PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

VOL. 13, NO. 3 ▽ MAY, 1932

HIGHWAY ENTERING WILSON CANYON IN NEVADA

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

Issued by the

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

G. P. St. CLAIR, *Editor*

Volume 13, No. 3 May, 1932

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

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HIGHWAY TRAFFIC CAPACITY

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

ONE of the fundamental factors of highway economics is the traffic capacity of a road. This paper reports a study of the relative traffic capacity of 2-lane, 3-lane, and 4-lane highways. The project was undertaken as a cooperative arrangement between the United States Bureau of Public Roads, the State Roads Commission of Maryland, and the University of Maryland, under the immediate supervision of the writer.

The basic data for this discussion are the result of traffic counts taken during the summers of 1930 and 1931. A tentative report on the work done in 1930 was published in the Proceedings of the Highway Research Board for 1930. It was evident that positive conclusions could not be reached from the data then at hand, and a second series of observations was made in 1931, closely paralleling that of the preceding year. There will be repeated here such general description of the work as is necessary to make this report complete in itself without reference to the tentative report noted above.

In 1930 the field work extended from June 26 to September 1, and in 1931 from July 1 to September 7. Observers in both years were recruited among senior engineering students at the University of Maryland.

The two observers traveled from point to point in a motor car and counted the traffic on roads known to have heavy traffic, endeavoring as far as possible to count during the rush hours on the respective roads. The stretches of highway selected were as free as possible from interference from crossroads or other features that would hinder the free flow of traffic.

During 1930, traffic was counted at 38 different points, scattered between Boston and Washington, 51 separate counts being made. In 1931, 33 stations were occupied, for a total of 56 counts, mostly in northern New Jersey and Pennsylvania because of the comparatively large number of three and four lane roads to be found in this territory. A complete list of the stations is given in Table 3, at the end of the article. A summary of the traffic counts according to geographic location and number of lanes of pavement width is shown in Table 1.

TABLE 1.—*Distribution of traffic counts by geographic location and number of lanes*

State	Year	Number of counts			
		2-lane roads	3-lane roads	4-lane roads	Total
Maryland	1930	17		4	21
	1931	4		1	5
New Jersey	1930	2	7	2	11
	1931	5	26	5	37
Pennsylvania	1930	3	3		6
	1931	9	6		14
New York	1930	2			2
Connecticut	1930	4		2	6
Massachusetts	1930	2		2	4
Virginia	1930	1			1
Total	1930	31	10	10	51
	1931	18	32	6	56
Total in both years		49	42	16	107

TRAFFIC CAPACITY AND CONGESTION DEFINED

For the purposes of this study it was first necessary to develop a definition of traffic capacity. The "working capacity" or "free-moving capacity" of a highway was taken to mean the point at which congestion first becomes apparent. When a road carries only a few vehicles all will move freely and there can be no question of congestion. As the number of vehicles increases there will be reached a point at which some will be delayed because they can not immediately pass slower vehicles ahead of them. This delay indicates congestion.

Beyond the free-moving capacity of a highway the number of vehicles passing in a given time may still increase, but traffic will move with more and more restrictions. The individual driver will have less and less freedom of action, being compelled to follow the vehicles directly ahead of him. The number of vehicles may increase until the rate of flow is at a maximum, when the ultimate capacity of the highway may be said to have been reached. Any attempt to put still more vehicles through will result in serious interference with the movement of traffic, and the number of vehicles passing a given point in a given time will actually decrease because of overcrowding.

The observers were instructed to make note of congestion under substantially the following conditions: Congestion is considered to occur on a road when the number of vehicles reaches a total great enough to fill the road and make turning out impracticable; this condition to last a sufficient length of time to be noticeable, the minimum amount of time being one minute. When congestion occurs, reduction of speed will be noticed, along with the tendency for drivers to crowd one another.

In all further discussion the term "congestion" is used as above defined and "capacity" is understood to mean "working capacity."

The purpose of the investigation made it necessary to count traffic through peak periods to get as nearly as possible the maximum traffic conditions. It will be readily appreciated, however, that there were many stations occupied which did not at the time develop sufficiently heavy traffic to approach the critical stage. There were, therefore, a number of counts made each year which had no influence upon the results. The rush hours during which traffic stations were occupied proved to be late afternoon or evening, generally between 3 and 7 o'clock.

CONSISTENCY OF OBSERVERS' JUDGMENT TESTED

One of the questions which arose during the analysis of the data was whether under similar traffic conditions like interpretations would be made by the same or different observers; in other words, whether the concept of congestion as formulated was sufficiently definite to serve as a fixed, objective standard. A study of the traffic counts submitted, making comparison between the conclusions reached by one party of observers and those of the other party under similar conditions showed very satisfactory agreement, indicating that such differences as did occur were due more to some other influence that would affect the traffic than to differing judgment on the part of the observers.

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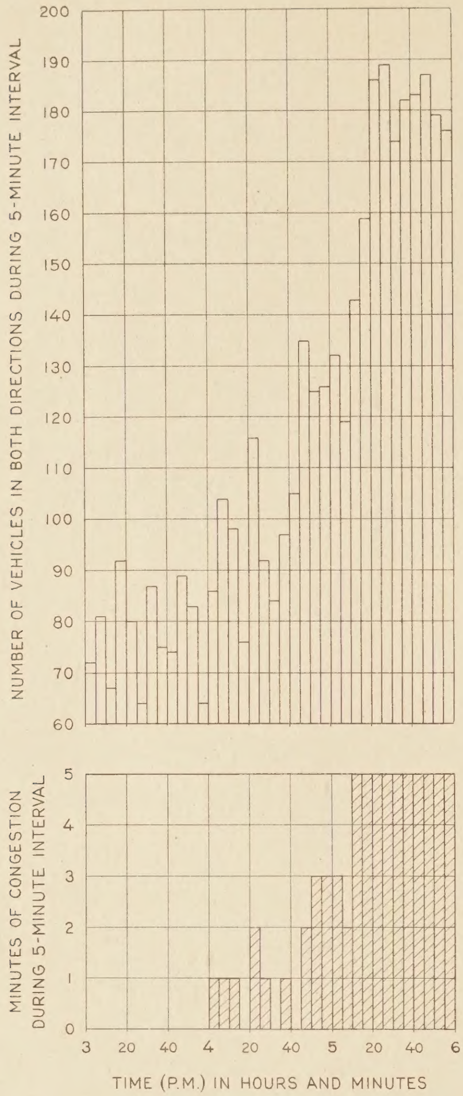
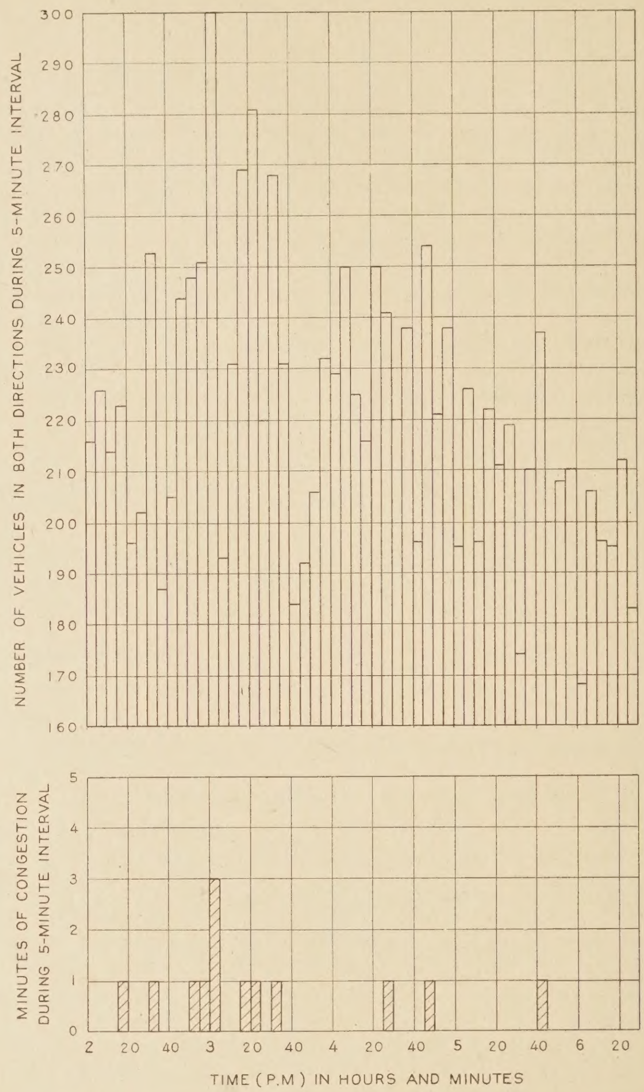


HOUR	TRAFFIC (VEHICLES)	PERCENTAGE IN EACH DIRECTION
3 TO 4	924	50/50
4 TO 5	1,243	41/59
5 TO 6	2,008	25/75

TRUCKS 10 PER HOUR
BUSSES 0
SPEED 25 TO 35 M.P.H.

Figure 1.—Traffic on 2-Lane Road in Druid Hill Park, Baltimore, Md., July 15, 1930



HOUR	TRAFFIC (VEHICLES)	PERCENTAGE IN EACH DIRECTION
2 TO 3	2,642	28/72
3 TO 4	2,805	32/68
4 TO 5	2,755	41/59
5 TO 6	2,484	53/47
6 TO 6:30	1,157	56/44

TRUCKS $3\frac{3}{4}$ PER CENT
BUSSES $\frac{1}{2}$ PER CENT
SPEED 35 TO 40 M.P.H.

Figure 2.—Traffic on 3-Lane Road, U. S. Route 9, 1 Mile North of South Amboy, N. J., August 1, 1931

As a further test of the judgment of the observers, stations that were occupied at the beginning of the season were again occupied at the close, the traffic at these points being about the same. The reports received were similar and indicated that the picture in the observer's mind of a congested condition, as here defined, was reasonably well fixed and precise.

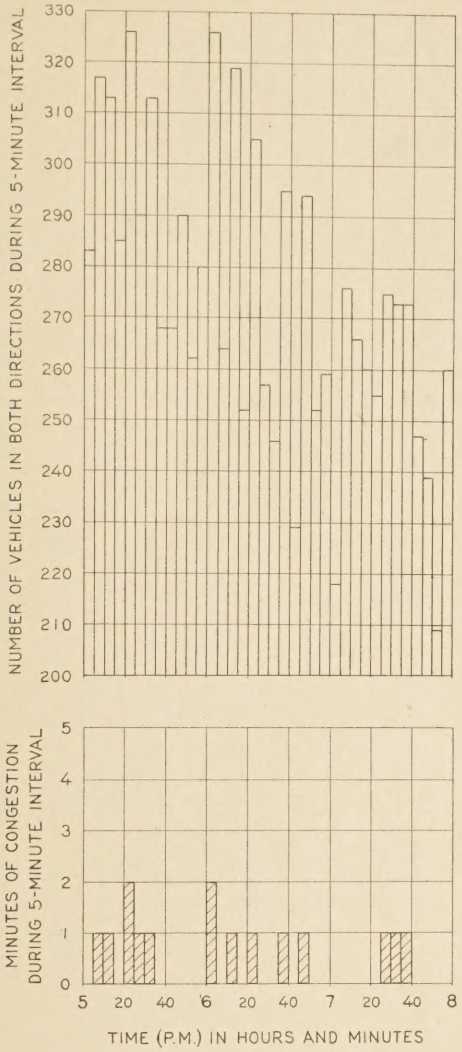
PROCEDURE DESCRIBED

At each station the traffic was recorded by 5-minute intervals, showing the number of vehicles in each direction or in each lane. Passenger automobiles, trucks, and busses were tabulated separately. The tally sheets provided space for indicating when the traffic was running freely and when it was congested. No record of congestion was made unless it extended for a period of one minute. Thus, during some 5-minute intervals there would be but one minute during which congestion occurred; in other instances two minutes, or more, up to the full five minutes.

The tally sheets were summarized for each count and the data plotted as shown in Figures 1, 2, and 3. These graphs give all the essential facts, such as date, location, actual traffic per hour, estimated average speed, number of trucks and busses, and the number of lanes available for traffic. The ordinates of the graph show the traffic for each 5-minute interval, while the number of minutes of congestion in each interval are shown by the shaded columns in the lower section of the graph.

Figure 1 gives the record of a traffic count on a 2-lane road by 5-minute intervals during the hours between 3 and 6 p. m. The maximum hourly traffic (5 to 6) was 2,008 vehicles, although the maximum rate per hour during a 5-minute period within this same hour was 2,268. This was the maximum hourly traffic observed on any 2-lane road and was about 89 per cent of the hourly rate of the maximum 5-minute interval.

Figure 2 shows a similar record for a 3-lane road where the actual hourly maximum was 2,805 vehicles.



HOUR	TRAFFIC (VEHICLES)	PERCENTAGE IN EACH DIRECTION
5 TO 6	3,496	70 / 30
6 TO 7	3,305	70 / 30
7 TO 8	3,068	78 / 22

TRUCKS 3½ PER CENT
BUSSES 0
SPEED 35 TO 40 M.P.H.

FIGURE 3.—TRAFFIC ON 4-LANE ROAD, U. S. ROUTES 1 AND 9, 15.5 MILES SOUTH OF JERSEY CITY, N. J.

The maximum hourly rate for a 5-minute interval was 3,600, the total traffic for the hour being about 78 per cent of the maximum rate based on a 5-minute count. This was the maximum hourly traffic observed on any 3-lane road.

Figure 3, for a 4-lane road, shows a maximum hourly traffic of 3,496, while the maximum rate per hour for a 5-minute interval was 3,912, the actual hourly traffic being about 89 per cent of the maximum 5-minute interval. This was the maximum hourly traffic observed on any 4-lane road.

In the analysis of the data to determine the point of incipient congestion, all 5-minute counts were assembled without regard for location or hour of day, each count being treated as a separate statistical unit. They were first grouped according to the major classification of 2-lane, 3-lane, and 4-lane roads. Each of these larger groups was then subdivided according to the proportion of traffic moving in each direction, viz., 50 per cent in one direction (approximately equal in both directions), 60 per cent in one direction (40 per cent in the opposite direction), 70 per cent and 80 per cent in one direction. There were then 12 groups into which the 5-minute counts for all stations were divided, and within each group the items were arranged in order from least to greatest. These were plotted as shown in Figures 4 to 7, inclusive, congestion occurring during any part of any 5-minute interval being indicated in the same manner as in Figures 1 to 3.

