U.S. DEPARTMENT OF AGRICULTURE

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OUTSTANDING FEATURES OF REPORT OF THE CALIFORNIA HIGHWAY STUDY

THE report of the Bureau of Public Roads on the study of the California highway system, undertaken in July, 1920, at the request of the California commission, was published in March by the commission. The report is divided into three parts, headed respectively, "Data," "Discussion," and "Conclusions." It is illustrated with numerous photographs and diagrams, which, however, represent only a small part of the 7,500 photographs and other data, which, it is stated, are on file in the Bureau of Public Roads.

The foreword by Thomas H. MacDonald, Chief of the Bureau of Public Roads, follows:

An adequate review of the results which have been secured by the development of any system of State highways must follow to-day an uncharted course. The essentials and nonessentials of such a task have not yet been sufficiently classified to avoid the gathering, on one hand, of material which modifies only slightly the final conclusions, or, on the other, to insure that all vital data and information is secured.

The California study is the most comprehensive study of results obtained through the development of a State highway system that has yet been undertaken. The work of this study has followed two principal lines; one that includes those questions that are engineering in character, and the other those that are economic in character. These two groups of questions are so interrelated and so interdependent that they can not be separated. All road improvement is a means to an end—improved transportation facilities. The proper development of such facilities ought to be based on both the engineering and economic considerations involved. But the practical application of these considerations is always modified by the attitude of the public.

For the purpose of this study, the principal operation was to classify all the pavement laid. This classification covered 1,262 miles, from which a complete record of condition of all concrete pavement for each one-tenth mile resulted and is supported by 7,500 consecutive photographs filed in the bureau. It is recorded completely by diagram. Associated with this classification there were drilled 638 cores through the pavement at intervals on 800 miles of the highway between Red Bluff and San Diego; 481 of these cores were tested and all were carefully examined and measured. A large number have been photographed for this report.

Twleve special, intensive studies of failed portions of the road surface resulted in a great volume of data which can only be summarized in the report, but which clearly establish in practically every instance the nature and cause of the defective pavement.

In connection with the many selected special studies, soil moisture determinations were made for cross sections of the road by borings at close intervals. Tests for moisture content, moisture equivalent, and for shrinkage were made at the laboratory of the University of California.

A complete classification of the subgrade soil under all the pavement on the State highway system was made by soil experts and plotted on the pavement condition diagrams. Below each concrete core, samples of soil were also removed and tested.

A State-wide traffic census was taken at 103 stations for an equivalent 16-hour week day, and many Sunday and supplementary counts were also taken. This traffic record revealed the amount and character of travel for the summer interval on the State highways. It has resulted in a set of traffic diagrams from which the total annual duty of the California highway system has been estimated, and also the corresponding revenue, or the operating income to the community.

Supporting the traffic count, extensive field studies were made of the producing agricultural areas for nine groups of agricultural crops and the peak load in tons and the peak interval in time for these crops was determined. This study covered the main valleys of the State.

During the progress of field investigation there were carried on at Sacramento a complete audit and analysis of all the books of the State highway commission office. This work resulted in a satisfactory and complete distribution of all costs of surveying, construction, engineering, and maintenance, and produced summaries that account for practically every dollar made available for the use of the commission.

Painstaking efforts have been made to secure all the data necessary to present the conclusions impartially and uncolored. There is much of value in the record to be made available after more research.

Within the past five years an unprecedented demand has been made upon the highway administrator and highway engineer to produce a large mileage of economical and serviceable highways. The extent to which he has produced this combined result is the true standard of measurement of his achievement.

Let the present traffic service rendered by the State highways of California, conservatively estimated, we believe, at 400,000,000 vehicle-miles per year be multiplied by any reasonable unit rate to indicate the present annual returns to the people on the total investment to date of about $42,000,000.

Now turn to one paragraph from the report selected as the most vital to be repeated here:

"The financial administration has been scrupulously honest and careful and the administrative and engineering costs have not been excessive, nor have final costs much exceeded the engineer's estimates."

There should be no hesitation in going forward with confidence.

The bureau gratefully acknowledges the cooperation and assistance extended by the Bureau of Soils of the Department of Agriculture, the Bureau of Standards of the Department of Commerce, the University of California, the California Highway Commission, and the highway engineer.

The field studies and the preparation of this report were carried forward under the immediate direction of Dr. L. I. Hewes and T. Warren Allen, general inspectors of the Bureau of Public Roads.

After a short historical sketch the report discusses the systems designed and the organization of the department with a complete presentation of the necessary tax requirements under the three bond issues. It is pointed out that the State highway system reflects the system laid out by the old bureau of highways in 1895, and is an excellent system of through trunk and market roads. The statement of the condition of the funds shows receipts of $42,007,330.07 and expenditures to July 1, 1920, of $41,790,884.

The report shows that of the total system of 5,360 miles laid out under the three bond issues, there have been graded and completely paved 1,345.4 miles and 377.1 miles have been graded and not paved. A length of 319.4 miles was in process of grading and not to be paved, and 206.8 miles were still in process of paving with Portland cement concrete, all on July 1, 1920. Of the paving 765 miles is Portland cement concrete unsurfaced, and 480.7 miles is surfaced with three-eighths inch of bituminous material and pebbles; 53.9 miles of concrete have been surfaced with Topeka and 4.2 miles with Willite. There are 33.8 miles of oil macadam. The total actually constructed to date is 1,930 miles.

There is a tabulated statement, arranged by division, routes, counties, and sections, showing as of July 1, 1920, details of type and costs of survey and construction. This table, covering all the contracts and all the day-labor jobs since the beginning of work in 1912, was made from an analysis and audit of the commission's books at Sacramento. It is shown that the total overrun on all construction was only 6.24 per cent above the engineer's estimate. The direct payment for labor and materials totaled to July 1, 1920, $30,936,871. On this construction the cost of surveys, engineering, and administration was 15.86 per cent.

The report contains a detailed table of Federal-aid postroad construction which shows that there have been approved for construction 221.34 miles of concrete pavement at an estimated cost of $5,081,562, 135.26 miles of graded earth road at an estimated cost of $1,801,762, one bridge estimated to cost $285,493, and 4.08 miles of gravel road estimated to cost $37,136.

There is a chapter on bridges and structures, with a detailed list of certain noteworthy and typical bridges.

It is shown that the State has expended from the motor-vehicle fund for maintenance, improvements, and reconstruction $5,780,551, and that the overhead and indirect charges on this work approximate 19.2 per cent, overhead alone 12.5 per cent. Tables of maintenance by types and divisions showing separate expenditures for general maintenance, improvement, and reconstruction are presented, also a table showing the detailed cost of construction and maintenance of oil-macadam roads. It is shown further that maintenance of the typical 15-foot by 4-inch concrete road costs $0.006 per square yard per year and for concrete constructed with three-eighth-inch oil top $0.009 per square yard per year on an average.

PRESENT CONDITION OF CONSTRUCTED ROADS.

The classification of the condition of the existing concrete pavement in the State for each one-tenth mile divides the roads into the following six classes:

(A) Pavement in which the plainly visible transverse cracks do not exceed the normal number expected of a pavement constructed without expansion joints, and which has no plainly visible longitudinal cracks.

(B) Pavement having more than the normal number of plainly visible transverse cracks or with some "crowfoot" cracks at the edges, or with both.

(C) Pavement similar to classes A and B with one plainly visible longitudinal crack or with a considerable number of "crowfoot" cracks.

(D) Pavement so cracked transversely and longitudinally that numerous slabs are formed of less area than in class C but that do not average less than about 50 square feet.

(E) Pavement in which the plainly visible transverse and longitudinal cracks are so numerous that it is broken into slabs having areas less than about 50 square feet but in which no general disintegration appears.

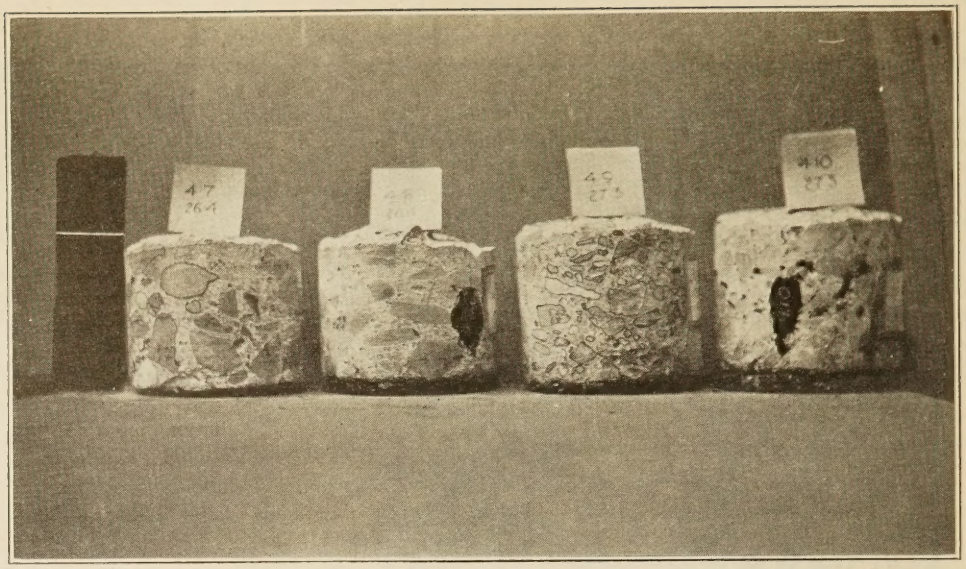
(F) Pavement badly broken and with disintegrated portions.

TABLE 1.—*Showing all classified concrete pavement built by the State (surfaced and unsurfaced).*

Class.	Year built.																Total.	
	1913		1914		1915		1916		1917		1918		1919		1920			
	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.
A	2.83	13.8	71.35	42.5	139.33	39.7	73.38	24.8	6.65	11.3	37.54	30.0	53.91	32.6	33.24	42.9	418.23	33.0
B	5.85	28.6	63.75	38.0	106.35	30.3	119.62	40.5	26.29	44.4	49.50	39.6	66.78	40.4	37.32	48.2	475.46	37.7
C	3.85	18.8	18.27	10.9	68.17	19.4	53.41	18.1	15.28	25.8	24.37	19.5	23.90	14.4	4.15	5.4	211.40	16.7
D	1.83	9.0	2.67	1.6	14.65	4.2	32.59	11.0	8.66	14.6	10.24	8.2	12.20	7.4	1.60	2.1	84.44	6.7
E	.10	.5	.40	.2	3.15	.9	11.55	3.9	2.29	3.9	3.29	2.66	8.23	5.0	1.00	1.3	30.01	2.4
F	6.00	29.3	11.50	6.8	19.14	5.5	5.13	1.7	0.00	.....	.05	.04	.25	.2	.10	.1	42.17	3.4
Total	20.46	100	167.94	100	350.79	100	295.68	100	59.17	100	124.99	100	165.27	100	77.41	100	1,261.71	100
Per cent of total each year	1.7	.....	13.3	.....	27.8	.....	23.4	.....	4.7	.....	9.9	.....	13.1	.....	6.1	.....	100	.....

RELIEF MAP OF CALIFORNIA SHOWING STATE HIGHWAY SYSTEMS FOR 1909, 1915, AND 1919.

The field classification was made with State highway layout books in hand showing each section and with miles measured by an automobile odometer. The classification notes were supported by 7,500 photographs taken at standard intervals of from one-tenth to one-half mile. From the field notes and the photographs, class-condition diagrams were developed for each State highway route, county, and section, and these plots were again checked by field inspection with the diagrams in hand. The classification result is given by the summary in Table I which shows that 12.5 per cent of the pavement on July 1, 1920, was found to be in classes D, E, and F, and the balance, or 87.5 per cent, in classes A, B, and C.



SAMPLE CORES DRILLED FROM THE CONCRETE PAVEMENT. THE NUMBERS ON THE PLACARDS IDENTIFY THE CORES. THE WHOLE NUMBER 4 IN THE UPPER NUMBER INDICATES THAT THE CORES WERE TAKEN ON ROUTE 4; THE DECIMAL FIGURE IS THE NUMBER OF THE CORE. THE LOWER FIGURE IS THE LABORATORY NUMBER. THE WHITE LINE ON THE SCALE INDICATES A HEIGHT OF 4 INCHES.

The condition diagrams were plotted on a horizontal scale of 2 miles to the inch and to an arbitrary, uniformly graduated, negative vertical scale showing five classes, B to F, inclusive, by tenths of a mile.

SAMPLE CONCRETE CORES.

For the purpose of determining the condition of the concrete actually in place, sample cores were drilled from approximately 800 miles of the pavement. In all, 638 4½ inch cores were drilled. One hundred and eighty-seven cores were drilled with the chilled-shot type of drill and the remainder with the diamond drill. The cores were shipped each night to the laboratory of the United States Bureau of Standards in San Francisco, where 481 were subjected to the following tests:

1. Inspection, with record of appearance.
2. Photographed.
3. Measured.
4. Planimetered to determine approximately the percentage of coarse aggregate.
5. Water absorption.
6. Weight per cubic foot.
7. Compression.

The results of the tests showed that the cores varied considerably in respect to the maximum size of coarse aggregate, its distribution, the coarseness and the grading of the sand. The depth of concrete varied considerably but in general ran greater than the specified 4 inches. Not much variation in density appeared. The photographs of the cores checked the notes on inspection. Measurements showed a surprisingly close average of 50 per cent coarse aggregate in both the 1 : 2 : 4 and 1 : 2½ : 5 concrete. The absorption showed an average of about 1½ per cent. The weight per cubic foot varied from 140 to 160 pounds, with some marked deviation in a few instances. After compression test examination showed, with few exceptions, a sound coarse aggregate of crushed or uncrushed fragments of gravel. The report gives sample tracings of the coarse aggregate and a full table of the results of the compression tests, etc., and notes that while the average compression test when corrected for cylinders 9 inches high by 4½ inches in diameter averaged well above 3,000 pounds there is a slight decrease in compression strength with the age of the concrete.

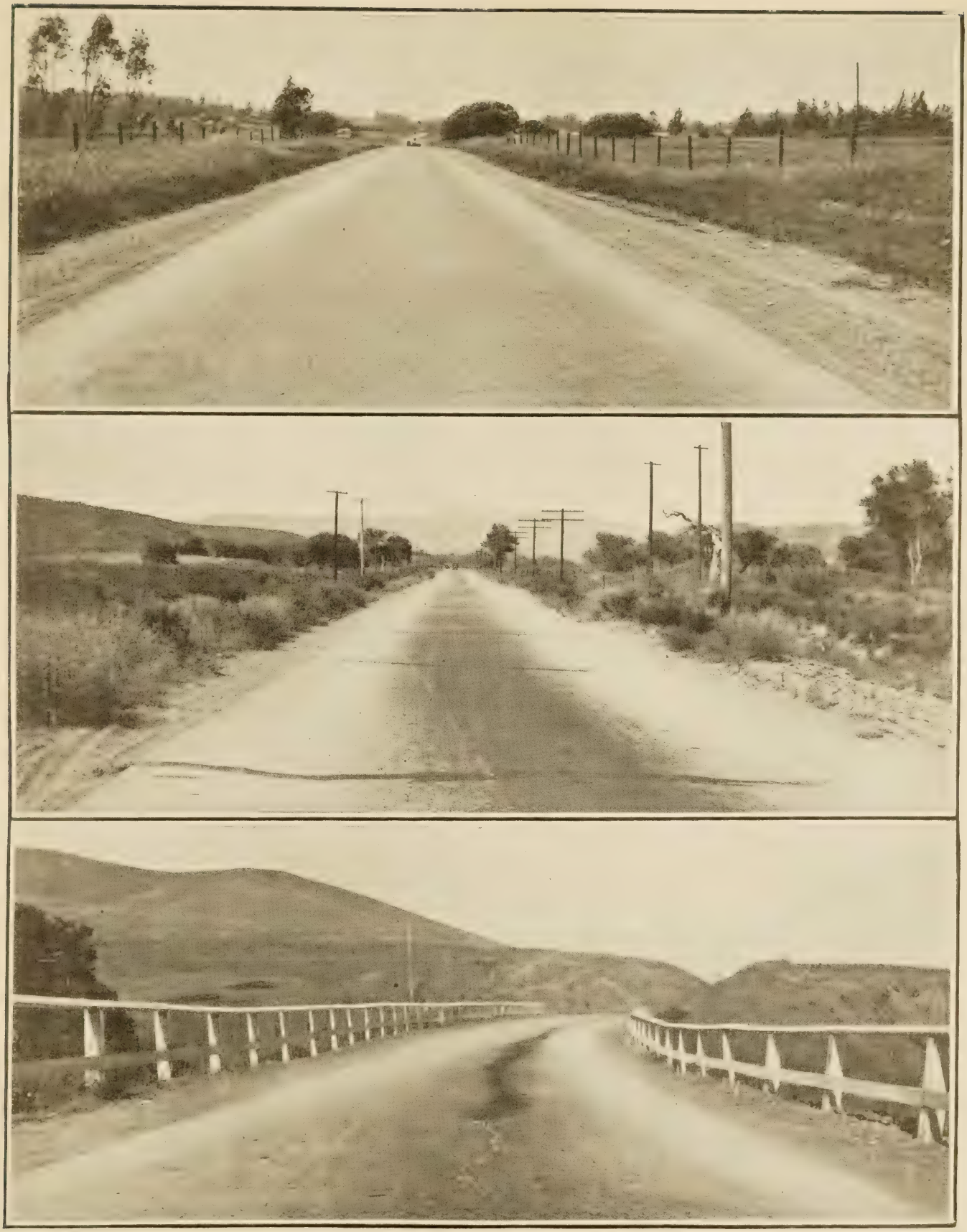
SUBGRADE SOILS.

In connection with the field classification of pavement, and with 12 special intensive studies, classification of the underlying subsoil was made with the cooperation of experts from the Bureau of Soils and the division of farm irrigation of the Bureau of Public Roads, all in the Department of Agriculture. The checked soil classification was plotted on the class-condition diagrams. The soil classification adopted was as follows:

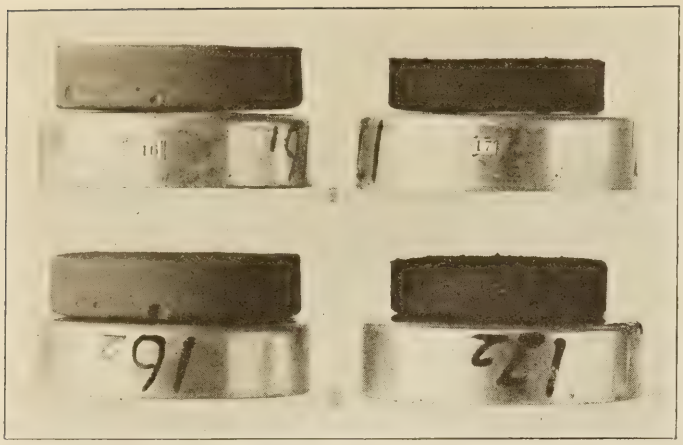
1. Clay and adobe soils (includes clay, silty clay, clay loam, and clay).
2. Marsh land (includes silt, marsh, and peat lands).
3. Loams (include loam, clay-loam, silt-loam, and silty-clay loam).
4. Sandy loam (includes coarse sandy loam, sandy loam, and fine sandy loam).
5. Sand and gravel.

The classification shows that approximately 70 per cent of the concrete pavement of classes D, E, and F occurs on soils of class 1.

Numerous moisture content and moisture equivalent determinations and shrinkage tests were made on soil



PAVEMENT CLASSES.
TOP, CLASS A; ROUTE 1, SONOMA COUNTY, SECTION C.
MIDDLE, CLASS B; ROUTE 4, LOS ANGELES COUNTY, SECTION A.
BOTTOM, CLASS C; ROUTE 2, SANTA BARBARA COUNTY, SECTION F.



SOIL SAMPLES TAKEN FROM ROUTE 1, SONOMA COUNTY, SECTION C.

samples from various parts of the State at the laboratory of the University of California and full tables of results are included in the report, also 13 cross sections of road plotted to show lines of equal moisture content in the subgrades.

ECONOMIC AND OTHER STUDIES.

The principal economic study consisted of a State-wide traffic census for one equivalent 16-hour day at 103 stations. The blanks used for counting traffic was subdivided into nine classes, as follows:

Light automobiles.
Heavy automobiles.
Busses.
Trucks less than 1 ton with pneumatic tires and less than $\frac{3}{4}$ ton with solid tires.
Trucks from 1 to $2\frac{1}{2}$ tons with pneumatic tires and from $\frac{3}{4}$ ton to $1\frac{1}{2}$ tons with solid tires.
Trucks from 3 to 5 tons with pneumatic tires and from 2 to 3 tons with solid tires.
Trucks, 5 tons and over, with pneumatic tires, and 3 tons and over with solid tires.
Horse-drawn vehicles.
Extra heavy vehicles.

