Effect of Shoulders on Speed and Lateral Placement of Motor Vehicles

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IN order for shoulders to be effective and safe, they must be of a design which will encourage vehicles to travel close to the pavement edge, thereby allowing the maximum lateral clearance between vehicles meeting one another. When two-lane pavements are 20 ft. in width or less, shoulders should be constructed with at least 4 ft. of stabilized material adjacent to the pavement, plus additional width of grass or gravel. The speed of moving vehicles is not substantially affected by the width of shoulder, providing the shoulder is more than 4 ft. in width. The lateral position of free-moving vehicles and the clearance between meeting vehicles bears no significant relation to the shoulder width above 4 ft. Well-maintained grass shoulders have the same effect on the speed and lateral position of moving vehicles as well-maintained gravel shoulders.

Absence of available facts indicate then that further studies be planned to: (1) determine if there is a relationship between shoulder types and widths and motor vehicle accidents and, if so, the extent of that effect; (2) learn to what extent shoulders are used for parking and the resultant effect upon traffic movement; and (3) determine the use of shoulders by disabled vehicles.

● IT is universally recognized that shoulders along highways provide some degree of actual benefit and some degree of assumed benefit to traffic movement. A committee, known as Project Committee No. 3, under the sponsorship of the Department of Traffic and Operations of the Highway Research Board, was organized in 1947 to evaluate these benefits from the standpoint of traffic operations as related to shoulders.

At the organizational meeting in New York on September 25, 1947, plans were formulated for the initiation of a program of research on this phase of a highway facility.

The aim of the committee was threefold. The first phase was to compile a bibliography of work previously done in the area of shoulders and to extract therefrom any substantial material of factual nature that could be used for this research project.

The second phase was to summarize the findings and conclusions of previous research on the subject.

The third phase centered upon new research to supplement the known information accumulated through the two earlier phases. The bibliography originally prepared in 1947 was brought up to date and, as supplemented, is contained at the end of this paper.

Problem Statement

In order to segregate the exploratory work in the fields of design, construction and maintenance of shoulders, the committee deemed it necessary to isolate the problem as it pertained to the movement of traffic. Hence, it was determined that the committee's initial endeavors should be directed to the influence of shoulders on speed and lateral placement of vehicles in motion.

Data of a factual nature were necessary, and to obtain such information, the committee solicited the assistance of its members in their respective states to undertake parallel field studies.

As a further step in the quest for reliable data on a national scope, the planning engineers and traffic engineers of the states and the division and district engineers of the Bureau of Public Roads were handed questionnaires pertaining to the availability of useful information.

The response, while not productive of an abundance of facts, indicated a broad interest in the research and confirmed the assumption of the committee that there existed a relationship between the reaction of drivers and the width and type of shoulders. The summary of replies is contained in appendix.

Although such beliefs and opinions were manifestations of a relationship between shoulders and operation, it highlighted the need for measureable facts.

A further indication that the problem has some scope may be illustrated by the following statement taken from the report *Highway Needs of the National Defense:*

> Of the 31,831 miles of the system [National System of Interstate Highways] is rural areas, 421 miles are built without shoulders, curbs replacing this normal feature of rural road design. Of the 31,410 miles built with shoulders, 6,273 miles have shoulders less than 4 feet wide; 15,990 miles have shoulders between 4 and 8 feet in width, and on 9,147 miles the shoulders are 8 feet wide or more.

The necessity for correlative studies was also brought out by means of a byproduct of a study of roadway widths made in 1945 by the Bureau of Public Roads.

AVAILABLE DATA

The committee decided at the outset on a program of determining the effect of shoulders on speed and transverse position of motor vehicles in motion. The committee feels that this phase of the program has been completed and the results of these studies are summarized below.

Public Roads Study, 1945

The only significant completed research on the subject was actually a byproduct of a comprehensive study completed in 1945 by the Bureau of Public Roads. This study, that of the effect of roadway width as traffic operations, revealed pertinent conclusions which heretofore not only have never been reputed but have been strengthened by the results of the studies conducted by members of this committee.

The study consisted of observing the behavior of traffic (as measured by volume, speed, lateral positions, clearance between vehicles traveling in the same and opposite directions, time spacings, etc.) on two-lane, level concrete pavements at nearly 100 locations throughout the country. The conclusions of importance to our problems are probably familiar to many students of the highway and traffic field. Because of their importance, it is felt that they should be repeated in this report. They are as follows:

1. Shoulder width in excess of 4 ft. does not influence the effective pavement width for moving vehicles when there are no vertical obstructions immediately adjacent to the shoulder. This must not be interpreted that shoulders wider than 4 ft. are not necessary for other important reasons.
2. Well-maintained grass shoulders have the same effect as well-maintained gravel shoulders (under dry weather conditions).
3. Bituminous-treated shoulders, 4 ft. or more in width, adjacent to 18- and 20-ft. pavements, increase the effective surface width approximately 2 ft.
4. Shoulder use increases rapidly with a decrease in pavement width below 22 ft. An insignificant number of moving vehicles use the shoulders on pavements of 22 ft. or more in width. On 18-ft. pavements with grass or gravel shoulders, however, 5 percent of the commercial vehicles use the shoulder as they meet oncoming traffic. The corresponding value is 17 percent on highways with bituminous shoulders.

