Vehicle Speed and Placement Survey

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The paper reports data obtained from three separate surveys, as follows:

1. Speed and placement by vehicle type, maneuver, and light condition on two-lane rural highways at twelve observations sites. The sites included lane widths from a minimum of 11 to a maximum of 19 ft. Shoulder conditions included asphalt sealed, gravel, and grass. The purpose of the study was to obtain data to support a possible change in recommended lane width.

2. Relative placements by vehicle type, maneuver, and light condition on six different width roadways of rural bridges from a minimum of 24 to a maximum of 44 ft were obtained. These data, plus vehicle speeds, were obtained on the approach roadway to each of these six structures. All approach pavements were 24 ft wide with sealed shoulders with fair to good color contrast. The purpose of this study was to obtain data to support a possible change in recommended width of restricted roadway bridges.

3. Relative effect on traffic operation of a parked vehicle on a 6-ft wide shoulder on a one-way 2-lane urban grade separation structure. This study was very limited in scope, but was made in an effort to gain a partial answer as to the effectiveness of this narrow shoulder. Speed and placement by vehicle type, maneuver, and light condition were obtained on each of two consecutive days. The first day was without a vehicle parked on the shoulder, the second day with a passenger vehicle parked on the shoulder. Although the presence of the parked vehicle had a marked effect on the traffic flow, the two lanes of traffic could move over the structure at reasonable speeds.

Copies of the complete published reports may be obtained from the authors or on loan from the library of the Highway Research Board.

Part 1: Two-Lane Rural Highways

●THIS STUDY was conducted primarily to obtain facts about vehicle behavior under various conditions on 2-lane roads as a guide to formulating future design standards. In general the study was limited to traffic volumes that can reasonably be accommodated on 2 lanes. The results and findings should, therefore, be applicable only to those roads which are not overloaded.

The principal variables which can be studied on a 2-lane road are somewhat limited, being primarily lane width, shoulder width and shoulder type. Obtaining data in sufficient quantities to hold all but one feature constant while that one was studied was found to be somewhat difficult but a fair sample was possible in each case.

By studying the speed and lateral placement of vehicles, it was hoped to obtain basic data which could be applied in the design of future roads and to the maintenance and redesign of existing roads.

Correlation of some of these data with the results of the Western Association of State Highway Officials, Idaho Road Test makes possible certain structural design criteria while correlation with known accident data allows the development of safety standards. The application of placement in the development of safety standards is in lieu of adequate accident records, but since these are not now available, and since it is possible to associate placement data with the available accident records, it is felt that a reasonable standard can be achieved.

METHODS

The equipment used in obtaining the field data consisted of combination speed-meters and transverse placement detectors. (1) This equipment was furnished and operated by the U.S. Bureau of Public Roads (Fig. 1).

The speed-meters were operated by use of pneumatic detectors that actuated a timing device which in turn recorded the speed of the vehicle on a moving paper tape. The speed was recorded by groups and for this survey there were twenty-five groups with the upper and lower limits being open classifications.

An electro-mechanical tape which actuated a recording device was used to record the transverse placement. This tape was separated so that most vehicles actuated only two pins on the recorder thus giving an accurate location of the vehicle.

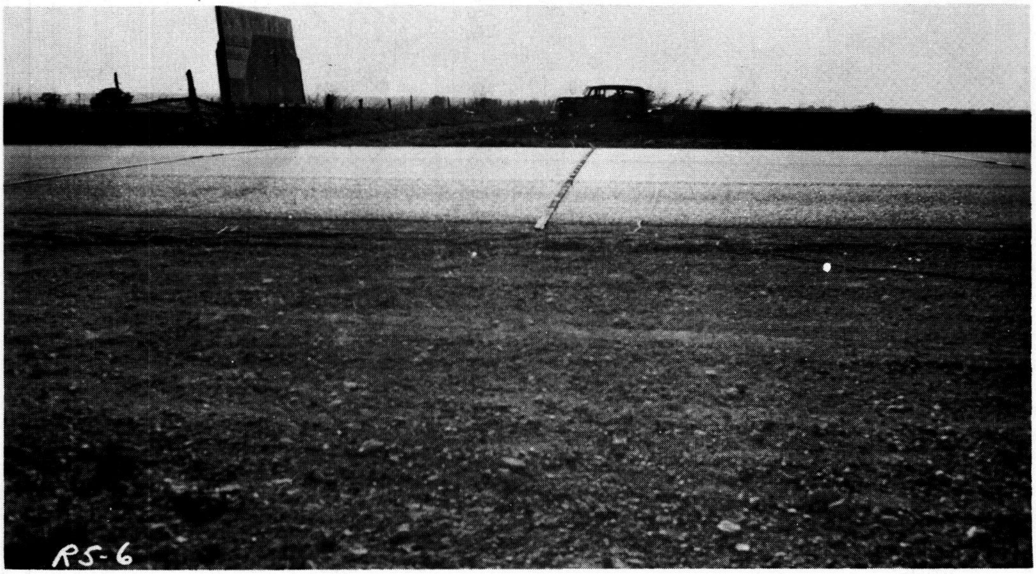


Figure 1. View of lateral placement and speed tapes with recording truck in the background.

The moving paper tapes used for recording were timed so that they moved past the pins at a constant rate. This made possible the classification of maneuvers by time spacing and also the matching of speed and placement for each vehicle. Manual notes were made on the paper tape for vehicles other than passenger cars and for the passing maneuver.

The truck containing the recording equipment was located well away from the road site and was hidden from view to as great an extent as was possible to avoid influencing driver behavior. The data were hand coded and transferred to punched cards for machine tabulation.

LOCATION AND DESCRIPTION OF SITES

The study was conducted primarily in the Austin area. Some data from a study which dealt primarily with bridges were also included (Sites 50-A and 52-A). The locations of the study sites are shown in Figures 2 and 3. The locations were selected on the basis of providing data which would be uninfluenced by any but the factors under study. The sites were located on long tangents and at spots where no outside influence which might affect traffic behavior would be present. The ideal was not always achieved but in the majority of cases, the external influence was slight. Table 1 gives pertinent data for each site. Traffic volumes, except for Site 2, are within the normal range for 2-lane roads. The number of examples for each condition was smaller than desirable

