	104.6	1,335,124	696,042	50.2				874,060
Colorado	959,959	501,483	56.3	398,410	211,194	16.8	143,050	79,530	5.2	400,549
Connecticut	69,450	34,705	1.3	46,934	23,267	.2	163,280	67,660	2.9	286,249
Delaware	22,730	11,365	5.3	80,840	40,420	17.5	56,990	28,495	7.6	239,720
Florida	20,122	10,061		516,233	257,300	12.1	287,900	143,950	14.8	463,794
Georgia	374,181	176,800	50.6	579,226	289,613	71.6	170,780	85,390	23.4	1,083,775
Idaho	448,491	203,954	46.9	191,253	102,695	13.0	35,913	19,682	3.4	331,508
Illinois	1,787,015	879,463	156.4	1,358,632	625,316	66.4	501,300	242,150	36.0	888,393
Indiana	661,294	275,217	75.8	808,750	395,375	68.7	460,097	208,283	35.1	727,450
Iowa										1,679,807
Kansas	163,438	81,718	14.8	121,922	60,961	17.3	392,736	196,368	19.0	1,367,800
Kentucky	799,835	245,084	106.1	701,106	181,576	23.0	899,303	254,970	96.2	410,817
Louisiana	144,531	67,635	11.6	657,715	283,640	52.4	361,231	167,160	31.8	421,213
Maine	368,580	180,745	23.3	259,316	124,811	12.5	27,500	13,750	2.1	145,106
Maryland				188,974	94,487	15.1	142,000	52,355	10.2	388,839
Massachusetts				149,795	74,781	2.3	599,990	296,430	11.8	481,512
Michigan	409,561	203,281	37.0	903,204	451,602	53.1	705,200	342,900	35.1	989,705
Minnesota	278,383	129,758	42.2	625,022	310,467	49.0	190,036	95,018	13.5	1,249,962
Mississippi				325,662	162,831	23.7	148,000	73,950	25.0	914,085
Missouri	420,585	201,478	53.0	594,560	256,400	48.5	506,280	240,970	90.4	814,788
Montana				76,186	43,082	4.2	449,526	252,544	34.2	1,044,267
Nebraska	582,032	287,750	96.0	690,138	336,113	126.1	126,024	63,012	26.2	617,583
Nevada	427,436	345,390	68.8	120,169	104,184	15.5	26,563	23,035	1.6	214,637
New Hampshire	218,766	108,446	6.0	60,759	29,708	2.4				181,847
New Jersey	123,040	61,520	2.4	293,890	138,210	5.5	182,553	90,995	9.3	580,253
New Mexico	625,191	381,292	42.1	546,286	332,384	35.8	137,262	79,009	7.5	253,381
New York	2,311,062	1,121,381	167.4	1,899,000	949,500	99.6				1,018,502
North Carolina	695,412	346,576	77.2	945,624	472,790	85.3	235,280	114,200	29.5	496,817
North Dakota	53,630	27,222	9.0	169,910	90,999	26.1	42,770	22,907	8.2	875,949
Ohio	147,535	73,767	3.8	273,610	143,580	10.7	524,440	262,220	29.0	1,889,552
Oklahoma	302,203	160,942	35.8	167,850	89,311	7.1	602,040	297,148	32.4	985,103
Oregon	453,217	263,260	58.5	207,851	125,392	25.3	324,711	194,880	36.0	419,825
Pennsylvania	1,765,882	835,010	125.7	1,869,669	917,053	101.3	471,430	235,715	26.0	763,166
Rhode Island	66,840	33,420	3.5	194,923	97,438	5.8	74,070	37,035	.9	93,123
South Carolina	461,400	200,382	55.8	798,427	332,669	80.2	169,800	66,200	12.4	278,661
South Dakota	11,519	6,250								1,058,050
Tennessee	259,120	129,560	14.8	766,884	310,542	34.2	137,080	68,540	.7	862,818
Texas	2,964,192	1,345,731	423.4	2,441,554	1,170,258	256.7	476,245	220,041	58.3	1,322,802
Utah	485,961	241,038	45.2	357,567	180,073	29.9	54,585	32,751	6.4	265,218
Vermont	238,385	109,790	13.8	90,306	45,153	4.0	43,300	20,500	.5	107,278
Virginia	571,443	244,241	61.4	868,214	421,640	69.2	171,950	77,767	13.6	421,080
Washington	550,138	286,426	63.7	715,043	375,696	41.1	42,369	22,300	1.2	280,706
West Virginia	242,491	119,673	21.4	153,296	76,648	8.3				515,658
Wisconsin	557,666	265,848	23.1	667,079	328,060	32.0	425,639	206,822	4.6	774,306
Wyoming	416,281	254,565	59.0	356,182	220,069	20.2	112,098	70,081	5.8	227,835
District of Columbia										73,125
Hawaii				68,130	34,065	2.4	124,850	62,425	3.5	223,510
Puerto Rico	224,621	110,876	11.3	131,605	64,530	8.8	88,818	43,395	4.3	101,199
TOTALS	23,886,623	11,829,430	2,328.8	26,089,099	12,932,222	1,837.5	11,290,469	5,533,569	878.8	31,817,263