Traffic was counted from 6 a. m. to 10 p. m. and the results are presented in a table the summary of which is given in Table 2. It is seen that for week days the total daily number of all vehicles averaged approximately 1,387, of which 2.7 per cent was horse-drawn traffic and 12.5 per cent truck traffic. The corresponding average Sunday traffic at 16 stations was 2.267 vehicles, of which horse-drawn traffic was only nine-tenths of 1 per cent and truck traffic 4.4 per cent (see Table 3). The report shows interesting statistics concerning traffic, including hourly variation for week days and Sunday and weekly variation.

A questionnaire was sent to 21,000 owners of solid-tire motor trucks which resulted in about 2,000 available replies, of which complete analysis was presented. A systematic study of the motor-bus traffic was also made and shows a total of 103 operating lines with an average of 610,747 passenger-miles daily on the State highway system. There was also an investigation of the motor-truck freight-carrying lines and a field study of the agricultural traffic. From the data developed it is estimated that at a 5-cent saving per vehicle-mile on State highway pavement alone the income to the State of California during the calendar years 1919 and 1920 has been $35,000,000. Complete text of the "Discussion" and "Conclusions" follows:

TABLE 2.—*Showing average 16-hour week-day traffic at 101 stations.*

Type.	Average vehicles per day.	Per cent of total traffic.	Per cent of total trucks.
Light automobiles	472	34.10	.....
Heavy automobiles	674	48.50	.....
Passenger busses	31	2.20	.....
Trucks, class 1	73	5.30	42.20
Trucks, class 2	41	3.00	23.70
Trucks, class 3	28	2.00	16.20
Trucks, class 4	29	2.10	16.80
Horse-drawn traffic	32	2.70	.....
Extra heavy traffic	2	.10	1.10
Total of all vehicles	1,387	100.00	100.00
Total of trucks only	173	.....	.....

1. Less than 1 ton with pneumatic and less than $\frac{3}{4}$ ton with solid tires.
2. One to $2\frac{1}{2}$ tons with pneumatic tires and $\frac{3}{4}$ to $1\frac{1}{2}$ tons with solid tires.
3. Three to 5 tons with pneumatic tires and 2 to 3 tons with solid tires.
4. Five tons plus with pneumatic tires and 3 tons plus with solid tires.

TABLE 3.—*Showing average 16-hour Sunday traffic at 16 stations.*

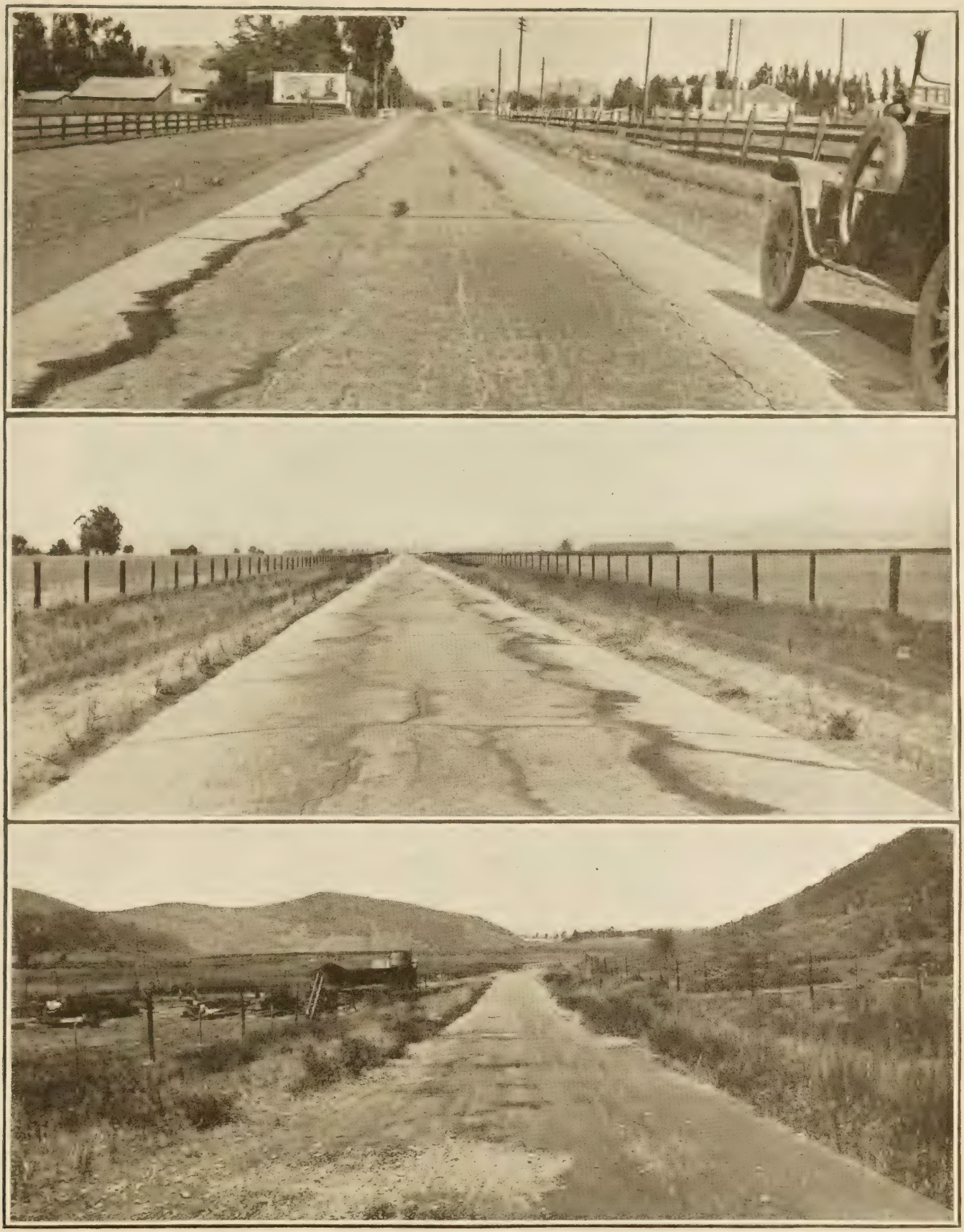
Type.	Average vehicles per Sunday.	Per cent of total traffic.	Per cent of total trucks.
Light automobiles	833	36.8	.....
Heavy automobiles	1,282	56.6	.....
Busses	29	1.3	.....
Trucks, class 1	62	2.7	50.5
Trucks, class 2	18	.8	14.6
Trucks, class 3	10	.4	8.1
Trucks, class 4	12	.5	9.7
Horse-drawn vehicles	21	.9	17.1
Extraordinarily heavy	.....	.....	.....
Total of all vehicles	2,267	100.0	100.0
Total of trucks only	123	.....	.....

BOND ISSUE, POLICY, AND SYSTEMS DESIGNED.

The system of 4,500 miles laid out in 1896 by the old State bureau of highways reached every county seat and traversed the main valleys. It was doubtless of value as a guide to the selection of the system of 5,560 miles now building—and the present system visibly reflects the original one.

Apparently the interval from 1896 to 1909 demonstrated the futility of attempting to create an adequate system of State highways by small special appropriations for selected roads.

The State highway bond issue of 1909–10 had been preceded by an issue of $1,250,000 in San Diego County and of $3,500,000 in Los Angeles County and by highway bond issues in Eastern States. The deferred serial type of bond chosen was in accord with the best practice, but the term of 45 years for the longest serial is unnecessary and will require a corresponding excessive total interest payment. The legal provisions fixing both the nominal interest and the sales price proved embarrassing to the highway commission. There is



PAVEMENT CLASSES.

TOP, CLASS D; ROUTE 8, SOLANO COUNTY, SECTION A.
MIDDLE, CLASS E; ROUTE 7, SOLANO COUNTY, SECTION D.
BOTTOM, CLASS F; ROUTE 2, VENTURA COUNTY, SECTION B.

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every evidence that the bonding principle itself at this period was sound.

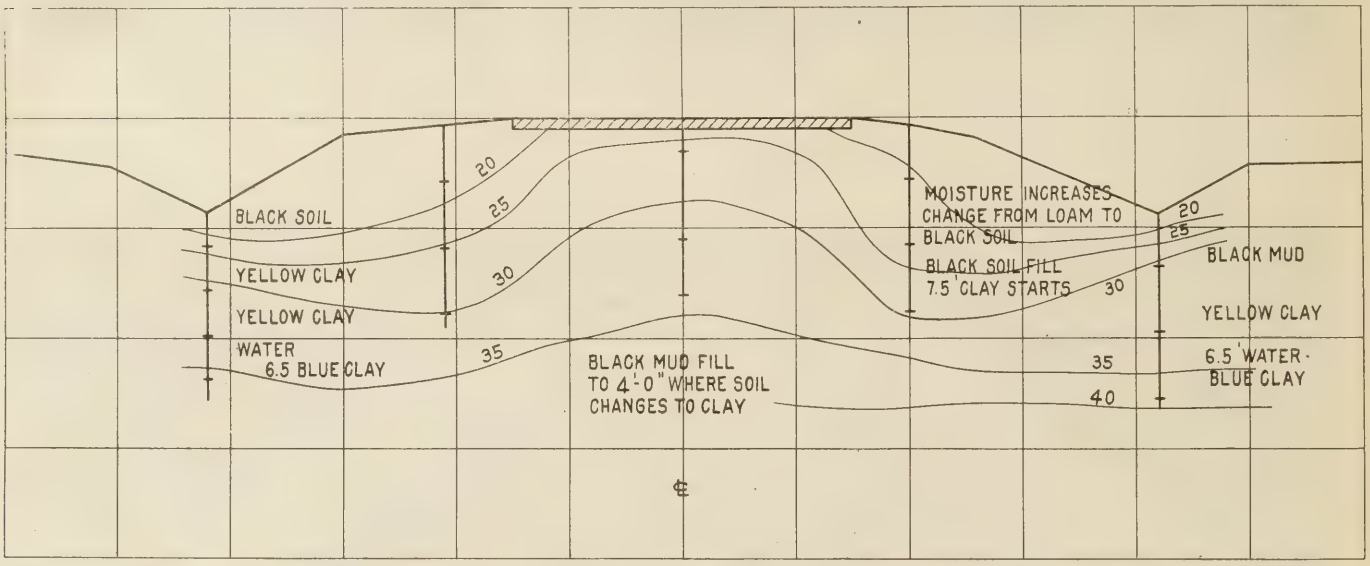
The highways act of 1909 created by implication a system of 3,082 miles, which was manifestly far in excess of the possible construction with the fund of $18,000,000 provided. The influence of this discrepancy has been far reaching. Tne State highway commission stated in their final report, "Notwithstanding the admittedly impossible task the commission endeavored by the employment of every honorable expedient to obtain the greatest possible return in roads for the money."[1]

Actually 1,300 miles, including graded roads, were built from the proceeds of the first bond issue.

The system of roads laid out under and by the various laws is an excellent one and the portions built by the commission prior to January, 1917 (when the funds of the first bond issue were exhausted), appear, in general, to have been most needed. The distribution and the order of this first construction may have been conditioned by necessary policy. Under the legal restriction governing the sale of bonds it became necessary for various counties to buy the bonds, and naturally roads in those counties which bought took some precedence. Counties were also obliged to pay the interest charges on the funds used for highways within their boundaries, and some of the poorer counties were not easily able to do this. In order to make the bond money go as far as possible the commission also influenced the various counties to furnish the necessary expensive bridges and rights of way, which action created some opportunity for preference in construction. In addition to these influences, which conditioned the distribution of construction, it was doubtless good policy to acquaint as many voters as possible with the proof of the advantages of improved roads by actual examples.

The success of the initial policy of the commission with respect to type of road and distribution of construction is evidenced by the increased majority for the second bond issue of 1915; and the still larger majority for the third issue of 1919 is evidence of its continued success.

The general policy of the commission, especially with respect to the order of construction, in attempting to carry out the terms of the laws which conditioned the sale of bonds and implied or prescribed excessive mileage to be built, must be judged by its progressive reaction on the whole State rather than by comparing it with other alternative policies that may now be apparent to a State community enlightened by the benefits of the improved roads. Such a possible alternative policy, for example, might have given priority to the trunk road from Los Angeles to San Francisco.



CROSS SECTION SHOWING SOIL MOISTURE CONTENT ROUTE 1, HUMBOLDT COUNTY, SECTION G.

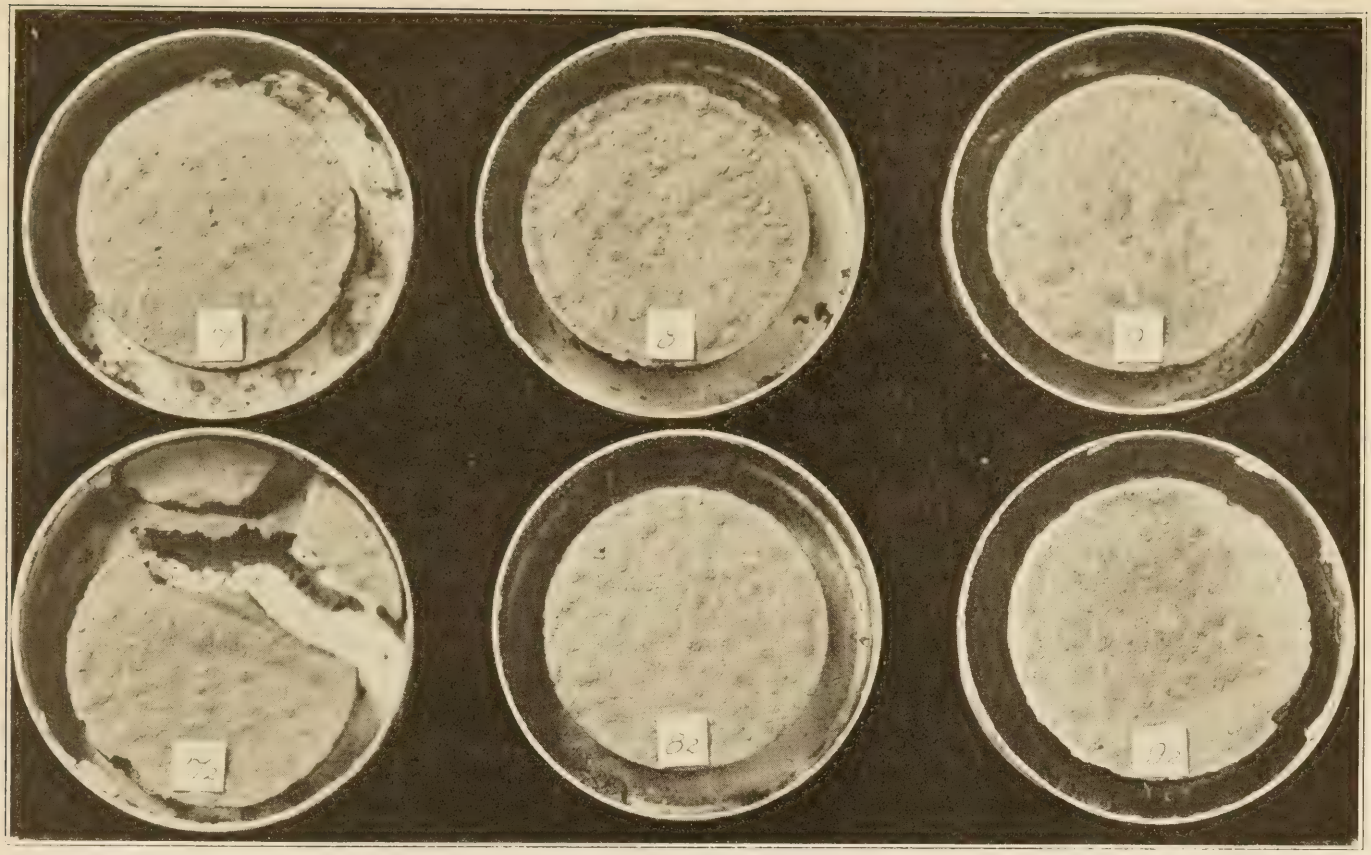
MANAGEMENT.

The actual construction work of the commission was also conditioned by the highway act (*a*) in respect to its permanent character and (*b*) by the first implied order for more than 3,000 miles of highway.

The commission obviously attempted to combine the element of durability in design with rapid extension of mileage. Although the money was theoretically available after the fall election of 1910, no construction was started until August, 1912. There were, theoretically, sufficient funds to allow large planning of the work and the commission took advantage of the opportunity to conduct business on a big scale. They began work deliberately.

In the fall of 1911 they made a comprehensive tour of the State with the highway engineer and established 7 divisions. On the 21st of October, 1912, they signed

[1] First Biennial Report of the Californ 'a Highway Commission, Dec. 31, 1918, p. 40.



SOIL SAMPLES TAKEN FROM ROUTE 5, ALAMEDA COUNTY, SECTION B.

contracts with the Natomas Consolidated of California (a corporation) for 500,000 tons of crushed cobbles at 45 cents per ton, f. o. b., and also contracts with the Russian River Gravel Co. and the Grant Gravel Co. for 175,000 tons of screened gravel at 27½ cents per ton, f. o. b. These were low figures for concrete aggregates and the commission states: "Tended to fix a low price, which had its influence on other producers of concrete aggregates." [2]

Effective October 30, 1912, the commission secured from the Southern Pacific Railroad Co. a local freight tariff for commodities "consigned to and for use by the California Highway Commission" at substantially one-half the prevailing rates. These rates were extended by tariff No. 742–C, one year later.

In the purchase of cement the commission states: "Under unwritten agreement the companies agreed with the commission that during the life of the work the price should not exceed $1.40 per barrel at the mills. This special price, far below the general market price, was made to encourage the use of cement in highway construction."[2] The actual yearly purchases of cement to July 1, 1920, with net prices, are tabulated below:

Year.	Barrels purchased.	Average mill base.	Cost at mill.
1912	142,465.50	$1.240	$176,683.24
1913	242,514.40	1.309	278,376.36
1914	677,790.05	1.325	898,403.48
1915	355,005.50	1.367	485,267.31
1916	110,090.00	1.371	150,958.28
1917	220,794.00	1.454	321,064.61
1918	221,418.00	1.621	359,036.76
1919	231,737.00	2.038	451,270.72
1920 (up to July 1)	43,048.00	2.158	89,699.56
Total and average	2,244,862.75	1.443	3,249,780.32

After the first bond issue of $18,000,000 was exhausted, the cement companies felt that their obligation should end.

When the railroads came under national jurisdiction during the war the preferential freight rates were abolished. On account of difficulty of delivery due to war conditions, which resulted in (valid) claims by the contractor and required stock piling at times, and due to the general rise in prices, the commission has temporarily discontinued to supply materials. They state that during the war the work progressed with increasing difficulty due to high costs, open-top car embargo, lack of bidders, restriction of the Capital Issues Committee and the United States Highway Council, but did not stop. The total of administration, engin-

[2] First Biennial Report of the California Highway Commission, p. 39.

eering, and other overhead costs are very reasonable with the possible exception of the total overhead on maintenance.

STANDARD PAVEMENT DESIGN.

The standard design adopted for the surface was a concrete "base" of 4 inches with a three-eighths-inch wearing surface of asphaltic oil and pebbles. The concrete mix was 1 : 2½ : 5 and the width was 15 feet with 3-foot earth shoulders.

Although the concrete surface was doubtless originally laid as a base, only approximately 43 per cent has been given the oiled surface. The average price of $1.14 per square yard obtained in the earlier years for the 4-inch 1 : 2½ : 5 concrete, including grading and structures, was remarkably low. This price was equivalent to about $10,000 per mile of completed 15-foot road and compared very favorably with the similar price of $1.21 per square yard for oil macadam. Neither price includes either indirect changes or overhead. The corresponding average price for the 4-inch 1 : 2 : 4 concrete laid since 1917 has been $1.84, which is also low. The concrete pavement has probably produced a smoother and more satisfactory riding surface than any of the other types incidentally laid.

This concrete pavement is the thinnest that has been extensively laid in any State and would have been rejected as too thin in any State subject to winter frosts. It is 1 foot narrower than the minimum width of concrete roads built in most other States, and it is believed that under present conditions it is in general 3 feet too narrow. The original mix of 1 : 2½ : 5 was leaner than that extensively used in other States and the present mix of 1 : 2 : 4 is not as rich as usual in several States, but it is believed to be adequate for the traffic. In this connection it is to be observed that California was the pioneer State in adopting concrete as the standard pavement for the State highway system.