West Virginia Before-and-After Studies, 1947 to 1948

Studies were conducted at two locations in West Virginia before and after 16-ft. compacted-earth shoulders were constructed on a road which previously had no shoulders. The pavement at both locations consisted of two 14-ft. lanes with the inner 2 ft. of each lane blackened by the use of pigment. The finish was of the same texture and there was no joint except in the center of the pavement. At the time of the studies it was observed that traffic used the facility more like it would a three-lane road rather than a two-lane road.

After the shoulders were constructed, free-moving passenger cars traveled between 3 and 5 mph. faster, on the average, than when no shoulders were evident. The speeds of trucks increased only about 1 mph. As stated by C. A. Rothrock, who was in charge of the studies, it is doubtful whether or not the shoulders were solely responsible for the somewhat higher speeds. Even though the weather was fair and the pavement dry during both study periods, the summer season, when the after studies were made, may have been responsible for the higher speeds.

Maryland Study, 1947 to 1948

From October 1947 to October 1948, a series of five successive studies of speed and lateral placement of vehicles was made at one location in Maryland where the pavement was undergoing the following five stages of development: (1) immediately following the placement of a 24-ft. bituminous surface (over an existing 18-ft. concrete pavement), without centerline markings and without shoulders (the adjacent shoulders were 4 to 8 in. below the new surface (October 9, 1947); (2) after loose shoulder material had been dumped but not leveled nor compacted and still no centerline (October 31, 1947); (3) the same as Stage 2 above, except centerline had been painted (November 18, 1947); (4) after a 4-ft. shoulder had been leveled with the surface and compacted by traffic over a 2-mo. period (January 8, 1948); and (5) after the shoulder had been in place for one year (October 12, 1948).

Because of the seasonal fluctuation in the traffic volume at this location, an analysis of the speed and lateral placements was made for the same hourly volume during the five conditions. The volume selected was 300 to 500 vehicles per hour. This series of studies revealed one significant point, namely, that except for the condition existing during Stage 2 (loose gravel dumped along the edge), no appreciable variation in the average speeds and lateral positions of vehicles was observed among the other four conditions. During Stage 2 however, speeds were found to be 3 to 4 mph. lower, and there was a tendency for vehicles to avoid the pavement edge by a greater margin than during the other stages of construction.

Speed Studies During 1948 in Several States

A number of states have been coöperating with the Bureau of Public Roads in conducting periodic speed studies for use in determining, among other things, the trend of vehicle speeds on our highway systems. In 1948 it was requested that, in addition to the speed data, the states submit a detailed description of each location, with particular emphasis on the pavement and shoulder width and type. As a result, a large amount of data from several states has been received and analyzed.

Information submitted by five states is of particular interest to this committee, because the only apparent variable in the geometric design features between two or more locations was that of shoulder width. Table 1 shows a summary of the data recorded at such locations on level tangent sections of highway. A close examination of the data in this table shows that there exists little relation between vehicle speeds and shoulder width.

This observation is especially true of the data recorded in Minnesota where the locations were chosen so that the type of traffic, the width and type of roadway, and the type of shoulders were the same. The only variable was the shoulder width. Stations 18 and 19 were on the same highway, about 2 mi. apart, and Stations 20 and 21 were also on the same highway, about 5 mi. apart. The data shown in Table 1 are for the summer and fall of 1948.

The state conducted additional studies at these four locations during the summer of 1948. For each period of study, the state reported that the width of shoulder in excess of 6 ft. "has no significant effect on speeds of vehicles."

Connecticut, 1948

In Connecticut, speed and lateral placement data were recorded for a total of 650 vehicles at four different locations. Unfortunately, the roadside culture was different at the sites and the pedestrian traffic presented a somewhat indeterminant effect on the behavior of the traffic. A final report on this limited study has never been prepared and an analysis of the summarized data seems to indicate that whatever differences in speed or lateral position of vehicles were recorded, such differences could not, with any assurance, be attributed only to the difference in shoulder width.

A limited study similar to the one conducted in Connecticut was also made in Ohio during the summer of 1948. Both of these so-called pilot studies served to reinforce the committee's original contention that to isolate the effect of only the shoulder on the speed and lateral position of moving vehicles, great care must be exercised to select locations identical in the geometric design, except of course, that of shoulder width or type. Roadside conditions, traffic conditions, proximity to urban areas, and other such factors that influence driver behavior also must be identical.