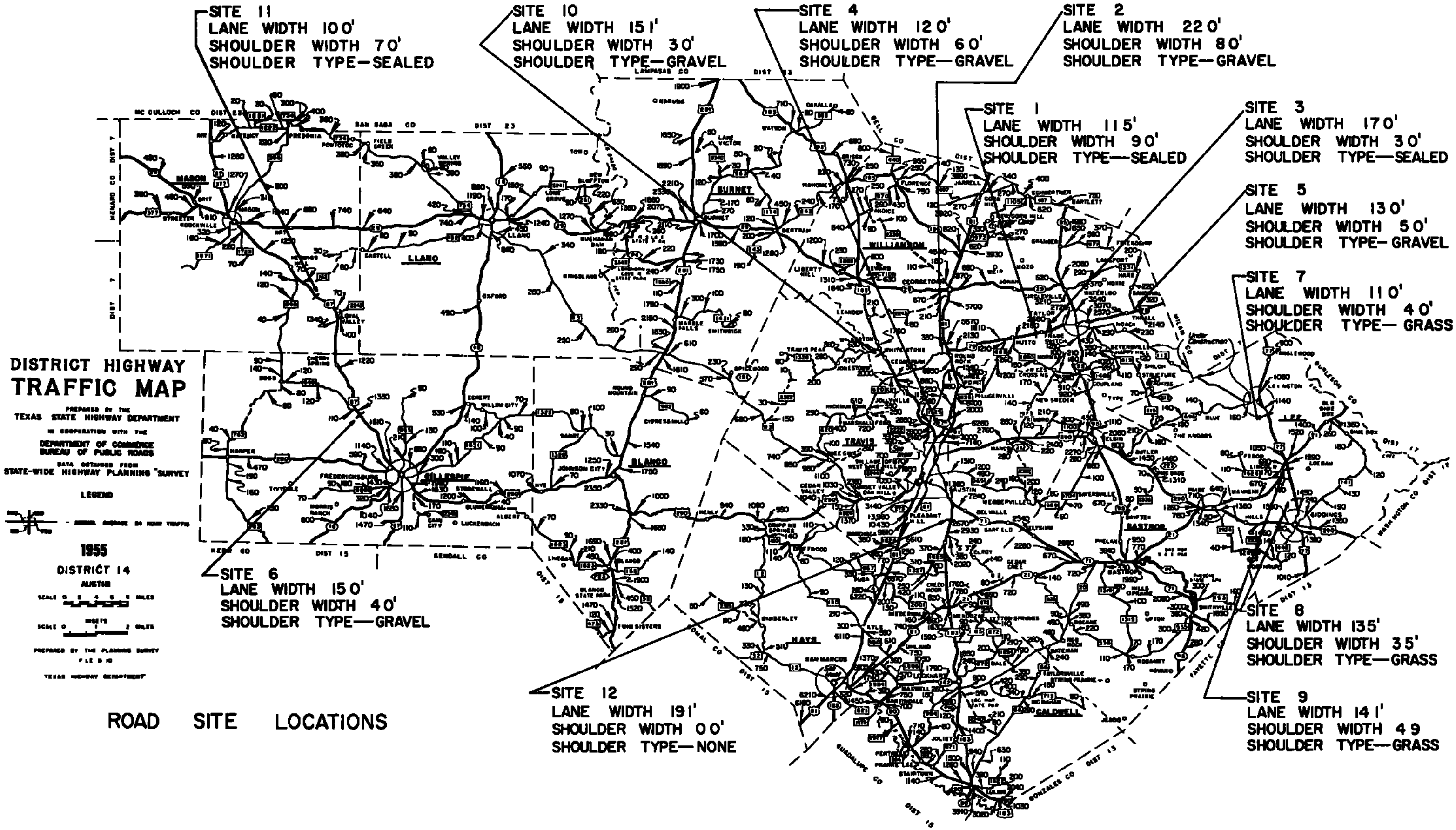

SITE 11
LANE WIDTH 10.0'
SHOULDER WIDTH 7.0'
SHOULDER TYPE—SEALED
SITE 10
LANE WIDTH 15.1'
SHOULDER WIDTH 3.0'
SHOULDER TYPE—GRAVEL
SITE 4
LANE WIDTH 12.0'
SHOULDER WIDTH 6.0'
SHOULDER TYPE—GRAVEL
SITE 2
LANE WIDTH 22.0'
SHOULDER WIDTH 8.0'
SHOULDER TYPE—GRAVEL
SITE 1
LANE WIDTH 11.5'
SHOULDER WIDTH 9.0'
SHOULDER TYPE—SEALED
SITE 3
LANE WIDTH 17.0'
SHOULDER WIDTH 3.0'
SHOULDER TYPE—SEALED
SITE 5
LANE WIDTH 13.0'
SHOULDER WIDTH 5.0'
SHOULDER TYPE—GRAVEL
SITE 7
LANE WIDTH 11.0'
SHOULDER WIDTH 4.0'
SHOULDER TYPE—GRASS
SITE 6
LANE WIDTH 15.0'
SHOULDER WIDTH 4.0'
SHOULDER TYPE—GRAVEL
SITE 12
LANE WIDTH 19.1'
SHOULDER WIDTH 0.0'
SHOULDER TYPE—NONE
SITE 8
LANE WIDTH 13.5'
SHOULDER WIDTH 3.5'
SHOULDER TYPE—GRASS
SITE 9
LANE WIDTH 14.1'
SHOULDER WIDTH 4.9
SHOULDER TYPE—GRASS
DISTRICT HIGHWAY
TRAFFIC MAP
PREPARED BY THE
TEXAS STATE HIGHWAY DEPARTMENT
IN COOPERATION WITH THE
DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
DATA OBTAINED FROM
STATE-WIDE HIGHWAY PLANNING SURVEY
LEGEND
1955
DISTRICT 14
AUSTIN
ROAD SITE LOCATIONS
MASON
LLANO
BURNET
WILLIAMSON
TRAVIS
BLANCO
GILLESPIE
HAYS
BASTROP
CALDWELL
LEE

Figure 2.

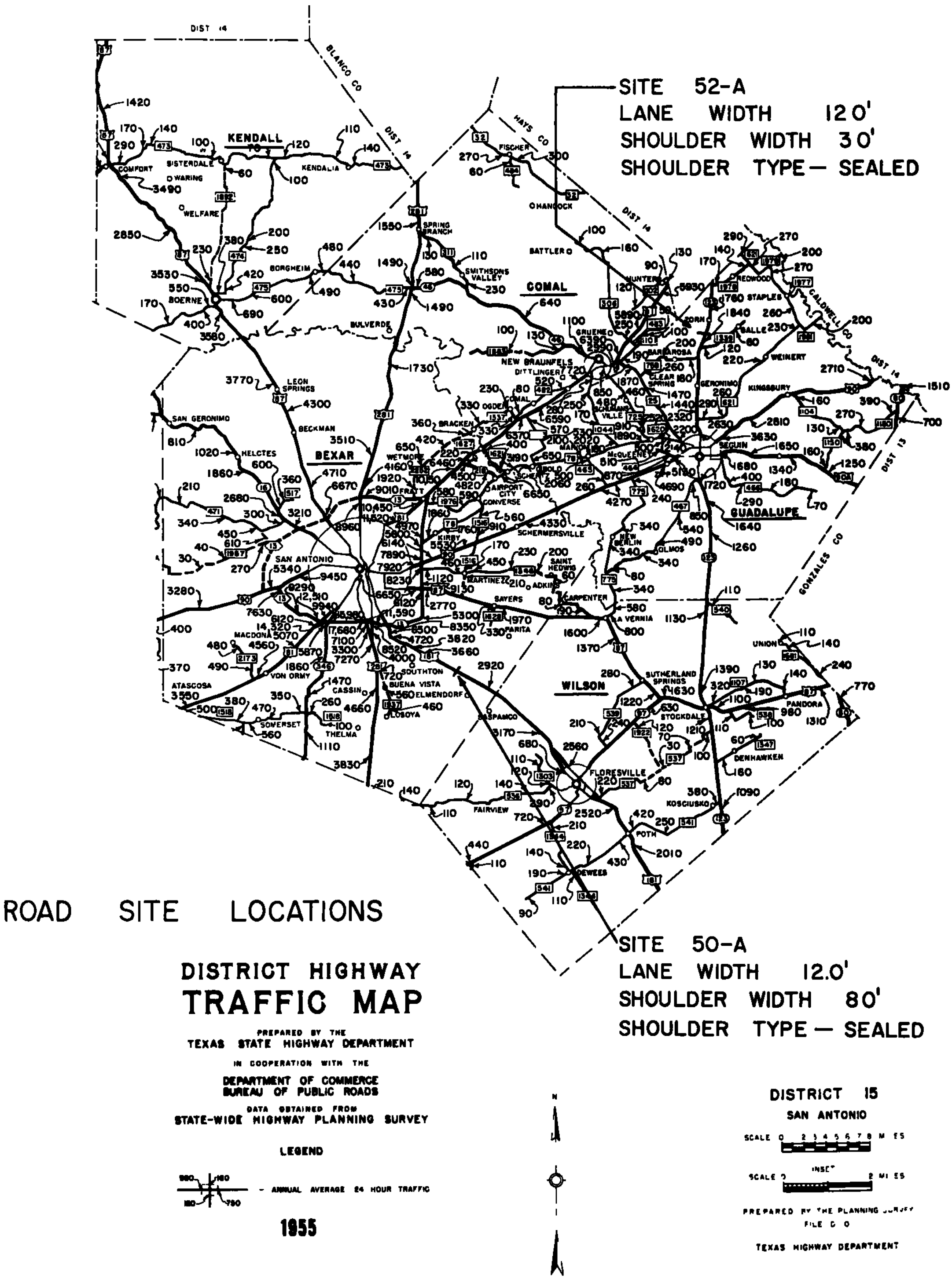

SITE 52-A
LANE WIDTH 12.0'
SHOULDER WIDTH 3.0'
SHOULDER TYPE — SEALED
KENDALL
COMAL
BEXAR
GUADALUPE
WILSON
SAN ANTONIO
NEW BRAUNFELS
SEGUIN
FLORESVILLE
BOERNE
COMFORT
SITE 50-A
LANE WIDTH 12.0'
SHOULDER WIDTH 8.0'
SHOULDER TYPE — SEALED
ROAD SITE LOCATIONS
DISTRICT HIGHWAY
TRAFFIC MAP
PREPARED BY THE
TEXAS STATE HIGHWAY DEPARTMENT
IN COOPERATION WITH THE
DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
DATA OBTAINED FROM
STATE-WIDE HIGHWAY PLANNING SURVEY
LEGEND
ANNUAL AVERAGE 24 HOUR TRAFFIC
1955
DISTRICT 15
SAN ANTONIO
TEXAS HIGHWAY DEPARTMENT

Figure 3.