The function of the three-eighth-inch asphaltic oil wearing surface or "skin top" has not been completely determined. That it is not a necessary element of construction is evident from a comparison of the service and condition of bare and covered concrete which now exists. It was probably considered that the asphaltic oil top would (*a*) take the wear of travel from the concrete, (*b*) protect to some extent the concrete base from impact, and (*c*) prevent the penetration of water through such cracks as occurred. It has not been observed that the bare concrete itself shows evidence of wear by rubber-tired traffic, which is now almost exclusively the traffic throughout California. Trucks with solid tires, however, cause disintegration at open cracks. It is doubtful if a three-eighth-inch bituminous layer materially lessons impact. A comparison of the data presented in the tables of classification and in the summary class diagram shows that the condition of the pavement covered with asphaltic oil top compares favorably with the bare concrete, but it is noted that because of the presence of the asphaltic oil top the classification of the concrete base beneath was made difficult and in all probability was higher than it would have been had the concrete base been uncovered throughout. To some extent the asphaltic top has sealed the concrete from water during the rainy periods and possibly it has thus prevented softening of the subgrade. It has cost about 8 to 9 cents per square yard and requires considerable repair and renewal, and under nonabrasive rubber-tired traffic it is not believed that it serves a purpose commensurate with its cost. It is more slippery in wet weather than is bare concrete.

The 4-inch plain concrete of lean mix has proved in places very durable. There are 580 (distributed) miles built prior to 1917 that are of classes A and B. Under adverse conditions, particularly of soil, it is evident, however, that a pavement of such thinness has a very low safety factor and is inadequate. Its use has now been abandoned and a minimum thickness of 5 inches of reinforced concrete is required.[3] The original construction produced considerable rough surfaced concrete which, as traffic developed doubtless materially increased impact. On the narrow 15-foot pavement loads passing each other necessarily traveled close to the edge. "The crowfoot" defects are doubtless due to such travel of trucks when the conditions were unfavorable. There is little, if any, decisive evidence that reinforcing introduced in the 4 or even in the 5 inch concrete (particularly of the triangular mesh variety) has proved effective on adverse soils or under combinations of adverse subgrade and traffic. Nor will the widening of a 4-inch pavement to 20 feet eliminate the "crowfoot" cracks which are observed on such width concrete, even in instances on sandy soil.

ORIGINAL DESIGN NOW HAS LOW FACTOR OF SAFETY.

The original concrete pavement design, in short, now has little or no factor of safety and under unfavorable conditions has not withstood the internal stresses produced by traffic flexure and variations in temperature and subsoil moisture. It is doubtful if such a safety factor can be introduced without considerably increasing the mass of concrete. It appears that under adverse soil condition there is considerable flexure with traffic.

To introduce sufficient steel to prevent flexure of a 4-inch or even 5-inch pavement over a shrunken or wet subgrade, or even a loose sandy subgrade is probably a doubtful economy. The existing longitudinal cracks that are accompanied by any separation or by "faulting" along the crack, or by displacement, are evidences of subgrade displacement or settlement or uneven subgrade shrinkage as a primary cause. Such defects are typical either with a single center crack or two longi-

[3] General Orders, 421 and 427, May 1 and Sept. 15, 1920, respectively.

tudinal quarter cracks and the soil moisture sections attached to the report appear to confirm this behavior.

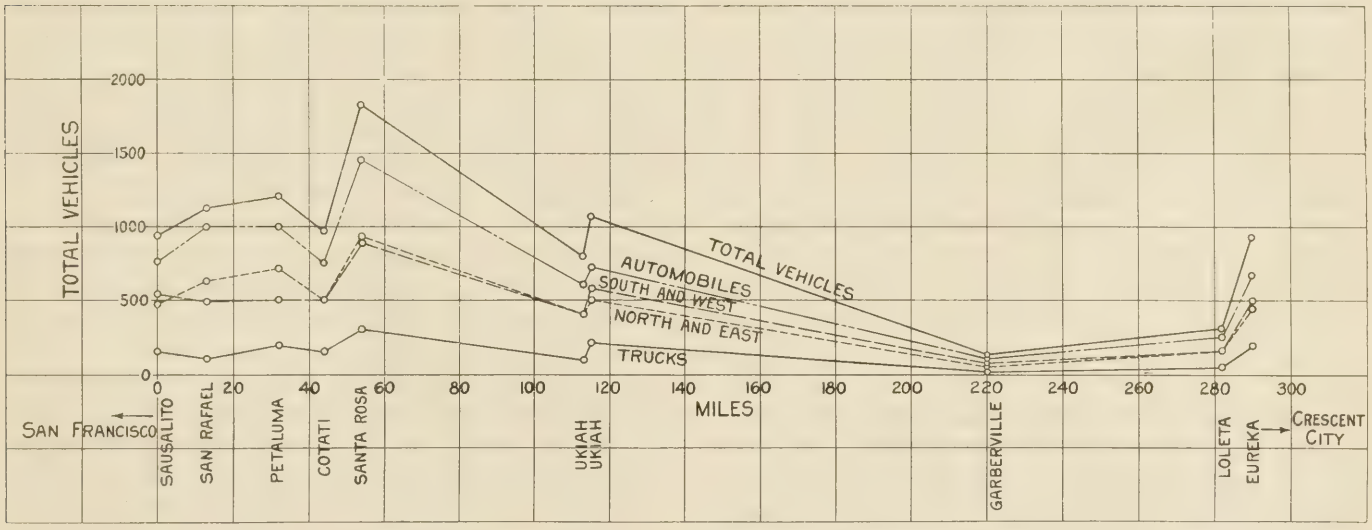
Some special treatment of adverse subgrade soils, particularly of class 1, will be necessary. Capillary action and high moisture retentiveness and violent shrinkage must be met. The amount of admixture or the thickness of protective layers of noncapillary and supporting soils is not yet known. A flat subgrade might help to a slight extent to counteract such defects by eliminating some transverse tension due to normal pressure. The crown of $2\frac{3}{4}$ inches in the present 15-foot standard design may well be reduced is to $1\frac{3}{4}$ inches and with a flat subgrade and an added $1\frac{3}{4}$-inch maximum thickness there is an added factor against center longitudinal cracks.

By January, 1917, the State highway commission had constructed a total of 835 miles, mostly of 4-inch by 15-foot concrete pavement. They continued to build the same type except that the mix was increased to 1:2:4. In the light of the increase in thickness and the addition of reinforcing steel rods in 1920, it must now be inferred that the commission was again in 1917 governed in policy by the necessity for increased mileage. They say with reference to the second bond issue: "The untoward condition accompanying the World War soon set at naught the expectation of completing the State highway system with the proceeds of the second bond issue and the commission for the second time confronting an impossible task is again forced to secure the greatest value receivable with the funds at its command." This bond issue was based upon estimate furnished from 1914–15 figures.

It is noted that the standard plans do not provide for widening the pavement or curves, although some widening of the "lune" type has been done subsequent to construction. The cross sections are in general noticeably "shallow" or "tight" and require a minimum amount of excavation. However, in the northern part of the State particularly, the climate appears to demand more pronounced drainage than has resulted from the present design. The sections do not provide for very pronounced superelevation, which is now frequently and successfully made one-half inch to 1 inch to the foot in many States. It is believed that the width of the main roads should be increased from the present width of 21 to 24 feet to a width of from 24 to 30 feet, except in heavy cuts. The crowns, as has been noted above, could well be reduced to $1\frac{3}{4}$ inches even on a wider pavement.

DESIGN OF GRADE, ALIGNMENT, AND SECTIONS.

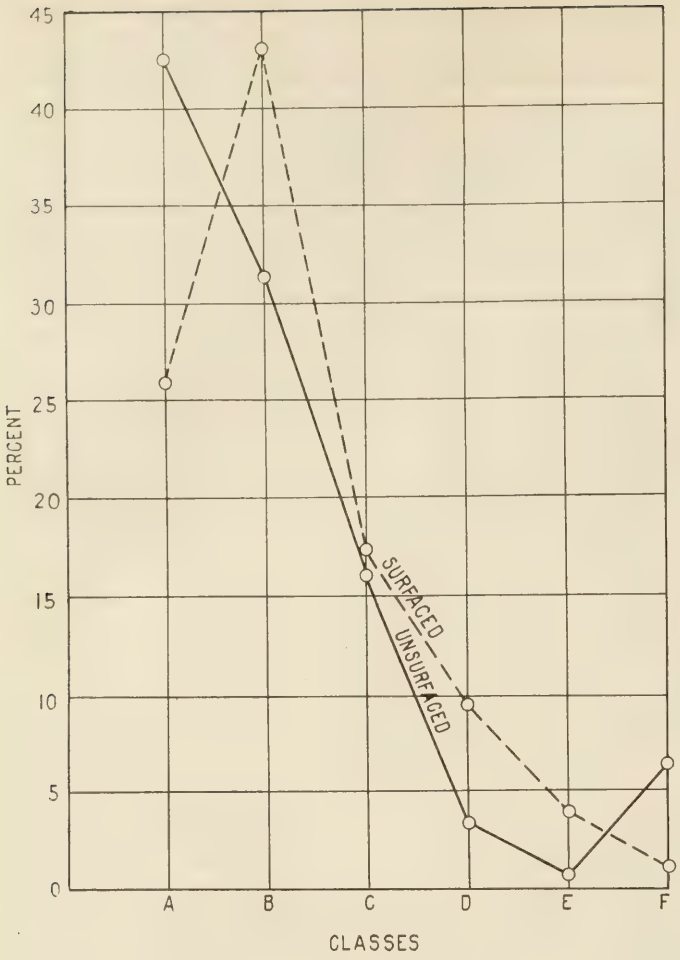
Many miles of the California State highways lie on flat valley floors and have excellent alignment. There are scores of other miles of good location including difficult mountain roads. It is disappointing in the valleys, therefore, to find any location defects such as right-angle section-corner turns and unnecessarily quick reverse curves in passing around railroad station sites and in the mountains and on steeper hills to encounter sharp, blind curves and unnecessary rise and fall. Compensation of grade has not in all cases been sufficient to prevent exceeding the maximum grade if in the future the radii are lengthened.



TRAFFIC DIAGRAM. ROUTE 1, SAN FRANCISCO TO CRESCENT CITY.

It appears that the defects in grade and alignment are due largely to a too strict adherence to a standard. That standard is not invariably economical. A bolder line with considerably increased grading between Eckley and Martinez, for example, would probably not have added much to the first cost and will possibly ultimately have to be built, as this is the main route from San Francisco to Sacramento and is now rather dangerous.

Other locations on hill and mountain roads evidence minimum standards that are too low for trunk lines under present traffic conditions. There are numbers of curves with radii of 50 and 60 feet and grades of 7



PERCENTAGE OF CONCRETE PAVEMENT CLASSES, IN SURFACED AND UNSURFACED PAVEMENT.

per cent that might have been eliminated or reduced at slight additional cost. In a few cases a radical change in line, though doubtless involving added right-of-way costs, would have been a great improvement.

It appears that valuable land has often been avoided and that a location that follows the topography closely has been the rule. These elements have at intervals impaired the alignment and grade.

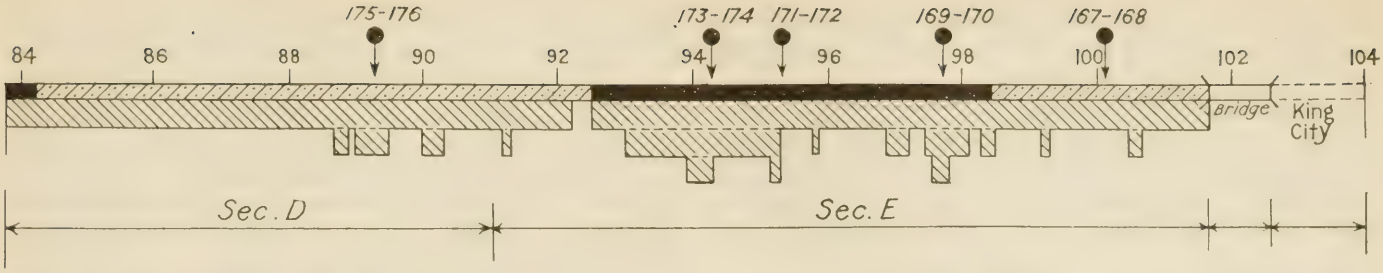
Although the first report of the commission states that travel can proceed at 30 miles per hour over the State highway pavement, it is not safe to travel at that speed at many points, partly because of the narrow pavement and lack of superelevation, but largely because radii are too short. It would appear that where the method of cutting the inside bank to improve sight has been adopted longer radii should have been selected in the first design. In the effort to economize in construction it appears that at times (for example on route 2 between King City and Santa Barbara) too many sharp vertical curves have been used in order to fit the ground.

THE SPECIFICATIONS.

The State highway commission has until recently adhered to the 1912 specifications with few changes. These specifications appear to have been rigidly enforced. The grading has been neatly finished and the subgrade evidently well prepared. The original lean concrete mix of 1 : 2½ : 5 for a pavement should have been abandoned sooner and the permission of 6 per cent of the fine aggregate passing a 100 screen allows a possible excessive clay content. The requirements for coarse aggregate, with respect to size, grading, quality, and cleanliness, are, in the light of recent developments, somewhat inadequate. It is believed the specifications should also exclude the use of alkaline or salt water and permit larger aggregate than 2½ inches. The originally required rough finish has been abandoned, but the finish now obtained can be improved. This rough finish was evidently for a pavement base but it shows through a ⅜-inch top and, where not covered, has doubtlessly tended to increase impact. The old specifications for mixing until texture and color were uniform were evidently unsatisfactory and have been abandoned in favor of a 10-turn or 1-minute mix. The requirements for curing by ponding or wet earth cover are excellent, but some checking due either to lax enforcement of this provision for curing or to a too wet mix has occurred. The omission of transverse joints appears to have been a justifiable innovation, particularly in a frostless country, but it is believed there should be exception to this practice. The present requirement for concrete mixture of 1 : 2 : 4 if laid dry it is believed should produce a good pavement for traffic preponderately rubber tired, but it is remarked that several States use a richer mix. Reinforcement has not been required until 1920, but the present specifications for about 42 pounds of one-half and three-eighths inch steel rods in the center plane per 100 square feet it is believed are excellent. The triangular mesh reinforcement used on Federal-aid project No. 1 was a failure due possibly to improper placement.

With reference to Topeka specifications it is believed that an asphaltic oil of penetration not exceeding 70 should be specified, especially where the temperatures exceed 100° F. and where traffic is also unusually heavy.

With reference to oil macadam, eastern experience indicates that a surface treatment with the largest quantity of oil specified (1¾ gallons) will work into ridges and lumps under traffic. It may be inferred also that with oil paid for by the barrel there will be a corresponding tendency to use the maximum amount. Numerous cases of "viscosity waves" are observable throughout the State.



CLASS CONDITION DIAGRAM. ROUTE 2, MONTEREY COUNTY. THE VARIED HATCHING IN THE UPPER RECTANGLE INDICATES DIFFERENCES IN THE SUBGRADE SOIL; SOLID BLACK REPRESENTS ADOBE AND CLAY AND THE OTHER MARKING SANDY LOAM. THE CLASS OF THE PAVEMENT IS INDICATED BY THE DEPTH OF THE RECTANGLES BELOW, ONE STEP REPRESENTING CLASS A PAVEMENT, TWO STEPS CLASS B, AND THREE STEPS CLASS C, ETC.

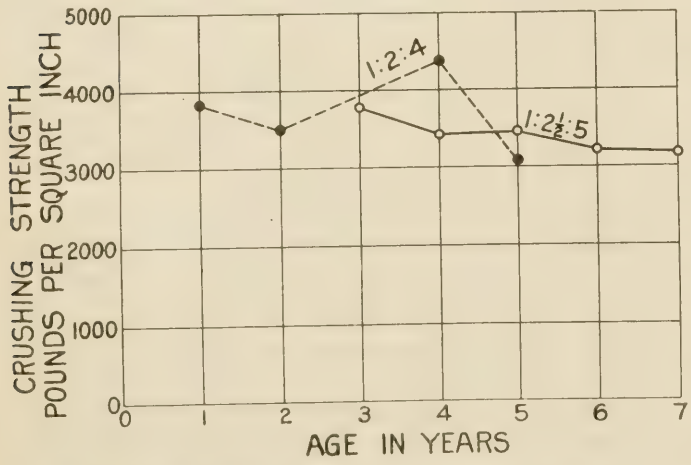
It is remarked that in general the specifications for concrete have, as shown by the tested samples, produced good quality and that they have permitted an economic use of local material with a minimum of failures.

FURTHER DISCUSSION OF POLICY OF EXTENSION OF MILEAGE.

It is necessary in a critical analysis of the standard design to which the State highway commission has adhered for eight years, to make full allowance for the advantage in extension of services made possible by its use. That this concrete construction was begun as a base, however, must not be overemphasized since it was continued for 694 additional miles notwithstanding that supplementary surfacing for financial or other reasons was omitted. The design must be judged as above indicated with reference to the *necessity to extend service and with respect to its continuance under the second bond issue, and in addition with reference to its upkeep and its adaptability to supplementary construction* in those cases where it fails owing to increase in volume or intensity of traffic or other causes.

It is to be remarked that the total motor-vehicle registration in 1920 is about six times that of 1912, and the total truck registration is approximately six times the 1915 figures. The State highway commission has as yet taken no State-wide traffic census.

That the thin, narrow pavement and close grading enabled the rapid extension of very serviceable miles of road is without question, and that the implied order in the legislative act of 1909 demanded extension is equally evident. The voting of the second bond issue in 1915 and the third in 1919 might, in a sense, indicate such a capacity for road financing by the State as to deny the assumption that the State of California, at any time, was obliged to take chances with thin pavement in order to produce mileage, but it is undeniable that the very extension of the pavement developed sufficient sentiment to provide additional money in 1915 and again in 1919. So it can not be said in 1920, in the light of the fact that the great usefulness of the highway system is now proved, that the State would have realized its usefulness and provided funds in equal volume had not the system been extended as rapidly as it was and at some sacrifice of either temporary or ultimate durability to increased mileage.



RELATION BETWEEN AGE OF CONCRETE IN YEARS AND CRUSHING STRENGTH.

There appears, however, to be a serious question, in the light of the fact that 70 per cent of the defective pavement of classes D, E, and F occur on clay and adobe soils, as to the wisdom of a policy which continued the risk of a thin slab on such soils. It is undeniable, however, that a large mileage of the same thin pavement and on adverse soil still remains of classes A, B, and C. We find, however, no conclusive final demonstration of the best construction on the adverse soils, and in that respect failure to vary the design on such soils in the past has postponed the solution of this problem.

The concrete itself is shown by the tests of the sample cores and other samples to be uniformly good; its weight per cubic foot and absorption are practically constant and the amount of coarse aggregate also. The crushing strength averages well above 3,000 pounds to the square inch. There is raised by the diagram of crushing strength by years a question as to whether or not the concrete may be slowly deteriorating, but this condition has not been conclusively proved. More study of this phenomenon is required before any conclusion can be reached. Certainly the slight indicated decrease in strength would not account for any of the adverse conditions found in the pavement.

The question of initial extension versus durability of design is further discussed under the topic of economics with reference to the indicated operating income. There seems grave question, however, as to

the decision in 1917 to continue with the construction of pavement of a low factor of safety. By that time it would seem that the behavior of the design on adverse soils should have been known. Still the change to a mix of 1:2:4 appears to be reflected in the class conditions since only 48 miles of the construction, beginning with 1917, has gone into classes D to F, inclusive, while 109 miles of construction prior to that time are in these classes.

The adaptability of the pavement laid to supplementary construction when it fails is indicated by about 37 miles of this work already done with 30-inch concrete shoulders and 1½-inch Topeka or other bituminous concrete surfacing and with "second-story" concrete. None of this work is sufficiently old to prove its ultimate durability. At present it appears to be carrying traffic with success. The expense of extensive repairing of certain sections prior to such reconstruction has been necessarily heavy. Much of the work so far done has been on roads in such sections that the cross section has not been a serious item, but in many places the roadbed will have to be widened before such supplementary construction of shoulders and surface top can be done.

PRESENT CONDITION OF CONCRETE PAVEMENT.