The point where traffic congestion first appeared was noted in each case. Thus, in Figure 4, which is a plot of the data for 2-lane roads with 50 per cent of the traffic in each direction, congestion is first observed when 80 vehicles pass in a 5-minute interval. The fact that no congestion was reported in this group of observations for any number less than 80 made it unnecessary to plot or to consider further those counts indicating a less amount of traffic. Similarly, in each of the suc-

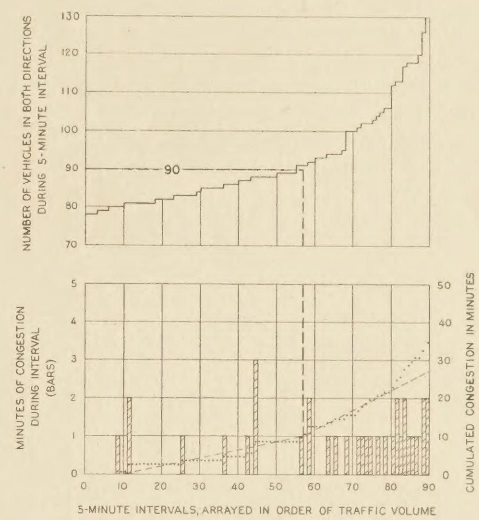


FIGURE 4.—DETERMINATION OF TRAFFIC CAPACITY OF 2-LANE ROADS, 50 PER CENT OF TRAFFIC IN ONE DIRECTION

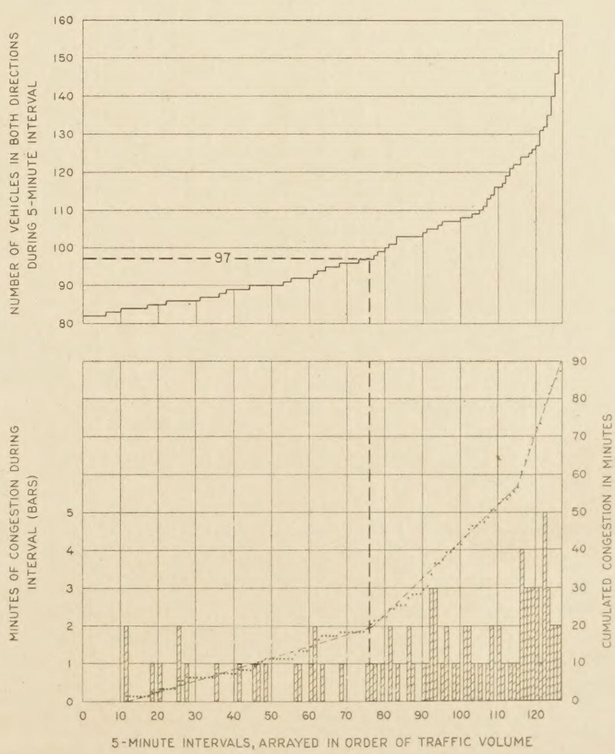


FIGURE 5.—DETERMINATION OF TRAFFIC CAPACITY OF 2-LANE ROADS, 60 PER CENT OF TRAFFIC IN ONE DIRECTION

ceeding diagrams no consideration was given to the observations that recorded traffic insufficient to produce the first instance of congestion.

The critical point to be established in each diagram is the point at which congestion becomes general. This can most easily be determined by inspection of the graphs, which show in nearly every case a fairly definite and sharp transition from a scattered and infrequent occurrence of congestion to a condition in which congestion is usual or normal. The height of the curve at this point indicates the working capacity of the type of highway under consideration.

The nature of the data appears hardly to justify a more elaborate or refined method of analyzing the graphs than that just described. As a check upon the reliability of the inspection method, a cumulative congestion curve was plotted on each diagram. In each case the break in the trend of the cumulative curve, as located by the intersection of straight lines fitted to the separate sections of the curve, coincided almost exactly with the point previously located by inspection.

It will be seen from Figure 4 that the working capacity of two-lane roads with 50 per cent of the traffic in each direction is reached at 90 vehicles per 5-minute interval. Beyond this point, as traffic increases, congestion becomes general for nearly all 5-minute intervals.

For 2-lane roads with 60 per cent of the traffic in one direction, congestion becomes general when traffic exceeds 97 vehicles per 5-minute interval, as shown in Figure 5. When the proportion of traffic is 70 per cent in one direction, congestion appears to become general at 90 vehicles per 5-minute interval, and with 80 per cent in one direction, traffic appears congested at about 105 vehicles per 5-minute interval.

Figures 6 and 7 further illustrate the method of analysis for 3-lane roads with 70 and 80 per cent of the traffic, respectively, in one direction.

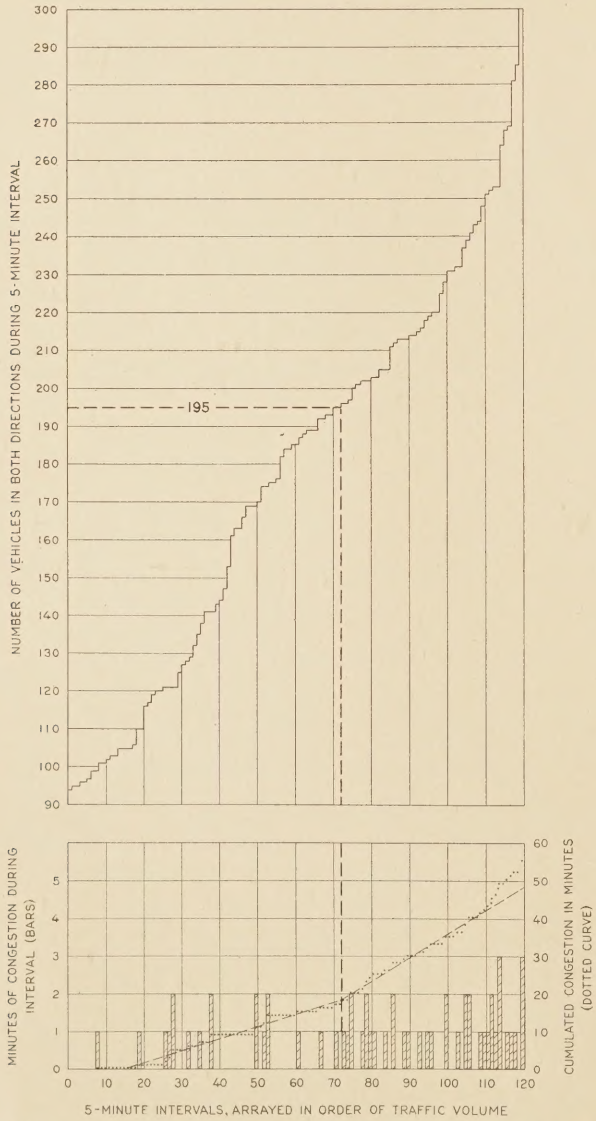


FIGURE 6.—DETERMINATION OF TRAFFIC CAPACITY OF 3-LANE ROADS, 70 PER CENT OF TRAFFIC IN ONE DIRECTION

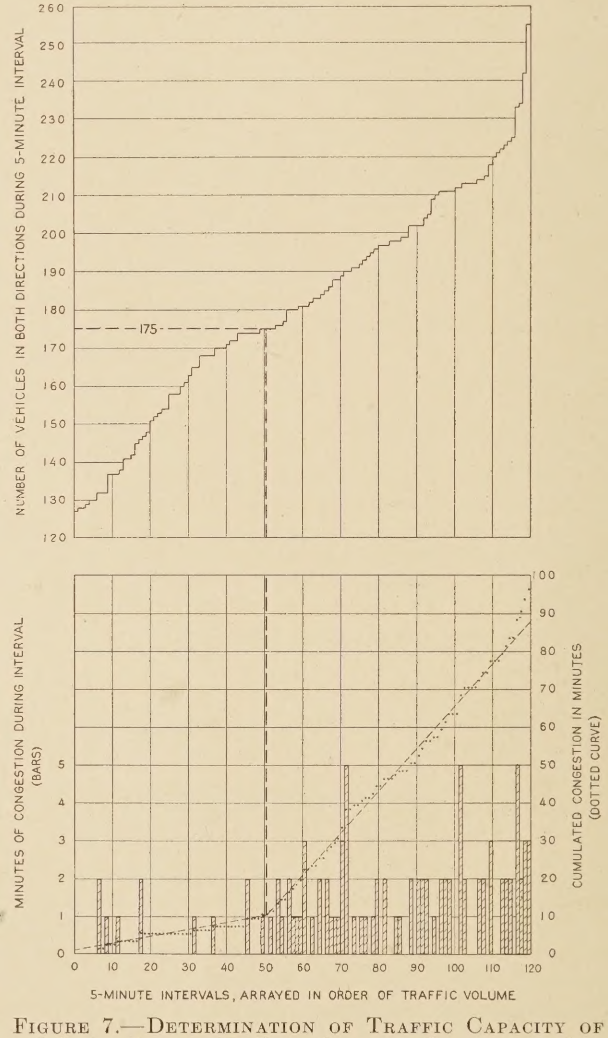


FIGURE 7.—DETERMINATION OF TRAFFIC CAPACITY OF 3-LANE ROADS, 80 PER CENT OF TRAFFIC IN ONE DIRECTION

The evidence brought out by the series of graphs is summarized in Table 2, showing apparent traffic capacity of 2-lane, 3-lane, and 4-lane roads under differing proportions of traffic in the opposing directions.

The values given for practical hourly capacity are based on the 5-minute rate, with reasonable allowance for the fact (demonstrated in figs. 1 to 3) that the maximum rate of traffic during any hour is rarely sustained for more than a small fraction of that hour.

From Table 2 it would appear that the effect of unbalanced traffic on the capacity of 2-lane roads is not marked until 80 per cent of the traffic is in one direction,

TABLE 2.—*Working capacity of 2-lane, 3-lane, and 4-lane highways*

Number of lanes	Vehicles per 5-minute interval					Practical hourly capacity (vehicles)
	Percentage of traffic in one direction				Average	
	50	60	70	80		
2	90	97	90	105	97	1,000
3	185	165	195	175	180	2,000
4	[1] 300	[1] 300	290	270	290	3,000

[1] Estimated.

when the capacity rises considerably above the average. On a 3-lane road the effect is not so definite, but the maximum capacity is reached when about 70 per cent of the traffic is in one direction.

The results for the 4-lane road are even less conclusive, as there was no congestion noted when the traffic was 50 or 60 per cent in one direction, although as many as 273 vehicles were counted during one 5-minute interval. The occasions when 4-lane roads were seen working to capacity were rare. With the traffic 70 per cent in one direction congestion was reported when 290 vehicles passed in five minutes, and when the traffic was 80 per cent in one direction congestion occurred with a count of 270 vehicles. These figures would indicate that, as the traffic becomes more unbalanced, the 4-lane road becomes less efficient.

CONCLUSIONS

The influence of the proportionate amount of traffic in one direction is not marked on 2-lane roads until the fraction increases to 80 per cent or more, when a greater volume of traffic is carried without congestion. The average working capacity for 2-lane roads is approximately 95 per 5-minute interval, or 1,000 per hour.

Three-lane roads appear to operate to slightly better advantage when 70 per cent of the traffic is in one direction. The average working capacity is approximately 180 per 5-minute interval or 2,000 per hour.

Four-lane roads (estimating the capacity as 300 vehicles in five minutes when traffic is 50 or 60 per cent in one direction) have an average working capacity of 290 vehicles per 5-minute interval.

These values give a ratio for 2-lane, 3-lane, and 4-lane roads of approximately 1:2:3. That is, the traffic capacity of a 3-lane road is twice that of a 2-lane road, and the 4-lane road has a capacity of at least three times that of the 2-lane road and 50 per cent greater than that of the 3-lane road.

The addition of one lane to a 2-lane road increases its width 50 per cent and its capacity 100 per cent. Addition of two lanes increases the width by 100 per cent and the capacity by 200 per cent. In other words, doubling the width of a 2-lane highway triples its capacity.

It should be clearly understood and emphasized that this study relates to traffic capacity only. No consideration has here been given to the relative safety of 2-lane, 3-lane, and 4-lane design in highways under varying volumes of traffic. There seems to be very general agreement among those who have observed the operation of 3-lane roads that as traffic increases the hazards increase in a greater ratio than in the case of the 2-lane or the 4-lane roads, but this conclusion must rest upon research of an entirely different nature from that here reported.