TABLE 1

CHARACTERISTICS OF ROADWAY AND TRAFFIC AT OBSERVATION STATIONS 1-12, 50-A AND 52-A

Observation Station No	1	2	3	4	5	6	7	8	9	10	11	12	50-A	52-A
Lane Width (ft)	11 5	22 0	17 0	12 0	13 0	15 0	11 0	13 5	14 1	15 1	10 0	19 1	12 0	12 0
Shoulder Width (ft)	9 0	8 0	3 0	6 0	5 0	4 0	4 0	3 5	4 9	3 0	7 0	0 0	8 0	3 0
Type of Shoulder	Sealed	Gravel	Sealed	Gravel	Gravel	Gravel	Grass	Grass	Grass	Gravel	Sealed	-	Sealed	Sealed
Color-Shoulder and Traffic Lane	Contrasting	Contrasting	Same	Contrasting	Contrasting	Contrasting	Contrasting	Contrasting	Contrasting	Contrasting	Same	-	Contrasting	Contrasting
Total Vehicles Counted	2,270	4,298	2,630	2,593	2,006	667	957	1,329	1,076	2,219	621	2,421	2,031	1,148
Percent Passenger Cars	88 7	77 0	89 1	89 8	83 1	68 1	82 0	80 7	78 3	85 6	76 8	85 1	82 2	78 3
Percent Trucks	8 4	20 1	8 4	8 8	14 3	24 4	15 8	14 8	18 4	11 2	19 5	12 3	15 7	17 4
Percent Buses	0 5	0 8	0 7	0 6	0 8	2 4	0 6	1 2	1 2	0 8	1 1	0 6	0 7	2 2
Percent Others	2 4	2 1	1 8	0 8	1 8	5 1	1 6	3 3	2 1	2 4	2 6	2 0	1 4	2 1
Night Vehicles Counted	455	1,141	585	426	340	119	119	178	181	402	117	475	224	195
Percent Passinger Cars	87 7	64 7	88 5	95 8	85 3	65 5	81 5	80 9	70 2	88 8	64 1	85 9	78 6	76 9
Percent Trucks	10 5	32 9	9 4	3 5	12 3	29 4	18 5	16 3	26 0	9 2	30 8	13 1	19 6	20 0
Percent Buses	0 9	1 0	1 4	0 7	1 8	1 7	0 0	0 6	1 1	0 8	1 7	0 4	0 9	1 0
Percent Others	0 9	1 4	0 7	0 0	0 6	3 4	0 0	2 2	2 7	1 2	3 4	0 6	0 9	2 1
1955 Average Daily Traffic	2,320	5,670	2,720	2,680	2,140	1,330	1,140	1,450	1,290	2,000	1,295	2,930	3,290	1,800
County	Williamson	Williamson	Williamson	Travis	Williamson	Gillispie	Lee	Lee	Lee	Williamson	Mason	Travis	Bexar	Guadalupe
Highway No	U S 79	U S 81	U S 79	U S 81	U S 79	U S 87	U S 77	U S 77	U S 77	U S 183	U S 87	U S 183	U S 181	S H 123
Control and Section	204-2	15-9	204-3	Business 15-11	204-4	71-6	211-3	211-4	211-4	151-5	71-5	152-1	100-2	366-2
Location	5 3 mi W of S H 95	1 1 mi N of U S 79	3 2 mi W of S H 95	2 2 mi N of U S 183	1 0 mi E of F M 1331	1 6 mi S of F M 648	6 2 mi N of S H 21	3 0 mi N of U S 290	1 1 mi N of F M 1624	0 7 mi S of F M 1328	8 6 mi N of Gillespie C L	1 7 mi S of S H 71	0 5 mi N W of Wilson C L	1 8 mi S of Hays C L

but the correlation of the data worked out well for the major factors studied. Complete data for each site condition have been published by the Road Design Division, Texas Highway Department (2).

STUDIES MADE

Speed

Speed studies were made at each of the sites and the data were plotted as a cumulative speed curve, showing the 85 percentile speed for passenger cars and trucks. All speeds fell within the normal range for the conditions studied. The 85 percentile speed for passenger cars ranged from 59 to 69 mph and from 45 to 59 mph for trucks. There does not appear to be a significant correlation between speed and the factors studied.

Lateral Placement

Bar charts showing vehicle placements for free-moving and meeting passenger cars and trucks were prepared for both day and night conditions. These charts showed the average placement for each condition and the percent of vehicles encroaching on the shoulder and across the centerline of the road and provided most of the basic data which were used in developing the average placement relationships and from which the conclusions were drawn (2).

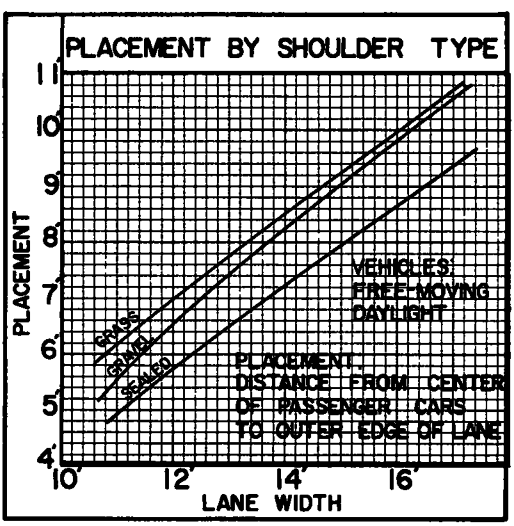


Figure 4.

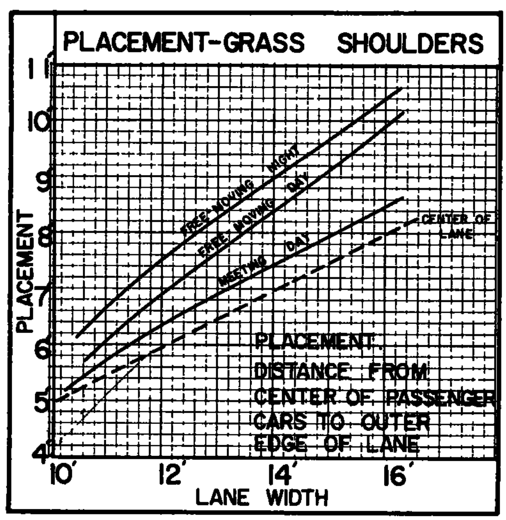


Figure 5.

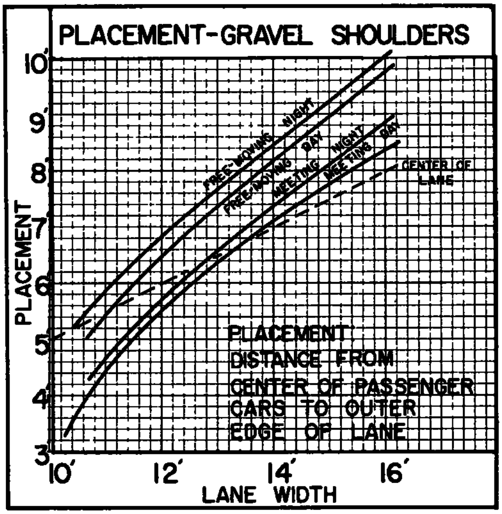


Figure 6.

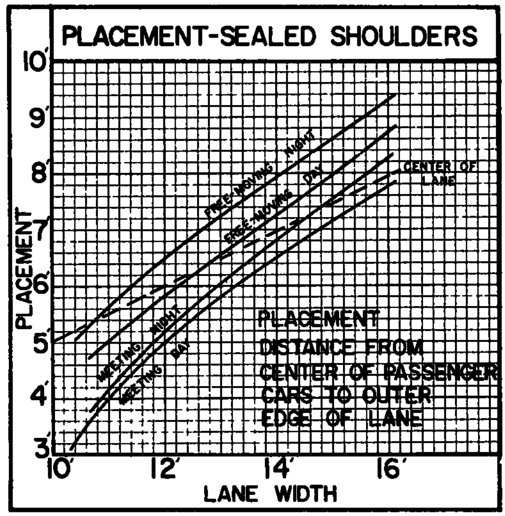


Figure 7.