With reference to the classification adopted for determining the present condition of concrete pavement, it is to be noted that for 4-inch concrete pavement class A is a rather abnormally high type. Pavement of class B, in the light of the present stage of development of concrete roads, appears to be a very normal type of concrete pavement; that is to say, transverse cracks at intervals of approximately 25 feet in a 4-inch pavement without joints may be considered characteristic. Pavement of class C where no separation or faulting follows or accompanies the longitudinal cracks in a 4-inch slab is not unexpected. But where faulting occurs along the longitudinal crack or where there is a distinct separation of the two edges of the crack, an unusual condition is present and the pavement must be regarded as considerably impaired as a structure. Such cases are not infrequent. Pavement of this class C may, however, and usually does, carry traffic without inconvenience. "Crowfoot" cracks at the edge of the pavement in any considerable number are distinct defects; they are not normal and are a characteristic type of defect, and, when followed by settlement or disintegration, impair the service of the road. Pavement of class D in which occurs many areas of concrete of about 50 square feet is decidedly defective, and when accompanied by settlement the service of the road is slightly impaired. Pavement of class E is a failure, and the classification F usually indicates that the concrete itself was bad or that the design of the pavement was inadequate. Travel on this type F is in some instances quite difficult.

The State laid 1,365 miles of concrete and 1,262 miles were classified. Of that classified, 157 miles, or 12.5 per cent, was found in classes D, E, and F, but the degree of impairment is somewhat greater than the percentage, since the defective pavement is distributed throughout the State. The pavement in class F was largely concentrated, and less than 6 miles remain unrestored. The pavement in classes E and D will require reconstruction or heavy repairs and supplementary construction in the immediate future; there are about 114 miles of these two classes.

CONSTRUCTION AND MAINTENANCE.

An analysis of construction and costs shows a rapid building of the important trunk highways to approximate completion and at a very reasonable cost. The total average percentage of construction costs on both day-labor and contract work, chargeable to administration, engineering, and overhead, is 15.86 per cent, and is reasonable. In view of the recent rise in prices, the overrun of 6.24 per cent over the engineer's estimate on final total payment is low. On day-labor jobs this corresponding percentage is higher, as expected, but it is not excessive. Analysis of the 20 jobs, both contract and day-labor, which presented the greatest apparent percentage of overruns shows adequate reasons in practically every instance for such overruns of the estimate.

The accounts in the headquarters office on all work were found very complete and without discrepancies, and the cost figures here presented are accurate and official.

The direct charges for maintenance and improvement are found not to be excessive; the overhead and indirect charges, however, are apparently 19.2 per cent, overhead alone 12.5 per cent, which seems rather excessive. The direct control of maintenance of State highways by the State and the application of the net automobile revenues to this work is believed to be an excellent arrangement. The organization of maintenance under a headquarters maintenance engineer operating through the seven division offices appears adequate, though in some instances rather important job work appears to require more competent direct supervision.

There are at present under maintenance a total of 3,293 miles of State-controlled roads. These include 1,524 miles of earth and gravel roads, including special State roads built prior to 1912, and about 150 miles of oiled county pavement which the State has acquired from the counties. The expenditure for maintenance and improvement of earth and gravel roads is nearly one-third of the entire expenditure.

Since the law now allows the automobile money accruing to the State highway commission to be used for "improvement" it is found that considerable gravel and other surfacing has been done from this fund. The complete analysis or tabulation of distributed maintenance and improvement costs for each original project built, by types and by years, was not attempted, but the data for such analysis, while sometimes confusing, exists in the headquarters records.

Sufficient investigation of the maintenance books was made to determine accurately the unit costs and the summary costs.

It appears that up to 1920 the commission has thought of necessary travel more in direct relation to the increasing maintenance costs rather than in respect to its influence on design of new construction. In this connection it is to be observed that in 1912 the increase of traffic could not be foreseen but it would appear that by the end of 1915 when 1912 registrations had nearly doubled that the 1918 registrations should have been foreseen.

ADMINISTRATIVE AND ENGINEERING ORGANIZATION.

The organization was highly developed. It has continued with little change since 1911. During the war, in common with other State highway departments, it was impaired by loss of personnel and its work hampered by bad industrial conditions. It is not unwieldy and in form is unusually well adapted for the large scale operation it has conducted. The salary scale is good.

The details of the engineering standards are carefully thought out and unusually complete. The standard plans and drawings are excellent, and the clear-cut precision of all engineering operation makes for speed and efficiency. The cost of all overhead and administrative and engineering items on contract jobs has averaged, as mentioned, 15.86 per cent, which in view of the average low cost of construction per mile, is very reasonable, as is similarly 15.88 per cent on day-labor jobs.

There is some evidence of a cramped condition in the functioning of the organization. It appears that headquarters' control is so complete that it may inhibit those reciprocal actions necessary for healthy growth. There is a good opportunity with such an organization to develop this reaction function and initiative of the engineering employees who are in first-hand contact with the job. With the extraordinarily efficient directive functioning in all details, a corresponding return functioning of the organization through the division engineers to headquarters is desirable to develop new ideas with the extension of contact with the job. More initiative and authority would increase efficiency; thus the significance of the adobe reaction might have developed sooner and better alignment could have been produced by changes authorized during construction from reports by resident engineers.

The procedure in advertising and letting of contracts appears to be satisfactory. Some of the early contractors were inexperienced in road work and lost money. This condition has frequently occurred in other States. There is some apparent delay in the completion of final payments due to the routing of the paper.

CONVICT LABOR A SUCCESS.

The State highway department officials report favorably regarding convict work. They bring out these points:

The inaccessible, difficult, inspiring, and remote regions selected proved of advantage as environment and eliminated any criticism of competition with free labor or contact with undesirable "free" citizens.

The kind of work selected—heavy grading and clearing and grubbing—has been well adapted for success.

Unguarded, honor, and long-term convicts work best.

Good camps and food pay, and the outdoor life is wholesome.

There was difficulty at the start, due to dual administrative control by the State prison authority and the State highway commission authority. This conflict was eliminated, and with reward for good behavior and punishment for misbehavior, the work of the convicts has proved economical, especially during the war.

ECONOMIC AND OTHER STUDIES.

The one-day traffic at 103 stations on the State highways is an index of the use of the roads. This traffic day was distributed between August 7 and October 14 and throughout the State, and the assumed daily average total of 2,500,000 vehicle-miles should be representative for the summer interval, or say from June 1 to November 1. The resulting total vehicle-miles of 375,000,000 is 70 per cent on the *State paved highways alone*. There results 262,500,000 vehicle-miles indicated service by such paved highway. The operating income at 5 cents a vehicle-mile is $13,125,000.

To this amount must be added an operating income for the service interval November 1 to June 1. This latter amount can not be based on a traffic figure, but a minimum figure would indicate a total annual operating income of $20,000,000 for 1920.

For preceding years when there were less miles of State pavement and fewer vehicles the operating revenue can not be placed at a greater figure than the corresponding per cent of this total. Thus in 1919 with an average of, say, 450,000 motor vehicles in use, or 90 per cent of the 1920 average, and 93 per cent as much paved highway, there could not have been more than 83 per cent as much corresponding operating income. If the figure is placed at $15,000,000 there results an indicated gross operating revenue in the last two years of $35,000,000.

The element of assumption in the above reasoning is regarded as conservative. It is unnecessary to extend the computation to make immediately evident that the operating income from the State paved highway system alone since 1913 has more than equaled the total expenditure for construction and for repair, improvement, and maintenance of the entire mileage paved and graded by the State. The operating income from the graded portion and the portion built by the counties and acquired and maintained by the State has been disregarded. A corresponding decrease in operating revenue to the community would have occurred had the mileage been shortened by constructing a more durable type.

It is observed that during the decade 1910 to 1920 the estimated value of agricultural products has in-

creased over 300 per cent, the population of the entire State 44 per cent and the *population on the highways*, exclusive of the two largest cities, 63 per cent.

These facts are evidence that the policy of extension of mileage of serviceable pavement was justified in the initial period. Highways, like the railroads, build up business, and a period of supplementary construction follows without financial strain because of increased operating revenues. The advertising value of the highway system has without question added to the population and to the tourist attraction.

STATE CAN NOW AFFORD TO RAISE STANDARD.

Although for the most part the service rendered by the roads built is still uniformly good, it is very evident that the State can now well afford to raise the standard of construction. This standard must satisfy all motor-vehicle operators. The increase in the use of the trucks will doubtless for a time be increasingly rapid. It has been over 500 per cent in seven years and 250 per cent during the past three years and will demand a greatly increased factor of safety in the pavement.

But the increase in motor-registration figures can not be the only index of the future duty of the roads. Additional information useful for the State highway commission can be secured by elaborating the form used for registration, but the necessity of comprehensive traffic census at frequent intervals is great. Only a traffic count will determine the distribution of highway operations and yield corresponding control both of design and maintenance allotments.

The maintenance and repair operation in the past period has involved excessive patching in certain sections due to the thin 4-inch pavement and the increase in traffic volume, weight, and speed. In the future, however, the demand for better quality of pavement service will become more exacting and the increased traffic will require maintenance for various items on any type or standard of pavement, so that as the system develops the aggregate maintenance charge may be expected to increase.

There is evidence that relatively few vehicles have excessive total loads, but field weighings showed a large percentage of overload of trucks per linear inch of solid tire. Unfortunately the exact record of this item was lost. It must be inferred that the infrequent and incidental heavy load is very destructive. Defects of the "crowfoot" type in the pavement are regarded as due solely to traffic impact on the thin slab with adverse subgrade condition. Not only heavy soils but also sandy soils underlie defects of this type, nor is a 4-inch pavement of greater width exempt from such defects. Excessive transverse cracks are also inevitable in a thin slab with any combination of adverse traffic and subgrade conditions.

Whatever design is adopted and whatever the legal speed and loading, there is evidence that increased enforcement of the law is required.

CONCLUSIONS DRAWN FROM THE STUDY.

The State highway system has, in general, been well selected and laid out. The mileage prescribed by law has far exceeded the funds and this discrepancy distorted the policy. The mileage remaining to be built is far in excess of the combined capacity of the third bond issue and all available Federal aid.

The deferred serial type of highway bond adopted is good, but the longest terms of every issue (44–45 years) are very excessive and the long terms will require millions of needless interest. The amounts of money were sufficient to permit planning of comprehensive construction programs and economy of large operations. The legal restrictions on the bonds were seriously embarrassing.[4]

The order of selection and construction of roads from year to year has been largely controlled by necessary policy.

The policy of permitting unpaved exceptions in small incorporated towns is uneconomical and impairs the efficiency of service of the State highways.

The financial administration has been scrupulously honest and careful and the administrative and engineering costs have not been excessive, nor have final costs much exceeded the engineer's estimates.

Convict work has been successful, especially during the war and from both aspects—the road work and reflex effect on the convict. It has been found necessary for success largely to eliminate dual control of convicts on the job. The State prison funds clearly should bear some expense.

There has been a conspicuous growth of motor vehicle registration in California during the past construction period and a corresponding increase in volume and intensity of traffic. The commission evidently did not anticipate this increase and did not provide for it in their original design, nor did they count the traffic throughout the State. A very careful traffic census should be taken at intervals.

It is not believed that modern rubber-tired traffic on a smooth concrete road is abrasive, although solid-tired vehicles doubtless produce some breaking down of edges of separated cracks. No definite correlation was found between total number of vehicles and condition of the concrete pavement itself, but the total traffic does largely determine the wear of shoulders and in many places it does indicate a too narrow width of pavement. It is believed that the impact of excessively heavy loaded trucks, particularly at high speeds, is very destructive to a thin narrow pavement on adverse soils, but it is evident from the data that such trucks are in a small minority in California. Truck traffic is increasing and size and number of commercial passenger busses is very noticeable and there may be expected a parallel increase in the development of commercial freight motor-truck traffic. Passenger busses are already operating on the 15-foot pavement

[4] Such restrictions were removed by the vote of Nov. 2, 1920.

to the disadvantage of other traffic and the law allows a total width of farm load of 10 feet, which is excessive for such pavement.

State authorities can not control the volume nor the distribution of traffic on the State highways, but complete and effective cooperation between the State highway commission and the motor-vehicle department controlling the character of traffic is necessary. The creation of a special State police exclusively to enforce the vehicle laws may be required.

ROADS HAVE PAID FOR THEMSELVES.

There is a very large annual operating revenue to the community from the State highways. The total of this revenue has probably paid for all construction costs to date and would have been correspondingly decreased with less mileage.

A sum equal to the total net motor-vehicle fees at the present average rate will probably always be required for the absolute maintenance and improvement of State highways as construction of the 5,560 miles progresses. The original theory of a license to operate a motor vehicle is obsolete in a community where 97 per cent of traffic is by motor and the registration fee becomes a charge for use of the road. Systematic financing of the upkeep will ultimately adjust the average fee to the requirement of upkeep and also adjust the fee to the vehicle type to more closely indicate the wear produced. An immediate increase of the State's share of the net automobile revenue would be good economy, as a large mileage of defective concrete road must be at once repaired and resurfaced.

The tables and the diagrams of condition and the statistics of sample core and soil tests clearly indicate:

(*a*) A correlation between defective pavements of classes D, E, and F, and adverse soil subgrades; about 110 miles or 70 per cent of 157 miles total of these three classes occur on soils of class 1, which includes all adobe soils.

(*b*) That since the average corrected testing strength of concrete cores is above 3,000 pounds to the square inch the concrete itself is not generally defective in strength nor does it show any wear by traffic.

(*c*) The average class condition of all concrete pavement indicates a slow progressive deterioration with the age of the pavement, and indicates also that the type built tends to reach its approximate stage of classification comparatively soon and thereafter to change more slowly.

(*d*) The diagram showing average strength as determined by cores tested from concrete laid during the various years indicates that there may be a slow progressive deterioration of the concrete itself, or "fatigue" in a thin slab subject to excessive flexure.

(*e*) There is no conclusive indication so far that the previous reinforcement in a 4-inch or 5-inch slab has produced a measurable increase in the quality or durability of the pavement.

(*f*) Diagrams in the report show a slight superiority in the average condition of the concrete pavement surfaced with the three-eighth inch oil top, but in view of obscured classification there is no demonstrated marked superiority of oil surfaced pavement.

(*g*) Typical longitudinal (and other) cracking found on adverse subgrade soils, and shown by many of the 7,500 photographs now on file in the Bureau of Public Roads, indicates a distortion of the subgrade due to varying moisture content and shrinkage. The diagram showing lines of equal moisture content clearly indicates the influence of the concrete pavement in preventing evaporation. The high capillarity of adobe soils and the great shrinkage in the long hot summers thus produce very unfavorable conditions for a thin pavement under increasing traffic.

All pavement of classes D to F, inclusive, which totals 120 miles and much of which is on adobe soils, is doubtless deteriorating and demands immediate repair and supplementary construction. It is doubtful if much of the pavement of these classes, especially on adobe, will ultimately prove an adequate base for a 1½-inch Topeka top. An adequate "second-story" concrete if extended to a total width of 20 feet to thus include two new concrete shoulders of full depth is to be preferred.

STRONGER PAVEMENTS DEMANDED.

There are sufficient typical failures to show that in the future only designs of increased strength and adapted to resist such failure should be used. Every possible precaution will be necessary to prevent failure on adverse subsoils of adobe, clay-adobe, or similar soils. On such soils, in the absence of any proved successful design, only short sections of tentative design should be attempted, or there should be first developed frank experimental construction to determine a workable and economical design.

Such a design will require the reinforcement now provided by the commission, a more massive type of concrete not less than 6 inches in average depth, some adequate corrective treatment of subgrade and possibly a form of "mulching" of shoulders to prevent evaporation. A flat subgrade is desirable and less crown.

It is believed that on the main roads more satisfactory results will follow a considerably bolder standard of location on hill and mountain grades and that an increase in width of pavement to a minimum of 18 feet is now desirable, with more systematic widening and superelevation on curves.

Under modern traffic conditions there is an increasing demand for unimpaired alignment and fast travel between centers. To this end designs of highways must produce in general a road that can be traversed at a speed of 30 miles per hour throughout and without excessive operating costs due to changing speeds, etc. Therefore, first economy in grading becomes of rapidly decreasing advantage and must give way to the increased safety and comfort of travel.

There would be advantage in some exceptions to the present standard of no transverse joints. In the hot valleys considerable buckling of the 4-inch slab occurs with attendant disintegration in infrequent instances. This tendency to buckle would doubtless be reduced by

a thicker slab. Experiments with transverse joints at varying intervals is desirable on adverse or adobe soils. The future pavement will require a much larger factor of safety.

The policy of construction of grading and drainage structures and gravel surface only on certain roads in districts 1, 2, and 3 in particular, was economically sound and deferring of paving up to the present doubtless justified. Through roads with a minimum of unimproved gaps and with adequate standard for most interstate travel have resulted from this policy.

A high standard of design and workmanship is displayed by the structures and the costs have been very reasonable. Many bridges exhibit attractive designs of unusual elegance. In many places the side-hill type of inlets is not functioning. The prevailing type of guardrail is a reflection of the original purpose to protect horse-drawn traffic and might be modified to advantage in maintenance cost. Railroad grade-crossing elimination, where undertaken, has been well done and will require constantly more attention and investment of State funds.

The standard of finish on concrete pavement has improved, but it is believed that still greater refinements will constantly be demanded and will probably pay in reduction of impact and resulting injury to, and by traffic. It is not believed that the continued use of the three-eighths-inch oil top is justified by past experience; the concrete should be laid not as a base but a wearing surface.

There is nothing presented by the entire California study that indicates that concrete is not a successful pavement. One of the clearest results is the emphasis on the need of better subgrade protection. Highway grading is more exacting than railroad grading.

There should be further studies in respect to—

(*a*) Traffic, with a new traffic census before June 1, 1921, and periodically thereafter.

(*b*) The indicated slow deterioration of the existing concrete, with continuing core tests.

(*c*) Soils, including a considerable elaboration of the moisture-content study in pavement protected subgrades, a determination of the thickness of necessary protective soils layers on adobe and of the required percentage of admixture to lessen shrinkage and increase the bearing power, and a further study of capillarity and critical moisture content.

(*d*) Alkali and its effect when present in the subgrade or in the mixing or ponding water.

It is believed that the motor-vehicle registration law should provide separate records of the numbers of (*a*) all commercial trucks, including rubber-tired trucks, (*b*) all public freight trucks of certain important classes, (*c*) all foreign cars, and (*d*) all public passenger-carrying busses and should contain strict provisions regarding tire conditions on all solid-tired trucks with respect to the minimum rubber cushions and flat tires, or projections, etc.

The work of the State highway commission and the highway engineer shows a continuous and intelligent devotion to public duty. Their construction operations have been widely extended under greatly varying conditions. A high degree of standardization was doubtless necessary and is evident. The failures (12.5 per cent of D, E, and F pavement) are not extensive and some were inevitable on large scale work. The 4-inch, 15-foot concrete pavement was continued beyond the point of success on adverse soils and more time will be needed to develop a type of construction certain of success on such soils. The operations have produced a large mileage of very serviceable road and from an economic standpoint are conspicuously successful and of continuing benefit to the State. The operating income from the highways is now sufficiently large to insure the economic success of a considerably increased standard of production.

OH, FOR A SIGN AT THE TURN OF THE ROAD.

"Where is the road to Tumbleday?"
I asked a farmer making hay.
"Just keep straight on, that 'airs the way,
You cain't git off the road, I'll say."

So we drove on a mile or more
And then let out a swearful roar;
For there the road was split in two
And we knew not the thing to do.

No sign was there to indicate!
The way to go was left to fate,
And she was mean; we took the right,
And lost a day and half a night.

That road was hard and smooth and fine,
For forty rods—or forty-nine.
Beyond, great bumps were on its spine;
Its health had entered a decline.

It narrowed down, by stone walls bound,
So autos could not turn around.
And ne'er a thing for us to see
But worse and worse variety.

Rocks, stumps, and gullies on it lay
Till goats could scarcely climb that way.
And sand and mud were there so deep,
Our engine quit and went to sleep.

Footsore and mad we found the end
Of that bum road around a bend.
And there we saw (with feelings hard)
It petered out in farmer's yard.

We also learned we should have took
That other road which we'd forsook!
It cost much time, and fifteen bones,
To get hauled back through mud and stones.

And now I plead for just one sign
Where forked roads do intertwine,
Or where they cross, or come and go,
To points the stranger can not know.

And how I wish there lived so keen
A man who had within his bean
A notion clear to give to you
Of how to get beyond his view.

—*George E. Ladd.*

9,231,941 MOTOR CARS AND TRUCKS REGISTERED BY THE STATES IN 1920

By ANDREW P. ANDERSON, Highway Engineer, Bureau of Pubic Roads.

A TOTAL of 9,231,941 motor cars, including commercial vehicles, were registered in 1920 in the 48 States and the District of Columbia. There were also registered a total of 239,102 motor cycles. The registration and license fees including those for chauffeurs, operators, and dealers, amounted to a total of $102,546,212.25.