TABLE 1
VEHICLE SPEEDS AS RELATED TO SHOULDER WIDTH ON SECTIONS WHERE ALL OTHER HIGHWAY DESIGN AND TRAFFIC FEATURES ARE SIMILAR

Station	Pavement		Shoulder		Average Speed	Vehicles Traveling Over	
	Width	Type	Width	Type		35 mph.	50 mph.
	ft.		*ft.*		*mph.*	%	%
Arizona—January to September, 1948							
1	20	Bit.	3	dirt	50.8	96.0	43.0
2	20	Bit.	3	gravel	48.9	93.0	40.0
3	20	Bit.	3	gravel	47.9	94.7	40.0
Avg. for 1 to 3	20	Bit.	3	gravel	49.2	94.6	41.0
4	20	Bit.	4	gravel	48.5	95.0	36.7
5	20	Bit.	5	gravel	51.3	99.0	50.7
6	20	Bit.	5	gravel	50.0	95.7	42.7
Avg. for 5 and 6	20	Bit.	5	gravel	50.7	97.4	46.7
7	22	Bit.	3	gravel	47.9	94.7	40.0
8	22	Bit.	5	gravel	52.6	96.5	53.0
Connecticut—May and June, 1948							
9	20	PCC	6	oiled gravel	42.5	90	8
10	20	PCC	10	oiled gravel	41.2	86	3
11	22	Bit.	3	oiled gravel	42.7	89	12
12	22	Bit.	8	armor coat	44.2	96	16
13	22	PCC	6	oiled gravel	41.0	89	4
14	22	PCC	10	oiled gravel	41.2	86	3
15	22	PCC	10	armor coat	49.1	99	33
Indiana—June, 1948							
16	18	PCC	6	*	48.4	92	49
17	18	PCC	8	*	47.5	96	38
Minnesota—May, 1948							
18	18	PCC	6	grass	48.6	95.7	41.2
19	18	PCC	11	grass	48.5	95.5	39.0
20	18	PCC	6	grass	49.0	96.5	40.6
21	18	PCC	12	grass	48.5	95.0	40.2
Minnesota—September, 1948							
18	18	PCC	6	grass	50.7	97.3	51.9
19	18	PCC	11	grass	52.2	98.2	61.3
20	18	PCC	6	grass	50.5	97.2	50.6
21	18	PCC	12	grass	51.3	97.9	55.5
Oregon—August, 1948							
22	22	PCC	8	gravel	50.4	96	47
23	22	PCC	10	gravel	51.5	97	53

* Not stated.

West Virginia, 1949

Following the earlier studies, exploratory in nature as they were, two sets of studies were conducted in 1949, one in West Virginia and the other in Ohio. Extreme care was exercised to hold all other variables constant, except that of shoulder width and type.

An excellent opportunity was afforded in West Virginia. Three study locations were selected on the same road (US 19) consisting of 18-ft. concrete pavement with approximately the same characteristics of surface smoothness and appearance. The study locations were located within a relatively short distance of each other in rural surroundings and the character of the traffic was practically the same on all three sections. In fact, most of the vehicles studied traveled over all three sections. Figure 1 shows the cross sections at the three locations.

The study at these three locations was made in three phases. The first phase consisted of studying speeds of vehicles at Station 1 to determine the difference in speed that could be attributed to the difference in the bituminous shoulder width for the two directions of travel. The results of this phase indicate that free-moving passenger cars traveled about 4 mph. faster when 6-ft. bituminous shoulders were available.

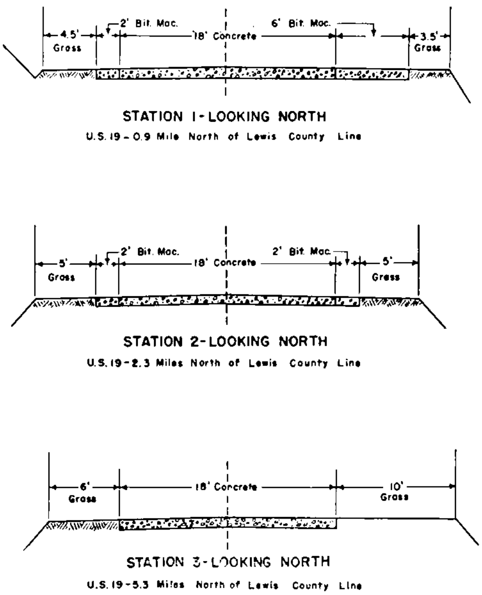

Figure 1. Cross sections of shoulder study in West Virginia, 1949.

A detailed analysis of the data in this table indicates that no definite relation exists between shoulder width or type and vehicle speed.

The third phase consisted of simultaneous observations of the lateral positions of nearly 700 vehicles at each of the three locations. The results of an analysis of these data disclose that the average position of the free-moving passenger cars and trucks were very nearly the same (an inconsistent difference of 0.1 ft. or less) at all three locations. This indicates that very little relation exists between the lateral positions of vehicles and the shoulder type, when ample width is available.

The percentage of vehicles using the shoulder and the percentage of vehicles encroaching upon the left lane as determined in this study, are shown in Table 3. The data show that no relation exists between the shoulder width and the percentage of vehicles using the shoulder. Nor is there any apparent relation between the shoulder width and the percentage of freely moving passenger cars encroaching in the left lane.