In plotting the average placement against various width factors such as centerline of road, edge of lane, and edge of shoulder, it was found that the best correlation resulted when the distance from the center of the vehicle to the outer edge of the lane was plotted against lane width. This was somewhat contrary to expectations, and it is concluded that the driver is influenced more in selecting his lateral position by the edge of the lane than he is by the centerline of the road.

Shoulder Width and Type

Several attempts were made to correlate placement to shoulder width without success. Since this study did not include any shoulders less than 3 ft in width, shoulders 3 ft wide or wider do not affect placement. There is undoubtedly some width of shoulders, less than 3 ft, that would have a definite effect on vehicle placement, but it was not within the scope of this study to determine that exact width. The type of shoulder has a very definite effect on the lateral placement of vehicles. This is illustrated in Figure 4 which is a series of curves averaged from the data. The relationship between vehicle placements for free-moving-daylight conditions, which

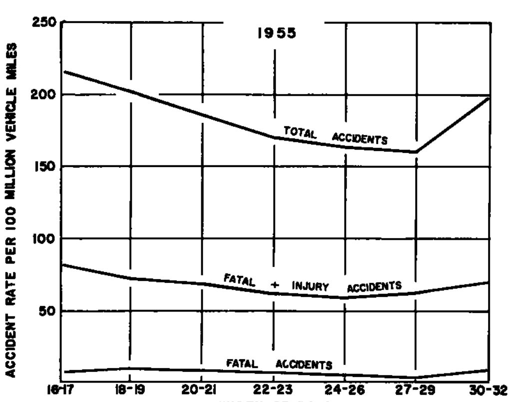


Figure 8. Rural accident rates by width of two-lane roads.

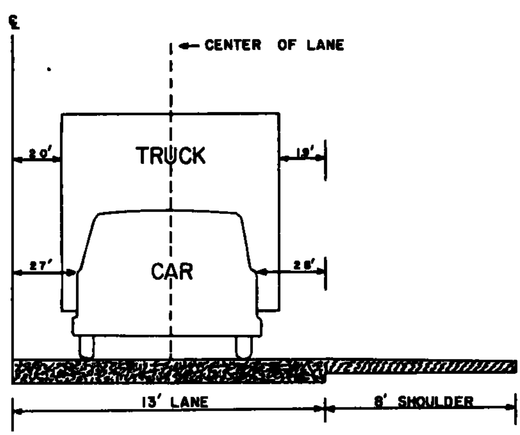


Figure 9. Typical placement range for a 13-ft lane with an 8-ft sealed shoulder for passenger cars and trucks.

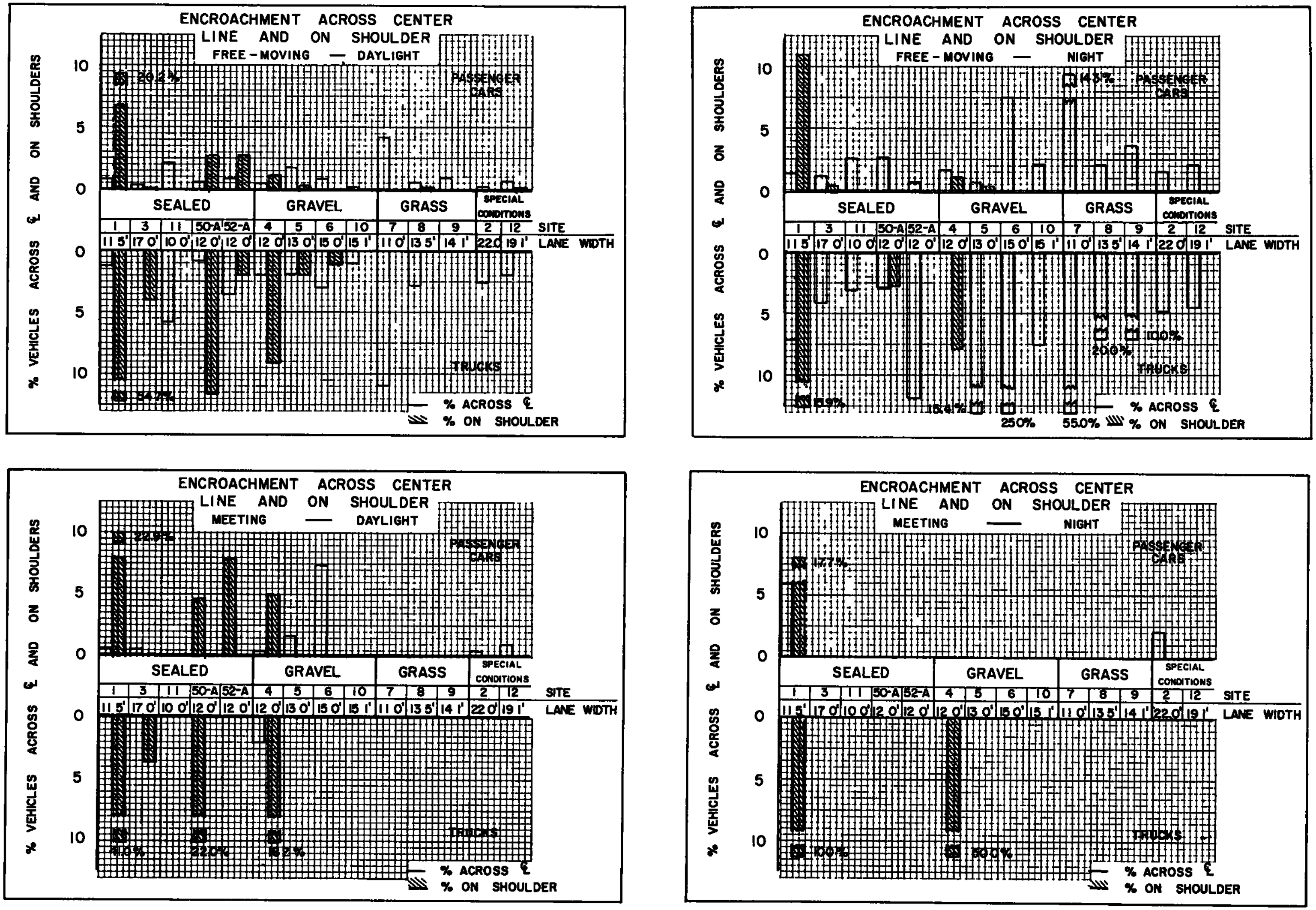

ENCROACHMENT ACROSS CENTER LINE AND ON SHOULDER
FREE - MOVING — DAYLIGHT
FREE - MOVING — NIGHT
MEETING — DAYLIGHT
MEETING — NIGHT
% VEHICLES ACROSS ℄ AND ON SHOULDERS
PASSENGER CARS
TRUCKS
SEALED
GRAVEL
GRASS
SPECIAL CONDITIONS
SITE
LANE WIDTH
% ACROSS ℄
% ON SHOULDER

Figure 10.

are the most representative, for the various types of shoulder, is shown. As the type of shoulder is improved, traffic drives closer to it. Gravel shoulders encourage traffic to travel closer to the edge than do grass, and surfaced shoulders have an even greater effect. All placements for grass shoulders lie closer to the centerline of the road than to the edge. A vehicle is centered in an 11-ft lane with gravel shoulders and is centered in a 13-ft lane with a surfaced shoulder.