As compared with 1919, the data for 1920 represent an increase of 22 per cent, or 1,666,495 motor cars. This increase alone lacks only about 4 per cent of being equal to the total registrations of the United States for the calendar year 1914. In this connection it is interesting to note that the number of motor cars registered in 1920 in the State of New York exceeded the total cars registered in the United States in 1910. Furthermore, the revenues derived from the registrations in the State of New York in 1920 were about equal to the entire registration revenues of the United States for the year 1913. The revenues derived from all registrations and licenses during the year 1920 exceed those of 1919 by 59 per cent or a total of $37,848,596.67, which increase is practically equal to the total registration revenues of the United States for the calendar year 1917.

GREAT INCREASE IN REVENUES.

The increase in the motor-car registrations and revenues in the United States during the past 14 years presents many interesting comparisons. This is especially true in respect to the use made of the revenues. In 1906 the total registrations were approximately 48,000 cars, paying a gross revenue of about $193,000, or about the same as that collected by the State of Arizona during the year 1920. In 1906 the gross registration revenues were equivalent to less than three-tenths of 1 per cent of the total rural road and bridge expenditures for that year, while the registration revenues for 1920 are equal to about one-fourth of the total rural road and bridge expenditures for the calendar year 1919. Furthermore, while in 1906 practically none of the motor-vehicle revenues was applied to road maintenance or construction, 95 per cent, or a total of $97,671,742.10, was used for this purpose in 1920, and of the total amount applied to road work, 79 per cent, or $77,527,518.29, was expended under the control or supervision of the several State highway departments. The remaining 5 per cent not applied to road work was expended very largely for number plates and in carrying out the provisions of the motor-vehicle registration laws in the several States.

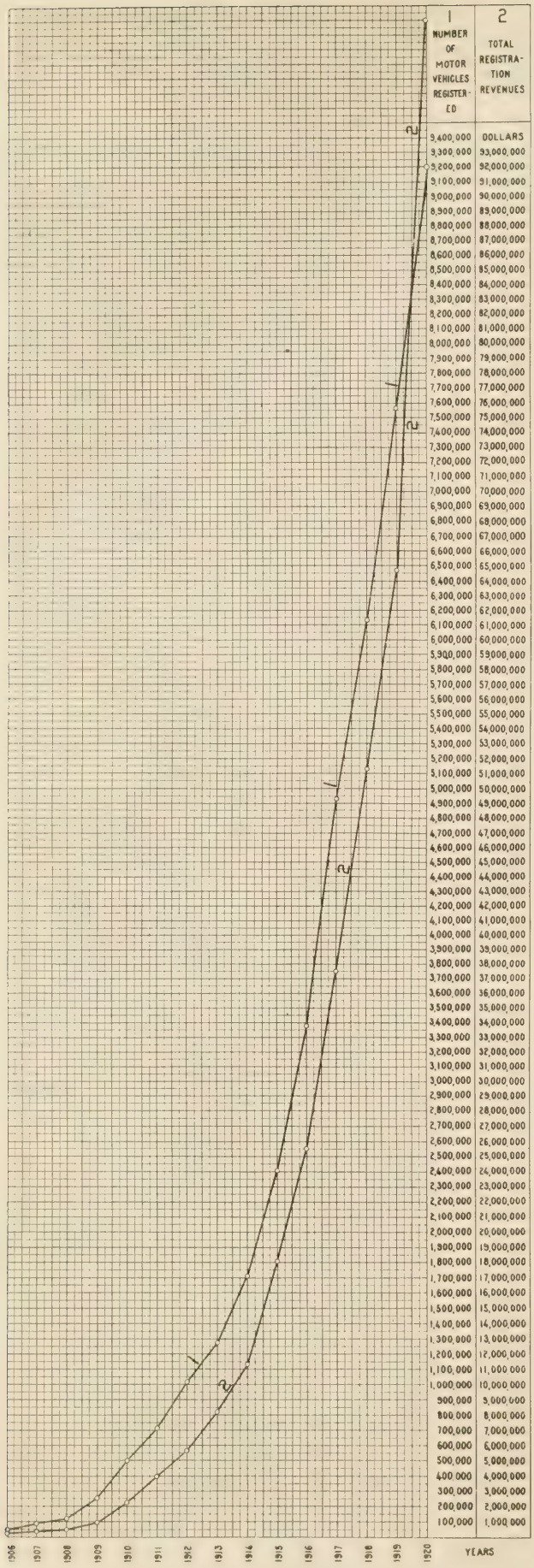
On January 1, 1921, every State but Minnesota had made provision for some definite form of annual State registration. In Minnesota a three-year registration period ended on December 31, 1920. The registration figures for Minnesota, therefore, are the total number of cars registered during the period of three years. How many of these cars have been removed from the State or have been scrapped there is no way of determining. A few States make as yet no distinction between original registrations and reregistrations or transfers. Consequently in these States the number of registrations is in excess of the actual number of cars. In most States, however, the registration figures represent fairly accurately the actual number of cars in the State during the year.

MORE MONEY GOES TO ROAD WORK.

For a number of years the general tendency toward devoting an ever-increasing portion of the net motor vehicle revenues to road work under the control and direct supervision of the State highway departments has been very noticeable. Prior to 1912 only a very small portion of the motor vehicle revenues was devoted to road work under the State highway departments. In 1920, however, 76 per cent of the total motor vehicle revenues, or $77,527,518.29 was applied to road work under the direct supervision of the State departments, and $20,144,223.81 additional was applied to road work by counties or other local subdivisions but with little or no direct supervision from the State highway departments.

In most States the motor-vehicle revenues are devoted to maintenance and repair of the State roads or other improved highways. These States thus seem to have solved fairly well the difficult problem of securing funds for the maintenance of the more important roads under the ever-increasing traffic requirements. As both the traffic and the revenues increase with the number of cars, there seems to exist a possibility of so adjusting the registration rates as to keep pace with the ever-growing maintenance changes.

A number of States having in general but a small mileage of improved roads have recently adopted the plan of capitalizing the motor-vehicle revenues and devoting these funds to road construction. These States are Illinois, Maine, Minnesota, Missouri, Nevada, Utah, and Wyoming. In these States bonds have been voted or issued for road construction, and the principal and in some cases also the interest is to be paid entirely from the motor-vehicle revenues. There seems to be no doubt that these revenues may be made sufficient for this purpose. The question as yet to be solved by these States is: From what other source can sufficient maintenance revenues be secured so as to prevent the deterioration of the roads constructed from the bond issues?



HIGHER TAXES FOR HEAVY MOTOR TRUCKS.

At the beginning of 1921 there were still seven States in which motor trucks were registered at the same rate as passenger cars. The past five or six years, however, have shown a very decided tendency toward increasing the fees required for heavy motor trucks over and above those required for passenger cars. This increase is usually based on the weight of the truck, its carrying capacity, its horsepower, or a combination of these factors. The most general practice seems to incline toward definitely limiting the maximum total loaded weight of the vehicle and basing the registration fee on the carrying capacity of the truck. Some few States have adopted a scale of fees which in actual practice serves to make the operation of very heavy trucks unprofitable. A number of States have also provided legislation to limit the maximum wheel load per inch of tire.

It is unfortunate that the term motor truck and commercial vehicle is as yet rather indefinitely defined in the laws of a number of the States. In a few States no distinction is made between passenger cars and freight-carrying vehicles, while in one State only trucks used for hire are classed as commercial vehicles.

SIX STATES TAX GASOLINE.

The States of Colorado, Kentucky, New Mexico, North Carolina, Oregon, and Washington in addition to the registration fees, also levy a State tax on gasoline or other products used for the propulsion of motor vehicles. In Alabama, Delaware, Idaho, Iowa, Michigan, New Hampshire, New York, North Dakota, Oklahoma, Oregon, South Carolina, Pennsylvania, Tennessee, and Vermont the registration fees are in lieu of all personal property taxes. In other States, however, motor cars are taxed as personal property in addition to the required registration fees. In comparing the registration rates in the several States this fact should be borne in mind.

The registration of automobiles, motor trucks, commercial vehicles, chauffeurs and operators, dealers and manufacturers, as well as the total gross revenues and the amount available for State road work, either by the State highway departments or under their supervision, and that available for local road work for the year 1920 are given in Table 1. The number of registrations in this table does not necessarily indicate the exact number of motor vehicles in use or existence in the several States except in so far as the laws of the several States require and enforce an annual registration under these classifications. All of the States with the exception of Minnesota now require an annual registration. Some States, however, do not segregate registrations from reregistrations, consequently the registration figures in these States exceed the actual number of cars by the number of transfers which have been made during the year. It

is unfortunate that, during 1920, only 36 States required motor trucks and commercial vehicles to be registered in separate classes. Consequently the data in column 3 in Table 1 do not give a very definite index as to the total number of trucks in existence except in those States requiring separate registration. Even where separate registration is required the classification as to what constitutes a motor truck is far from uniform. Consequently, in some cases, a vehicle which is classed as a truck or commercial vehicle in one State may, in another, be included among passenger or motor cars for registration purposes. Reference to the principal requirements for the registration of motor vehicles are given in Table 4 and these will serve to make clear what the data in Table 1 actually represent.

Table 2 gives a compilation of the total registrations and total revenues for the years 1915 to 1920, inclusive. For further information in regard to registrations and revenues previous to 1913 the reader is referred to Public Roads Bulletin No. 48, Repair and Maintenance of Highways, pages 68 to 71, inclusive, and also to the files of Public Roads for the years 1919 and 1920.

TABLE 1.—Motor-Vehicle Registrations and Revenues, 1920.

State.	Automobiles.	Motor trucks and commercial vehicles.	Motor cycles.	Reregistrations or transfers.	Owners' and chauffeurs' licenses.	Manufacturers' and dealers' licenses.	Total gross motor-vehicle registration and license revenues.	Motor-vehicle revenues available for road work.		Average gross revenue return per motor-car registration.	Population per motor car.	Motor cars per mile of public rural road.
								By or under State highway department.	Under direction of local authorities.			
Alabama	61,941	12,696	1,035	1,200	3,413	1,411	$835,178.00	$668,142.40		$11.23	31	1.3
Arizona	29,868	4,733	542	1,816	417	251	192,368.92	189,868.92		5.55	10	2.9
Arkansas	59,082	[1]	[2]	333	478	548	591,464.50	550,000.00		10.01	30	1.2
California	541,934	41,689	20,564	126,827	865,699	3,524	5,714,717.40	2,441,601.45	$2,441,601.45	9.79	5	9.5
Colorado	121,506	7,749	3,420	11,509	131,449	2,822	819,872.74	375,699.01	375,699.01	6.34	7	3.2
Connecticut	95,123	24,011	[3] 6,543	20,156	139,843	814	1,852,591.00	1,852,591.00		15.55	12	8.5
Delaware	18,300	[1]	674	[1]	22,023	606	329,980.00	329,980.00		18.03	12	5.0
District of Columbia	[4] 29,131	[5] 5,030	2,648	1,189	17,767	927	266,285.00			7.78	13	
Florida	63,466	10,448	1,275	1,544	2,190	719	554,695.14	554,695.14		7.63	13	4.1
Georgia	134,000	12,000	1,382	2,894	5,055	976	1,919,338.92	1,851,540.82		13.14	20	1.8
Idaho	50,861	[1]	764	851	802	581	882,034.51	220,508.65	661,525.86	17.34	8	2.0
Illinois	504,250	64,674	10,369	[1]	566,701	6,239	5,915,700.17	[6] 5,915,700.17		10.40	11	5.9
Indiana	300,226	32,841	8,823	[1]	9,758	1,500	2,029,694.00	1,902,363.00		6.09	9	4.5
Iowa	407,578	29,800	4,000	90,000	3,870	2,575	7,507,202.08	[7] 7,244,450.00		17.16	5	4.2
Kansas	294,159	[1]	3,605	12,598		2,411	1,419,345.50		1,327,308.00	4.83	6	2.6
Kentucky	99,437	13,246	1,543	[1]	5,000	1,016	815,549.31	815,549.31		7.24	21	1.9
Louisiana	66,000	7,000	512	602		515	390,000.00		350,000.00	5.34	25	3.0
Maine	55,395	7,512	1,566	[1]	78,539	637	818,755.50	[6] 818,755.50		13.02	12	2.7
Maryland	[8] 87,625	[9] 15,216	5,222	9,960	54,269	4,368	2,124,924.84	1,537,540.00	384,385.00	20.53	14	6.2
Massachusetts	223,112	51,386	15,143	30,000	361,546	2,011	3,860,231.70	3,500,000.00		14.07	14	14.7
Michigan	366,946	45,771	8,011	35,640	195,477	1,638	5,754,900.96	2,745,715.10	2,737,138.35	13.94	9	5.6
Minnesota [10]	[10] 324,166	[1]	7,546	5,716	8,920	641	143,794.50	143,794.50		.44	7	3.5
Mississippi	63,721	4,765	194	834	63,267	260	[11] 800,000.00	[11] 750,000.00		11.68	26	1.5
Missouri	297,008	[1]	3,954	16,400	323,799	2,520	2,111,696.85	2,111,696.85		7.11	11	3.1
Montana	59,450	1,200	675	862	1,490	429	416,245.00	280,557.37	93,519.12	6.86	9	1.5
Nebraska	200,000	19,000	2,100	[1]		3,000	[11] 2,800,000.00	[11] 2,100,000.00	[11] 700,000.00	12.78	6	2.7
Nevada	10,464	[1]	125	[1]		75	103,318.33	[6] 103,318.33		9.87	7	.9
New Hampshire	[12] 30,240	4,440	2,542	4,475	43,993	252	654,702.04	580,342.23		18.69	13	2.5
New Jersey	204,125	23,612	11,041	41,351	294,438	2,671	3,503,936.76	3,441,770.32		15.39	14	15.3
New Mexico	22,100	[1]	219	[1]		175	200,000.00	180,000.00		9.05	16	.6
New York	524,271	[16] 151,934	30,092	[1]	358,022	3,560	8,863,250.59	6,721,174.52	2,142,076.07	10.14	15	8.3
North Carolina [11]	127,405	13,455	1,418				1,785,000.00	1,785,000.00		10.26	18	2.7
North Dakota	90,840	[1]	898	10,150			691,500.00	274,257.70	274,257.69	7.61	7	1.3
Ohio	[13] 538,090	83,300	23,300	[1]		24,244	[11] 6,400,000.00	[11] 3,100,000.00	[11] 3,100,000.00	10.30	9	7.2
Oklahoma	204,300	8,580	1,360	[1]		1,202	[11] 2,500,000.00	[7] 2,294,404.67		11.74	10	2.0
Oregon	103,790	[1]	3,434	16,568	142,962	751	2,085,168.50	1,469,145.28	489,715.10	20.09	7	2.8
Pennsylvania	521,835	48,329	23,981	57,712	261,183	13,154	8,090,873.04	8,090,873.04		14.01	15	6.2
Rhode Island	40,914	9,563	2,260	5,790	58,710	231	531,462.75	468,162.75		10.51	12	23.3
South Carolina	93,843	[1]	908	1,933		1,541	527,868.13	92,529.19	329,765.31	5.63	18	2.2
South Dakota	112,589	7,806	777	2,545		1,071	[11] 784,000.00		[11] 700,000.00	6.51	5	1.2
Tennessee	90,214	11,638	1,151	5,754		564	1,215,776.04	571,816.72	571,816.72	11.94	23	2.2
Texas	427,693	[1]	4,290	121,280	23,385	3,624	3,510,355.97	1,468,474.63	1,715,416.13	8.21	11	3.3
Utah	37,060	5,556	1,114	[1]	1,120	235	350,933.29	[6] 325,000.00		8.23	11	4.8
Vermont	28,709	2,916	946	3,290	39,201	192	555,422.38	515,736.76		14.40	11	2.2
Virginia	101,800	13,670	2,233	[1]	5,514	2,972	1,822,736.16	1,730,921.18		15.70	20	2.1
Washington	[14] 144,131	29,789	4,915	13,337		3,977	2,828,896.10	[11] 1,800,000.00	[11] 1,000,000.00	16.15	8	4.1
West Virginia	69,862	10,802	1,659	[1]	10,552	886	1,280,193.28	1,096,662.43		15.87	18	2.5
Wisconsin	277,093	16,205	8,002	[1]		1,946	3,127,073.00	2,250,000.00	750,000.00	10.67	9	3.8
Wyoming	23,926	[1]	327	[1]		201	267,179.35	[4] 267,179.35		11.16	8	1.6
Total and average	8,379,579	852,362	239,102	718,116	4,100,852	106,473	102,546,212.25	77,527,518.29	20,144,223.81	11.11	11	3.8

[1] Included under automobiles.
[2] Registration not required.
[3] Includes 2,178 side cars.
[4] Does not include 14,797 nonresident cars.
[5] Does not include 1,790 nonresident trucks.
[6] To pay interest and provide sinking fund for State highway bond issue; remainder for State highway work.
[7] Distributed to counties, but expended under supervision of State highway department; 2½ per cent of grand total to State highway department for expenses.
[8] Does not include 13,500 nonresident registrations.
[9] Includes 4,022 buses and vehicles used for hire.
[10] Registrations cover a period of three years ending Dec. 31, 1920. Number of cars given are for total period; revenues are for calendar year only.
[11] Approximate.
[12] Does not include 2,359 nonresident and neutral zone cars.
[13] Does not include 2,683 State, county, and city cars.
[14] Does not include 1,287 exempt cars.
[15] Data covered period of 18 months ending Dec. 31, 1920.
[16] Includes 26,533 omnibuses.

TABLE 2.—Motor-Vehicle Registrations and Gross Motor-Vehicle Revenues, 1915 to 1920.