Examination of the data for the free-moving trucks and busses indicates that the type rather than the width of shoulder effects a better positioning of the commercial vehicles on the pavement. Twice as many trucks and busses encroached upon the left lane on the section which had only grass shoulders as on the section where bituminous shoulders of 6 ft. in width were available.

TABLE 2
RELATION BETWEEN SHOULDER WIDTH AND SPEED OF FREE-MOVING VEHICLES
US 19, Lewis County, West Virginia

Station Number	1		2		3	
Direction of Travel	NB	SB	NB	SB	NB	SB
Width of bituminous shoulder (ft.)	6	2	2	2	0	0
Width of grass shoulder (ft.)	3.5	4.5	5	5	10	6
Free-moving passenger cars						
Average speed (mph.)	52.6	51.3	51.1	49.7	45.8	49.6
85 percentile speed (mph.)	63.0	56.2	60.0	54.0	57.5	57.1
Percent over 50 mph.	56.5	55.4	62.5	57.0	31.9	52.4
Free-moving trucks						
Average speed (mph.)	38.0	35.8	37.2	37.0	31.6	39.6
85 percentile speed (mph.)	50.1	48.2	46.5	48.2	40.5	54.0
Percent over 50 mph.	15.4	5.9	5.3	0	5.4	12.0

The second phase consisted of simultaneous observations of speeds of over 400 vehicles at each of the three stations. A summary of the data is shown in Table 2. First, it will be noticed that vehicles having the wider bituminous shoulder travel faster than the vehicles having the narrow bituminous shoulder. This agrees with the results obtained during Phase 1 but the difference is only 1 to 2 mph.

Ohio, 1949

In Ohio, two pairs of locations were studied. The cross sections at the first pair of locations is shown in Figure 2. The study points were located 4.5 mi. apart on the same road, having a 20-ft. bituminous surface with 3 ft. of gravel shoulders and grass shoulders extending to the ditch line. Figure 3 shows the cross-sections of each pair. Over 4,000 samples were recorded at each pair of locations during volumes ranging from 300 to 350 vehicles per hour.

TABLE 3

RELATION BETWEEN SHOULDER WIDTH, PERCENTAGE OF VEHICLES USING SHOULDER, AND PERCENTAGE OF VEHICLES ENCROACHING UPON LEFT LANE

US 19, Lewis County, West Virginia

Station Number	1		2		3	
Direction of Travel	NB	SB	NB	SB	NB	SB
Width of bituminous shoulder (ft.)	6	2	2	2	0	0
Width of grass shoulder (ft.)	3.5	4.5	5	5	10	6
Free-moving passenger cars						
Percent on shoulder	0.3	0	0	0.4	0	0
Percent encroaching upon left lane	28.9	16.8	21.0	26.6	26.7	17.7
Average for both directions	22.8		23.8		22.2	
Free-moving trucks and busses						
Percent on shoulder	0	11.9	4.8	2.6	0	1.3
Percent encroaching on left lane	22.5	27.9	40.4	40.4	58.4	42.5
Average for both directions	25.2		40.4		50.9	

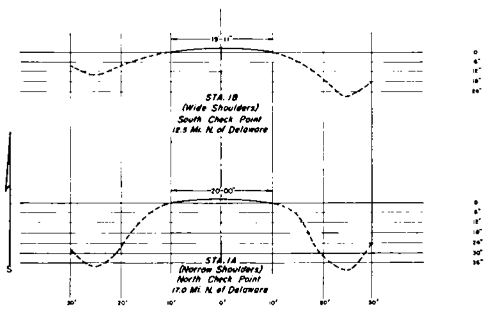

Figure 2. Cross sections of two check points, Station 1, Marion County, Ohio.

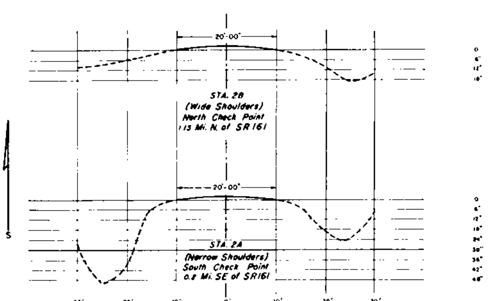

Figure 3. Cross sections of two check points, Station 2, Union County, Ohio.

of each location at the second pair of locations which also were on the same road and only 1½ mi. apart.

Both vehicle speeds and lateral positions were studied simultaneously at the two locations of each pair.

The results of this study are as follows:

1. A definite (though small) trend toward higher speeds was found to prevail on the sections having wider shoulders. Vehicle speeds were 0.5 to 3.0 mph. higher at the sections with the wide shoulders as compared with the sections with the narrow shoulders. The difference was greater for passenger cars than for commercial vehicles.
2. The difference in the grassed shoulder slopes at the two locations had practically no effect upon the lateral positions of free-moving vehicles. The average difference was 0.2 ft. in favor of the flatter grass shoulder at one pair of locations and 0.05 ft. in favor of the steeper grass shoulder at the other pair of locations.
3. When passenger cars met oncoming passenger cars, there was a somewhat greater margin of lateral clearance afforded on the gentle sloping shoulders as compared with the steeper shoulders. There was no significant difference noted in the lateral clearances of commercial vehicles meeting other vehicles.
4. These two types of shoulders had no apparent effect on the speeds or lateral positions of overtaking and passing vehicles.