Lane Width

The relationship between lane width and vehicle placement is shown in Figures 5, 6, and 7. These are average curves taken from the original plottings (2). The figures

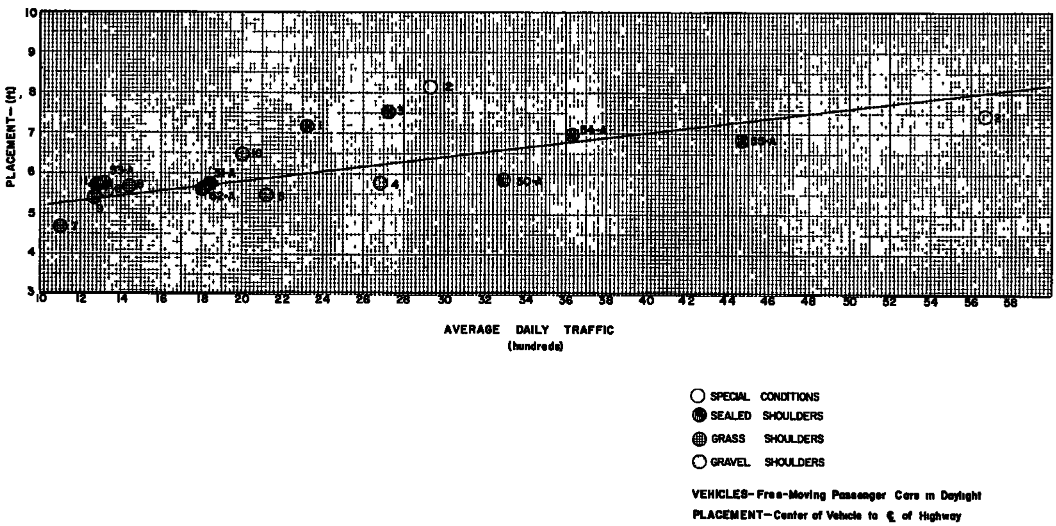


Figure 11.

show, by the shape of the data lines, that as the pavement is widened the vehicles move out, but for each foot added to the lane, vehicles move an average of 3 in. from the centerline and 9 in. from the edge of the pavement or in a ratio of about 1 to 3. All indications are that no matter how much the pavement is widened, the vehicles would continue to move out, staying somewhere near the center of the lane. This can undoubtedly be carried too far both economically and from a safety standpoint. Figure 8 shows the accident rates[1] for 2-lane pavements of various widths. The rates indicate a definite decrease up to a 23-ft pavement. Between 23 and 29 ft, they are somewhat erratic and start back up for pavement wider than 29 ft. This would indicate that the safest lane width is somewhere between 11.5 and 14.5 ft. None of these factors is conclusive in itself, but together they make a rather strong case for a 13-ft lane with 8-ft surfaced shoulders. Figure 9 shows the typical placement range for this type pavement. Adequate clearance between meeting vehicles is provided for both passenger cars and trucks;

[1]Rates were compiled by the Traffic Engineering Section of the Division of Maintenance Operations and included all 2-lane roads in Texas for 1955.

the lane width falls in that range found to have the lowest accident rate and the vehicles tend to center themselves in the lane, thereby making full use of the available facility.

If surfaced shoulders are to function as a shoulder and are not to be considered by the motorist as a part of a very wide lane, a good contrast of color and width should be maintained between the shoulder and the lane. The surfaced shoulder should also have sufficient slope to render it uncomfortable to use as a driving lane but still safe for emergency use. It is believed that a slope of ¾ in. per ft would accomplish this result.

Encroachment Across Centerline and on Shoulder

Considerable encroachment on both the shoulder and across the centerline was found. The percentage at the various sites is shown in Figure 10. Several attempts were made to correlate this data, but no consistent relationship was found. Several things are evident from the figures. Encroachment by meeting vehicles on both the shoulder and across the centerline is less than that for free-moving vehicles and is less at night than in the daylight. This could probably be taken to indicate that drivers are more alert when meeting and are consciously placing their vehicle in the lane. Figures 5, 6, and 7 show that meeting vehicles drive on an average 1 ft closer to the edge than do non-meeting vehicles.

The percentage of encroachment on the shoulder was considerably higher where shoulders were surfaced. This is to be expected, especially since some of the surfaced shoulders studied did not contrast greatly with the pavement on the travel lane, and drivers could see little reason for not driving on them when it suited their purpose. Figure 11 shows the average placement for free-moving passenger cars for each of the sites studied plotted against traffic volume. It indicates a definite trend to a placement nearer the edge of the pavement as volume increases. This was true regardless of lane width, shoulder width, and shoulder type.

Encroachment can undoubtedly be reduced by making the shoulder less attractive to drive on by providing distinct contrast in both color and texture; however, from Figure 11, it seems probable that an overloaded condition on the road will result in encroachment regardless of the contrast and that 4-lane operation will nearly always result where the shoulder is surfaced and traffic volumes are great enough that they cannot be efficiently accommodated on a 2-lane road.

Trucks

A considerable number of trucks were included in the study (Table 1). These data were somewhat more erratic than for passenger cars, but the general trend was very similar to that for passenger cars. Trucks appeared to drive a little closer to the edge of the pavement, especially on extra wide pavements, probably because they try to stay out of the way of faster moving vehicles.

SUMMARY

1. Speed was apparently not a factor in the elements studied.
2. Drivers are apparently influenced in their lateral placement more by the edge of the pavement than they are by the centerline of the road.
3. Should width of 3 ft or more did not appear to affect the lateral placement of vehicles.
4. The type of shoulder had a definite effect on the lateral placement of vehicles. The higher the quality of construction, the closer to the shoulder traffic will drive.
5. Lateral placement appears to be a function of lane width. As lane width increases traffic moves farther from the centerline but in a ratio of about 3 to 1. For every foot of widening, the average placement moved 3 in. from the centerline and 9 in. from the edge of the lane.
6. Vehicle encroachment across the centerline and on the shoulder is a definite problem. Encroachment on surfaced shoulders can be reduced considerably by providing good contrast between the pavement and the shoulder, but even this will not prevent encroachment if the road is overloaded.

7. Trucks behaved about the same as passenger cars. Their over-all average placement was a little closer to the edge of the pavement but with their greater width there was slightly less clearance to the centerline.

8. Encroachment on surfaced shoulders by trucks was very evident. This is probably brought about by a desire on the part of truckers to not obstruct traffic. They seem to drive on the shoulder so that faster passenger cars can get by them. This might be combatted by an informational campaign and by designing the shoulder so it does not appear to be a traffic lane.

9. There was not enough data on passing maneuvers to arrive at any definite conclusions in this study. Speed curves are therefore not included in this report.

Part 2: Two-Lane Rural Bridges

The general objective of this study was to determine the effect of the width of 2-lane roadway bridges on the lateral placement of vehicles as compared with the lateral placement on a 2-lane road. The lateral placement near the end and near the middle of a long bridge was also measured to determine whether or not the vehicles moved laterally while driving across a long bridge.

It was hoped through this study of traffic behavior to find some indication as to what the proper width for 2-lane roadway bridges should be.

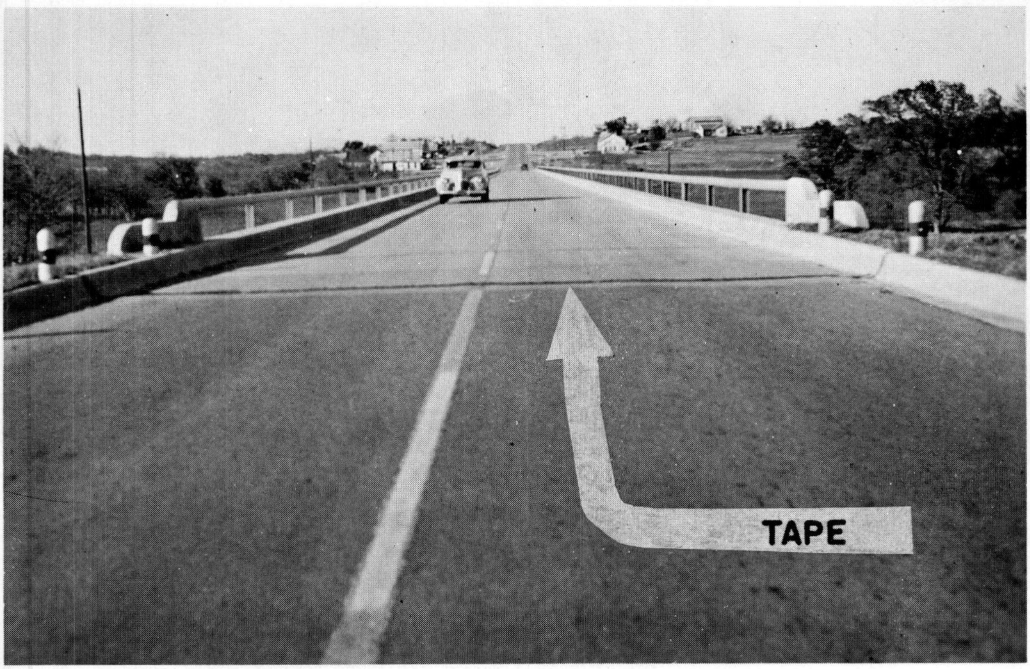


Figure 12. View of bridge showing tape for measuring lateral placement.