TABLE 3.—*List of stations occupied for traffic counts*

Name of road	Location	Number of lanes	Date	Hours
MARYLAND				
Baltimore-Washington Blvd., U. S. Route 1	100 yds. S. of S. E. Branch, Anacostia River, Bladensburg.	2	June 27, 1930	3 to 6 p. m.
			July 19, 1930	11 a. m. to 3 p. m.
			Aug. 27, 1930	3 to 6 p. m.
Do	College Park Experiment Station.	2	June 26, 1930	Do.
Do	1 mi. N. of Laurel	4	July 19, 1931	2 to 4 p. m.
Do	S. of rd. to Dorsey	4	June 28, 1930	3 to 6 p. m.
			Aug. 30, 1930	1 to 4 p. m.
			Aug. 31, 1930	4 to 7 p. m.
			Sept. 1, 1930	Do.
Baltimore-Philadelphia Rd., U. S. Route 1.	1 mi. N. of Conowingo.	2	June 29, 1930	3 to 6 p. m.
			July 23, 1931	4 to 6 p. m.
Baltimore-Philadelphia Rd., U. S. Route 40.	1 mi. N. of Baltimore city line.	2	July 18, 1930	4 to 7 p. m.
Do	1 mi. S. of Havre de Grace.	2	July 6, 1930	2 to 5 p. m.
			July 8, 1931	3 to 6 p. m.
Do	1½ mi. N. of Baltimore city line.	2	Aug. 19, 1930	4 to 6 p. m.
Baltimore-Annapolis Blvd.	3 mi. S. of Glenburnie.	2	July 20, 1930	1 to 4 p. m.
			Aug. 24, 1930	Do.
Do	Opposite Brooklyn ball park.	2	July 17, 1930	4 to 7 p. m.
			Aug. 25, 1930	4 to 6 p. m.
Harford Rd	10 mi. N. of Baltimore.	2	July 22, 1931	Do.
Frederick Rd	3½ mi. E. of Ellicott City.	2	Aug. 12, 1930	Do.
Druid Hill Park Rd., Baltimore.	Opposite Flower Garden.	2	July 15, 1930	3 to 6 p. m.
Charles St. Ave	2 mi. S. of Towson	2	Aug. 20, 1930	4 to 6 p. m.
Reistertown Rd	1 mi. W. of Baltimore city line.	2	Aug. 22, 1930	Do.
Rhode Island Ave. Ext., Mt. Rainier.	William St	2	July 1, 1931	2.45 to 5.45 p. m.
Defense Highway, U. S. Route 50.	¼ mi. E. of rd. to Landover.	2	Aug. 17, 1931	4 to 6 p. m.
NEW JERSEY				
White Horse Pike, U. S. Route 30.	4 mi. E. of Haddon Heights.	3	July 5, 1930	6 to 8 p. m.
			July 4, 1931	10 a. m. to 1. p. m.
			July 25, 1931	4 to 6 p. m.
Do	9 mi. of E. of Berlin	3	July 18, 1931	Do.
Do	10 mi. W. of Atlantic City.	3	July 12, 1930	3 to 6 p. m.
			July 13, 1930	10 a. m. to 1 p. m.
			July 13, 1930	3 to 6 p. m.
			July 4, 1931	5 to 8.30 p. m.
			July 5 , 1931	5 to 9 p. m..
			July 26, 1931	4.30 to 8.30 p. m.
			Aug. 9, 1931	5 to 8.30 p. m.
			Aug. 29, 1931	3 to 6 p. m.
			Aug. 30, 1931	6 to 9 p. m.
Do	7 mi. W. of Atlantic City.	4	Aug. 9, 1930	4 to 6 p. m.
			Aug. 10, 1930	4 to 8 p. m.
Do	6 mi. W. of Atlantic City.	4	July 5, 1931	10.15 a. m. to 1.30 p. m.
Shore Road, U. S. Route 9	1 mi. S. of Woodbridge.	3	Sept. 6, 1931	5 to 8 p. m.
Do	1 mi. N. of South Amboy.	3	July 9, 1930	4 to 6 p. m.
			Aug. 7, 1930	4 to 8 p. m.
			July 11, 1931	3 to 7 p. m.
			Aug. 1, 1931	2 to 6.30 p. m.
			Aug. 15, 1931	3 to 7 p. m.
			Sept. 4, 1931	5 to 8 p. m.
			Sept. 5, 1931	6 to 8 p. m.
Do	1 mi. S. of South Amboy.	2	Aug. 11, 1931	5 to 7 p. m.
			Aug. 14, 1931	4 to 7 p. m.
South Amboy-Eatontown Rd., N. J. Route 35.	5 mi. S. of South Amboy.	3	July 12, 1931	Do.
Do	1 mi. N. of Eatontown.	3	July 11, 1930	3 to 6 p. m.
N. J. Route 33	1 mi. W. of Ocean Grove.	2	Aug. 8, 1930	4 to 6 p. m.
Point Pleasant-Eatontown Rd. N. J. Route 35.	1 mi. S. of Eatontown.	3	July 10, 1931	Do.
Atlantic City-Pleasantville Rd., U. S. Route 40.	½ mi. W. of Atlantic City.	3	July 9, 1931	3 to 6 p. m.
			July 27, 1931	2 to 5 p. m.
Ocean City - Cape May Rd., N. J. Route 4.	10 mi. N. of Cape May.	2	Aug. 8, 1931	3 to 6 p .m.
Broad St., U. S. Route 130.	3 mi. E. of Trenton	3	Sept. 1, 1931	5 to 7 p. m.
Trenton-Jersey City Rd., U. S. Route 1.	1½ mi. S. of Cloverleaf intersection (Woodbridge).	3	July 14, 1931	3 to 5 p. m.
Trenton-Jersey City Rd., U. S. Routes 9 and 1.	15.5 mi. S. of Jersey City.	4	Aug. 2, 1931	5 to 8.20 p. m.
			Aug. 16, 1931	3 to 8 p. m.
			Sept. 5, 1931	3 to 5 p. m.
			Sept. 7, 1931	5 to 8 p. m.
Jersey City-Albany Rd., U. S. Route 9W.	2 mi. S. of Alpine	3	July 15, 1931	5.15 to 9 p. m.
			July 16, 1931	8 to 10 p. m.
			July 31, 1931	5 to 8 p. m.
			Aug. 13, 1931	6 to 8 p. m.

TABLE 3.—*List of stations occupied for traffic counts*—Continued

NEW JERSEY—Continued

Name of road	Location	Number of lanes	Date	Hours
Westfield-Dunellen Rd., U. S. Route 22	1 mi. W. of Westfield.	2	July 10, 1930 July 13, 1931	3 to 6 p. m. 5 to 7 p. m.
Somerville-N. Plainfield Rd., N. J. Route 29.	1 mi. N. of North Plainfield.	3	July 17, 1931	4 to 6 p. m.
Dover-Denville Rd., N. J. Route 6.	1 mi. E. of Dover	2	Aug. 12, 1931	Do.

PENNSYLVANIA

Name of road	Location	Number of lanes	Date	Hours
Baltimore-Philadelphia Rd., U. S. Route 1.	1 mi. S. of Clifton Heights.	2	July 1, 1930 Aug. 3, 1931	3 to 6 p. m. 6 to 9 p. m.
Do	Memorial Bridge, 3 mi. S. of Swarthmore.	2	July 2, 1931	4.20 to 8 p. m.
Roosevelt Blvd., U. S. Route 1.	S. of Frankfort Ave.	3	July 3, 1930 Aug. 23, 1931	3 to 6 p. m. 3 to 5 p. m.
Do	N. of Vankirk St	3	Aug. 28, 1931	4 to 6 p. m.
Philadelphia-Trenton Rd., U. S. Route 1.	1 mi. N. of Philadelphia city line.	2	Aug. 17, 1931 Aug. 22, 1931	3 to 5 p. m. 3 to 6 p. m.
Do	4 mi. S. of Trenton	2	Sept. 2, 1931	4 to 6 p. m.
River Drive, Philadelphia.	Fairmount Park-Ormiston Valley.	3	July 2, 1930 July 3, 1931 July 28, 1931 Aug. 27, 1931	3 to 6 p. m. Do. 4.30 to 6.30 p. m. 3 to 6 p. m.
City Ave., Philadelphia, U. S. Route 1.	W. of Schuylkill River.	2	July 5, 1930 July 6, 1931 July 24, 1931 Aug. 24, 1931	1 to 4 p. m. 3 to 5 p. m. 3 to 6.30 p. m. 4 to 6 p. m.
Old York Rd., U. S. Route 611.	2 mi. S. of Willow Grove.	2	July 4, 1930 July 29, 1931	2 to 6 p. m. 4 to 6 p. m.
Susquehanna Trail, U. S. Route 22.	3 mi. N. of Harrisburg.	3	June 30, 1930 Aug. 25, 1931	3 to 6 p. m. 3 to 4 p. m.

CONNECTICUT

Name of road	Location	Number of lanes	Date	Hours
Boston Post Rd., U. S. Route 1.	Greenwich	4	Aug. 6, 1930	4 to 6 p. m.
Do	Washington Bridge Milford town line.	4	July 27, 1930	4 to 8 p. m.
Do	½ mi. W. of Milford	2	July 25, 1930 Aug. 5, 1930	4 to 7 p. m. Do.
New Haven Ave	Woodmont	2	July 26, 1930	1 to 4 p. m.
U. S. Route 5	S. of Hartford city line.	2	July 28, 1930	4 to 6 p. m.

NEW YORK

Name of road	Location	Number of lanes	Date	Hours
U. S. Route 9W	½ mi. S. of West Point.	2	July 22, 1930	4 to 6 p. m.
U. S. Route 9	1 mi. N. of Tarrytown.	2	July 24, 1930	3 to 6 p. m.

MASSACHUSETTS

Name of road	Location	Number of lanes	Date	Hours
U. S. Route 1	1 mi. N. of Dedham	2	Aug. 1, 1930	4 to 7 p. m.
Massachusetts 3A	4 mi. E. of Quincy	4	Aug. 2, 1930 Aug. 3, 1930	Do. Do.
U. S. Route 20	1 mi. W. of South Sudbury.	2	July 31, 1930	Do.

VIRGINIA

Name of road	Location	Number of lanes	Date	Hours
Washington-Alexandria Rd., U. S. Route 1.	2 mi. N. of Alexandria.	2	Aug. 16, 1930	2 to 5 p. m.

CORRECTION

In the April issue of PUBLIC ROADS there was printed, on page 40, a table entitled "Motor-vehicle registration fees, licenses, permits, fines, etc., 1931." It has been found necessary to revise the figure given in the last column of this table for the District of Columbia, and the resulting grand total. The correct figures are as follows:

Disposition of gross receipts

	For other purposes
District of Columbia	$483, 900
Grand total	11, 297, 175

CONCRETE PAVEMENT DESIGN FEATURES, 1931

Reported by R. D. BROWN, Senior Highway Engineer, Division of Design, U. S. Bureau of Public Roads

OF THE total of 88,713 miles of roads improved with Federal aid up to June 30, 1931, 28,009 miles were paved with Portland cement concrete. This represents the greatest mileage of any type of improvement or group of related types except untreated gravel, of which 28,646 miles have been constructed. The proportion of concrete pavement to other types constructed with Federal aid during the calendar year 1931 is even greater, clearly indicating the increasing importance of concrete pavement.

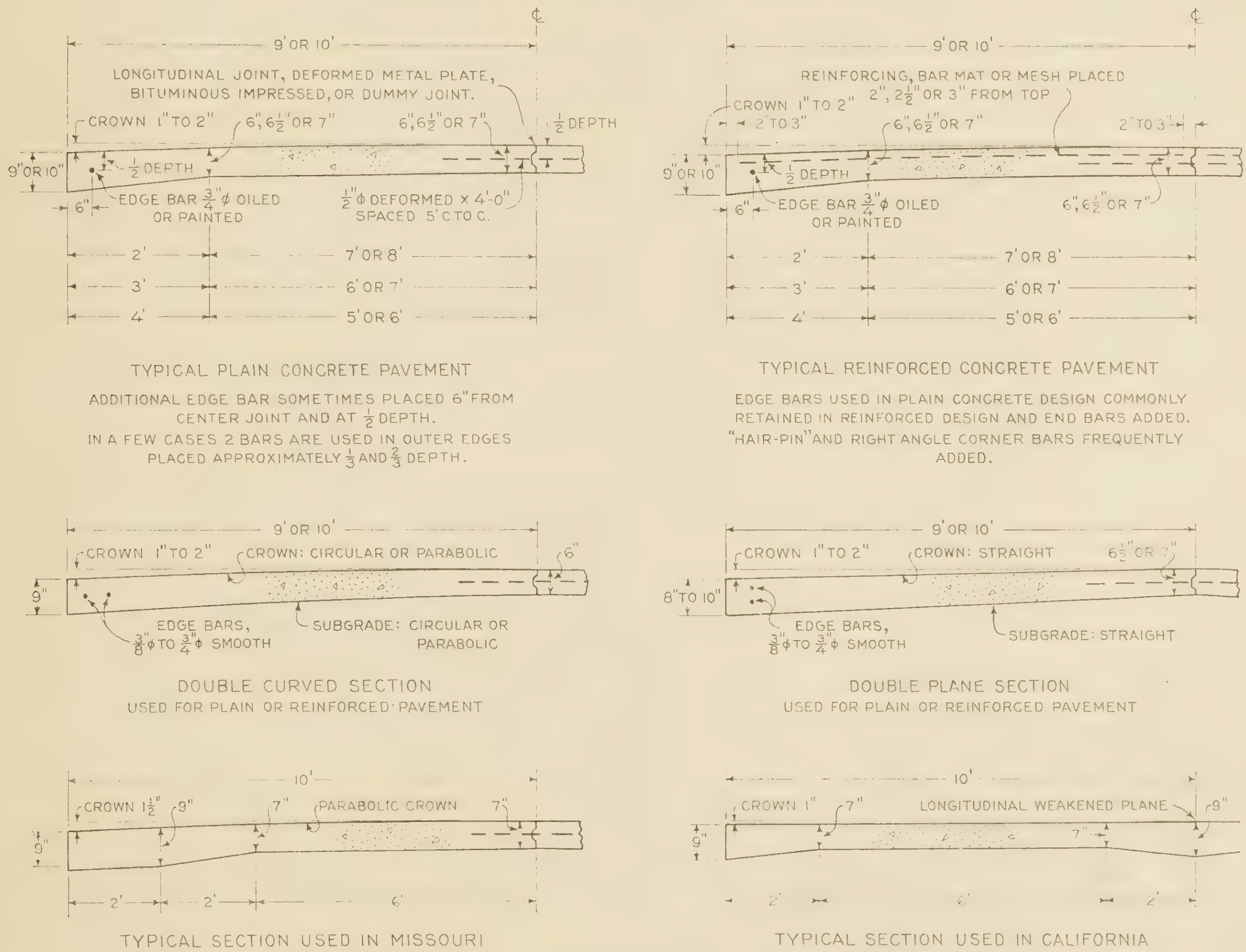


Figure 1.—Typical Cross-Section Designs

Considerable progress has been made in the past few years toward standardization of the design of concrete pavements. Further progress in this direction is possible in spite of the acknowledged fact that complete uniformity of design is impracticable because of varied conditions of climate, subgrade, and loading in the various States. Starting with only a vague understanding of the structural requirements of cement concrete as a pavement material, intensive research and observation of the earlier designs has pointed the way to rational methods of design affecting not only the shape of the pavement cross section and its dimensions but also the proportions of cement and aggregates, amount and location of steel, and character and location of joints.