New Jersey, 1950

In New Jersey, a study was initiated in 1948 to determine the influence, if any, of the shoulder width upon the speed of traffic. The report was released in 1950. Data were taken for free-moving and meeting vehicles separately for passenger cars and for trucks.

Level tangent sections of concrete pavements on two-lane roads were studied. Four locations where the shoulder widths ranged from 5 to 11 ft. were selected. Two sections, on different roads and in different parts of the state, had bituminous shoulders. The shoulders were 5 ft. in width at one section and 9 ft. in width at the other section. The two additional sections were on the same highway (Route 25) and the pavements were flanked by 10 and 11-ft. gravel shoulders.

This report states that for improved shoulders such as used in New Jersey, a width of 10 ft. reflects a recorded benefit for traffic compared to a 5-ft shoulder. The speeds of vehicles at the 9-, 10-, and 11-ft. shoulder sections are practically the same. At the section with the 5-ft. bituminous shoulders, lower speeds were recorded. This was no doubt due to the posted speed limit, which was 40 mph. at this location and 45 mph. at the other three locations. At all locations, the average recorded speeds were practically the same as the respective speed limits.

New York, 1950

Graduate students of Cornell University made a limited study of speeds at one pair of locations having 22-ft. concrete surfaces. One site had narrow shoulders and the other wide shoulders. With the exception of the 22-ft. pavement width, the cross sections were very similar to the pair of locations studied in Ohio in 1949, which have been shown in Figure 3.

The results showed slightly higher speeds (2 to 3 mph.) at the narrow shoulders as compared with the speeds at the wide shoulders. Only one conclusion is given in this report: "results indicate that there is no fixed relationship between the widths of shoulders and vehicle speeds."

Oregon, 1950

Speeds were observed at two locations on the same road in Oregon. One section had 9-ft. shoulders and the other had 10-ft. shoulders. The locations were within ½ mi. of one another and the speed of each vehicle was recorded at both sites.

At these locations, vehicles actually decreased their speeds by 5 to 6 mph. when traveling from the section with the narrower shoulders to the section with the wider shoulders. The pavements were 23.5 ft. in width at both locations and the sections were separated by an intersecting minor highway. It is obvious that the 1-ft. difference in shoulder width did not cause the large recorded difference in speeds.

Purdue University, 1951

A graduate research assistant at Purdue University conducted a study of the lateral positions of vehicles as affected by shoulders adjacent to 18-ft. and 22-ft. pavements. The 18-ft. pavement had poor gravel shoulders on 75 percent of its length and good gravel or bituminous shoulders on the remaining 25 percent. The 22-ft. pavement had grass shoulders throughout its length.

This study, unlike any other study here reported, made use of a motion-picture camera, installed in a car. The car followed a selected vehicle for study at a predetermined and uniform distance throughout the observation. A motion picture was made of the lateral position of the vehicle at progressive stations. The film was then projected on a screen and the lateral positions scaled.

The primary purpose of the study was to determine the adaptability of the equipment to this type of research and the statistical stability of the data observed. From the limited data gathered, the author concluded: (1) shoulders do influence traffic operations on a narrow pavement; (2) the influence on traffic operation of good and poor shoulders adjacent to 18-ft. pavements is not significantly defined because the drivers of vehicles are not sure of the relative safety of these shoulders and tend to remain as far away from them as possible; and (3) bituminous shoulders greatly influence the lateral position of vehicles on 18-ft. pavements.

SUMMARY

A summary of the foregoing discussion reveals that well over 50 locations, in more than 15 states, have been studied in the attempt to evaluate the effect of shoulders on the speed and lateral position of motor vehicles in motion. In nearly all of these studies, vehicle speeds have been investigated. Lateral placement data have been recorded in only four states, and of those, extensive analyses were made only of the data recorded in Maryland, Ohio, and West Virginia.

It is the strong feeling of the committee that the results of enough studies are available to permit reasonable safe conclusions to be drawn. The committee further feels that this report fulfills its obligation to the Department of Traffic and Operations of the Highway Research Board with respect to the evaluation of the effect of shoulders on the speed and transverse position of motor vehicles.

CONCLUSIONS

Subject to the general remarks made above in the summary, the following conclusions are drawn from the several reports submitted by members of this committee and from all other available published data:

1. Adequate shoulders adjacent to a traveled highway are very important and serve many purposes.
2. In order for shoulders to be effective and safe, they must be of a design which will encourage vehicles to travel close to the pavement edge, thereby allowing the maximum lateral clearance between vehicles meeting one another.
3. When two-lane pavements on main highways are 20 ft. in width or less, shoulders should be constructed with at least 4 ft. of stabilized material adjacent to the pavement, plus additional width of grass or gravel.
4. The speed of moving vehicles is not substantially affected by the width of shoulder, providing the shoulder is more than 4 ft. in width.
5. The lateral position of free-moving vehicles and the clearance between meeting vehicles bears no significant relation to the shoulder width above 4-ft.
6. Well-maintained grass shoulders have the same effect on the speed and lateral position of moving vehicles as well as well-maintained gravel shoulders.