	Motor-car registration.[1]						Total gross revenues.					
	1915	1916	1917	1918	1919	1920	1915	1916	1917	1918	1919	1920
Alabama	11,634	21,636	32,873	46,171	58,898	74,637	$180,744	$203,655	$217,700	$470,274	$541,348.70	$835,178.00
Arizona	7,753	12,300	19,890	23,905	29,575	34,601	45,579	73,000	117,643	142,288	164,755.68	192,368.92
Arkansas	8,021	15,000	28,693	41,458	49,450	59,082	80,551	150,000	205,176	410,649	500,970.00	591,464.50
California	163,797	232,440	306,916	407,761	477,450	583,623	2,027,432	2,192,699	2,846,030	3,524,036	4,468,721.67	5,714,717.40
Colorado	28,894	43,296	87,460	83,244	104,865	129,255	120,801	197,795	296,808	379,559	490,432.31	819,872.74
Connecticut	41,121	56,048	74,645	86,067	102,410	119,134	536,970	768,728	1,080,757	1,285,164	1,516,136.01	1,852,591.00
Delaware	5,052	7,102	10,700	12,955	16,152	18,300	55,596	85,249	133,883	232,449	286,333.00	329,980.00
District of Columbia	8,009	13,118	15,493	30,490	35,400	34,161	29,396	47,624	55,928	220,753	274,184.00	266,285.00
Florida	[2] 10,850	20,718	[3] 27,000	54,186	55,400	73,914	[3] 60,000	127,176	[3] 170,000	345,775	401,317.40	554,695.14
Georgia	25,000	46,025	70,324	104,676	137,000	146,000	125,000	154,735	229,653	331,816	429,848.00	1,919,338.92
Idaho	7,071	12,999	24,731	32,289	42,220	50,861	121,259	213,758	412,641	576,555	729,702.94	882,034.51
Illinois	180,832	248,429	340,292	389,620	478,438	568,924	924,906	1,236,566	1,588,835	2,764,330	3,262,714.00	5,915,700.17
Indiana	96,915	139,065	192,194	227,160	227,255	333,067	587,318	817,285	1,096,159	1,293,128	1,558,740.50	2,029,694.00
Iowa	145,109	198,587	254,462	278,313	364,043	437,378	1,533,054	1,776,170	2,249,655	2,547,596	3,077,445.81	7,507,202.08
Kansas	72,520	112,122	159,343	189,163	228,600	294,159	387,588	585,762	830,878	978,837	1,150,000.00	1,419,345.50
Kentucky	19,500	31,500	47,420	65,884	90,008	112,683	117,117	184,741	287,314	402,250	565,520.21	815,549.31
Louisiana	11,380	17,000	28,394	40,000	51,000	73,000	75,600	112,000	166,835	240,000	306,000.00	390,000.00
Maine	21,545	30,972	41,499	44,572	53,425	62,907	268,412	363,562	491,695	570,171	685,570.25	818,755.50
Maryland	31,047	44,245	60,943	74,666	95,634	102,841	386,565	565,302	807,395	1,189,984	1,776,410.22	2,121,924.84
Massachusetts	102,633	136,809	174,274	193,497	247,182	274,498	1,235,724	1,602,958	1,969,994	2,184,821	2,667,853.85	3,860,231.70
Michigan	114,845	160,052	247,006	262,125	325,813	412,717	373,833	1,739,344	2,471,271	2,875,266	3,719,433.39	5,754,900.96
Minnesota	93,269	[4] 46,000	[5] 54,009	204,458	259,741	324,166	[3] 160,540	82,469	100,000	1,076,811	218,469.50	143,794.50
Mississippi [3]	9,669	25,000	36,600	48,400	59,000	68,486	76,700	175,000	250,000	335,000	400,000.00	800,000.00
Missouri	76,462	103,587	147,528	188,040	244,363	297,008	323,289	439,315	617,942	1,394,762	1,725,076.70	416,245,00
Montana	14,540	25,105	42,749	51,053	59,324	60,650	33,120	52,768	290,936	350,914	407,848.00	2,111,696.85
Nebraska	59,000	101,200	148,101	173,374	200,000	219,000	[3] 183,000	311,334	451,303	536,897	304,450.55	2,800,000.00
Nevada	2,009	4,919	7,160	8,159	9,305	10,464	7,875	20,116	31,166	31,083	37,550.75	103,318.33
New Hampshire	13,449	17,508	22,267	24,817	31,625	34,680	257,776	344,434	425,305	509,335	599,621.25	654,702.04
New Jersey	81,848	109,414	141,918	155,519	190,873	227,737	1,062,923	1,406,806	1,923,164	2,431,757	2,931,904.15	3,503,936.76
New Mexico	5,100	8,228	14,086	17,647	18,082	22,100	29,625	47,865	80,843	105,631	111,150.00	200,000.00
New York	255,242	314,222	406,016	459,292	566,511	676,205	1,991,181	2,658,042	4,284,144	4,945,298	5,984,659.50	8,863,250.59
North Carolina	21,000	33,904	55,950	72,313	109,017	140,860	123,000	206,101	321,923	394,739	1,313,950.73	1,785,000.00
North Dakota	24,908	40,446	62,993	71,678	82,885	90,840	79,245	125,283	211,536	471,429	636,842.40	691,500.00
Ohio	181,332	252,431	346,772	412,775	511,031	621,390	984,622	1,286,405	1,766,427	2,125,426	2,593,000.00	6,400,000.00
Oklahoma	25,032	52,718	100,199	121,500	144,500	212,880	154,892	555,011	853,659	1,102,380	1,178,130.27	2,500,000.00
Oregon	23,585	33,917	48,632	63,324	83,332	103,790	108,881	146,232	196,787	461,422	602,239.00	2,085,168.50
Pennsylvania	160,137	230,578	325,153	394,186	482,117	570,164	1,665,276	2,325,057	3,268,025	4,048,186	5,090,921.00	9,080,873.04
Rhode Island	16,362	21,406	37,046	35,218	44,833	50,477	206,440	264,737	346,117	385,608	477,223.25	531,462.75
South Carolina [2]	15,000	[6] 25,000	38,332	55,492	70,143	93,843	15,000	10,000	113,557	300,217	389,034.68	527,868.13
South Dakota	28,724	44,271	67,158	90,521	104,628	120,395	[3] 180,000	140,746	210,592	282,742	322,340.50	784,000.00
Tennessee	[7] 7,618	[3] 30,000	48,000	63,000	80,422	101,852	[3] 34,000	186,953	322,200	390,000	585,181.95	1,215,776.04
Texas [2]	40,000	[6] 125,000	192,961	251,118	331,310	427,693	20,000	20,000	858,978	2,039,589	2,624,334.29	3,510,355.97
Utah	9,177	13,507	24,076	32,273	35,236	42,616	[3] 60,000	93,494	170,707	229,203	291,325.96	350,933.29
Vermont	11,499	15,671	21,633	22,553	26,807	31,625	218,480	297,992	363,541	398,856	460,190.87	555,422.38
Virginia	21,357	35,426	55,661	72,228	94,100	115,470	176,875	271,266	518,566	684,636	900,000.00	1,822,736.16
Washington	38,823	60,734	91,337	117,278	148,775	173,920	238,717	350,052	519,526	875,391	2,325,323.53	2,828,896.10
West Virginia	13,279	20,571	31,300	38,750	50,203	80,664	128,952	198,436	359,339	447,705	1,008,083.31	1,280,193.28
Wisconsin	79,741	115,645	158,637	196,253	236,290	293,298	431,977	615,721	861,278	2,076,701	2,502,852.00	3,127,073.00
Wyoming	3,976	7,125	12,523	16,200	21,371	23,926	19,880	35,625	57,421	80,000	102,114.50	267,179.35
Total	2,445,664	3,512,996	4,983,340	6,146,617	7,565,446	9,231,941	18,245,711	25,865,370	37,501,233	51,477,417	64,697,255.58	102,546,212.25

[1] Does not include motor cycles nor dealers' and manufacturers' licenses.
[2] State registrations only.
[3] Estimated.
[4] Cars registered during 1916; total number of cars, approximately 138,000.
[5] Cars registered, 1917.
[6] Estimated number of cars in State.
[7] Registrations 1915 only.

TABLE 3.—Motor Vehicle Registration and License Fees in Force January 1, 1921.

State.	Motor cycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
Alabama	$5; with sidecar attachment, $7.50.	Less than 25 horsepower, $11.25; 25 to 29 horsepower, $18.75; 30 to 39 horsepower, $26.25; 40 horsepower and over, $30; electric cars, $20.[1]	Less than 1 ton, $15; 1 to 2 tons, $22.50; 2 to 3 tons, $37.50; 3 to 4 tons, $56.25; over 4 tons, $75.	Original, $5; renewal, $2.50.	None	$25 to $125.
Arizona	$2	25 horsepower and under, $5; 26 to 40 horsepower, $10; over 40 horsepower, $15.	Same as passenger cars	Perpetual, $5.	do	1 vehicle of each class at passenger-car rates.
Arkansas	None	All motor vehicles, $10	do	$1	do	Do.
California	$2	Electric cars, $5; all others, 40 cents per horsepower; trailers, $2.	Equipped with pneumatic tires, same as passenger cars; others pay additional; less than 2 tons unloaded, $5; 2 to 3 tons, $10; 3 to 5 tons, $15; over 5 tons, $20.	Original, $2; renewal, $1.	No fee	Regular rates for each set of plates.
Colorado	Same rate as passenger cars.	One-half of 1 per cent of cost price; minimum fee, $5.	1 ton, $10; 2 tons, $17.50; 3 tons, $25; 4 tons, $37.50; 5 tons, $50, and $25 per ton for each additional ton, carrying capacity.	$2	None	$20; additional tags, $2.50 per set.
Connecticut	$2	50 cents per horsepower	½ ton or less, $11; 1 ton, $15, and increasing to $200 for 8 tons, and $100 per ton for each ton additional.	License, $2; examination, $2.	License, $2; examination, $2.	$50 for 5 pair of plates, additional plates, $10 per pair.[2]
Delaware	$5	$2 each 500 pounds gross weight of car and load; passengers figured at 125 pounds each.	Same as passenger cars	$3	$3; family, $8.	$20 for 2 pairs of tags; extra tags, $10 per pair.

[1] Cars used for transportation of passengers paying fare, 5 or less passenger capacity, $37.50; 6 to 9 passenger capacity, $40; 10 or more passenger capacity, $90; operating between towns or cities 10 miles or more apart, a flat fee of $60.
[2] In case of manufacturers, $25, plus $1 for each car tested on public roads.

TABLE 3.—Motor Vehicle Registration and License Fees in Force January 1, 1921—Continued.

State.	Motor cycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
District of Columbia.	$2	24 horsepower or less, $3; 25 to 30 horsepower, $5; over 30 horsepower, $10.	Same as passenger cars	$2	$2	Regular rates for each car demonstrated on public roads.
Florida [3]	$2	22 horsepower or less, $5; 23 to 27 horsepower, $8; 28 to 35 horsepower, $12; above 35 horsepower, $15 any car seating more than 9 persons, $100.	1 ton or less, $10; 1 to 2 tons, $25; 2 to 4 tons, $50; more than 4 tons, $100. Trailers over 500 pounds capacity same rate as trucks.	$2	None	5 cars, $15.
Georgia	$5	Not exceeding 23 horsepower, $11.25; over 23 horsepower 60 cents per horsepower.	Not exceeding 1 ton capacity, $15; others, $15 plus $7.50 for each ½ ton over 1 ton; 4 tons, $75; 5 tons, $150; 6 tons, $375; 7 tons, $1,125.	$2	do	$50 for 5 number plates.
Idaho	$5	All weighing less than 2,001 pounds, $15; 2,001 to 3,000 pounds, $20; 3,001 to 4,000 pounds, $30; over 4,000 pounds, $40.	Same as passenger cars	$2	do	$35 for one make and $25 each additional make.
Illinois [4]	$4	25 horsepower or less, $8; 26 to 35 horsepower, $12; 36 to 50 horsepower, $20; over 50 horsepower, $25; electric cars, $12.	Total loaded weight, 5,000 pounds or less, $12; 5,000 to 12,000 pounds, $22.50; 12,000 to 15,000 pounds, $35; over 15,000 pounds, $60.	Original, $5; renewal, $3.	do	$12 for 2 plates and $12 for each pair duplicates.
Indiana	$2	Electric cars, $5; others, 25 horsepower or less, $5; 26 to 40 horsepower, $8; 41 to 50 horsepower, $15; over 50 horsepower, $20.	Less than ¾ ton, $6; 1 ton, $8; 1 to 2 tons, $10; 2 to 3½ tons, $20; 3½ to 5 tons, $30; 5 to 7½ tons, $40; over 7½ tons, $50.	$2	do	$25; duplicate plates, $1 each.
Iowa	$5	One per cent of values of car plus 40 cents per 100 pounds of weight of vehicle. Minimum fee, $10.	With pneumatic tires—1-ton capacity or less, $15; 1½ tons, $22.50; 2 tons, $30; 2½ tons, $45; 3 tons, $65; 3½ tons, $90; 4 tons, $105; 4½ tons, $120; 5 tons, $135; 6 tons, $165. With solid rubber tires—less than 2-ton capacity, same as above, 2½ tons, $55; 3 tons, $75; 3½ tons, $100; 4 tons, $115; 4½ tons, $130; 5 tons, $145; 6 tons, $175; trailers, $10 to $70.	$2	None	$25
Kansas	$2	All cars, $5 each	Same as passenger cars	None	do	$15 for 3 sets of tags; extra tags, 50 cents each.
Kentucky	$10	60 cents per horsepower	½ ton or less, $22; 1 ton, $30; and increasing to $150 for 5 tons, and $50 per ton for each ton additional.	$2	do	$25 for one set of plates; additional plates, $1 per set.
Louisiana	$2	25 cents per horsepower, with a minimum fee of $5 per car.	All motor trucks, $7.50 each	None	do	1 regular registration for each make; secondhand dealers, $10
Maine	$3	15 horsepower or less, $5; 16 to 35 horsepower, $10; over 35 horsepower, $15.	$10 per ton capacity for cars to 5-ton capacity, then $15 per ton for each ton above 5-ton capacity.	$2	$2	$25 for 5 pairs of plates; extra plates, 75 cents each.
Maryland	$5; with side car, $8.	60 cents per horsepower; minimum charge, $10; $1.20 per horsepower if operated for hire.	With solid tires to 3-ton capacity, $20 per ton; 4-ton, $100; 5-ton, $150; 6-ton, $300; 7-ton, $500; electrics, one-half of above rates; trailers to 1-ton capacity, $10; others, $20 per ton.	$3	$2	$25 for 2 sets of tags and $12 for each additional set. For dealers in motor cycles, 4 tags, $20; additional tags, $5 each.
Massachusetts	$5	Under 30 horsepower, $10; 30 to 39 horsepower, $15; 40 to 49 horsepower, $20; 50 horsepower and over, $25.	$10 for each ton capacity or fraction thereof; trucks with pneumatic tires, one-half above rates.	$2; examination, $2.	$2; examination, $2.	$25 for 5 cars, and $5 additional for each car over 5 operated on public roads.
Michigan	[5]	Electric cars, $1 for each motor horsepower plus 35 cents for each 100 pounds of weight; others, 25 cents per horsepower plus 35 cents for each 100 pounds of weight.	Same rates as passenger cars. Trailers, 50 cents for each 100 pounds of weight.	$2	$0.50	$30 for 3 cars and $10 for each additional car.[6]
Minnesota	$2	All cars, $2 for year 1920	Same as passenger cars	Original, $1.50; renewal, $1.	None	$20; extra plates, $1 per set.
Mississippi	$12	Electric cars, $15; others, $2 plus 50 cents per horsepower.	1-ton capacity or less, $12; 1½ tons, $17; 2 tons, $32; 3 tons, $57; 4 tons, $117; 5 tons, $202; 6 tons, $252; over 6 tons, $75 per ton.	None	do	Regular rates for 4 sets of plates.
Missouri	[5]	Less than 12 horsepower, $4; 12 to 23 horsepower, $6; 24 to 35 horsepower, $10; 36 to 47 horsepower, $14; 48 to 59 horsepower, $16; 60 to 71 horsepower, $20; 72 power and over, $24.	Same as passenger cars	$1.50	do	$10; for each duplicate, $5.
Montana	$5	23 horsepower or less, $5; 24 to 50 horsepower, $10; over 50 horsepower, $15.	1-ton capacity or less, $5; over 1 ton and less than 2, $15; over 2 tons and less than 3, $25; over 3 tons, $40.	$2	do	Cars, $50; motor cycles, $15.
Nebraska	$5	$10, plus 50 cents for each 100 pounds car weighs over 2,000 pounds.	$10, plus 50 cents for each 100 pounds total weight of loaded car exceeds 2,000 pounds.	None	do	Registration for each class.
Nevada	[5]	35 cents for each 100 pounds of total weight of loaded car.	Same as passenger cars	do	do	$20 for 4 number plates; $1 for each duplicate.
New Hampshire	$2	15 horsepower or less, $10; 16 to 30 horsepower, $15; 31 to 40 horsepower, $20; 41 to 50 horsepower, $25; 51 to 60 horsepower, $30; over 60 horsepower, $40.	do	Original, $5; renewal, $1.	Original, $3; renewal, $1.	$50 for 6 pair of plates; additional plates, $5 per pair.

[3] Any county or municipality may charge an additional license tax, not to exceed 50 per cent of State license tax, on motor vehicles used for hire.
[4] Both cars and trucks may be registered in municipality in which owner resides.
[5] Same rate as passenger cars.
[6] In case of manufacturers, motor cycles $20, including 10 number plates.

TABLE 3.—Motor Vehicle Registration and License Fees in Force January 1, 1921—Continued.

State.	Motor cycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
New Jersey	$2	10 horsepower or less, $4.50; 11 to 29 horsepower, $7.50; 30 horsepower or over, $15.	With solid tires loaded weight ½ ton or less, $6, and $3 additional for each ½ ton gross weight to 2 tons; then $4 for each additional ton; trailers, $3.	$3	$3	$5 per car not to exceed 5.
New Mexico	$3	40 cents per horsepower	50 cents per horsepower	None	None	$25; additional tags, $5 each.
New York	$2.50	25 cents per horsepower plus 40 cents per $100 of list price.	Gross loaded weight 2 tons or less, $10, and $5 each additional ton to 14; 14 tons, $70, and $10 each additional ton.	Original, $5; renewal, $2.	Original, $2; renewal, $1.	$15, plus $5 for each duplicate set.
North Carolina	$5	26 horsepower or less, $10; 26 to 30 horsepower, $15; over 30 horsepower, $20.	1-ton capacity or less, $12.50; 1 to 2 tons, $25; 2 to 3 tons, $40; 3 to 4 tons, $65; 4 to 5½ tons, $100. Trailers, 1-ton capacity, $10, plus $20 for each additional ton.	None	None	$25, plus $5 for each duplicate pair of plates.
North Dakota	$3	10 cents per horsepower, plus 5 mills per dollar of selling price and 20 cents per 100 pounds net weight of car. Minimum fee, $5. Electric cars, $2.	Same as passenger cars, plus following fee for capacity rating: To 3 tons, $3 per ton; to 4 tons, $5 per ton; over 4 tons, $10 per ton. Trailers, one-fourth truck fee.	do	do	Dealer pays regular fee and transfers tags to purchaser.
Ohio	$2.50; side cars, $1.50.	25 horsepower or less, $8; 25 to 35 horsepower, $12; over 35 horsepower, $20; electrics, $8.	Same as passenger cars, plus 20 cents for each 100 pounds of total loaded weight.	$3	do	$20; extra plates, $2 per pair.
Oklahoma	$10	$10 per car if list price is $500 or less; if list price exceeds $500, then 75 cents additional for each $100 of list price.	1,500 pounds capacity or less $15; 2,000 pounds, $20; 3,000 pounds, $25; 4,000 pounds, $40; 6,000 pounds, $60; 8,000 pounds, $100; over 8,000 pounds capacity, $300.	None	do	$25 for 2 tags and $12.50 each for additional set of tags.
Oregon	$6	Electric cars, $18; others, 23 horsepower and less, $15; 23 to 26 horsepower, $22; 26 to 30 horsepower, $28; 30 to 36 horsepower, $36; 36 to 40 horsepower, $48; over 40 horsepower, $56.	Electric trucks, $30; others, 1½ to 2 tons, $32, and $12 for each additional ½ ton up to 5 tons; over 5 tons allowed only on special permits.	$4	25 cents	$30 for 2 tags and $5 for duplicate sets.
Pennsylvania	$3	40 cents per horsepower; minimum fee, $10.	Less than 1 ton weight same as passenger cars; others, 1 to 1½ tons, $20; 1½ to 2½ tons, $25; 2½ to 3 tons, $30; 3 to 3½ tons, $50; 1½ to 4 tons, $75; 4 to 5 tons, $100; over 5 tons, $150. With metal tires double above rates. Trailers, $2 to $15.	$2	No fee	Regular rates for each set of plates.
Rhode Island	$2	15 horsepower or less, $5; 16 to 30 horsepower, $10; 31 to 40 horsepower, $15, over 40 horsepower, $25.	Carrying capacity 1 ton or less, $7, with $3 additional for each ton to 4 tons, and then $4 for each ton above 4 tons; over 9-ton capacity, $40 each; trailers, $10 to $30 each.	$1	$1	$25 for 5 vehicles and $5 for each additional vehicle.
South Carolina	$3	Cars weighing 2,000 pounds or less, $6; others $2 additional for each 500 pounds over 2,000.	Capacity 1 ton or less, $15; 2 tons, $30; 3 tons, $60, 4 tons, $100; 5 tons, $200; 6 tons, $250, 7 tons and over, $350.	None	None	$25 for first make and $15 for each additional make.
South Dakota	$3	All cars $6 each	Capacity 2 tons or less, $6; 2 to 3½ tons, $10; 3½ to 5 tons, $15.	do	do	$25 for 6 plates, duplicates $3 each.
Tennessee	(5)	50 cents per horsepower	50 cents per horsepower, plus $5 per ton carrying capacity.	do	do	$25.
Texas	$3	35 cents per horsepower	Capacity 1 ton or less, same as passenger cars; others, 1 to 2 tons, $16; 2 to 3 tons, $32; 3 to 4 tons, $48, 4 to 5 tons, $80; above 5 tons, $100 for additional ½ ton. County license also required.	$3	do	$15; extra numbers, $5 each.
Utah	$3	Electric cars, $10; others, 25 horsepower and less, $5; 26 to 40 horsepower, $10; above 40 horsepower, $15.	Total loaded weight 1 ton or less, $10; 1 to 2 tons, $15; over 2 tons, $7.50 per ton. With pneumatic tires two-thirds and with metal tires double above rates.	$2	do	$25, and $2 for each set of duplicate plates.
Vermont	(5)	First registration, $1 per horsepower; second, 75 cents per horsepower; third registration and thereafter, 50 cents per horsepower.	Less than 3-ton capacity, $20 per ton; 3 tons and over $25 per ton.	$3; examination, $2.	$2	$50.
Virginia	60 cents per horsepower; minimum, $5.	60 cents per horsepower; minimum fee, $10.	$15 for first ton capacity, plus $5 for each ½ ton additional capacity. Trailers, $10 first ton capacity, plus $3 for each ½ ton additional.	$5	None	$50 for 3 sets of plates; additional sets, $15 each.
Washington	$6	$10, plus 60 cents for each 100 pounds car weighs over 1,500 pounds.	$10, plus 40 cents for each 100 pounds that total loaded weight exceeds 1,500 pounds unless empty truck weight exceeds 6,500 pounds, then 50 cents per 100 pounds. Trailers same rates.	None	do	Cars, $50; extra plates, $10 per pair; motor cycles, $10.
West Virginia	$5	Cars weighing 1 ton or less, $10, and 25 cents additional for each 100 pounds over 1 ton.	Same as passenger cars. Special rates for trucks used for hire.	$3	do	Cars, $15 per set of plates; motor cycles, $5.
Wisconsin	$4	All cars $10 each	Capacity less than 2,100 pounds, $15; 2,100 to 5,100 pounds, $20; 5,100 pounds or more, $25.	(7)	do	$25 for 4 plates; extra plates, $1 each.
Wyoming	$5	40 cents per horsepower	75 cents for each 100 pounds of weight of vehicle.	None	do	$50 for 1 plate; $2 for each additional plate.