A study of concrete pavement designs submitted by the several States during 1931 for use on Federal-aid projects has been made; and in order to facilitate comparison of the different State designs and also comparison with earlier studies,[1] the attached table has been prepared.

The data presented in the table cover the designs for only 43 States, since 5 States either did not submit any projects during 1931 involving the construction of concrete pavements or submitted so small an amount of such work as to be of little value in determining their typical practice.

One important fact brought out by the study is the practically complete acceptance of the 9-foot traffic lane as a minimum width. Highway engineers are almost unanimously agreed upon the desirability of the 10-foot traffic lane and in 20 States it is the standard width. Twenty-two States continue to build 2-lane roads, 18 feet wide, but in all except seven of these States 20-foot pavements are used on their more important routes.

[1] Public Roads, vol. 8, No. 1, March, 1927, and vol. 10, No. 5, July, 1929.

In all cases where pavements of more than two lanes are built, the width is a multiple of 10 feet.

In the matter of depth of pavement it is found that pavements of uniform depth are still constructed to some extent, particularly in the northeastern States and in connection with rather heavy steel reinforcement. Although there is no question that these designs have proved adequate as to strength there would appear to be grounds to warrant doubt as to the economy of the design. The edge thickness most commonly used on thickened edge designs is 9 inches, although nine States use an edge thickness of 8 inches, one 7½ inches, two 7 inches, and one State occasionally uses a 6-inch uniform depth. Only two States use a double-thickened section. Seventeen States use a 6-inch center depth either as a standard design or for their less important roads. Five States us a 6½-inch center depth, eighteen use 7 inches, and no State uses more than 7 inches at the center except those which use the double-thickened section or uniform 8-inch or 9-inch pavements.

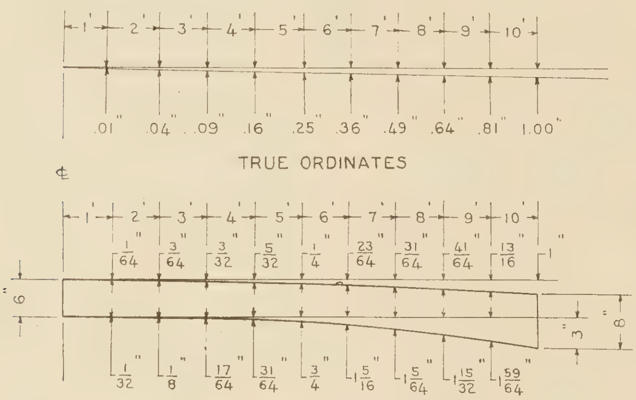


Figure 2.—Diagram Showing True Ordinates for Parabolic Crown of 1 Inch in 10 Feet and Practicable Ordinates for Both Crown and Subgrade

The use of a curved subgrade, usually parabolic, in connection with thickened edge designs, has become a more general practice in the past few years because of the greater ease with which a subgrade of this shape is prepared and properly compacted as compared with the angular-shaped subgrade. Ten States now use the curved subgrade with thickened edge designs. One State uses a 2-plane subgrade, the pavement depth increasing uniformly from the center to the edges. The transition distance between edge and center depth in other designs varies from 2 feet to 4 feet. One State uses a uniform edge depth for the outer 2 feet of width, reducing the thickness in the next 2 feet to the center depth.

The reduction in the amount of crown used in concrete pavements in the past five years is notable. In 1926 only two States used a crown as low as 1 inch for a 20-foot pavement and only three used 1 inch for an 18-foot pavement. In 1931, 14 States regularly used a 1-inch crown for a 20-foot pavement and only four use as much as 2 inches. The crown shape is usually parabolic or circular although there is no apparent advantage in this shape over a straight or uniform slope. In case a two-lane pavement with parabolic crown is to be widened by building an additional lane on either side it will be found that this crown shape is objectionable because it produces a break in the pavement slope at the edge of the old pavement unless an

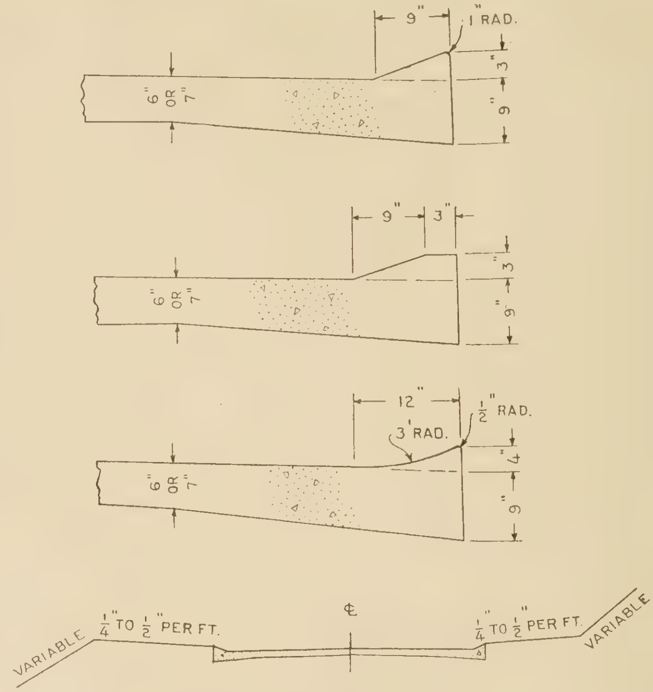


Figure 3.—Lip or Sloping Curb Designs

unnecessarily heavy crown is used on the new outer lanes.

On 4-lane pavements a parabolic crown produces an excessive slope in the outer lanes and a straight crown is much to be preferred. A crown of 3 or 3½ inches for a 40-foot pavement is adequate for all ordinary conditions. Of this total crown 1 to 1½ inches may be used on the inner 10-foot lane and 2 inches in the outer lane. On the Mount Vernon Memorial Highway the normal width of pavement is 40 feet, the center 18 feet of which is crowned to conform to the arc of a circle with a rise of 1 inch in 9 feet. The outer lanes are 11 feet wide, the crown being straight and having a rise of 2½ inches. This crown treatment gives a pleasing appearance and lends itself readily to future widening of the pavement.

In recognition of the public demand for smooth riding qualities and also with a view to reducing impact stresses, the surface trueness requirement has been set at not more than ⅛-inch variation in 10 feet in 11 States. With machine methods of finishing and reasonably close attention to finishing details there does not appear to be any difficulty in meeting this requirement. It is anticipated that many of the States which now permit a variation of ¼-inch in 10 feet will soon adopt a more stringent requirement.

Steel has been used as a reinforcing element in cement concrete for buildings, bridges, and other structures for a long time and quite definite design requirements for such structures have been established. A concrete pavement, however, presents conditions considerably at variance with such structures. The pavement slab receives more or less continuous support from the subgrade but frictional stresses and volumetric changes in the subgrade introduce variable tensile stresses indicating the use of steel. In determining the classification of the various pavement designs as between reinforced and plain, it was considered that a reinforced pavement is one in which the steel is used as a network bonded with the concrete and distributed generally throughout the slab. Marginal bars, end bars, and corner bars when used alone are not considered as reinforcement but when used in addition to a bar mat or mesh reinforcement their weight is included in the tabular data as reinforcement.

Reinforcement is most commonly placed 2 inches from the top of the pavement. Two of the New England States, however, place the reinforcement 2 inches from the bottom and two other New England States use double reinforcement; that is, in both the top and the bottom of the pavement. The severe climatic con-

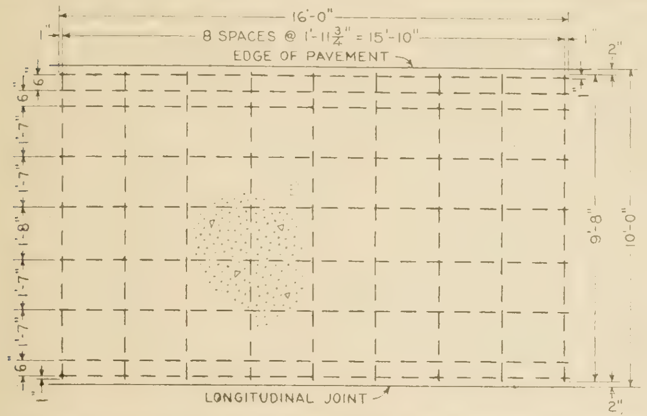


Figure 4.—Typical Bar Mat for Reinforced Pavement; Bars ¼ to ½ Inch Round, Welded, Clipped, or Wired at All Points of Intersection; Mats Lapped 12 to 14 Inches

ditions in these States are undoubtedly accountable for these departures from the general practice. Fifteen States used reinforced designs exclusively, while eight others used the reinforced design only on certain projects. The use of reinforcement is not confined to any geographical area, but most of the States using this design are in the area where frost conditions are rather severe. The smallest amount of steel used in reinforced designs is 25 pounds per 100 square feet and the maximum is 119 pounds. There is a noticeable tendency toward the use of reinforcement for crack control.

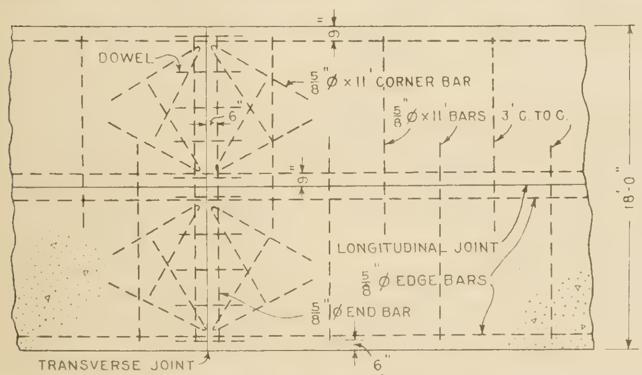


Figure 5.—Design of Semireinforced Slab

In the 28 States submitting plain concrete pavement designs, 13 used varying amounts of steel in the form of edge bars, end bars, and corner bars. In some cases the amount of steel so used exceeds the amount used in reinforced designs in other States.

The use of the longitudinal joint is the most universally accepted feature of concrete pavement design. Only two States now build two lane pavements without longitudinal joints. A few years ago it was the standard practice to use a deformed metal plate in the longitudinal joint but the dummy joint or bituminous impressed joint is now permitted as an alternate with the steel plate in 17 States and is used exclusively in four

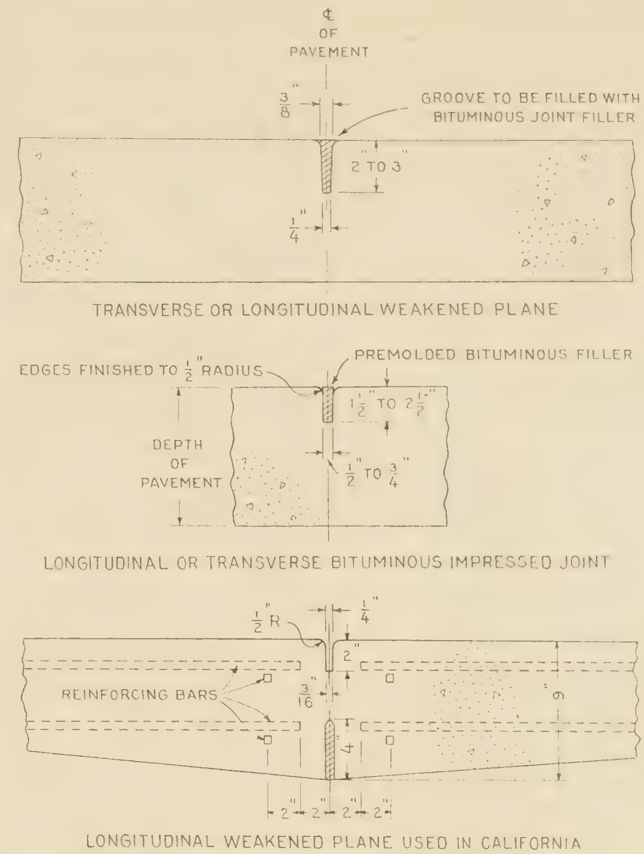


Figure 6.—Typical Designs of Weakened Plane or Dummy Joint

other States. In four States the longitudinal joint is a simple expansion joint without tie bars or dowels. Five States use a construction joint with or without tie bars and 11 States still specify the deformed metal separator.

The practice with reference to transverse joints continues to vary greatly among the States, but there is a definite trend toward the use of expansion joints and the use of intermediate dummy contraction joints. Two States use wide expansion joints, 3 inches and 4 inches, spaced at wide intervals, and four States do not provide for any transverse joints except necessary construction joints when the mixer is stopped for 30 minutes or more. The majority of the States use slip dowels across the expansion joints, but no dowels or tie bars across transverse dummy joints. Twenty States permit the use of either premolded expansion joint material or a poured mastic, at the option of the contractor. Four States specify a poured mastic and 15 specify premolded material.

No attempt was made to tabulate data with reference to the mix proportions of the concrete used in the several States for the reason that no simple and satisfactory basis of comparison has been established. Beginning with the construction season of 1930 it has been required that weight batching of aggregates be used on Federal-aid projects. In some States volumetric proportions are converted directly to batch weights for the job aggregates but the principles of a designed mix are more commonly used. It is believed that the requirement of weight batching is well justified as it produces more uniform concrete at no increase in cost and in the States which have adopted the principle of a designed mix considerable economy has resulted from reduction in the cement content while maintaining high strength.