METHOD OF STUDY

The method of study was the same as that described previously, but with some additions.

Vehicles were classified into 10 types but samples in some types were small and operating characteristics were similar. For analysis only two classifications were

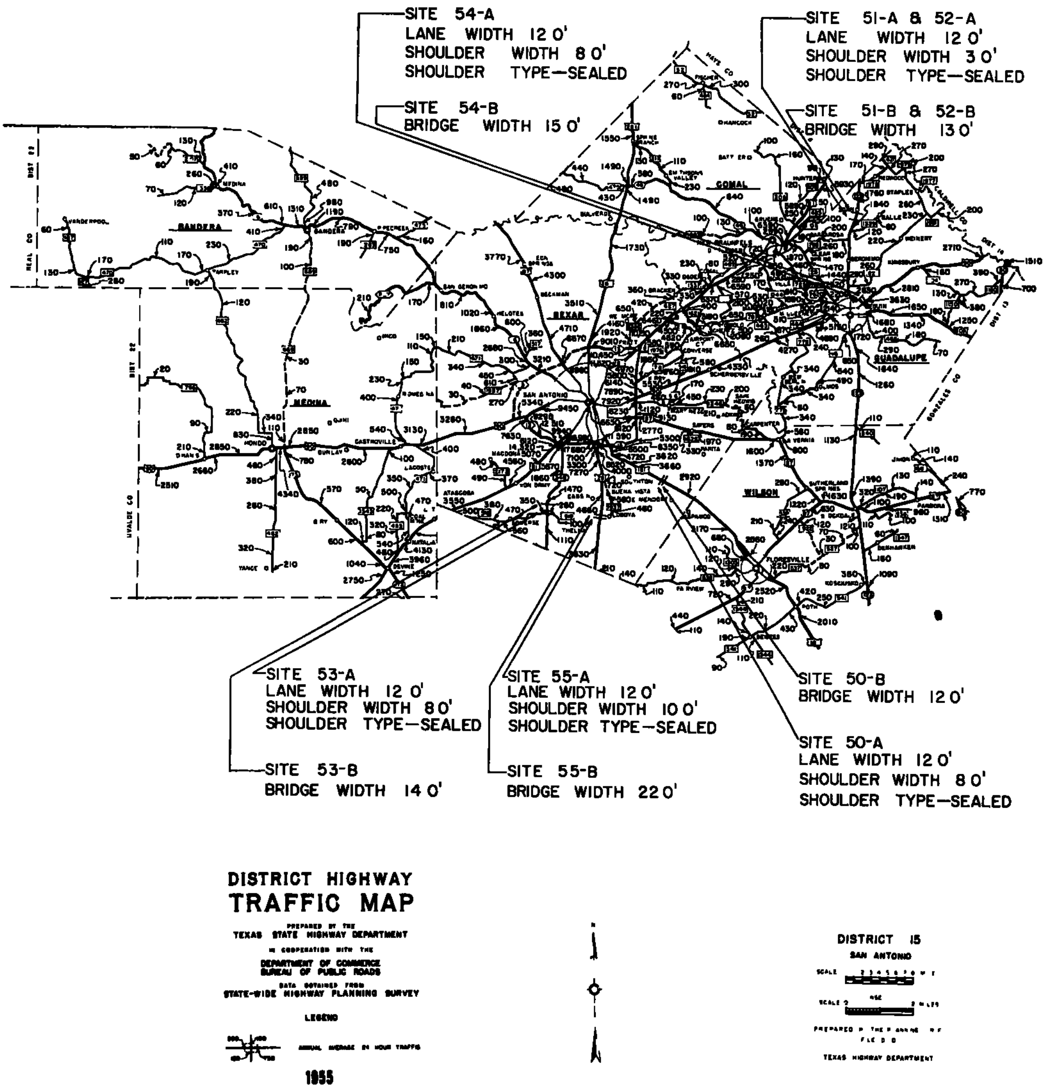


Figure 13. Road and bridge site locations.

used. One included passenger cars and pick-ups, and the other included buses and all trucks.

In addition to the meeting and free-moving maneuvers, the data were recorded for passing and trailing and all combinations thereof, but samples in these categories were small for analysis.

The following classifications of vehicle maneuvers were made:

Free-moving	- Over 7.2 sec to nearest vehicle both directions.
Trailing	- Less than 3.6 sec to next vehicle ahead traveling same direction, and over 7.2 sec to next vehicle ahead traveling opposite direction.
Meeting	- Less than 3.6 sec to next vehicle ahead traveling opposite direction
Passing	- 1.8 sec or less behind or ahead of car being passed.
Being Passed	- 1.8 sec or less behind or ahead of car passing.
All others.	

TABLE 2

CHARACTERISTICS OF ROADWAY AND BRIDGES AT SITES 50-A THROUGH 55-B

Site No	50-A	50-B Bridge	51-A	51-B Bridge	52-A	52-B Bridge	53-A	53-B Bridge	54-A	54-B Bridge	55-A	55-B Bridge
Bridge Width (ft)		12 0		13 0		13 0		14 0		15 0		22 0
Bridge Length (ft)		360 0		960 0		960 0		201 5		200 0		156 0
Lane Width (ft)	12 0		12 0		12 0		12 0		12 0		12 0	
Shoulder Width (ft)	8 0		3 0		3 0		8 0		8 0		10 0	
Shoulder Contrast (All Sealed)	Good		Fair		Fair		Good		Fair		Good	
Total Vehicles Counted	2,031	1,774	1,071	1,103	1,148	1,144	1,067	1,318	3,556	2,873	2,630	2,161
Percent Passenger Cars	82 2	83 7	79 3	79 2	78 3	79 1	80 6	83 4	84 1	85 7	77 1	80 3
Percent Trucks	15 7	14 7	16 1	16 5	17 4	16 7	18 6	15 7	14 2	12 5	20 8	18 2
Percent Buses	0 7	0 6	1 3	1 4	2 2	2 2	0 5	0 4	0 4	0 4	0 8	0 6
Percent Others	1 4	1 0	3 3	2 9	2 1	2 0	0 3	0 5	1 3	1 4	1 3	0 9
Night Vehicles Counted	224	222	153	170	195	201	140	194	776	601	414	430
Percent Passenger Cars	78 6	78 8	69 9	71 8	76 9	77 1	90 7	93 8	88 7	85 7	67 6	70 2
Percent Trucks	19 6	19 8	24 8	23 5	20 0	19 9	8 6	6 2	10 6	13 5	30 7	28 6
Percent Buses	0 9	0 5	2 0	2 4	1 0	1 0	0 0	0 0	0 2	0 3	0 7	0 5
Percent Others	0 9	0 9	3 3	2 3	2 1	2 0	0 7	0 0	0 5	0 5	1 0	0 7
1955 Average Daily Traffic	3,290	3,290	1,840	1,840	1,840	1,840	1,350	1,350	3,630	3,630	4,500	4,500
County	Bexar	Bexar	Guadalupe	Guadalupe	Guadalupe	Guadalupe	Bexar	Bexar	Guadalupe	Guadalupe	Bexar	Bexar
Highway No	US 181	US 181	SH 123	SH 123	SH 123	SH 123	SH 346	SH 346	US 90	US 90	US 281	US 281
Control and Section	100-2	100-2	366-2	366-2	366-2	366-2	613-1	613-1	29-2	29-2	73-2	73-2
Location	Approx 850' NW of Bridge 50-B	4 mi NW of Wilson C L	1 4 mi S of Bridge 51-B	4 0 mi S of Hays C L	1 4 mi S of Bridge 52-B	4 0 mi S of Hays C L	Approx 1 mi S of Bridge 53-B	4 8 mi N of Atascosa C L	8 mi W of Bridge 54-B	2 0 mi E of S H 123	3 mi S of Bridge 55-B	7 8 mi S of Loop 13

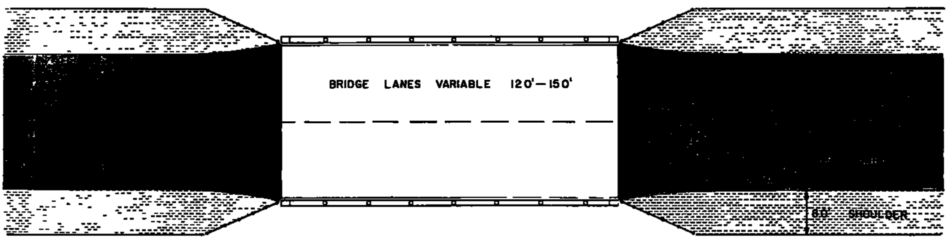


Figure 14. Typical bridge showing fixed and variable conditions.