[5] Same rate as passenger cars.

[7] Drivers of cars operating for hire may be licensed by municipality.

TABLE 4.—Administrative Provisions in Force Jan. 1, 1921, Affecting Motor-Vehicle Registrations, Licenses, and Revenues.

State.	Registration and licenses.					Revenues from registrations and licenses.				Traffic regulations made by—
	Official or department in charge.	Renewals.		Requirements for operators' and chauffeurs' licenses.	Non-residents' exemption.	Applied to—	Proportion expended for roads under supervision of—		Revenues from fines and penalties applied to roads.	
		Car registrations.	Operators' and chauffeurs' licenses.				State highway department.	Local road authorities.		
Alabama	State tax commission through probate judge.	Annual, Oct. 1.	Chauffeur, annual, Oct. 1.	Chauffeur, must be 18 years old.	Reciprocity.	80 per cent to state highway fund.	All of net	None	None	Statute.
Arizona	Secretary of state	Annual, Jan. 1.	Chauffeur, perpetual.	No examination.	6 months.	State road tax fund.	All of net	do	do	Statute and local ordinance.
Arkansas	Commissioner of State lands, highways and improvements.	do	Chauffeur, annual from date.	Chauffeur, must be 18 years old.	Reciprocity.	State and county road work.	One-half	One-half	One-half of penalty for delinquency.	Do.
California	Superintendent of motor-vehicle department.	do	Chauffeur, annual, Jan. 1.	do	3 months.	State and county road work.	One-half net.	One-half net.	All, by local community.	Do.
Colorado	Secretary of state	do	do	Certificate as to competency.	90 days	State and county road work.	do	do	Same as registration revenues.	Do.
Connecticut	Commissioner of motor vehicles.	do	All operators, annual, Mar. 1.	Examination	30 days	Maintenance state roads.	All of net	None	do	Do.
Delaware	Secretary of state	do	All operators, Jan. 1.	Must be 16 years old; no examination.	Reciprocity.	State highway department.	All	do	None	Do.
District of Columbia.	Automobile board	do	All operators, perpetual.	Examination	do	General fund	None	do	do	
Florida	State comptroller	do	Chauffeur, annual, Jan. 1.	Chauffeur, examination.	30 days	State highway department and state, maintenance fund.	All of net	do	do	Do.
Georgia	Secretary of state	Annual, Mar. 1.	Chauffeur, annual, Mar. 1.	Must be 16	30 days	Net to state aid road fund.	do	do	do	Do.
Idaho	Secretary of state through county assessor.	Annual, Jan. 1.	Chauffeur, annual.	Chauffeur, must be 18 years of age.	Reciprocity.	State highway fund.	25 per cent	75 per cent	Same as registration revenues.	Do.
Illinois	Secretary of state	do	Chauffeur, annual, Jan. 1.	Chauffeur, examination.	60 days	State road fund.	All [1]	None	All, by local community.	Do.
Indiana	do	do	do	do	do	State highway fund.	All of net	do	County road fund.	Do.
Iowa	do	do	do	Chauffeur must be 18 years of age and competent.	Reciprocity.	State road work.	[2]	do	Local road work.	Do.
Kansas	Secretary of state through county treasurer.	Annual, July 1.	do	Must be 14 years of age.	60 days	Net, maintenance county and township roads.	None	All of net	None	Statute and city ordinance.
Kentucky	State tax commission through county clerk.	Annual, Jan. 1.	do	Chauffeur, must be competent.	Reciprocity.	Net to state road fund.	All of net	None	do	Statute and local ordinance.
Louisiana	Secretary of state	do	None	[3]	do	Net to parish road work.	None	All of net	Same as registration revenues.	Local ordinance.
Maine	do	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination optional.	30 days	State road work.	All [1]	None	None	Statute and local ordinance.
Maryland	Commissioner of motor vehicles.	do	Owner, perpetual; chauffeur, annual.	do	Reciprocity; 3 months.	Net 20 per cent Baltimore street work; 80 per cent state road maintenance.	80 per cent of net.	do	Same as registration revenues.	Do.
Massachusetts	Department of public works.	do	All operators, annual from date.	Examination all operators.	Reciprocity.	Net 20 per cent small town roads; 80 per cent maintenance state roads.	All net	do	do	Statute, department of public works and local ordinance.
Michigan	Secretary of state	do	Chauffeur, annual, Jan. 1.	Examination optional.	Reciprocity to 90 days.	State and county road work.	One-half net.	One-half net.	None	Statute and local ordinance.
Minnesota	do	Triennial, 1918–1920.	do	Chauffeur, examination.	30 days	Net, state road and bridge fund.	All net	None	do	Do.
Mississippi	State auditor and county tax collector.	Annual, Jan. 1.	None	None	30 days	Net to state highway fund.	do	do	Net, same as county revenue.	Local ordinance.
Missouri	Secretary of state	Annual, Feb. 1.	Chauffeur, annual, Feb. 1.	Must be 18 years of age; no examination.	60 days	State road fund.	All of net	do	None	Statutes and local ordinance.
Montana	do	Annual, Jan. 1.	Chauffeur, annual, Jan. 1.	No examination.	No limit	Net to state and county road work.	Three-fourths net.	One-fourth net.	do	Do.
Nebraska	Department of public works through county treasurer.	do	None	Must be 16 years old.	30 days	do	Three-fourths.	One-fourth	do	Statute, department of public works and local ordinance.
Nevada	Secretary of state	First Monday in February	do	do	do	Net to state highway bond fund.	None	None	do	Do.

[1] Must first set aside amount necessary to finance state highway bonds.
[2] 94 per cent for construction of primary roads, 2½ per cent for maintenance of highway department, and 5 per cent for registration expenses.
[3] Municipalities of more than 10,000 population may license chauffeurs.

TABLE 4.—Administrative Provisions in Force Jan. 1, 1921, Affecting Motor-Vehicle Registrations, Licenses, and Revenues—Continued.

State.	Registration and licenses.					Revenues from registrations and licenses.			Revenues from fines and penalties applied to roads.	Traffic regulations made by—
	Official or department in charge.	Renewals.		Requirements for operators' and chauffeurs' licenses.	Nonresidents' exemption.	Applied to—	Proportion expended for roads under supervision of—			
		Car registrations.	Operators' and chauffeurs' licenses.				State highway department.	Local road authorities.		
New Hampshire.	Commissioner of motor vehicles.	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination, all operators.	20 days.	Road maintenance.	All of net.	None.	Same as registration revenues.	Statute, department of public works and local ordinance.
New Jersey.	do.	do.	do.	do.	Reciprocity; 15 days.	do.	do.	do.	do.	Statute and motor vehicle commission.
New Mexico.	Secretary of state.	Annual, Jan. 1.	None.	Must be 14 years old.	30 days.	Net State and county road work.	All of net.	do.	None.	Statute and local ordinance.
New York.	do.	Annual, Feb. 1.	All operators, annual, Feb. 1.	Chauffeur, examination.	Reciprocity.	State and local road work.[4]	75 per cent gross.	25 per cent gross.	Maintenance of State roads.	Statute, State highway commission, and local ordinance.
North Carolina.	do.	Annual, July 1.	None.	Must be 16 years of age.	Reciprocity to 60 days.	State road fund.	All net.	None.	None.	Statute and local ordinance.
North Dakota.	Motor vehicle registration department.	Annual, Jan. 1.	do.		No limit.	Net to State and county road work.	One-half.	One-half.	do.	Do.
Ohio.	Secretary of state.	do.	do.		do.	State and local road maintenance.	do.	do.	do.	Statute, State highway department, and local ordinance.
Oklahoma.	Department of highways.	do.	do.		Reciprocity; 60 days.	10 per cent appropriated for State highway department; 90 per cent county road work.	All.		All.	Statute and local ordinance.
Oregon.	Secretary of state.	do.	Chauffeur, annual, Jan. 1.	Must be 16 years of age; no examination.	Reciprocity.	Net to State and county road work.	Three-fourths.	One-fourth	County road fund.	Do.
Pennsylvania	State highway department.	do.	do.	Affidavits as to competency.	do.	Maintenance of State highways.	All gross.	None.	State and local road work.	Statute, State highway department, and local ordinance.
Rhode Island	State board of public roads.	do.	All operators, annual from date.	Examination, all operators.	Reciprocity; 10 days.	Maintenance State roads.	All net.	do.	Same as registration revenues.	State board of public roads statute, and local ordinance.
South Carolina.	State highway department.	do.			30 days.	Maintenance highway department and county road work.	do.	do.	None.	Statute an local ordinance.
South Dakota	Secretary of state through county treasurer.	do.		Must be 15 years old.	Reciprocity.	90 per cent county road work.	None.	90 per cent	do.	Do.
Tennessee.	State department of highways through county clerk.	do.			30 days.	Net to State and county road work.	All net.		Same as registration revenues.	Do.
Texas.	State highway department through county tax collector.	do.	Chauffeur, annual, Jan. 1.	Must be 18 years of age.	90 days.	Net to State and county highway funds.	50 per cent	50 per cent	County road work.	Do.
Utah.	Secretary of state.	Annual, Mar. 1.	do.	No examination.	30 days.	Motor vehicle registration fund.	All net [5]	None.	None.	Do.
Vermont.	do.	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination, chauffeur.	Reciprocity.	State maintenance fund.	do.	do.	do.	Do.
Virginia.	Secretary of commonwealth.	do.	Chauffeur, annual, Jan. 1.	Certificate of competency.	2 periods of 7 days each.	Net to construction and maintenance of State roads.	do.	do.	do.	Do.
Washington.	Secretary of state through county auditor.	Annual, Mar. 1.	None.	Operators must be 15 years of age, chauffeurs 21.	90 days.	Net for maintenance and construction.	50 per cent[6]	50 per cent[6]	Same as registration revenues.	Do.
West Virginia	State road commission.	Annual, Jan. 1.	Chauffeur, annual, Jan. 1.	Must be 14 years of age.	Reciprocity.	State road fund.	All.	None.	None.	Statute, State road commission, and local ordinance.
Wisconsin.	Secretary of state.	do.	None.	Must be 16 years of age.[7]	do.	Net to State highway fund and county road work.	75 per cent net.	25 per cent net.	do.	Statute and local ordinance.
Wyoming.	do.	do.	do.	Must be 15 years of age.[1]	Reciprocity to 90 days.	All to State roads.[5]	All [5]	None.	do.	Statute.

[1] Must first set aside amount necessary to finance State highway bonds.
[4] Does not apply to revenue collected within New York City, one-half of which goes to the city general fund.
[5] To pay interest and sinking fund on State road bonds.
[6] Approximate, exact division made by legislature when funds are appropriated.
[7] Drivers of cars operating for hire may be licensed by municipalities.

RESURFACE CONCRETE ROAD WITH REINFORCED CONCRETE

By T. M. KEENE, District Engineer, Bureau of Public Roads

THE resurfacing of a worn-out concrete pavement with a thin concrete slab instead of the usual topping of bituminous material is perhaps sufficiently unusual to render of interest a brief rehearsal of the main features of this type of construction.

This type of resurfacing has been proposed and approved for Idaho Federal aid project No. 49, which comprises 1.54 miles of the Idaho-Pacific highway on the outskirts of Boise, Idaho. This section of roadway was paved in 1912 with one course of 6-inch concrete, rather poorly laid, which under the heavy traffic imposed upon it has gone to pieces in many places, and so many cracks and potholes have developed that some method of reconstruction has become imperative.

Traffic on this section amounts to about 2,800 vehicles daily, of which 250 are motor trucks. The old pavement was laid 16 feet wide, and in view of the heavy traffic above noted, this width has become manifestly inadequate, and any improvement must involve the widening of the pavement to a standard double-track width of 18 feet.

BIDS FAVORED CONCRETE SLAB.

Since the original intention was to retop this pavement with a bituminous mix, bids were asked for on a top of this type as well as on a conctete slab, but resulting prices were so greatly in favor of the latter construction that in spite of its comparative novelty its use was recommended and approved. Bids were respectively $2.10 per square yard for a 2-inch bituminous concrete top, and $1.30 per square yard for a 3-inch cement concrete slab.

Construction of the concrete slab topping will involve, first, the placing of an extra strip of concrete 1 foot in width on each side and to the full depth of the old pavement. These strips will consist of a 1:2:4 mix, struck off even with the old surface. At the same time the old slab itself will be cleaned and all depressions filled with the same mix and struck off so that a base slab 18 feet wide with a uniform surface shall be obtained. The new concrete is to be thoroughly cured before placing the top slab.

While the use of a bituminous top requires as close a bond as possible between the top and the concrete base, a topping of cement concrete calls for a method which will result in an entire absence of bond between the top and base. The extent of contraction and expansion in the two courses would vary considerably and bonding the two together would doubtless increase the tendency to crack, whereas a complete separation of the two slabs will permit of a slight movement in each slab independent of the other. Therefore, after the new portions of the reconstructed base are sufficiently hardened the surface is to be thoroughly cleaned and sprinkled with a light uniform coating of hot Tarvia. There will then be placed on the Tarvia-coated base a layer of concrete of a 1:2:3 mix 1½ inches in depth. On this layer is to be placed a reinforcing fabric consisting of a flat steel wire mesh weighing not less than 28 pounds per 100 square feet, and additional concrete is to be immediately deposited to secure a completed thickness of 3 inches.

Since the old pavement had expansion joints at 30-foot intervals, similar joints are to be placed in the concrete topping at the same points, although it is planned to break joints in a few instances as an experiment to determine the comparative value of such spacing for future work.

METHOD DESERVES CONSIDERATION.

The adoption of a concrete slab topping might be inadvisable in places where grades are fixed within very narrow limits, as, for instance, on curbed streets; also, on account of the length of time that the road must be closed to traffic, this construction might be objectionable where no suitable detours are available. In general, however, it would appear that this method should be given careful consideration as affording a competitive type of resurfacing for concrete roads, which, even if not adopted, would tend to reduce bids on other types with consequent ultimate economy.

The experience of the board of county commissioners of Wayne County, Mich., has been of value in forming recommendations in regard to this somewhat unusual method of resurfacing, and thanks are expressed for their courtesy in furnishing details of their methods and the results of their experience.

MERCHANTS' ASSOCIATION CONDEMNS OVERLOADING AND SPEEDING MOTOR TRUCKS.

The Merchants' Association of New York, by unanimous action of its board of directors, at a meeting held March 10 adopted a resolution strongly condemning the practice, now altogether too prevalent, of overloading and speeding motor trucks, with resulting injury of the highways.

After stating that the practice results in serious damage to roads and in many cases their complete destruction, and that the result of such operation is creating in the public mind an unfriendly attitude, the resolution calls for a more rigid enforcement of existing laws and the enactment of adequate laws where such practices are not now specifically prohibited. This resolution is signed by the special committee on highway development, of which Lee J. Eastman is chairman.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN FEBRUARY, 1921.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Arkansas	37	Washington	[2] 3.230	Gravel	Feb. 12	[2] $3,402.74	[2] $9,000.00
	51	Conway	[2] 2.330	Macadam	...do...	[2] 35,604.45	[2] 15,000.00
	78	Lincoln	[2] 2.090	Gravel	Feb. 18	[2] 20,242.64	[2] 10,000.00
	79	Conway	[2] 2.240	Macadam	Feb. 15	[2] 14,611.78	[2] 25,000.00
	92	Grant	[2] 4.310	Gravel	Feb. 19	[2] 19,639.95	[2] 10,000.00
	101	Polk	38.050	.....do	Feb. 7	132,153.72	55,036.07
	115	Madison	[3] 5.350	.....do	Feb. 23	[3] 16,950.78	.....
	118	Drew and Chicot	7.110	.....do	Feb. 26	177,695.87	82,797.00
Colorado	94	El Paso and Fremont	3.068	Sand-clay	Feb. 12	37,016.32	18,508.16
	102	Ouray	1.051	Earth	Feb. 8	45,942.93	21,020.00
	172	Gunnison	3.201	Gravel	Feb. 26	49,268.56	24,634.28
	178	Rio Grande	.....	Bridge	...do...	44,000.00	22,000.00
	182	Eagle	3.257	Earth	Feb. 21	119,152.00	59,576.00
Georgia	73	Richmond	.....	Bridge	Feb. 8	[1] 12,584.00	[1] 6,292.00
	127	.....do	.....	.....do	Feb. 21	129,530.06	1,000.00
	137	Bibb	[1] 4.000	Concrete	Feb. 9	[1] 141,940.99	[1] 55,000.00
	206	Tattnall	3.220	Sand-clay	Feb. 23	38,745.42	19,372.71
	214	Bartow	1.000	.....do	Feb. 26	21,848.75	10,924.37
	218	Polk	1.000	Chert	Feb. 15	31,268.60	15,634.30
Indiana	28	Vanderburg and Gibson	10.000	Brick, concrete, or bituminous concrete.	...do...	415,662.50	207,831.25
Louisiana	17	Tangipahoa	4.910	Sand-clay and gravel	Feb. 24	[1] 65,541.08	32,770.54
	18	Caldwell	[1] 2.400	.....do	Feb. 21	[1] 11,462.99	5,000.00
	27	Rapides	11.810	Sand-clay, washed gravel	Feb. 19	[3] 157,388.35	[3] 78,694.17
	29	Franklin	[1] 10.470	Sand-clay, gravel	Feb. 24	[1] 100,496.81	[1] 50,000.00
	43	Calcasieu	[1] 11.790	Gravel and shell	Feb. 27	[1] 245,092.59	[1] 122,546.29
	68	Gaddo	9.500	Macadam base	Feb. 24	[1] 371,447.73	[1] 185,723.86
	73	Richland	[3] 20.190	Sand-clay, gravel	Feb. 25	[3] 430,605.56	[3] 171,221.78
Michigan	53	Ogemaw and Arenac	20.000	Gravel	Feb. 8	353,409.32	176,704.66
	54	Shiawassee and Genesee	16.500	Concrete or bituminous concrete	Feb. 19	767,734.00	330,000.00
	59	Van Buren	5.231	Concrete	Feb. 12	212,267.17	104,620.00
Minnesota	30	Wright	[2] 21.860	Earth	Feb. 21	[3] 17,454.09	.....
	119	Faribault	27.250	.....do	Feb. 16	202,216.08	52,000.00
	189	St. Louis	1.530	Gravel	Feb. 14	26,823.50	13,000.00
	201	.....do	1.030	Brick, concrete, or asphalt	Feb. 19	63,985.68	20,000.00
Mississippi	45	Yalobusha	21.000	Earth	Feb. 8	132,715.00	66,357.50
	95	Pike	6.400	Brick	Feb. 26	203,568.20	101,784.10
	99	Tallahatchie	13.100	Earth	Feb. 12	200,607.00	100,000.00
	110	Lauderdale	5.100	Gravel	Feb. 8	36,567.85	18,283.92
Missouri	147	Monroe	7.500	.....do	Feb. 28	66,374.00	33,187.00
	179	Stoddard	8.500	.....do	...do...	88,200.00	44,100.00
	180	Buchanan	6.500	Concrete	Feb. 8	351,532.00	130,000.00
	181	Osage	.....	Bridge	Feb. 12	48,000.00	24,000.00
Montana	139	Ravalli	7.000	Gravel	Feb. 19	79,677.51	39,838.75
Nebraska	168	Holt and Rock	21.700	Earth	Feb. 7	102,135.00	51,067.50
New Hampshire	133	Grafton	0.400	Gravel	Feb. 28	9,000.00	4,500.00
New Jersey	29	Atlantic	[1] 9.356	Concrete	Feb. 2	[1] 492,250.00	[1] 187,120.00
North Dakota	96	Ramsey	[4] 2.500	Earth	Feb. 16	[2] 23,300.00	[2] 1,650.00
	110	Grand Forks	5.100	Gravel	Feb. 21	63,982.05	31,991.02
	117	.....do	10.000	Earth	...do...	46,200.00	23,100.00
	119	Emmons	4.500	.....do	...do...	20,790.00	10,395.00
	120	Towner	11.500	.....do	Feb. 18	66,792.00	33,396.00
	121	Nelson	11.000	.....do	Feb. 16	50,820.00	25,410.00
	123	Logan	14.000	.....do	Feb. 18	64,680.00	32,340.00
	124	Barnes	14.500	.....do	...do...	65,714.00	32,857.00
	125	Grand Forks	11.000	Gravel	Feb. 24	147,620.00	73,810.00
	126	Barnes	10.000	Earth	...do...	50,820.00	25,410.00
	127	Burke	7.500	.....do	...do...	34,650.00	17,325.00
	129	Ransom	11.000	.....do	Feb. 21	50,820.00	25,410.00
	130	Towner	9.000	.....do	...do...	41,580.00	20,790.00
	131	Grand Forks	11.000	.....do	...do...	50,820.00	25,410.00
Oklahoma	40	McCurtain	52.000	Gravel	Feb. 18	781,516.66	390,758.33
	43	Rogers	5.000	Brick and gravel	...do...	100,000.00	50,000.00
South Carolina	45	Richland	7.952	Topsoil	Feb. 12	69,275.01	34,637.50
	59	Berkeley	15.176	Sand-clay	Feb. 26	141,775.59	70,887.79
	76	Pickens	6.130	Topsoil	Feb. 15	90,335.95	22,316.68
	99	Colleton	15.707	Sand-clay	Feb. 7	121,815.21	40,638.08
	127	Aiken	.....	Bridge	Feb. 21	129,530.06	64,765.03
South Dakota	70	Custer	11.830	Earth and gravel	Feb. 8	169,270.20	84,635.10
	71	Hoakon and Zieback	.....	Bridge	Feb. 15	119,373.10	59,686.55
	72	Hoakon	3.494	Gravel	Feb. 24	52,948.83	26,474.41
Texas	227	Titus	20.170	.....do	Feb. 8	209,221.91	104,610.95
	231	Angelina	8.000	.....do	Feb. 21	96,250.00	24,062.50
Vermont	22	Rutland	1.200	Concrete	Feb. 26	47,615.70	23,807.85
Virginia	71	Fairfax	1.920	.....do	Feb. 8	73,539.40	36,769.70
	82	Powhatan	8.010	Topsoil	...do...	51,456.24	25,728.12
	104	Bedford and Roanoke	9.260	Macadam	Feb. 18	357,616.05	178,808.02
	112	Fairfax	2.790	Bituminous macadam	Feb. 8	81,977.50	40,988.75
Wisconsin	127	Dunn	4.050	Concrete	Feb. 7	162,314.68	54,000.00
	135	Buffalo	[2] 1.580	.....do	Feb. 18	[2] 109,974.65	[2] 36,258.22
	194	Columbia	2.040	Gravel	Feb. 26	24,003.98	10,000.00
	208	Grant	1.000	Concrete	Feb. 7	59,544.10	25,000.00
	209	.....do	.570	.....do	Feb. 18	54,564.95	11,000.00
Wyoming	108	Washakie	17.343	Topsoil	Feb. 8	154,385.00	77,192.50