GENERAL FEATURES OF DESIGN OF CROSS SECTION OF CONCRETE PAVEMENTS ON FEDERAL-AID PROJECTS SUBMITTED IN 1931

State	Width	Thickness: Edge	Thickness: Center	Thickness: Edge	Width of thickened edge, in feet	Crown	Maximum surface variation in 10 feet	Steel in reinforced type: Bars, pounds per 100 sq. ft.	Steel in reinforced type: Mesh, pounds per 100 sq. ft.	Steel in reinforced type: Location	Steel in plain type
	Feet	Inches	Inches	Inches		Inches	Inches				
Alabama	18, 20	9	6	9	3	2	⅛		25	3 ins. from top; two ¾-in. round edge bars.	Two ¾-in. edge bars; dowels.
Arizona	18	9	[1]	9	2	1⅛	¼				None.
Arkansas	18, 20	9	6	9	Curved	1½, circular	¼		41 or 49	2½ ins. from top; four ⅝-in. round edge bars.	Four ⅝-in. round edge bars; dowels.
California	20	9	[2]	9	2	1	⅛				Four ½-in. square edge bars; end bars.
Colorado	18, 20	9	6½	9	3	1½, parabolic	¼				None.
Connecticut	20	8	8	8		1, circular	¼	79.41	70.22	2 ins. from bottom [3]	
Delaware	18	8	6	8	Curved	1½ to 2	⅛				Dowels only.
	20	8	8	8							
Florida	20	9	6	9	3	1¼	¼				Do.
Georgia	20	9	6	9	3	1½	¼				Do.
Illinois	18	9	6	9	2	1, circular	⅛				Two ¾-in. edge bars; dowels.
	20	9	7	9	3	do	⅛				Two ⅞-in. edge bars; dowels.
Indiana	18, 20	9	7	9	2½	1¼	¼				Two ¾-in. edge bars; dowels.
Iowa	18	10	7	10	4	2	¼	55		3⅜ ins. from top	
Kansas	18, 20	9	7	9	4	1, parabolic	¼		49	2 ins. from top; edge bars	Two ¾-in. edge bars; ¾-in. end bars.
Kentucky	18	9	6	9	2	1	¼				Dowels only.
	20	9	6½	9	2	1	¼				Two ¾-in. edge bars.
Louisiana	18	8	6	8	Parabolic	1, parabolic	⅛		44	2 ins. from top	Dowels only.
	20	8	7	8	do	1¼, parabolic					
Maine	20	9	7	9	4	1½	¼	119		1½ ins. from top and bottom	
Maryland	16	9	6½	9	Parabolic	1	¼				None.
	18					1⅛					
	20					1¼					
Massachusetts	20	8	8	8		2½	¼	103		2 ins. from bottom	
	30					2¾					
	40					3⅞					
Michigan	20	9	7	9	3	1½	¼	60	60	2 ins. from top	
Minnesota	20	9	7	9	4	1	¼				Six ⅝-in. edge bars; end bars.
Mississippi	20	9	6	9	3	1½	⅛		48.8	2 ins. from top; edge bars	Six ¾-in. edge bars; dowels.
Missouri	20	9	6	9	4	1½, parabolic	¼				Four ¾-in. edge bars; dowels; end bars.
Nebraska	20	9	7	9	3	do	¼	25		2½ ins. from top	
New Hampshire	20	9	6	9	2	1	¼		65.8	2 ins. from top	
New Jersey	20, 40	8	8	8		1½, 2½	⅛	83	78	do	
		9	9	9							
New York	20	8	7	8	10	1¼, straight	¼	78.8	81.1	2½ ins. from top	
		8	8	8							
North Carolina	[4] 18	6	6	6		1½	5/16				Dowels only.
		8	6 or 7	8	Curved						
North Dakota	20	9	7	9	4	1	¼	48.3	57	2 ins. from top	
Ohio	20	9	7	9	2	1¼	¼	51.8	51.4	do	Two ¾-in. round edge bars; dowels.
Oklahoma	20	10	7	10	4	1, parabolic	¼	40.8		3 ins. from top	
Oregon	20	9	7	9	3	1½	¼				Dowels only.
Pennsylvania	18, 20	9	7	9	Curved	1, parabolic	⅛	40 to 44	46	2 ins. from top; corner bars	Six ⅝-in. round edge bars; end and corner bars; dowels.
Rhode Island	20, 40	8	8	8		1½, 4½	¼		45	2 ins. from top; end bars	
South Carolina	18, 20	7½	6	7½	Parabolic	1½	⅛				Dowels only.
South Dakota	20	9	6	9	4	1¼	¼		64.7	2½ ins. from top; edge and end bars.	
Tennessee	18, 20	8	6	8	Parabolic	1	⅛				Dowels only.
Texas	18, 20	9	6	9	4	1, circular	5/16				Four ½-in. round edge bars; end and corner bars.
Utah	18, 20	9	6	9	2	1	¼				Dowels only.
Vermont	18	7	7	7		1, straight	¼	83		2 ins. from top and bottom	
Virginia	18	8	6	8	Curved	1.01	[5] ⅛				None.
Washington	18	9	6½	9	2	1, straight	¼				Dowels only.
		10	7	10							
West Virginia	18	7	7	7		1, parabolic	⅛		43	2 ins. from top	
Wisconsin	20	9	6½	9	4	do	⅛		58	do	Dowels only.

[1] Two 9–6–9-inch sections, 9 feet wide.
[2] Two 9–7–9-inch sections, 10 feet wide.
[3] One panel (5 feet 2 inches wide) of reinforcement placed 2 inches from top, adjacent to transverse joint on each side.
[4] Six-inch uniform section with stone aggregate corresponds to 8–6–8-inch section with gravel aggregate; 8–6–8-inch section with stone aggregate corresponds to 8–7–8-inch section with gravel aggregate.
[5] In 16 feet.

GENERAL FEATURES OF DESIGN OF CONCRETE PAVEMENTS ON FEDERAL-AID PROJECTS SUBMITTED IN 1931

State	Longitudinal joints: Type	Longitudinal joints: Gage, or width, in inches	Longitudinal joints: Tie bars	Transverse joints: Type	Transverse joints: Spacing to nearest even foot, in feet	Transverse joints: Width (Inches)	Transverse joints: Filler	Transverse joints: Dowels
Alabama	Steel plate or Bituminous impressed.	16 g; ¾ by 1½	½-in. round, deformed, 5 ft. c. to c.; None	Expansion	[1] 30; 40	¾; ½	Poured or premolded.	Eight ¾-in. round, 4 ft. long, 1 end fixed.
Arizona	Expansion, premolded.	½	None	do	30	1	Premolded	None.
Arkansas	Steel plate or Dummy joint	16 g	½-in. round, deformed, 5 ft. c. to c.	do	50	¾	Poured	Six ½-in. round, 1 end fixed.
California	Dummy joint		End bars only	Expansion with dummy joint.[2]	60	½	Premolded	Edge bars only.
Colorado	do		None	Expansion	60	½	do	None.
Connecticut	Expansion	¼	None	do	61	½	Poured or premolded.	None.
Delaware	Steel plate or Dummy joint	16 g	½-in. round, 3 ft., 3 ins. c. to c.	do	80 to 85	¾	Premolded	Eight ¾-in., 2 ft. long, 1 end fixed.
Florida	Steel plate	18 g	½-in. round, deformed, 4 ft. long, 5 ft. c. to c.	do	40	⅝	Poured or premolded.	Ten ½-in. round, 4 ft. long, 1 end fixed.
Georgia	do	16 g	½-in. round, deformed, 4 ft. long, 4 ft. c. to c.	do	50	¾	do	Eight ⅝-in. round, 4 ft. long, 1 end fixed.
Illinois	do	18 g	½-in. round, deformed, 4 ft. long, 5 ft. c. to c.	do	800 to 1,000	1	Poured	None.
Indiana	do	16 g	⅝-in. round, deformed, 4 ft. long, 5 ft. c. to c.	Construction	Necessary			Four or six ¾-in., 1 ft. long, 1 end fixed.
Iowa	Steel plate or Dummy joint	18 g	⅝-in. round, smooth, 11 ft. long, 3 ft. c. to c.	Expansion [3]	40, 60, 80	1, ¾, ½	Poured or premolded.	Ten ⅝-in. round, 2 ft. long, 1 end fixed.
Kansas	Steel plate, Bituminous impressed or Dummy joint	(4); ⅜ by 2¾	½-in. round, deformed, 4 ft. long, 5 ft. c. to c.	Expansion with dummy joint.[5]	116	1	do	None.
Kentucky	Steel plate	16 g	do	Construction	Necessary			None.
Louisiana	do	16 g	do	Dummy joint	40 to 60		Poured or premolded.	Eight ¾-in., 4 ft. long, 1 end fixed
Maine	Construction		None	Expansion	40	½	Premolded	Ten ¾-in., 3 ft. long.
Maryland	Bituminous impressed; or Dummy joint	⅛ by 2¾	None	Bituminous impressed, or dummy joint.	40		Poured or premolded.	None.
Massachusetts	Construction		½-in. square, deformed, 4 ft. long, 5 ft. c. to c.	Expansion	60	½	do	Eight, twelve, or sixteen ½-in. square, 4 ft. long, 1 end fixed.
Michigan	Steel plate or Dummy joint	16 g	½-in. round, 4 ft. long, 20 ins. c. to c.	Expansion	100	1	Premolded	None.
Minnesota	Steel plate or Dummy joint	16 g	½-in. round, deformed, 4 ft. long, 5 ft. c. to c.	Expansion with dummy joint.[6]	81	½	Poured or premolded.	Eight ¾-in., 2 ft. 6 in. long, 1 end fixed.
Mississippi	Steel plate or Bituminous impressed.	18 g; ⅜ by 2½	½-in. round, deformed, 4 ft. long, 5 ft. c. to c.	Expansion with dummy joint.[6]	60	¾	do	Eight ¾-in., 4 ft. long, 1 end fixed.
Missouri	Steel plate or Bituminous impressed.	16 g; ⅜ by 2½	do	do [6]	81	1	Premolded	Eight ¾-in. round, 2 ft. 6 ins. long, 1 end fixed.
Nebraska	Steel plate or Bituminous impressed.	18 g; ⅜ by 2½	⅝-in. round, smooth, 12 ft. long, 3 ft. c. to c.	Expansion with dummy joint.[5]	100	1	Poured or premolded.	Ten ⅝-in. round, 2 ft. long, 1 end fixed.; None.
New Hampshire	Construction		⅝-in. round, deformed, 4 ft. long, 3 ft. c. to c.	Expansion	50	½ to ¾	Premolded	Ten ⅝-in. round, 2 ft. long, greased.
New Jersey	Expansion	½	None	do	34 or 45	½ to ¾	Poured or premolded.	Twelve to twenty-four ¾-in. round, 1 ft. 8 ins. long.
New York	Construction		None	do	78	¾	do	Ten ¾-in. round, 1 ft. 8 ins. long, 1 end fixed.
North Carolina	None			Construction	Necessary			Nine ¾-in. round, 4 ft. long, oiled.
North Dakota	Steel plate or Dummy joint	16 g	½-in. round, deformed, 4 ft. long, 4 ft. c. to c.	Expansion with dummy joint or steel plate.[6]	81	1	Poured or premolded.	Eight ¾-in. round, 2 ft. 6 ins. long, 1 end fixed.
Ohio	Steel plate or Dummy joint	14 g	½-in. round, deformed, 5 ft. long, 5 ft. c. to c.	Expansion with dummy joint.[2]	105 to 120	1	do	Six ¾-in. round, 4 ft. long, 1 end fixed.
Oklahoma	Steel plate or Dummy joint	(4)	½-in. round, deformed, 19 ft. 6 ins. long, 5 ft. c. to c.[7]	Expansion joint; Dummy joint	50, 100; 50	1	Poured	None.
Oregon	Steel plate	18 g	½-in. round, deformed, 3 ft. long, 4 ft. 6 ins. c. to c.	Expansion with dummy joint.[2]	60	½	Premolded	Four ¾-in. round, 3 ft. long, 1 end fixed.
Pennsylvania	Steel plate or Dummy joint	14 g	½-in. round, deformed, 4 ft. 6 ins. long 5 ft. c. to c.	Expansion	Designed	½	do	None.
Rhode Island	Expansion	¾	None	do	100	¾	do	Eight to sixteen ½-in. round, 2 ft. long, painted.
South Carolina	Steel plate [9]	16 g. to 18 g.	½-in. round, deformed, 4 ft. long, 5 ft. c. to c.	do	40	½ to ¾	Poured or premolded.	None.
South Dakota	do	18 g	do	do	40	⅜	Premolded	Eight ¾-in. round, 2 ft. 6 ins. long, 1 end fixed.

[1] For reinforced type, 30-foot spacing, ¾-inch width; for plain type, 40-foot spacing, ½-inch width.
[2] Dummy joints at third points between expansion joints.
[3] Spacing and width of expansion joints dependent on type of aggregate.
[4] Gage of metal strip not specified.
[5] Dummy joints at fourth points between expansion joints.
[6] Dummy joint halfway between expansion joints.
[7] Transverse reinforcing bars used as dowels; no short dowels used.
[8] Alternate expansion and contraction joints used, Apr. 15 to Oct. 15, at 50-foot spacing; expansion joints at 50-foot spacing, Oct. 15 to Apr. 15.
[9] On clay subgrade.

GENERAL FEATURES OF DESIGN OF CONCRETE PAVEMENTS ON FEDERAL-AID PROJECTS SUBMITTED IN 1931—Continued

State	Longitudinal joints			Transverse joints				
	Type	Gage, or width, in inches	Tie bars	Type	Spacing to nearest even foot, in feet	Width	Filler	Dowels
						Inches		
Tennessee	Steel plate	16 g	½-in. round, deformed, 4 ft. long, 5 ft. c. to c.	Expansion	500	2½	Poured or premolded.	None.
Texas	do	18 g	½-in. round, smooth, 4 ft. long, 5 ft. c. to c.	do	200 to 500	3	Poured	None.
Utah	Dummy joint		½-in. round, 4 ft. long, 5 ft. c. to c.	Expansion with dummy joint.[2]	60	¾	Premolded	Do.
Vermont	Construction		⅝-in, round, deformed, 4 ft. long, 2 ft. 10 ins. c. to c.	Expansion	55	½	Poured or premolded.	Eight ¾-in. round, 2 ft. long, 1 end fixed.
Virginia	None			Construction	Necessary			Twenty ¾-in. round, 2 ft. long, 1 end fixed.
Washington	Dummy joint		½-in. round, deformed, 2 ft. long, 4 ft. c. to c.	Expansion with dummy joint.[6]	40	½ to ⅝	Premolded	None.
West Virginia	Steel plate; Dummy joint or Construction joint.	14 g	None	Expansion with dummy joint.[6]	93	¾	do	None.
Wisconsin	Steel plate or Dummy joint	18 g	½-in. round, deformed, 4 ft. long, 2 ft. c. to c.	Expansion with dummy joint.[2]	90	1	Poured or premolded.	Ten ⅝-in. round, 2 ft. 6 ins. long.