DESCRIPTION OF SITES

The study was conducted on bridges in Highway Department District 15 with headquarters at San Antonio. The locations of the study sites are shown in Figure 13 and a tabulation of data for each of the sites is shown in Table 2. In each case, the location on the bridge is designated with a B, and the road site near the bridge is designated with an A. Complete data for each site have been published previously (7).

As far as possible, all of the bridges studied were similar in appearance as far as the driver was concerned. Rail and curb designs were substantially the same. The bridges varied in length from 156 ft to 360 ft plus the 960 ft bridge.

To make the bridge placement measurements valid, it was felt that the design of the roadway on either side of the bridges should be held constant (Fig. 14). The roadway in each case consisted of two 12-ft lanes with surfaced shoulders. At three of the six sites studied, the road shoulders were 8 ft wide, at sites 51 and 52 the shoulders were 3 ft wide, and at site 55 they were 10 ft wide. It was determined previously that shoulders 3 ft wide and wider did not affect the lateral placement of vehicles; therefore, it was felt that the inclusion of these sites was valid. Sites 51 and 55 were, however, eliminated from the final analysis for other reasons. The roadway locations at sites 51 and 52, because they were actually at the same place, could not be considered as two locations in a statistical analysis. These were made in conjunction with the bridge sites near the middle and near the end of this 960-ft bridge. Site 51 was therefore omitted.

Site 55 was located on a highway carrying 4,500 vehicles per day, which would require a 4-lane facility by highway department standards and it was felt that vehicle placement measurements under these conditions would not be comparable to those at the other sites, particularly since there is a farily definite relationship between volume and lateral placement. Rain during a part of the study at this site probably also had some influence on the data. Another factor at site 55 making the data here somewhat doubtful was the fact that the pavement was flared to the width of the bridge for about 200 ft on either side of the bridge.

Four sites were included in the actual analysis, each having comparable characteristics. Bridge lane widths measured from the centerline of the bridge to the edge of the traveled surface were 12 ft, 13 ft, 14 ft, and 15 ft. The analysis is then actually based on the following sites:

Site 50 bridge lane width 12 ft;
Site 52 bridge lane width 13 ft;
Site 53 bridge lane width 14 ft;
Site 54 bridge lane width 15 ft.

Sites 51 and 52 which were on the same bridge were to determine whether or not a consistent placement existed over the length of a long bridge. This bridge was 960 ft long. Site 51 was near the middle of the bridge and Site 52 was near the end. No significant difference in the placement was found.

DISCUSSION AND ANALYSIS

Speed

Speed studies were made at each of the road sites. Speeds were not measured on the bridges. Cumulative speed curves showing the 85 percentile speed at each of the road sites were plotted (7). There does not appear to be a significant correlation between speed and the factors studied.

Lateral Placement

Lateral placement of vehicles was measured at each of the sites, both on the road and on the bridges. The studies on the road were made far enough from the bridges so

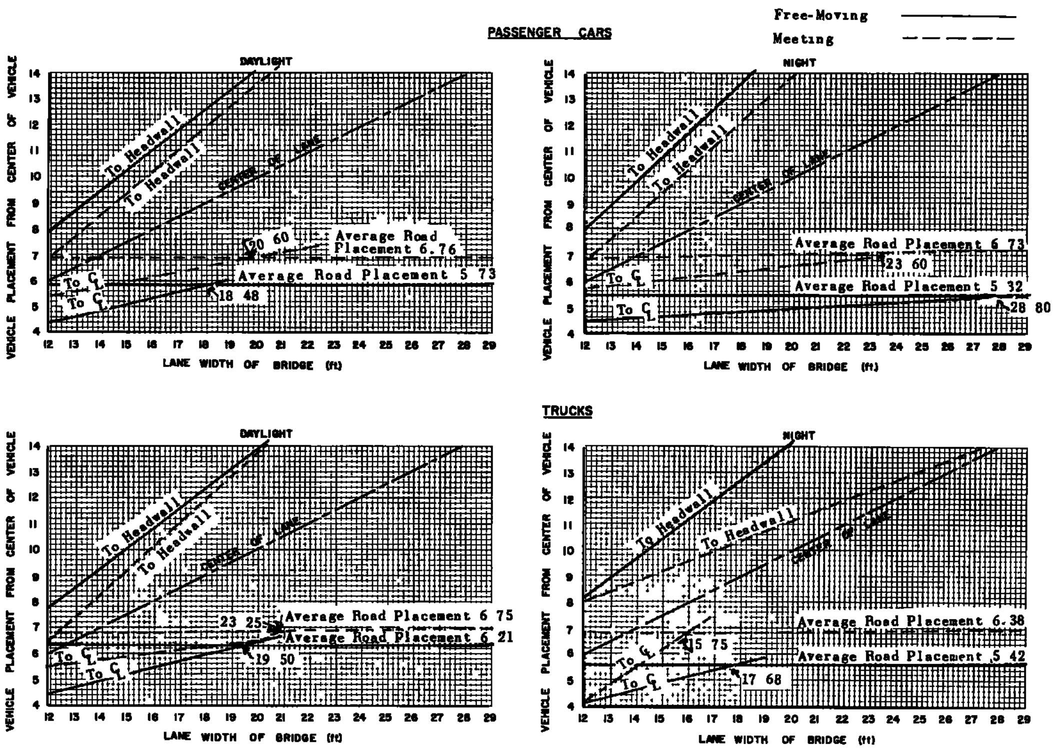


Figure 15. Placement of vehicles on bridges vs. bridge lane width.

that the bridge did not influence placement. The minimum distance from the road site to the bridge was 850 ft.

The basic data from which the conclusions were extracted were a series of bar charts representing the vehicle placements at the sites (7).

In attempting to relate placement data to a basis for the determination of a bridge width several approaches were tried. Walker (8) developed a formula by which he computed a bridge width. It consisted of the sum of the following three items:

TABLE 3

BRIDGE LANE WIDTHS FOR VARIOUS CONDITIONS

	Passenger Cars	Trucks
Free-Moving - Daylight	18.48	19.50
Free-Moving - Night	28.80	17.68
Meeting - Daylight	20.60	23.25
Meeting - Night	23.60	15.75
Average Daylight	20.45	
Average Night	21.46	
Average Meeting	20.40	
Average Total	20.95	

1. "The distance of the left wheel to the right of the centerline for vehicles meeting on the tangent section, which is equivalent to one-half the clearance between the left wheels of vehicles when meeting."
2. "The distance freely moving vehicles preferred to allow between their right wheels and the curb or parapet of the bridge."
3. "The tread width of the average car, or approximately 5 feet."

In attempting to apply this formula, it was found that item 2 was not a consistent figure but varied with the width of bridge. For this reason, this approach did not seem applicable.

It was thought, however, that a bridge width which would encourage a vehicle to maintain the same lateral position on the bridge that it occupied on the road would result in the safest operation — that least likely to result in accidents. This would mean that the driver would be only slightly aware of the presence of a bridge and would not feel that it was necessary to take any action because of the bridge.

In order to establish what this bridge width would be, it was first necessary to establish the average position of vehicles on the road for the various light conditions and maneuvers which could not be kept constant. These averages are represented by the horizontal lines in Figure 15. They were derived by averaging the placement figures for the road sites near the bridges. They do not agree exactly with the results of Part 1, but are within reasonable range. These placement figures were measured to the centerline of the road or bridge.

Vehicle placement figures for the various bridges were also plotted on Figure 15. The plotting of these data with reference to the centerline of the bridge produces a line which when extended intersects the horizontal or average road placement line. This point of intersection then represents the width of bridge lane necessary for the average vehicle to pass over it without altering its lateral placement with respect to the centerline. These intersection points vary for the different conditions. Based on this approach to bridge width determination, Table 3 shows the widths required for the various conditions. However, these widths were derived from data on 12- to 15-ft bridge lanes. It is possible that rather than a straight line, as assumed in Figure 15, the bridge placement data would curve up and intersect the road placement line at some lesser bridge width. Absence of data on bridge lane widths wider than 15 ft places some doubt on how the bridge placement data would behave in this area. Studies on wider bridges would tie the placement down more accurately but in the absence of this information, it was thought that the straight line expansion of the known data was reasonable.