RECOMMENDATIONS

In view of the fact that previously accumulated data have supplied a basis for reaching a conclusion concerning the effect of shoulders on speed and lateral placement of vehicles, it is not believed necessary to pursue that phase any further.

However, since there is evidence that shoulders do have an important effect upon other phases of traffic operation, it is the opinion of the committee that facts should be obtained thereon.

Absence of available facts indicate then that further studies be planned to: (1) determine if there is a relationship between shoulder types and widths and motor-vehicle accidents and, if so, the extent of that effect; (2) learn to what extent shoulders are used for parking and the resultant effect upon traffic movement; and (3) determine the use of shoulders by disabled vehicles.

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——, Gravel shoulders save pavement. Better Roads, V 12, No. 11, November 1942, p. 36. (Minnesota Department of Highways has saved a large mileage of its old heavily traveled 18-foot pavement, where concrete is still in good condition but slab is generally considered obsolete because of its narrow width, by simple expedient of putting a 3-foot width of compacted gravel at edge of traveled way.)

WHEELER, JOHN W., What the 1941 maneuvers taught us. New England Construction, V 7, No. 2, July 1942, p. 24. (Outstanding requirement brought out is need for wide shoulders. Should make all shoulders 12 feet wide except where topography is so rugged that it is economically out of question.)

GORDON, GEORGE B., Road shoulder development needed on defense highways; heavily traveled roads are only as good as their shoulders; how to improve them. Contractors and Engineers Monthly, V 38, No. 11, November 1941, p. 2.

——, Four hundred miles of shoulders widened in modernizing State highway system. Increased safety and convenience built into roads—utilize 140,000 man-months of work on WPA cooperative projects. Outdoor Indiana, V 8, No. 7, August 1941, p. 19.

LOCKRIDGE, EARL B., Widening of shoulders on main highways, Public Works, V 72, No. 1, January 1941, p. 16. (Important for providing turnouts and storage space. Three principal phases in widening highways.)

HAMLIN, GEORGE E., Shoulder-hardening treatment makes wider roads in Connecticut: improved bituminous shoulder treatment methods increase the serviceability of older highways under modern traffic conditions and eliminate expensive maintenance operations. Better Roads, V 9, No. 4, April 1939, p. 42. (Includes costs of treatment.)

WILLIAMSON, D. D., Trends in asphalt construction: a review of some developments in its use during the past year. Roads and Streets, V 82, No. 1, January 1939, p. 35. (Sidewalks, safer shoulders, shoulder widening and resurfacing, economics, cities, cotton roads, road building in the South, construction.)

——, Off the pavement. Safety Bulletin (Illinois), V 4, No. 3, March 1938, p. 1. (Records of Illinois Division of Highways show that of 4,929 motor vehicle accidents on rural numbered State highways during year 1937, 9 percent or 444, in which 64 persons were killed and 795 were injured, resulted when vehicles ran off edge of pavement onto earth shoulders.)

SIMONSON, WILBUR H., Streamlined shoulders increase road safety: grading costs balanced by savings effected in reduced need of guard rail in many places. Contractors and Engineers Monthly, V 34, No. 9, September 1937, p. 2.

——, Complete the job: editorial. Engineering News-Record, V 119, No. 11, September 9, 1937, p. 419. (Roads with inadequate and dangerous shoulders should be completed without delay in interests of road transport as well as of public safety.)

——, Pavement widening in Kansas: unstable shoulders and drops from pavement to shoulder are hazards to traffic and make maintenance troublesome. Bituminous strips have been built on Kansas State highway shoulders to help in eliminating these difficulties. Better Roads, V 7, No. 2, February 1937, pp. 37–38.

——, Firming up soft shoulders with cotton: New facts and procedure developed in Rhode Island in stabilizing sand shoulders on highways and in redressing tar roadways with a cloth and bituminous armor coat. Engineering News-Record, V 117 No. 22, November 26, 1936, p. 749.

Report of the Joint Committee on Roadside Developments of the American Association of State Highway Officials and the Highway Research Board, November 18, 1936, pp. 69–82. (Pamphlet published by the Highway Research Board, June 1937.) This report contains articles on design, use and safety features of shoulders. Articles by C. N. Conner, James E. Lawrence, and Frank T. Sheets.

TINEY, B. C., Shoulder stabilization: An effective highway safety measure, Roads and Streets, V 79, No. 7, July 1936, p. 44.

ADAMS, JAMES D., Indiana's roads in relation to her future development. Public Works, V 67, No. 4, April 1936, p. 12. (Extracts from paper presented at 22nd annual Purdue road school January 20–24, 1936.) During snow period there were no wrecks on ten miles of widened shoulder as compared to 22 wrecks in 20 miles where shoulder had not been widened. Since fall of 1933 State has extended shoulders on 837 miles of highways and widened several thousand culverts and bridges making possible planting of trees and shrubs along roadways.)