STATUS OF FEDERAL-AID GRADE CROSSING PROJECTS

AS OF APRIL 30, 1939

STATE	COMPLETED DURING CURRENT FISCAL YEAR					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
			NUMBER					NUMBER					NUMBER			
	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 251,110	$ 250,911	6		5	$ 1,229,179	$ 1,227,324	15	1	1	$ 4,800	$ 4,800			1	$ 895,506
Arizona						229,905	227,701	3								527,973
Arkansas	492,462	490,404	10			210,157	209,877	5			104,053	104,053	2			1,298,166
California	1,362,358	1,361,783	5	3		1,726,257	1,725,162	10			80,272	80,272	1			1,261,848
Colorado	84,715	81,327	2		2	440,348	440,348	3			117,900	114,138	1		19	903,714
Connecticut						18,930	12,665				171,920	171,520		1		827,380
Delaware	35,784	35,305			14	45,420	45,420	2		9						510,525
Florida	10,616	10,616				434,894	434,894	3			79,700	79,700	1		1	1,158,058
Georgia						436,950	436,950	7			112,970	112,970	2	1	5	2,344,750
Idaho	180,246	172,543	4			280,682	249,386	4			131,898	120,500	1			442,220
Illinois	400,280	400,280	2		11	2,362,545	2,362,545	17	2	53	1,036,590	979,590	5	1	23	2,493,011
Indiana	690,037	584,751	4	4		894,116	867,216	3	1	89	169,040	169,040		1	10	1,307,641
Iowa	1,038,978	1,001,309	12	2	20	247,534	230,900	4			166,547	136,706	8		1	1,744,114
Kansas	535,159	535,054	5		5	955,333	955,333	12			164,619	164,619	2		8	1,424,461
Kentucky	145,000	145,000	1			449,315	449,315	5	1	31	434,574	386,625	6	3		1,189,951
Louisiana	11,980	11,980				435,221	428,478	4			394,361	393,570	10			1,053,899
Maine	53,997	53,877	2			329,136	329,136	3	2		147,150	147,150	1	1	1	296,231
Maryland						72,188	72,188	1			18,200	18,200			4	1,137,108
Massachusetts	54,710	54,710		1		316,093	315,372	1	3		262,260	261,410	1	1		1,690,082
Michigan	932,761	924,372	8	1	35	588,806	588,806	5	2	10	292,820	292,820	1		9	2,128,334
Minnesota	38,606	38,332		1	1	780,054	779,733	3	5	2	290,819	290,819		1	7	1,862,250
Mississippi	253,500	253,500	3			576,014	576,014	7			126,800	126,800	2			938,487
Missouri	296,960	295,421	4	1		447,800	447,800	2	1		1,026,220	959,930	4	2		1,918,286
Montana	355,586	350,704	4			870,293	870,293	9								364,726
Nebraska	162,252	156,459	6			743,908	743,908	14			618,287	618,287	16		33	593,445
Nevada	158,241	158,241		3	5	209,031	209,031	1	1		56,717	46,408			7	142,893
New Hampshire	70,205	69,765		1	2	87,856	87,797	5		1	102,775	102,302	3			331,386
New Jersey	116,891	111,665	1	1		431,161	431,161	1	2	2	151,050	151,050	1			1,665,995
New Mexico	275,206	275,206	7	1		15,276	15,276				87,240	87,240	2		1	640,726
New York	992,501	991,800	4	3	2	2,020,155	2,011,005	5	10		141,300	140,850		1	1	4,962,223
North Carolina	154,540	154,540	2	1	1	1,287,640	1,252,540	7	7	3	367,770	367,770	2	1	35	1,170,521
North Dakota	209,450	208,387		1		639,692	591,290	4	1		221,220	221,220	4			867,488
Ohio						642,800	642,800	7	1		490,180	449,180	6		2	3,971,041
Oklahoma	40,774	30,792			4	322,590	288,590	2		40	46,970	46,970			11	2,370,198
Oregon	308,391	307,742	1	2		422,059	287,701	1			129,997	129,997	2			484,121
Pennsylvania	213,129	197,923	2			1,735,939	1,524,040	4	1		255,686	255,686		1		4,883,502
Rhode Island						438,791	438,791	1	3							152,459
South Carolina	55,856	55,406	1	1	2	456,943	402,427	15	2	2	355,054	355,054	3		36	969,965
South Dakota	129,150	128,517	2		9	281,970	281,970	5	2		35,050	35,050			8	1,143,378
Tennessee	7,360	7,360			2	323,910	323,910		3	2	472,400	472,400	3		5	1,461,550
Texas	482,860	481,127	9	3		2,199,487	2,168,782	18	4		1,084,101	994,375	10			2,787,694
Utah	101,648	101,648	2		4	47,359	47,359	2			262,300	262,300			98	291,230
Vermont	243,221	229,239	6	2	7	7,406	7,406				25,490	25,300			8	316,385
Virginia	476,532	475,459	15	2	1	461,604	372,604	7	1	2	406,404	406,404	4	2	21	918,196
Washington	247,816	236,347	2	3	2	822,574	821,164	10	1		86,637	86,637		1	13	541,588
West Virginia	218,401	217,381	1		3	337,441	321,681	5		2	64,400	64,400	2		1	981,352
Wisconsin	202,131	200,987	3			1,194,012	1,153,188	11			316,850	295,726	4		4	1,309,682
Wyoming	154,992	154,992		2	4	207,460	128,040	1	1		17,010	17,010			7	508,822
District of Columbia	30,215	30,215		1							283,544	243,750	1			134,198
Hawaii						201,200	201,200	3	1		29,220	29,220	2			360,830
Puerto Rico	61,900	61,550	2			222,399	220,980	6			180,009	179,127	3			418,719
TOTALS	12,338,507	12,094,927	138	40	141	30,137,833	29,257,497	263	59	249	11,621,174	11,198,945	116	18	380	64,098,308