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

PROJECT AGREEMENTS EXECUTED IN FEBRUARY, 1921.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Arkansas	23	Jackson	[2] 3.190	Gravel	Feb. 26	[2] $36,107.10	[2] $20,000.00
	36	Washington	38.800	do	Feb. 5	214,106.22	100,000.00
	50	Phillips		Bituminous concrete	Feb. 21		[2] 20,000.00
	94	Crittenden	9.370	Clay-bound gravel	Feb. 16	105,814.50	40,000.00
	113	Lawrence	2.150	Gravel	do	29,523.34	12,600.00
Colorado	23	Meso		do	Feb. 21	[2] 12,853.25	[2] 6,426.63
	28	Summit		Earth	Feb. 1	[2] 8,199.51	[2] 4,099.75
	47	El Paso	1.748	Gravel	Feb. 21	38,217.41	19,108.70
	68	Rio Grande		do	Feb. 23	[2] 1,874.85	[2] 937.43
	74	Moffat		do	Feb. 21	[2] 4,507.99	[2] 2,254.00
	82	Jefferson		Concrete	Feb. 2	[2] 4,664.47	[2] 1,344.88
	87	Boulder	1.334	do	do	57,970.54	26,680.00
	101	La Plata	4.091	Gravel	Feb. 21	53,073.71	26,536.85
	124	Conijos		Bridge	Feb. 23	14,722.29	7,361.14
	185	Garfield	1.270	Earth	Feb. 21	59,334.83	25,400.00
Florida	17	Manatee	7.870	Brick and concrete	Feb. 1	331,278.00	157,400.00
	17	Manatee		do	Feb. 23	[3] 44,031.84	[3] 13,776.92
Georgia	1	Clayton, Henry, Spalding, Pike, Monroe.	[4] 9.310	Concrete and sand-clay	Feb. 4	[2] 20,420.58	[2] 10,550.46
	8	Montgomery and Wheeler		Concrete and steel bridge	do	[2] 10,525.52	[2] 5,262.76
	18	Dooly		Sand-clay	Feb. 21	[2] 22,486.03	[2] 11,243.01
	44	Hall	[2] 10.631	Concrete	Feb. 25	[2] 115,762.23	[2] 57,881.11
	125	Lee	[2] 8.365	Sand-clay	Feb. 21	[2] 51,053.74	[2] 25,526.87
	134	Coweta	19.850	Topsoil	Feb. 19	251,780.26	65,000.00
	143	Laurens		Reinforced concrete bridge	Feb. 25	133,513.91	66,756.95
	152	Grady		Bridge	do	60,436.07	22,207.03
	153A	Newton	0.900	Sand-clay	Feb. 15	62,336.62	31,168.31
	163	Stewart	1.515	do	Feb. 12	28,634.61	12,500.00
	186	Johnson	3.100	Gravel	Feb. 4	29,447.13	14,723.56
	189	Hart	3.831	Sand-clay	Feb. 25	31,257.43	15,628.71
	196	Early	6.000	Topsoil	Feb. 21	44,552.02	22,276.01
	200	Webster		Bridge	Feb. 25	9,984.02	4,992.01
	204	Lowndes and Echols	5.663	Sand-clay	Feb. 28	33,301.01	16,650.50
Idaho	9	Adams and Idaho	[4] 3.020	Earth	Feb. 1	[2] 70,183.19	[2] 35,091.60
	19A	Bonner	12.569	Broken stone	Feb. 18	166,734.01	83,367.00
	21A	Bonneville	3.863	Bituminous concrete	Feb. 11	175,871.82	80,750.31
	31A	Benewah	8.248	Gravel	Feb. 15	211,293.23	89,098.22
	33B	Nez Perce	2.970	Earth	Feb. 24	68,393.24	34,196.62
	37	Jerome	4.260	Gravel	Jan. 29	94,952.05	47,452.35
	42	Gooding	5.034	Crushed rock	do	53,734.45	26,499.77
	46A	Bonneville	2.042	Bituminous concrete	Feb. 18	53,604.46	40,846.00
	47	Kootenai	8.240	Gravel	Feb. 11	83,200.00	6,600.00
Illinois	15–1	Williamson	5.812	Earth	Feb. 19	76,076.59	19,019.14
	18–2	Champaign	0.379	do	do	63,563.55	15,890.88
	18–5, 6, 7	Champaign and Piatt	2.624	do	Feb. 14	62,750.35	15,687.57
	18–12	Mason	1.508	do	do	19,991.89	4,997.97
	18–20	Sangamon	3.069	do	do	45,712.74	11,293.18
	18–26	do	1.073	do	do	27,379.69	6,844.92
	19–18, 19	Stephenson	2.634	do	do	106,075.03	26,518.75
	20–2 to 8	Henry and Bureau	16.627	do	do	272,635.60	68,158.89
	20–10, 11	Bureau	1.117	do	Feb. 19	28,228.94	7,057.22
	21–2	Warren	0.935	do	Feb. 14	49,092.02	12,273.00
	22–1	Kankakee	0.322	do	do	7,095.04	1,773.76
	23–2	Effingham	1.932	do	Feb. 19	32,342.72	8,085.68
	23–4 to 8	Effingham, Clay, and Wayne	7.504	do	Feb. 14	446,379.17	111,594.77
Iowa	11	Warren	16.260	do	Feb. 24	103,731.43	50,000.00
	38BC	Plymouth	20.842	do	Feb. 10	97,873.27	45,000.00
	53	Louisa	20.840	do	do	131,039.42	65,500.00
	66	Kossuth	23.340	do	do	114,847.97	57,000.00
	75ABC	Marion	13.362	do	Feb. 24	99,406.67	49,000.00
	94	Hancock	24.349	Brick or concrete	Feb 27	1,297,552.08	476,600.00
Kansas	47	Chase	2.898	Earth	Feb. 23	24,031.34	8,694.00
	48 CHD	Jefferson	10.742	Bituminous macadam	Feb. 12	706,411.55	95,000.00
	54	Sedgwick	5.599	Bituminous filled brick	Feb. 15	410,584.07	73,950.00
	58	Shawnee	7.965	Earth and brick, concrete or bituminous macadam.	Feb. 8	71,028.63	23,865.00
Louisiana	17	Tangipahoa	[1] 4.910	Sand-clay, gravel	Feb. 24	[1] 65,541.08	[1] 32,770.54
	18	Caldwell	[1] 2.400	do	Feb. 21	[1] 11,462.99	[1] 5,000.00
	29	Franklin	[1] 10.470	do	Feb. 24	[1] 101,635.93	[1] 50,000.00
	43	Calcasieu	[1] 11.790	Gravel and shell	Feb. 27	[1] 245,092.59	[1] 122,546.29
	68	Caddo	[1] 9.500	Macadam base, Kentucky rock asphalt.	Feb. 24	[1] 371,102.72	[1] 185,551.36
	77	Rapides	7.840	Sand-clay	Feb. 14	98,382.62	49,191.31
Maryland	25B	Charles	3.930	Gravel	Feb. 16	49,692.17	24,846.08
	33C	Carroll	2.260	Earth	do	47,746.27	23,873.13
	35A	Washington	0.840	Sheet asphalt	Feb. 10	24,350.04	12,175.02
	41	Garrett	1.990	Graded	Feb. 5	50,292.00	25,146.00
	44	Kent	0.950	Concrete	Feb. 10	38,905.90	19,000.00
	46	Somerset	0.710	Bridge and earth	do	20,918.42	10,459.21
	47	St. Marys	4.440	Gravel	Feb. 16	86,939.90	43,469.95
Michigan	38	St. Clair		Concrete	Feb. 18	[2] 103,140.81	[2] 580.37
	43C	Muskegon	7.929	do	Feb. 15	330,220.96	165,110.48
Minnesota	2	Chisago		Gravel	Feb. 23	[2] 8,639.40	[2] 4,319.70
	25	Stearns		do	Feb. 7	[2] 26,588.83	[2] 16,668.97
	26	Todd		do	Feb. 1	[2] 217.76	[2] 5,377.72
	88	Chippewa		do	Feb. 7		[3] 10,000.00
	95	Chisago		Gravel, brick, bituminous concrete	Feb. 16	[2] 11,269.18	[2] 5,645.56
	122	Chippewa		Gravel	Feb. 1		[2] 10,000.00
	132B	Becker	4,410	do	Feb. 9	40,436.81	13,966.14
	145A	Lac qui Parle	7.060	do	Feb. 1	82,813.77	33,461.84
	147	Houston	18.030	Sand-clay	Feb. 23	325,248.70	150,000.00
	160	Otter Tail	8.440	Gravel	Feb. 18	119,134.15	59,000.00
	194	Lac qui Parle	10.360	do	Feb. 8	30,794.12	10,000.00
	198	do	5.780	do	Feb. 5	14,370.52	5,000.00

[1] Canceled.
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[3] Modified agreement. Amounts given are decreases over those given in the original agreement.
[4] Decrease in mileage.

PROJECT AGREEMENTS EXECUTED IN FEBRUARY, 1921—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Missouri	26	Dunklin		do	Feb. 8	[2] $17,156.50	[2] $8,578.26
	27	Cooper		Bituminous macadam	do	[2] 452.61	[2] 226.30
	30	Morgan		Gravel	do	[2] 242.56	[2] 121.28
	47A	Cedar	9.736	Earth	Feb. 28	43,615.26	21,807.63
	56	Jasper		Concrete	Feb. 8	[2] 2,892.10	[2] 1,446.05
	81	do		do	do	[2] 969.88	[2] 484.94
	83	Jasper and Newton		do	do	[2] 6,675.18	[2] 3,337.59
	84	Jasper		do	do	[2] 3,919.55	[2] 1,959.78
	88	Cedar	7.420	Earth	do	21,479.71	10,739.85
Montana	10	Cascade		Gravel	Feb. 2	[2] 25,249.92	[2] 12,624.96
	22	Ravalli		do	Feb. 19	[2] 10,590.12	[2] 5,295.06
	53A	Yellowstone		do	Feb. 1	[2] 8,258.66	[2] 4,129.33
	61	Wibaux		do	Feb. 2	[2] 8,896.36	[2] 4,448.18
	79	Roosevelt		Bridge	do	18,557.00	9,278.50
	99	Flathead	3.780	Gravel	do	20,411.76	10,205.88
	114	Rosebud		do	Feb. 1	[2] 6,178.80	[2] 3,089.40
	125	Sweet Grass		Bridge	Feb. 16	16,562.15	8,281.07
	129	Stillwater	1.160	Earth	Feb. 10	32,368.36	16,184.18
	134	Yellowstone	3.234	Gravel	Feb. 2	39,484.58	19,742.29
Nebraska	42	Loup		Earth	Feb. 5	[2] 32,061.91	[2] 16,030.96
Nevada	6	White Pine		Gravel	Feb. 1	[2] 11,757.59	[2] 5,878.79
	14	Douglas		do	Feb. 16	[2] 13,770.75	[2] 6,885.37
	29AB	Washoe	0.010	Concrete	do	[2] 41,674.39	[2] 1,942.36
	35	Clark		Bridge	do	7,491.00	3,745.50
New Hampshire	132	Strafford	0.340	Gravel	Feb. 1	9,981.20	4,990.60
North Carolina	58	Johnston		Topsoil	Feb. 5	[2] 1,526.25	[2] 763.13
	71	Durham	[2] 0.022	Concrete base, bituminous top	Feb. 12	[2] 28,823.96	[2] 440.00
	73	Nash	8.729	Topsoil	Feb. 2	159,913.16	79,956.58
	82	Davidson	4.536	do	do	62,454.75	31,227.37
	84B	McDowell	6.425	do	do	109,659.49	54,829.74
	99B	Chatham	21.817	do	Feb. 21	259,931.59	129,965.79
	101A	Randolph	10.040	do	Feb. 12	123,893.99	61,946.99
	107	Madison	2.459	do	do	70,910.40	35,455.20
	117	Wilson	6.251	do	Feb. 12	41,828.93	20,914.46
	127	do	7.629	do	Feb. 15	49,218.94	24,609.47
North Dakota	20	Wells	[2] 0.233	Grading	Feb. 1	[2] 82,258.99	[2] 41,129.50
	36	Barnes		Earth	do	[2] 5,893.58	[2] 2,946.79
	55	Stutsman	5.980	do	do	39,636.33	19,818.16
	59	Richland	14.430	do	Feb. 24	67,135.26	33,567.63
	62	McLean	9.970	do	Feb. 1	72,030.11	36,015.05
	78AB	Divide	10.050	do	Feb. 23	71,110.63	35,555.31
	100	Morton and Burley		Bridge	Feb. 17	[2] 316,871.90	[2] 158,435.95
Oklahoma	9	Leflore		do	Feb. 21	[2] 672.31	[2] 336.16
	10	do		do	do	[2] 19,192.25	[2] 9,596.13
	17	Canadian and Grady		do	do	[2] 6,340.57	[2] 3,170.28
Oregon	48	Harney	10.460	Broken stone	Feb. 14	168,107.50	74,053.75
Pennsylvania	88	Indiana	2.688	Reinforced concrete	Feb. 15	273,512.98	53,760.00
South Carolina	38	Oconee	7.165	Topsoil	Feb. 4	49,714.64	24,857.32
	66	Richland	15.136	Concrete or asphalt concrete	Jan. 31	147,062.71	73,531.35
	88	Anderson	9.019	Topsoil	Feb. 17	45,323.68	22,661.84
South Dakota	1	Coddington		Gravel	Feb. 1	[2] 35,157.90	[2] 17,578.95
	3	Grant		do	do	[2] 58,936.97	[2] 29,468.49
	6	Moody		do	Feb. 5	[2] 4,432.64	[2] 2,216.32
	10	Clark		do	Feb. 1	[2] 53,402.58	[2] 26,701.29
	12	Minnehaha	[2] 0.863	Gravel and concrete	do	[2] 161,729.58	[2] 73,356.55
Tennessee	4	Moore and Bedford		Macadam and gravel	Feb. 11	[2] 87,037.07	[2] 43,518.53
	41B	Knox	12.760	Bituminous macadam	Feb. 8	427,024.76	213,512.38
	43	Shelby		do	Feb. 25	[2] 37,715.42	[2] 14,330.85
Texas	129	Milan	8.710	Gravel	Feb. 21	68,669.06	34,334.53
	161	Limestone	23.370	do	do	390,543.83	59,400.00
	177	Hays	17.050	Earth	do	63,877.89	30,000.00
	180B	San Patricio	15.060	Gravel on shell base	Feb. 14	178,352.58	84,000.00
	191C	Milan	5.710	Gravel	do	33,541.57	16,770.78
	199A	Stephens		Bridge	Feb. 11	77,698.29	38,849.14
Utah	4H	Emery	0.550	Earth	Feb. 15	38,086.77	19,043.38
Vermont	5	Franklin		Water-bound macadam	Feb. 24	[2] 5,382.74	[2] 2,691.37
Virginia	39	Buckingham		Topsoil	Feb. 3	[2] 3,328.95	[2] 1,664.48
	43	Albemarle		Water-bound macadam	Feb. 2	[3] 7,490.23	[3] 3,745.12
	72C	King William	6.400	Topsoil and gravel	Feb. 4	65,939.00	32,969.50
	103	Arlington	1.704	Concrete	do	74,933.52	34,558.94
	108	Henrico	3.260	Bituminous concrete	do	100,308.23	50,154.11
Washington	52	Stevens		Gravel	Feb. 19	[2] 19,541.94	[2] 10,200.00
	68	Grant		Crushed rock	Feb. 15	[2] 3,167.01	[2] 2,000.00
	81	Skamania and Klickitat	0.170	Earth	Feb. 3	29,371.76	3,400.00
	82	Kittitas	1.280	do	Feb. 25	65,414.36	25,600.00
West Virginia	10	Mason	[3] 1.580	Concrete	Feb. 26	[3] 2,817.25	
	47	Wetzel		do	Feb. 9	[2] 8,790.00	[2] 4,395.00
	58B	Pleasants	1.890	Earth	do	27,000.00	6,290.00
	67	Berkeley		Bituminous macadam	Feb. 19	[2] 31,160.00	[2] 15,580.00
	89	Logan	2.460	Earth	Feb. 18	68,931.10	34,465.55
	107A	Morgan	3.710	do	do	44,309.50	22,154.75
Wisconsin	80	Green	1.433	do	Feb. 15	[2] 257,231.67	[2] 77,910.75
	84	Jackson	[2] 0.950	do	do	[2] 16,049.55	[2] 7,130.60
	124	Polk	2.380	do	do	45,060.95	19,060.95
	129	Marinette	7.820	do	Feb. 24	72,020.52	33,332.70
	146	Vilas	5.660	Gravel	Feb. 15	55,296.63	19,000.00
	166	Langlade	7.670	Earth	Feb. 8	54,397.16	19,709.30
	178	Ashland	5.980	Earth and sand-clay	Feb. 19	41,720.14	14,110.07
Wyoming	86	Johnson	[2] 0.152	Selected material	Feb. 8	[2] 6,891.50	[2] 3,445.75
	93	Wasakie		Bridge	do	6,102.25	3,051.12
	99	Goshen	3.270	Selected material	do	142,038.82	71,019.41
	106	Wasakie	2.735	do	do	40,269.46	20,134.73

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[4] Decrease in mileage.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

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

REPORTS

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

DEPARTMENT BULLETINS.

Dept. Bul.*105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
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220. Road Models.
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*249. Portland Cement Concrete Pavements for Country Roads. 15c.
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DEPARTMENT CIRCULAR.

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FARMERS' BULLETINS.

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505. Benefits of Improved Roads.
597. The Road Drag.

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SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. 727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

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

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*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
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Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
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Public Roads Vol. III, No. 25. Automobile Registrations, Licenses, and Revenues in the U. S. 1919.
Public Roads Vol. III, No. 29. State Highway mileage 1919.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

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

* Department supply exhausted.