——, Motorists back highway program to widen shoulders as safety move: fewer deaths, accidents on widened sections—ask aid in acquiring necessary rights-of-way. Outdoor Indiana, V 2, No. 2, March 1935, p. 30.

ADAMS, JAMES D., Whither are we motoring? Twenty-five years of road building progress has brought with it a menace, a problem and an obligation which we cannot forget. The author not only discusses it, but is doing something about it in his State. Highway Magazine, V 26, February 1935, p. 51. (Widening shoulders and flattening ditch and backslopes makes for fewer lives lost.)

——, Barriers on road shoulder keep cars on highway. Popular Mechanics, V 61, No. 1, January 1934, p. 78. (Spaced barriers erected on shoulders of roads in parts of Illinois.)

——, Shoulders on paved roads—a perennial problem. Better Road, V 2, No. 7, July 1932, p. 14. (Safety and convenience of traveling public call for an adequate width of strip and the elimination of dangerous ruts; highway department is interested in meeting demand for smooth surfacing in most economical manner.)

HAMLIN, GEORGE E., Evolution of the shoulder and methods of treatment in Connecticut. Highway Magazine, V 21, No. 11, November 1930, pp. 283–5. (By treatment of shoulders, to give additional width required for travel and reduce need for continual maintenance caused by weather conditions. Highway maintenance department of Connecticut has been endeavoring to keep cost at lowest possible figure.)

KEASBEY, H. B., New Developments in shoulder and drain maintenance: higher speeds make more substantial shoulders necessary. Slips and slides avoided by proper location, or stopped by extensive drainage. Erosion prevented by seeding of slopes. Maintenance with machinery, becoming more popular. Pacific Street and Road Builder, V 26, No. 2, February 1930, p. 20. Also in Proceedings, American Road Builders' Association 1930, p. 689.

WALDROP, JOHN D., Shoulder Widths. Engineering News-Record, V 104, No. 1, January 2, 1930, p. 26.

HENDERSON, GEORGE H., Shoulders of new and old roads made safe for parking. American City, V 42, No. 1, January 1930, p. 91.

GOETZ, W. ALBERT, Shoulder work and the contractor: Widening of Maryland highway accomplished without holding up traffic. Successful Methods, V 8, No. 5, May 1926, p. 8.

APPENDIX

STATUS OF REPLIES FROM DIVISION AND PLANNING ENGINEERS ON THE QUESTION OF THE EFFECT OF SHOULDERS ON TRAFFIC OPERATIONS

State	Person Replying	Date	Remarks
Alabama	A. Reese Harvey, Chief of Planning Survey	July 26, 1949	No information available
Arkansas	A. R. Johnson, Chief Engineer	July 29, 1949	No information of value to Committee
Arkansas	F. R. Oliver, District Engineer	Sept. 8, 1949	We are "shoulder conscious" and have embarked on a program of shoulder improvement
California	G. T. McCoy, State Highway Engineer	Aug. 23, 1949	Interested, but nothing available
California	C. C. Morris, Division Engineer	Sept. 8, 1949	No information available
California	E. C. Brown, District Engineer	Sept. 7, 1949	No information available
Colorado	A. V. Williamson, District Engineer	Aug. 11, 1949	The standards of shoulder widths vary from 8 to 10 feet in rolling and plains country, mountainous areas shoulder widths of 4 feet. These standards do not introduce any appreciable hazard to the traveling public
Delaware	William J. Miller, Jr., Traffic and Planning Engineer	Aug. 2, 1949	Under study. Shoulder maintenance is one of the most important features in our overall program
Florida	R. B. Smith, District Engineer	Aug. 30, 1949	No information available
Florida	W. M. Parker, Division Engineer	July 29, 1949	We are entering a program of widening and resurfacing using a standard width of 22 and 24 feet shoulders
Idaho	L. M. Huggins, District Engineer	Aug. 30, 1949	No information available
Illinois	Frederick M. Johnson, District Engineer	Aug. 22, 1949	Under study
Illinois	David M. Baldwin, Traffic Engineer	Sept. 7, 1949	I am sending you two copies of the report prepared on this work, because you may be interested
Indiana	H. C. Oakes, District Engineer	Aug. 15, 1949	No information available. Refers to paper by Harold G. Beverly, Michigan State Highway Dept.
Iowa	D. D. Mickey, District Engineer	Aug. 22, 1949	No information available
Kansas	E. E. Buell, District Engineer	Aug. 12, 1949	No information available. I should like to emphasize the importance of your work and would appreciate a copy of the completed report
Kansas	Paul G. Martin, Engineer of Highway Planning	Aug. 15, 1949	We have no statistical data on the effect of shoulder widths and shoulder stability but through observation there is a growing feeling in the department that 9 and 10 feet shoulders should be provided on roads carrying heavy traffic.
Kentucky	Mack Galbreath, District Engineer	Aug. 8, 1949	Several years ago we made a study of shoulders over the state of Kentucky and submitted report to Public Roads Washington. No other is information available.
Maine	Fred G. Eaton, Director, Planning Division	July 28, 1949	No information available
Maine	H. D. Fallon, District Engineer	Aug. 18, 1949	No information available
Minnesota	A. L. Overbee, District Engineer	Aug. 9, 1949	Minnesota State Highway Dept. is presently engaged in two studies of shoulder widths and much of it still remains in the study stage