[2] Dummy joints at third points between expansion joints.
[6] Dummy joints halfway between expansion joints.

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U. S. DEPARTMENT OF AGRICULTURE

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The bureau will supply without charge only selected issues of the magazine for the current year. Earlier issues (and current issues if desired) can be purchased from the Superintendent of Documents, Government Printing Office, at 10 cents per copy (stamps not accepted).

Certain publications are marked "Free supply" and single copies can be obtained from the bureau or they can be purchased from the Superintendent of Documents in those cases where a price is indicated. Those marked "Available by purchase only" should be purchased from the Superintendent of Documents. Where more than one copy of any publication is desired it should be obtained by purchase.

Important articles in PUBLIC ROADS of which the entire supply is exhausted are so indicated and are included in the list for the convenience of investigators who may wish to consult them in libraries. Upon request, correspondents will be advised of near-by libraries receiving the magazine.

The bureau has discontinued the issuance of a series of bulletins describing current practice in constructing the various types of road, since this subject is now covered by numerous textbooks. A list of books on highway engineering subjects can be supplied on request.

HIGHWAY LOCATION, SURVEYS, AND GENERAL DESIGN

Miscellaneous Circular 62 MC. Standards Governing Plans, Specifications, Contract Forms, and Estimates for Federal-Aid Highway Projects. 5c. (Free supply available.)

Tentative Standard Specifications for Highway Materials and Methods of Sampling and Testing, published by American Association of State Highway Officials, National Press Building, Washington, D. C. These specifications have been approved for use in Federal-aid work. (Available only by purchase from publishers, $1.50.)

REPORTS IN PUBLIC ROADS

*Superelevation and Easement as Applied to Highway Curves, by A. L. Luedke and J. L. Harrison, vol. 3, No. 31, November, 1920.

*Effect of Increased Speed of Vehicles on the Design of Highways, by A. G. Bruce, vol. 10, No. 1, March, 1929.

SUBGRADE AND SOIL STUDIES

Reports on Subgrade Soil Studies. Reprint from PUBLIC ROADS, vol. 12, Nos. 4, 5, 7 and 8. 40c. (Free supply available.)

REPORTS IN PUBLIC ROADS

*Practical Field Tests for Subgrade Soils, by A. C. Rose, vol. 5, No. 6, August, 1924. (Supply exhausted.)

*The Supporting Value of Soil as Influenced by the Bearing Area, by A. T. Goldbeck and M. J. Bussard, vol. 5, No. 11, January, 1925. (Supply exhausted.)

*Vertical Pressure of Earth Fills Measured, by C. N. Connor, vol. 6, No. 1, March, 1925.

*Field Methods Used in Subgrade Surveys, by A. C. Rose, vol. 6, No. 5, July, 1925.

*Earth Pressures Against Abutment Walls Measured With Soil Pressure Cells, by J. V. McNary, vol. 6, No. 5, July, 1925.

*The Present Status of Subgrade Studies, by A. C. Rose, vol. 6, No. 7, September, 1925. (Supply exhausted.)

*Adaptation of Atterberg Plasticity Tests for Subgrade Soils, by A. M. Wintermyer, vol. 7, No. 6, August, 1926. (Supply exhausted.)

*Simplified Soil Tests for Subgrades and Their Physical Significance, by Dr. Charles Terzaghi, vol. 7, No. 8, October, 1926.

*Earth Pressures on Culvert Pipes, by G. M. Braune, vol. 7, No. 11, January, 1927. (Supply exhausted.)

*Fill Settlement in Peat Marshes, by V. R. Burton, vol. 7, No. 12, February, 1927.

*Determination of Consistency of Soils by Means of Penetration Tests, by Dr. Charles Terzaghi, vol. 7, No. 12, February, 1927.

* Available only by purchase from Superintendent of Documents.

*Landslides and Their Relation to Highways—Report of Observations Made in West Virginia and Ohio to Determine the Cause of Slides and Devise Means of Control. Part I, by Dr. George E. Ladd, vol. 8, No. 2, April, 1927.
*Principles of Final Soil Classification, by Dr. Charles Terzaghi, vol. 8, No. 3, May, 1927.
*Elementary Proof of Shale Likeness of Clay Particles, by Dmitry P. Krynine, vol. 8, No. 11, January, 1928.
*Present Status of Subgrade Soil Testing, by C. A. Hogentogler, Dr. Charles Terzaghi, and A. M. Wintermyer, vol. 9, No. 1, March, 1928.
*Landslides and Their Relation to Highways—Report of Observations Made in West Virginia, Ohio, and Southwestern Pennsylvania. Part II, by Dr. George E. Ladd, vol. 9, No. 8, October, 1928.
*Interrelationship of Load, Road, and Subgrade, by C. A. Hogentogler and Dr. Charles Terzaghi, vol. 10, No. 3, May, 1929.
*Simple Laboratory Experiments on Capillary Movement and Entrapped Air in Clays, by Dmitry P. Krynine, vol. 10, No. 6, August, 1929.
*Earth Pressure Experiments on Culvert Pipe, by G. M. Braune, William Cain, and H. F. Janda, vol. 10, No. 9, November, 1929.
*The Mechanics of Shear Failures on Clay Slopes and the Creep of Retaining Walls, by Dr. Charles Terzaghi, vol. 10, No. 10, December, 1929.
*Illustrations of frost and ice phenomena, by Ira B. Mullis, vol. 11, No. 4, June, 1930.
*Some Points of Contact Between Soil Science and Highway Engineering, by J. S. Joffe, vol. 11, No. 4, June, 1930.
*Freezing and Thawing of Soils as Factors in the Destruction of Road Pavements, by Stephen Taber, vol. 11, No. 6, August, 1930.
*Subgrade Soil Constants, Their Significance, and Their Application in Practice, by C. A. Hogentogler, A. M. Wintermyer, and E. A. Willis:
  Part I, vol. 12, No. 4, June, 1931.
  Parts II and III, vol. 12, No. 5, July, 1931.
*The Soil Profile and the Subgrade Survey, by W. I. Watkins and Henry Aaron, vol. 12, No. 7, September, 1931.
*Procedures for Testing Soils for the Determination of the Subgrade Soil Constants, by A. M. Wintermyer, E. A. Willis, and R. C. Thoreen, vol. 12, No. 8, October, 1931.
*Graphical Solution of the Data Furnished by the Hydrometer Method of Analysis, by E. A. Willis, F. A. Robeson, and C. M. Johnston, vol. 12, No. 8, October, 1931.

EARTH, SAND-CLAY, GRAVEL, AND LOW-COST BITUMINOUS MIXES

REPORTS IN PUBLIC ROADS

*Rythmic Corrugations in Gravel Roads, by Dr. George E. Ladd, vol. 5, No. 7, September 1924. (Supply exhausted.)
*Oiled Earth Roads on Long Island, by A. T. Goldbeck, vol. 5, No. 7, September 1924. (Supply exhausted.)
*Tar Surface Treatment of Gravel Roads, by N. M. Isabella, vol. 6, No. 2, April, 1925. (Supply exhausted.)
*Light Asphaltic Oil Road Surfaces, by C. L. McKesson and W. N. Frickstad, vol. 8, No. 7, September, 1927. (Supply exhausted.)
*Surface Treatment of Topsoil roads, by J. T. Pauls, vol. 8, No. 9, November, 1927.
*Study of Gravel, Topsoil, and Sand-Clay Roads in Georgia, by Dr. C. M. Strahan, vol. 10, No. 7, September, 1929.
*Bituminous Surface Treatment of Sand-Clay and Topsoil Roads—Report on a cooperative study by the Bureau of Public Roads and the Asphalt Industry, vol. 10, No. 11, January, 1930.
*Investigation of Oil-Treated Earth Roads in Missouri, by F.V. Reagel, Henry Aaron, and W. I. Watkins, vol. 12, No. 3, May, 1931.
Bituminous Treatments on Sand-Clay and Marl Bases in South Carolina, by H. C. Jones and E. L. Tarwater, vol. 12, No. 9, November, 1931.

BITUMINOUS SURFACES, MATERIALS, AND MIXTURES

REPORTS IN PUBLIC ROADS

*Stability Test for Bituminous Mixtures, by W. J. Emmons, vol. 6, No. 4, June, 1925. (Supply exhausted.)

* Available only by purchase from Superintendent of Documents.

*Study of the Effect of Temperature on the Stability of Asphaltic Pavements, by W. J. Emmons, vol. 7, No. 2, April, 1926.
*Researches on Bituminous Paving Mixtures, by W. J. Emmons, vol. 7, No. 10, December, 1926.
*Report on Connecticut Avenue Experimental Road, vol. 9, No. 3, May, 1928.
*Bradley Lane Experimental Road, vol. 9, No. 12, February, 1929.
*Machine for Molding Laboratory Specimens of Bituminous Paving Mixtures, by J. T. Pauls, vol. 10, No. 2, April, 1929.
*Bituminous Surface Treatment Experiments in Department of Agriculture Grounds, by J. T. Pauls and Paul F. Critz, vol. 10, No. 8, October, 1929.
*Progress Report of the Connecticut Avenue Experimental Road, by Paul F. Critz and J. H. Eldridge, vol. 11, No. 4, June, 1930.
*Bituminous Treatments Used on Roads of Intermediate Type in the Western States, by J. T. Pauls, vol. 11, No. 10, December, 1930.
*The Most Recent Methods Adopted for the Use of Tar, Bitumen, and Asphalt in Road Construction—Report by American Engineers to the Sixth International Road Congress, vol. 11, No. 10, December, 1930.

CONCRETE, CONCRETE MATERIALS, AND CONCRETE ROADS

*Department Bulletin 532 D. The Expansion and Contraction of Concrete and Concrete Roads, 10c.

REPORTS IN PUBLIC ROADS

*Accelerated Wear Tests by the Bureau of Public Roads, by F. H. Jackson and C. A. Hogentogler, vol. 4, No. 2, June, 1921.
*Wear of Concrete Pavements Tested, by F. H. Jackson, vol. 5, No. 3, May 1924. (Supply exhausted.)
*Friction Tests of Concrete on Various Subbases, by A. T. Goldbeck, vol. 5, No. 5, July, 1924.
*Reinforcing and the Subgrade as Factors in the Design of Concrete Pavements, by J. T. Pauls, vol. 5, No. 8, October, 1924. (Supply exhausted.)
*Static Load Tests on Pavement Slabs, by J. T. Thompson, vol. 5, No. 9, November, 1924. (Supply exhausted.)
*Comparisons of the Strength of Concrete in Tension and Compression, by N. M. Finkbiner, vol. 5, No. 11, January, 1925. (Supply exhausted.)
*Reinforced Concrete Pavement Survey, by C. A. Hogentogler. vol. 5, No. 12, February, 1925.
*Effect of Grading on Sand Strength Ratios, by C. E. Proudley, vol. 6, No. 4, June 1925. (Supply exhausted.)
*The Interrelation of Longitudinal Steel and Transverse Cracks in Concrete Roads, by A. T. Goldbeck, vol. 6, No. 6, August, 1925. (Supply exhausted.)
*A New Test for Consistency of Concrete Applicable to Dry Paving Mixtures, by F. H. Jackson, vol. 6, No. 6, August, 1925. (Supply exhausted.)
*The Six-Wheel Truck and the Pavement, by L. W. Teller, vol. 6, No. 8, October, 1925.
*Action of Sulphate Water on Concrete, by Dalton G. Miller, vol. 6, No. 8, October, 1925.
*Protection of Concrete Against Alkali, by Dr. E. C. E. Lord, vol. 6, No. 11, January 1926. (Supply exhausted.)
*Stresses in Concrete Pavements Computed by Theoretical Analysis, by Dr. H. M. Westergaard, vol. 7, No. 2, April, 1926.
*Tests of Vibrolithic Concrete, by L. W. Teller, vol. 7, No. 2, April, 1926.
*Comparison of Transverse and Compressive tests of Concrete, by H. F. Clemmer, vol. 7, No. 3, May 1926. (Supply exhausted.)
*Tests of Concrete in Tension, by A. N. Johnson, Vol. 7. No. 4, June, 1926. (Supply exhausted.)
*Strength of Mortar and Concrete as Influenced by the Grading of the Sand, by J. G. Rose, vol. 7, No. 5, July, 1926. Discussion by T. C. Powers, vol. 7, No. 8, October, 1926.
*Tests of Concrete Curing Methods, by J. T. Pauls, vol. 7, No. 10, December, 1926.
*Action of Calcium Chloride on Cements, vol. 7, No. 12, February, 1927.
*Proportioning Concrete Aggregates by Weight, by R. W. Crum, vol. 8, No. 1, March, 1927. (Supply exhausted.)
*Standard Sizes of Crushed Stone, by F. H. Jackson, vol. 8, No. 2, April, 1927.
*Analysis of Stresses in Concrete Roads Caused by Variations of Temperature, by Dr. H. M. Westergaard, vol. 8, No. 3, May, 1927.
*Effect of Salts in Mixing Water on Strength of Mortar Studied, vol. 8, No. 5, July, 1927.