State	Person Replying	Date	Remarks
Missouri	S. M. Rudder, Highway Planning Engineer	Sept. 22, 1949	No information available
Montana	Albert W. Greiner, Planning Survey Engineer	Aug. 31, 1949	Under study, and investigation has not been completed
Montana	K. S. Chamberlain, District Engineer	Aug. 16, 1949	No information available
Nebraska	W. H. Mengel, Highway Planning Engineer	Aug. 18, 1949	No data available. Generally speaking, our traffic volumes are not sufficiently heavy to warrant studies along this line
Nevada	W. T. Holcomb, State Highway Engineer	July 28, 1949	No such information available in the state. We have for a number of years conducted annual checks on vehicle speeds of sites having various surface widths and shoulder treatments. Would be happy to forward copies of results
Nevada	Wm. Howard Smith, District Engineer	Aug. 16, 1949	Under study. Nevada since the end of World War II has been constructing shoulders of the same thickness of base and surfacing as the highway surface. On heavily traveled highways shoulders are 8 feet wide.
New Hampshire	David L. Fosbough, Manager, Planning Survey	July 29, 1949	No information available
New Jersey	J. E. Mincher, District Engineer	Aug. 19, 1949	No information available
New Mexico	W. J. Keller, District Engineer	Aug. 17, 1949	To allow safe and efficient operation of traffic, shoulders should be wide enough to permit halted vehicles to be parked entirely off the traveled roadway. It is our opinion and we believe you will agree
New York	J. E. Ayres, District Engineer	Aug. 5, 1949	Forward your letter to Mr. C. E. Swain
New York	C. E. Swain, Division Engineer	Aug. 16, 1949	There is a growing realization in this area of the need for sloping shoulders away from the pavement on superelevated curves to keep melting snow from producing an ice slick on the pavement, from infiltrating the subgrade and reducing its bearing power
North Carolina	A. L. Hooper, District Engineer	Aug. 10, 1949	North Carolina main highways were built some 25 years ago. Shoulder widths at that time did not appear to be important. As a compromise we constructed where convenient widened shoulders for temporary parking. These have proved to be very popular
North Dakota	H. E. Fowler, District Engineer	Aug. 10, 1949	No information available
Ohio	August Shofer, District Engineer	Aug. 2, 1949	No information available
Oklahoma	Maurice Cline, Chief, Dept. of Statistics	Aug. 2, 1949	Under study
Oklahoma	E. E. Stubblefield, District Engineer	Sept. 19, 1949	Attaches copy of Oklahoma Design Standards
Oregon	T. M. Davis, District Engineer	Aug. 29, 1949	Submitted with Mr. Davis' letter are pictures of various widths and types of shoulders also
Rhode Island	H. J. McKinney, District Engineer	Aug. 23, 1949	No information available
Tennessee	T. C. McEwen, Engineer Director	Aug. 12, 1949	If the traffic is of a very high volume no shoulders should be built. The full road bed should be paved with a curb and extra emergency lanes constructed for distressed vehicles
Tennessee	E. V. Stevenson, District Engineer	Aug. 10, 1949	No information available
Texas	J. M. Page, District Engineer	Aug. 18, 1949	This office has made no special study of the subject
Texas	G. G. Edwards, Manager, Texas Highway Planning Survey	Aug. 23, 1949	No information available
Utah	Howard R. Williams, Planning Engineer	Aug. 8, 1949	No information available
Utah	F. W. Smith, District Engineer	Sept. 19, 1949	In Utah a tendency toward bituminous shoulders
Vermont	H. F. Farrington, State Manager	Aug. 3, 1949	No information available
Vermont	A. M. Snow, District Engineer	Aug. 10, 1949	No information available
Virginia	K. G. McWane, Traffic and Planning Engineer	Aug. 18, 1949	No information available
Washington	W. A. Bugge, Director of Highways	July 29, 1949	Under study. A very small sample at present, but will begin a repeat survey in August
Washington	Fred J. Dixon, District Engineer	Sept. 9, 1949	No information available. Refers to report of State Maintenance Engineer
West Virginia	C. A. Rothrock, Planning Engineer		Chairman of committee conducting the studies
Wisconsin	W. D. Ryan, Director of Highway Commission	Aug. 22, 1949	Under study. A complete tabulation on roadbed and surfacing and shoulders in this letter
Wyoming	G. T. Bath, Planning Engineer	Aug. 15, 1949	No information available
Wyoming	John D. Slys, District Engineer	Aug. 26, 1949	Under study. The Wyoming State Highway is now building a 24 ft. bituminous surface with 10 ft. gravel shoulders