*Protection of Concrete Against Alkali, By Dr. E. C. E. Lord, vol. 8, No. 6, August, 1927.
*Effect of Quality of Portland Cement upon the Strength of Concrete, by F. H. Jackson, vol. 8, No. 6, August, 1927.
*Further Tests of Vibrolithic Concrete, by L. W. Teller and C. E. Proudley, vol. 8, No. 8, October, 1927.
*The Action of Sulphate Water on Concrete, by Dalton G. Miller, vol. 8, No. 9, November, 1927.
*Effect of Salts in Mixing Water on Compressive Strength of Mortar, vol. 8, No. 11, January, 1928.
*Comparative Tests of Crushed Stone and Gravel Concrete in New Jersey, by F. H. Jackson, vol. 8, No. 12, February, 1928. (Supply exhausted.)
*Report on Connecticut Avenue Experimental Road, vol. 9, No. 3, May, 1928.
*Virginia Demonstration Road, by A. C. Benkelman, vol. 9, No. 4, June, 1928.
*Resistance of Portland Cement Concrete to the Action of Sulphate Waters as Influenced by the cement, by Dalton G. Miller, vol. 9, No. 4, June, 1928.
*Determination of Proportions of Constituents in Concrete, by L. G. Carmick, vol. 9, No. 4, June, 1928.
*Lip Curb for Concrete Pavements, by St. Clair T. Thomas, vol. 9, No. 5, July, 1928.
*The Design of Pavement Concrete by the Water-Cement Ratio Method, by F. H. Jackson, vol. 9, No. 6, August, 1928.
*Field Experiments in the Curing of Concrete Pavements—Report on Cooperative Experiments Conducted by the Maryland State Roads Commission and the U. S. Bureau of Public Roads, by F. H. Jackson and George Werner, vol. 9, No. 7, September, 1928.
*Strength Characteristics of Concrete as Indicated by Core Tests—Results of Compression Tests on Cores Drilled from Maryland Highways Analyzed, by A. N. Johnson, vol. 9, No. 7, September, 1928.
*Modulus of Elasticity of Cores from Concrete Roads—Results of Determinations Made on Cores Drilled from Maryland Highways, by A. N. Johnson, vol. 9, No. 8, October, 1928.
*Strength Characteristics of Concrete—Results of Study of Modulus of Elasticity, Effect of Moisture on Strength ,and Behavior under Repeated Loading, by A. N. Johnson, vol. 9, No. 9, November, 1928.
*Influence of Mineral Composition of Sand on Mortar Strength, by Dr. E. C. E. Lord, vol. 9, No. 11, January, 1929.
*Concrete in Tension, by A. N. Johnson, vol. 9, No. 12, February, 1929.
*Qualities Required in Paving Concrete, by F. H. Jackson, vol. 9, No. 12, February, 1929.
*Mechanics of Progressive Cracking in Concrete Pavements, by Dr. H. M. Westergaard, vol. 10, No. 4, June, 1929.
*Effect of Type and Gradation of Coarse Aggregate Upon the Strength of Concrete, by W. F. Kellermann, vol. 10, No. 4, June, 1929.
*A Test for Indicating the Surface Hardness of Concrete Pavements, by L. W. Teller, vol. 10, No. 5, July 1929.
*General Features of Design of Cross Section of Concrete Pavements on Federal-aid Projects Submitted in 1928, vol. 10, No. 5, July, 1929.
*Effect of Method of Fabrication on Strength and Uniformity of Concrete Flexure Specimens, by L. W. Teller, vol. 10, No. 6. August, 1929.
*Effect of Moisture Content on the Strength of Cement Mortar Specimens, by D. O. Woolf and Baxter Smith, vol. 10, No. 6, August, 1929.
*Need for Simplification of Sizes of Sand and Gravel Industry, by F. H. Jackson, vol. 10, No. 12, February, 1930.
*The Arlington Curing Experiments, by L. W. Teller and H. L. Bosley, vol. 10, No. 12, February, 1930.
*Progress Report of the Connecticut Avenue Experimental Road, by Paul F. Critz and J. H. Eldridge, vol. 11, No. 4, June, 1930.
*Results Obtained by the Use of Cement—Report of American Engineers to the Sixth International Road Congress, vol. 11, No. 9, November, 1930.
*A Study of Methods of Curing Concrete Pavements—Report of a Field Investigation in Tennessee Conducted Jointly by the Tennessee Department of Highways and the U. S. Bureau of Public Roads, by F. H. Jackson and E. W. Bauman, vol. 11, No. 11, January, 1931.
*Effect of Vibration on the Pressure of Concrete Against Form Work, by L. W. Teller, vol. 12, No. 1, March, 1931.
*Effect of the Dimensions of Test Specimens on the Flexural Strength of Concrete, by F. V. Reagel and T. F. Willis, vol. 12, No. 2, April, 1931.
*Action of Sulphate Water on Concrete, by Dalton G. Miller and Philip Manson, vol. 12, No. 3, May, 1931.
*Effect of Water-gas Tar on the Strength and Alkali Resistance of Concrete, by Dr. E. C. E. Lord, vol. 12, No. 4, June, 1931.
*Studies of Paving Concrete, by F. H. Jackson and W. F. Kellermann, vol. 12, No. 6, August, 1931.
*Some Observations on the Modulus of Rupture of Frozen Concrete Beams, by Andrew P. Anderson, vol. 12, No. 7, September, 1931.
*The Effect of Materials and Methods of Placing on the Strength and Other Properties of Concrete Bridge Floor Slabs, by L. W. Teller and George W. Davis, vol. 12, No. 10, December, 1931.
Relation Between the Strength of Cement and the Strength of Concrete, by F. H. Jackson, vol. 12, No. 11, January, 1932.
The Resistance of Concrete to Frost Action, by F. H. Jackson, vol. 13, No. 2, April, 1932.

BLOCK PAVEMENTS (BRICK, ETC.)

REPORTS IN PUBLIC ROADS

*Brick Pavements in the Middle West, by A. T. Goldbeck and F. H. Jackson, vol. 1, No. 10, February, 1919. (Supply exhausted.)
*Accelerated Wear Tests by the Bureau of Public Roads, by F. H. Jackson and C. A. Hogentogler, vol. 4, No. 2, June, 1921.
*"Rolled-Base" Brick Roads in Ohio, by A. T. Goldbeck and F. H. Jackson, vol. 4, No. 7, November, 1921. (Supply exhausted.)
*Brick Roads of Florida, by C. A. Hogentogler, vol. 5, No. 2, April, 1924. (Supply exhausted.)
*Effect of Size of Brick on Rattler Loss, by F. H. Jackson, vol. 7, No. 5, July, 1926.
*Thin Brick Pavements Studied, by L. W. Teller and J. T. Pauls, vol. 7, No. 7, September, 1926. (Supply exhausted.)

MOTOR VEHICLE IMPACT

REPORTS IN PUBLIC ROADS

*Motor-Truck Impact as Affected by Tires, Other Truck Factors, and Road Roughness, by J. A. Buchanan and J. W. Reid, vol. 7, No. 4, June, 1926. (Supply exhausted.)
*Static and Impact Strains in Concrete, by J. T. Thompson, vol. 7, No. 5, July, 1926.
*An Instrument for the Measurement of Relative Road Roughness, vol. 7, No. 7, September, 1926. (Supply exhausted.)
*Downward Kick of the Rear Wheels of Vehicles in Starting from Rest to Motion, by Thomas K. A. Hendrick, vol. 7, No. 11, January, 1927. (Supply exhausted.)
*Static and Impact Loads Transmitted to Culverts, vol. 8, No. 6, August, 1927.
*Effect of Pavement Type on Impact Reaction, by J. T. Thompson, vol. 9, No. 6, August, 1928.
*Calibrations of Accelerometers for Use in Motor Truck Impact Tests, by J. A. Buchanan and G. P. St. Clair, vol. 11, No. 5, July, 1930.
*Motor Truck Impact as Affected by Rubber Tread Thickness of Tires, by J. A. Buchanan, vol. 11, No. 7, September, 1930.
*Interrelated Effects of Load, Speed, Tires, and Road Roughness on Motor Truck Impact, by J. A. Buchanan, Vol. 11, No. 7, September, 1930.
*Impact Reactions Developed by a Modern Motor Bus, by J. A Buchanan, vol. 12, No. 2, April, 1931.

HIGHWAY CONSTRUCTION COST AND EFFICIENCY STUDIES

*Miscellaneous Circular 93 MC. Direct Production Costs of Broken Stone. 25c.

REPORTS IN PUBLIC ROADS

Effect of Haul on the Cost of Earthwork, by J. L. Harrison, vol. 5, No. 7, September, 1924. (Supply exhausted.)
Cost of Grading with Fresnoes, by J. L. Harrison, vol. 5, No. 8, October, 1924. (Supply exhausted.)
Economical Use of Wheel Scrapers, by J. L. Harrison, vol. 5, No. 10, December, 1924. (Supply exhausted.)
The Wagon and the Elevating Grader, by J. L. Harrison:
Part I. An Economic Study of the Wagon-Elevating Grader Combination, vol. 6 ,No. 2, April, 1925. (Supply exhausted).
*Part II. The Influence of Design on Elevating Grader Costs, vol. 6, No. 3, May, 1925.
Part III. Estimating the Cost of Elevating Grader Work, vol. 6, No. 4, June, 1925. (Supply exhausted.)

* Available only by purchase from Superintendent of Documents.

Efficiency in Concrete Road Construction, by J. L. Harrison:
- *Part I. Efficient Production, vol. 6, No. 9, November, 1925.
- Part II. Transportation of Materials, vol. 6, No. 10, December, 1925. (Supply exhausted.)
- Part III. Efficiency of Equipment, vol. 6, No. 11, January, 1926. (Supply exhausted.)
- *Part IV. Organization and Equipment of a Concrete Paving Operation, vol. 6, No. 12, February, 1926.
- *Part V. Speeding up Construction Work, vol. 7, No. 1, March, 1926.

*The Value of the Foreman on Fresno and Wheel Scraper Work, by Andrew P. Anderson, vol. 7, No. 3, May, 1926. (Supply exhausted.)

*Direct Production Costs of Broken Stone, by Dr. George E. Ladd, vol. 7, No. 8, October, 1926.

*Time Losses in Concrete Road Construction, by Andrew P. Anderson, vol. 7, No. 10, December, 1926.

*Power-Shovel Operation in Highway Grading, by T. Warren Allen and Andrew P. Anderson.
- Part I. Vol. 8, No. 12, February, 1928. (Supply exhausted.)
- Part II. Vol.. 9, No. 1, March, 1928.
- Part III. Vol. 9, No. 2, April, 1928.

*Effect of the Length of the Mixing Period on the Quality of Concrete Mixed in Standard Pavers, by J. L. Harrison, vol. 9, No. 5, July, 1928.

*Truck Operation and Production in Concrete Paving Work, by Andrew P. Anderson, vol. 11, No. 12, February, 1931.

*High-Speed Production on Asphalt Concrete Paving Work, by R. W. Edwards and N. L. James, vol. 11, No. 12, February, 1931.

Effect of Size of Batch and Length of Mixing Period on Rate of Production and Quality of Concrete Mixed in Standard 27E Pavers, by T. C. Thee, vol. 12, No. 11, January, 1932.

Some Studies of Drilling and Blasting in Highway Grading, by Andrew P. Anderson, vol. 12, No. 12, February, 1932.

HIGHWAY FINANCE AND ADMINISTRATION

Statistical tables, annual. (Free supply.)
- Motor vehicle registrations and fees.
- Gasoline taxes.
- State highways built during year.
- State highways existing at end of year.
- State highway income during year.
- State highway expenditures during year.
- Local roads built during year.
- Local roads existing at end of year.
- Local highway income during year.
- Local highway expenditures during year.

Annual reports. (Free supply.)
- Report of the Chief of the Bureau of Public Roads, 1924.
- Report of the Chief of the Bureau of Public Roads, 1925.
- Report of the Chief of the Bureau of Public Roads, 1927.
- Report of the Chief of the Bureau of Public Roads, 1928.
- Report of the Chief of the Bureau of Public Roads, 1929.

*Department Bulletin 136 D, Highway Bonds, 20c.

*Department Bulletin 660 D. Highway Cost Keeping, 10c.

Department Bulletin 1279 D, Rural highway mileage, income and expenditures 1921 and 1922. 15c. (Free supply available.)

Miscellaneous Circular 109, Federal Legislation and Regulation Relating to the Improvement of Federal-Aid Roads. (Free supply available.)

REPORTS IN PUBLIC ROADS

*Road Bond Issues in Relation to Total Debt, by Henry R. Trumbower, vol. 5, No. 3, May, 1924. (Supply exhausted.)

*The Incidence of the Highway Tax Burden, by Henry R. Trumbower, vol. 5, No. 4, June, 1924. (Supply exhausted.)

*Regulation of Motor Vehicles as Common Carriers, by Henry R. Trumbower, vol. 5, No. 6, August, 1924. (Supply exhausted.)

*Motor Vehicle Fees and Gasoline Taxes, by Henry R. Trumbower, vol. 5, No. 7, September, 1924. (Supply exhausted.)

*Constitutionality of Motor Vehicle License Fees and the Gasoline Tax by Henry R. Trumbower, vol. 5, No. 9, November, 1924. (Supply exhausted.)

*Highway Income from the Motor Vehicle, by Henry R. Trumbower, vol. 5, No. 11, January, 1925. (Supply exhausted.)

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*Common Carrier Truck Fees and Taxes, by Henry R. Trumbower, vol. 6, No. 11, January, 1926. (Supply exhausted.)

*Urban Aspects of Highway Finance, by Jacob Viner, vol. 6, No. 11 (supply exhausted), and No. 12, January and February, 1926.

*Collection and Disposition of Motor Vehicle Revenues, by Henry R. Trumbower, vol. 7, No. 11, January, 1927. (Supply exhausted.)

*Technical Basis for Apportioning Motor Vehicle Taxes, by Charles F. Marvin, jr., vol. 11, No. 3, May, 1930.

*North Carolina County Road and Finance Survey—Report of a Cooperative Investigation by the North Carolina State Highway Commission, the North Carolina State Tax Commission, and the U. S. Bureau of Public Roads, vol. 11, No. 12, February, 1931.

*Toll Roads, by H. H. Kelly, vol. 12, No. 1, March, 1931.

HIGHWAY TRANSPORT AND TRAFFIC

The following traffic reports are available from the bureau without charge (not available from Superintendent of Documents):

Report of a Survey of Transportation on the State Highway System of Ohio, 1927.

Report of a Survey of Transportation on the State Highways of Vermont, 1927.

Report of a Survey of Transportation on the State Highways of New Hampshire, 1927.

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio, 1928.

Report of a Survey of Transportation on the State Highways of Pennsylvania, 1928.

Report of a Survey of Traffic on the Federal-aid Highway Systems of Eleven Western States, 1930.

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*Transportation of Milk by Motor Truck, by H. R. Trumbower, vol. 5, No. 5, July, 1924.

*Traffic Control and Safety, by E. W. James, vol. 5, No. 6, August, 1924. (Supply exhausted.)

*Transportation of Hogs by Motor Truck, by E. L. Browne, vol. 5, No. 6, August, 1924. (Supply exhausted.)

*A Study of Motor Vehicle Accidents in Montana, Oregon, and Washington, by A. C. Rose, vol. 5, No. 12, February, 1925.

*Transverse Distribution of Motor Vehicle Traffic on Paved Highways, by J. T. Pauls, vol. 6, No. 1, March, 1925.

*Maine Highway Transportation Survey—Preliminary Report, by J. G. McKay and O. M.Elvehjem, vol. 6, No. 3, May, 1925.

*Transportation of Milk by Motor Truck in the Chicago Dairy District, by E. L. Browne, vol. 6, No. 5, July, 1925.

*Commodity Transportation by Motor Truck, by J. G. McKay, vol. 6, No. 6, August, 1925. (Supply exhausted.)

*Colors and Forms of Traffic Signals, vol. 6, No. 6, August, 1925. (Supply exhausted.)

*Railroad Abandonments and their Relation to Highway Transportation, by H. R. Trumbower, vol. 6, No. 8, October, 1925.

*Motor Bus as a Common Carrier, by H. R. Trumbower, vol. 6, No. 10, December, 1925. (Supply exhausted.)

*Cook County Transportation Survey, by J. G. McKay, vol. 7, No. 1, March, 1926.

*Modern Highway Traffic and the Planning of State Highway Systems, by J. G. McKay, vol. 7, No. 9, November, 1926.

*The Use of Hiring Cars and Busses on Rural Highways, by H. R. Trumbower, vol. 7, No. 9, November, 1926.

*Comparison of Truck and Railroad Tonnage Between Columbus and Selected Ohio Cities, vol. 8, No. 5, July, 1927.

*Statistical Analysis of Highway-Railroad Grade-Crossing Accidents in 1926, by A. B. Fletcher and W. G. Eliot, 3d., vol. 8, No. 11, January, 1928.

*Highway Transportation an Important Factor in Marketing Fruits and Vegetables, vol. 9, No. 4, June, 1928.

*Truck is a Big Factor in Fruit Transport, vol. 9, No. 6, August, 1928.

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Technical Bulletin 55 T, Highway Bridge Surveys. 20c. (Free supply available.)
Technical Bulletin 265 T, Electrical equipment on Movable Bridges. 35c. (Free supply available.)
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*Progress Report of Skew Arch Tests, by George W. Davis, Vol. 6, No. 9, November, 1925.
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*Concrete Compared with Timber for Highway Bridge Floors, by O. L. Grover, Vol. 7, No. 8, October, 1926.
*Analysis of Concrete Arches, by W. P. Linton and C. D. Geisler. Part I, vol. 8, No. 4, June, 1927; Part II, vol. 8, No. 5, July, 1927. Available as a reprint from Public Roads under a single cover, 10c.
*Tests of the Delaware River Bridge Floor Slabs, by George W. Davis, vol. 8, No. 8, October, 1927.
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*Loading Tests on a Reinforced Concrete Arch—Report on Tests Made on Yadkin River Bridge in North Carolina, by Albin L. Gemeny and W. F. Hunter, vol. 9, No. 10, December, 1928.
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*Flow of Water Through Pipe Culverts, by D. L. Yarnell, Sherman S. Woodward, and Floyd A. Nagler, vol. 5, No. 1, March, 1924. (Supply exhausted.)
*General Formula for Waterways, by C. S. Jarvis, vol. 6, No. 12, February, 1926.
*Retards in Stream Control, by John R. Chamberlain, vol. 7, No. 3, May 1926. (Supply exhausted.)
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*Some Aspects of Flow of Water Around Bends and Bridge Piers, by D. L. Yarnell, vol. 10, No. 2, April, 1929.
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*Department Bulletin 347 C. Methods for the Determination of the Physical Properties of Road-Building Rock, 10c.

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*Design of a Constant Temperature Moist Closet, by Wallace F. Purrington, vol. 7, No. 12, February, 1927.
*Relation between sodium sulphate soundness test and absorption of sedimentary rock, by D. O. Woolf, vol. 8, No. 10, December, 1927.
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*Need for Tree Planting Along the Public Highways, by F. W. Besley, vol. 4, No. 5, September, 1921. (Supply exhausted.)
*How Massachusetts is Improving Her Roadsides, by R. E. Tribou, vol. 9, No. 2, April, 1928.
*Parkway features of interest to the highway engineer, by E. W. James, vol. 10, No. 2, April, 1929.
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*Drinking fountains along Oregon highways, by T. M. Davis. vol. 11, No. 2, April, 1930.

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*Cooperative Survey of Corrugated Metal Culverts on the Austin-San Antonio Post Road, by E. F. Kelley, vol. 11, No. 9, November, 1930.
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* Available only by purchase from Superintendent of Documents.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

CURRENT STATUS OF FEDERAL-AID ROAD CONSTRUCTION

AS OF

APRIL 30, 1932

STATE	COMPLETED MILEAGE	UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS	STATE
		Estimated total cost	Federal aid allotted	MILEAGE			Estimated total cost	Federal aid allotted	MILEAGE				
				Initial	Stage[1]	Total			Initial	Stage[1]	Total		
		$	$				$	$				$	
Alabama	2,379.6	2,008,496.70	982,352.29	88.5		88.5						5,469,694.24	Alabama
Arizona	1,250.7	2,010,847.26	1,438,177.82	122.4	1.2	123.6	396,558.93	298,569.20	3.7	21.2	24.9	1,204,333.27	Arizona
Arkansas	1,955.0	2,686,026.78	1,243,958.18	64.8	50.2	115.0	362,032.53	181,016.26	17.3		17.3	2,090,050.06	Arkansas
California	2,301.2	9,724,527.57	4,436,914.36	205.1	38.7	243.8	3,445,989.62	1,623,236.20	68.8	17.0	85.8	206,985.78	California
Colorado	1,575.4	4,388,534.62	2,319,304.94	185.5	50.3	235.8	346,846.72	168,815.57	14.2	.5	14.7	2,077,729.82	Colorado
Connecticut	288.5	3,084,244.77	1,151,757.90	22.9		22.9	227,508.93	104,160.72	4.0		4.0	610,083.83	Connecticut
Delaware	345.2	760,393.25	380,196.62	30.5		30.5	210,556.00	105,278.00	15.9		15.9	167,140.82	Delaware
Florida	617.5	4,232,614.05	1,935,392.29	111.3		111.3	241,813.52	120,906.75	12.2		12.2	2,880,867.20	Florida
Georgia	3,100.0	5,385,405.11	2,480,059.86	106.1	151.0	257.1	1,827,452.26	883,262.82	44.1	45.0	89.1	1,306,477.79	Georgia
Idaho	1,485.0	1,888,362.34	1,097,031.63	90.0	80.7	170.7	500,986.83	302,407.99	34.4	38.5	72.9	1,182,677.78	Idaho
Illinois	2,632.6	24,676,208.29	11,511,846.55	736.4	28.7	765.1	3,481,472.92	1,389,059.28	107.4	12.8	120.2	2,077,789.15	Illinois
Indiana	1,788.6	9,343,751.67	4,592,634.05	278.4	3.2	281.6	3,221,784.39	1,572,088.33	133.7	4.4	138.1	603,704.86	Indiana
Iowa	3,390.8						4,095,531.28	1,912,725.18	191.2	54.0	245.2	887,080.02	Iowa
Kansas	3,656.8	4,723,234.79	2,279,133.06	280.0	15.5	295.5	2,682,780.55	1,310,276.73	125.1	219.1	344.2	1,017,871.44	Kansas
Kentucky	1,869.8	2,584,916.67	1,148,079.52	140.9	4.0	144.9	879,379.99	390,003.50	38.5	46.0	84.5	1,504,550.07	Kentucky
Louisiana	1,557.0	6,794,954.68	3,173,425.78	96.2	10.6	106.8	956,563.32	478,281.66	.5		.5	815,611.31	Louisiana
Maine	706.0	1,804,346.15	789,080.76	31.4		31.4	2,236,243.22	939,451.37	75.5		75.5	421,951.71	Maine
Maryland	776.8	338,200.10	97,983.36	8.9		8.9	645,409.70	297,634.62	26.7	.6	27.3	588,690.84	Maryland
Massachusetts	814.8	7,521,359.24	3,084,570.72	66.8	.1	66.9	101,788.80	50,894.40	3.2		3.2	637,533.67	Massachusetts
Michigan	1,998.3	9,651,288.88	4,486,294.53	425.7	50.9	476.6	282,361.19	56,765.37	13.1	6.1	19.2	3,139,277.43	Michigan
Minnesota	4,144.8	3,654,812.07	1,250,809.01	65.7	103.1	168.8	8,335,406.65	2,689,063.46	154.8	210.1	364.9	35,903.63	Minnesota
Mississippi	1,805.1	3,843,939.79	1,888,599.47	162.2	75.9	238.1	63,967.53	31,983.76	6.4		6.4	5,324,677.74	Mississippi
Missouri	2,976.7	3,175,745.17	1,356,569.71	96.3		96.3	5,801,737.71	2,532,888.42	143.0	100.2	243.2	586,603.68	Missouri
Montana	2,717.8	4,031,970.32	2,268,927.77	351.7	17.6	369.3	399,015.07	223,670.27	57.2	.5	57.7	3,670,527.48	Montana
Nebraska	4,172.8	4,269,855.99	2,101,892.43	190.2	66.3	256.5	290,799.88	145,301.24	13.3		13.3	2,638,132.15	Nebraska
Nevada	1,327.2	1,250,055.74	968,855.55	38.7	100.0	138.7	786,529.05	698,603.39	3.3	70.1	73.4	614,139.07	Nevada
New Hampshire	418.4	636,114.46	246,912.44	12.1	2.5	14.6						553,268.42	New Hampshire
New Jersey	605.7	3,760,915.32	1,327,092.02	36.3	.3	36.6						1,592,693.57	New Jersey
New Mexico	2,196.9	2,338,839.50	1,516,435.95	115.9	17.7	133.6	1,016,475.46	647,378.40	41.1	6.5	47.6	876,109.05	New Mexico
New York	3,262.5	11,445,100.00	5,288,075.00	267.7		267.7	7,862,149.00	3,031,744.50	164.2		164.2	2,752,586.03	New York
North Carolina	2,222.8	1,311,744.48	632,975.21	68.9		68.9	232,703.74	116,351.85	11.1	9.0	20.1	3,801,553.52	North Carolina
North Dakota	5,076.5	2,533,360.10	1,271,292.64	271.1	210.7	481.8	1,751,459.58	889,107.72	148.1	337.8	485.9	1,585,594.75	North Dakota
Ohio	2,854.4	6,347,538.56	2,227,113.68	91.5	18.4	109.9	3,643,238.52	1,278,440.74	79.8	17.6	97.4	3,004,724.56	Ohio
Oklahoma	2,255.3	4,053,069.67	1,921,207.88	113.2	61.2	174.4	1,243,378.68	629,434.87	112.1	6.8	118.9	1,737,715.26	Oklahoma
Oregon	1,529.0	4,080,678.53	2,262,172.42	119.3	47.1	166.4	779,316.22	467,080.91	5.2	40.0	45.2	1,321,125.41	Oregon
Pennsylvania	3,020.0	1,722,045.11	681,721.34	38.0		38.0	5,176,651.13	2,232,360.32	158.6		158.6	2,943,259.13	Pennsylvania
Rhode Island	255.4	890,586.30	441,180.98	16.6	2.2	18.8						365,211.86	Rhode Island
South Carolina	2,008.6	2,477,211.20	1,054,161.02	56.9	37.4	94.3	804,446.34	386,000.00	25.6	13.3	38.9	1,042,551.03	South Carolina
South Dakota	4,038.8	3,451,363.76	1,951,959.42	230.1	181.9	412.0	269,938.45	187,615.53	49.1		49.1	1,080,793.57	South Dakota
Tennessee	1,669.0	1,018,377.27	498,947.20	33.6	10.7	44.3	574,928.81	279,752.44	26.4		26.4	3,545,556.85	Tennessee
Texas	7,630.8	14,372,646.52	6,531,027.59	776.7	187.2	963.9	3,000,299.08	1,334,024.90	136.7	108.8	245.5	5,121,710.29	Texas
Utah	1,212.3	908,505.04	646,990.90	70.5	6.6	77.1	723,417.96	535,329.16	32.8	85.9	118.7	869,349.93	Utah
Vermont	339.1	104,832.58	52,345.06	4.3		4.3	1,086,289.88	492,855.54	31.8		31.8	89,110.73	Vermont
Virginia	1,917.1	1,985,427.19	992,579.58	117.2		117.2	159,197.59	79,598.79	5.4		5.4	2,065,478.19	Virginia
Washington	1,184.3	2,755,425.96	1,321,468.56	84.7	11.1	95.8	820,867.76	401,300.00	31.3	10.7	42.0	1,225,142.23	Washington
West Virginia	882.9	1,882,429.90	835,314.59	44.7	10.5	55.2	473,910.17	213,288.81	10.9		10.9	1,038,154.78	West Virginia
Wisconsin	2,672.7	3,874,672.71	1,572,633.84	131.0	7.8	138.8	1,796,381.83	786,000.00	42.0	24.7	66.7	1,518,163.91	Wisconsin
Wyoming	1,956.3	3,240,861.84	1,946,522.75	225.1	136.4	361.5	334,624.92	214,182.54	16.5	32.1	48.6	438,609.36	Wyoming
Hawaii	74.2	700,101.47	312,800.22	18.9		18.9	424,052.28	349,164.42	6.7	3.6	10.3	1,691,776.18	Hawaii
TOTALS	100,917.0	199,725,939.47	93,996,778.45	6,940.9	1,797.7	8,738.6	73,994,243.99	33,057,355.93	2,442.9	1,542.9	3,985.8	82,020,323.45	TOTALS

[1] The term stage construction refers to additional work done on projects previously improved with Federal aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.

U. S. GOVERNMENT PRINTING OFFICE: 1932