The required widths vary from a low of 15.75 ft for trucks meeting at night to a high of 28.80 ft for free-moving cars at night. The average bridge lane width for all of the conditions was 20.95 ft.

It might be considered proper in a situation of this kind to design for the extreme condition which would mean a bridge lane width of 28.80 ft or a total bridge width of 57.60 ft. However, the 28.80 lane is for free-moving cars at night. Free-moving trucks at night require a width of only 17.68 ft indicating that the passenger car drivers are probably allowing an unnecessarily large clearance to the bridge headwall.

Meeting vehicles probably represent the most realistic condition on which to base a conclusion. It is somewhat surprising that this does not call for the widest bridge. It does seem significant, however, that all of the various averages shown in Table 3 are in the vicinity of 20 ft.

Figure 15 also shows the placement of vehicles to the bridge headwall and how it varies with the width of the bridge. The lines representing the placement distance to the bridge headwall are much steeper than those representing the placement to the centerline, with the ratio between the two being as great as 19 to 1 for free-moving passenger cars at night. The least ratio is 1 to 1 for meeting trucks at night, and the average is approximately 6 to 1.

The use of placement data as a basis for determining bridge widths is at best a substitute for adequate accident data. It can be considered indicative of desirable conditions, however, and in the absence of a sufficiently long and detailed accident survey, it appears to be the most reasonable basis available for studying bridge widths.

CONCLUSIONS

The conclusions are somewhat general and lend themselves to discussion rather than numerical listing. The purpose of the study was to determine the effect of bridge width on traffic behavior. It was established that the bridge width has a definite influence on lateral placement of vehicles. It was not possible to arrive at a definite recommendation for widths of 2-lane highway bridges but the data do indicate that a bridge lane width 2 ft wider than the road lane adjacent to the bridge causes the average driver to deviate considerably from the lateral position he assumes on the roadway.

It appears that the average driver needs a bridge lane width of about 20 ft in order to cross the bridge with little or no deviation in lateral position from that assumed on the approach roadway. Negligible difference was found in the lateral placement measured near the middle of a 960-ft bridge and near the end of the same bridge.

Part 3: Freeway Bridge

The purpose of this study was to determine the effect on traffic behavior of a vehicle stopped on the 6-ft shoulder of a 2-lane one-way freeway overpass. In the course of the study, however, it became evident that the data being collected were adaptable to further analysis dealing with the general operating characteristics of traffic. The speed and lateral placement of vehicles under various traffic volume conditions are indicative of the adequacy of the design with respect to horizontal clearances, lane width, and shoulder width.

The conditions without and with vehicle on 6-ft emergency shoulder are shown in Figures 16 and 17.

CLASSIFICATIONS

The following classifications of vehicle maneuvers were made:

Passing - 1.8 sec or less behind or ahead of car being passed. Passing vehicles are always in the left lane.

Being Passed - 1.8 sec or less behind or ahead of car passing. Being-passed vehicles are always in the right lane.

Non-Passing - Includes all vehicles in either lane not included in the two classifications above.

LOCATION AND DESCRIPTION OF SITE

The study was conducted on the westbound lanes of State Highway 550 Freeway Bridge crossing over Camp Bowie Boulevard in Fort Worth. The over-all site is shown in Figure 18. The location of the study is shown in Figure 19.

The freeway bridge roadway is 24 ft wide with standard guardrail, plus a 6-ft emer-

Figure 16. Site 25 — shoulder clear.

gency shoulder on the right and a 3½-ft shoulder on the left (Fig. 20). The roadway at the point of the study is on a 2 deg curve to the right.

The freeway at this point carries a considerable amount of traffic bound for the Convair Aircraft Plant and Carswell Air Force Base, which causes a high peak interval for a relatively short duration. The average daily traffic at this point for the one-way 2-lane bridge is 15,760 vehicles, while the highest hour studied was 1,414 vehicles. A 5-min volume counted during the peak interval, which lasted about 20 min, resulted in an hourly volume of 2,484 vehicles when expanded.

DISCUSSION

The study was conducted from 7:00 a.m. to 12:00 midnight on March 19, 1956 and March 20, 1956. On the first day the 6-ft shoulder was clear (Fig. 16). On the second

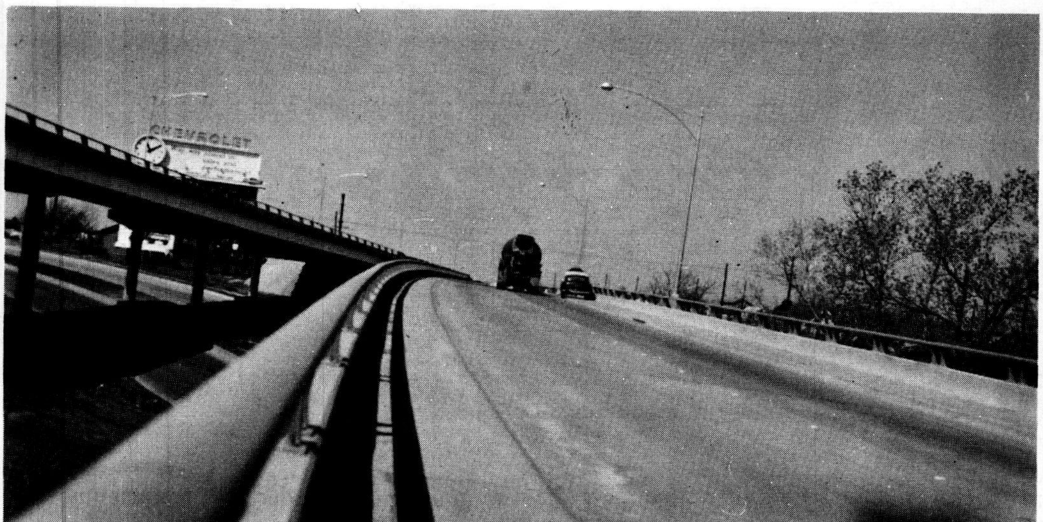


Figure 17. Site 26 — Passenger car parked on partial shoulder with hood raised, simulating disabled vehicle.

Figure 18.

TABLE 4

AVERAGE HOURLY TRAFFIC VOLUMES

TIME	VOLUME CONDITION	SITE NO.	PASSENGER VEHICLES LANE 1	PASSENGER VEHICLES LANE 2	COMMERCIAL VEHICLES LANE 1	COMMERCIAL VEHICLES LANE 2	TOTAL VEHICLES LANE 1	TOTAL VEHICLES LANE 2	AVERAGE HOURLY TRAFFIC VOLUME
7:45 A.M.	PEAK EXPANDED FROM 5 MINUTE PEAK INTERVALS	25	1440	1032	—	—	1440	1032	2472
		26	1308	1176	—	—	1308	1176	2484
		AVERAGE	1374	1104	—	—	1374	1104	2478
7 to 8 A.M.	PEAK HOUR	25	892	501	21	—	913	501	1414
		26	827	494	19	1	846	495	1341
		AVERAGE	860	497	20	1	880	498	1378
2 to 6 P.M.	MID-PEAK	25	418	120	6	—	424	120	544
		26	363	158	8	1	371	159	530
		AVERAGE	390	139	7	1	397	140	537
8 A.M. to 2 P.M. 6 to 7 P.M.	NORMAL	25	188	19	10	—	198	19	217
		26	153	41	10	—	163	41	204
		AVERAGE	170	30	10	—	180	30	210
7 to 11:59 P.M.	NIGHT	25	152	16	—	—	152	16	168
		26	118	39	—	—	118	39	157
		AVERAGE	135	28	—	—	135	28	163

ALL FIGURES ARE HOURLY AVERAGES FOR THE TIMES INDICATED.

LANE 1 - RIGHT LANE OR SHOULDER LANE
LANE 2 - LEFT LANE OR MEDIAN LANE

SITES 25 & 26 ARE THE SAME LOCATION
SITE 25 - SHOULDER CLEAR
SITE 26 - VEHICLE ON SHOULDER

day a car, supposedly a disabled vehicle, was stopped on the shoulder with the hood raised (Fig. 17). There was no one visible around the parked car. Speed and lateral placement were studied under both of these conditions.

Because of the similarity of volumes during parts of the time period studied, certain

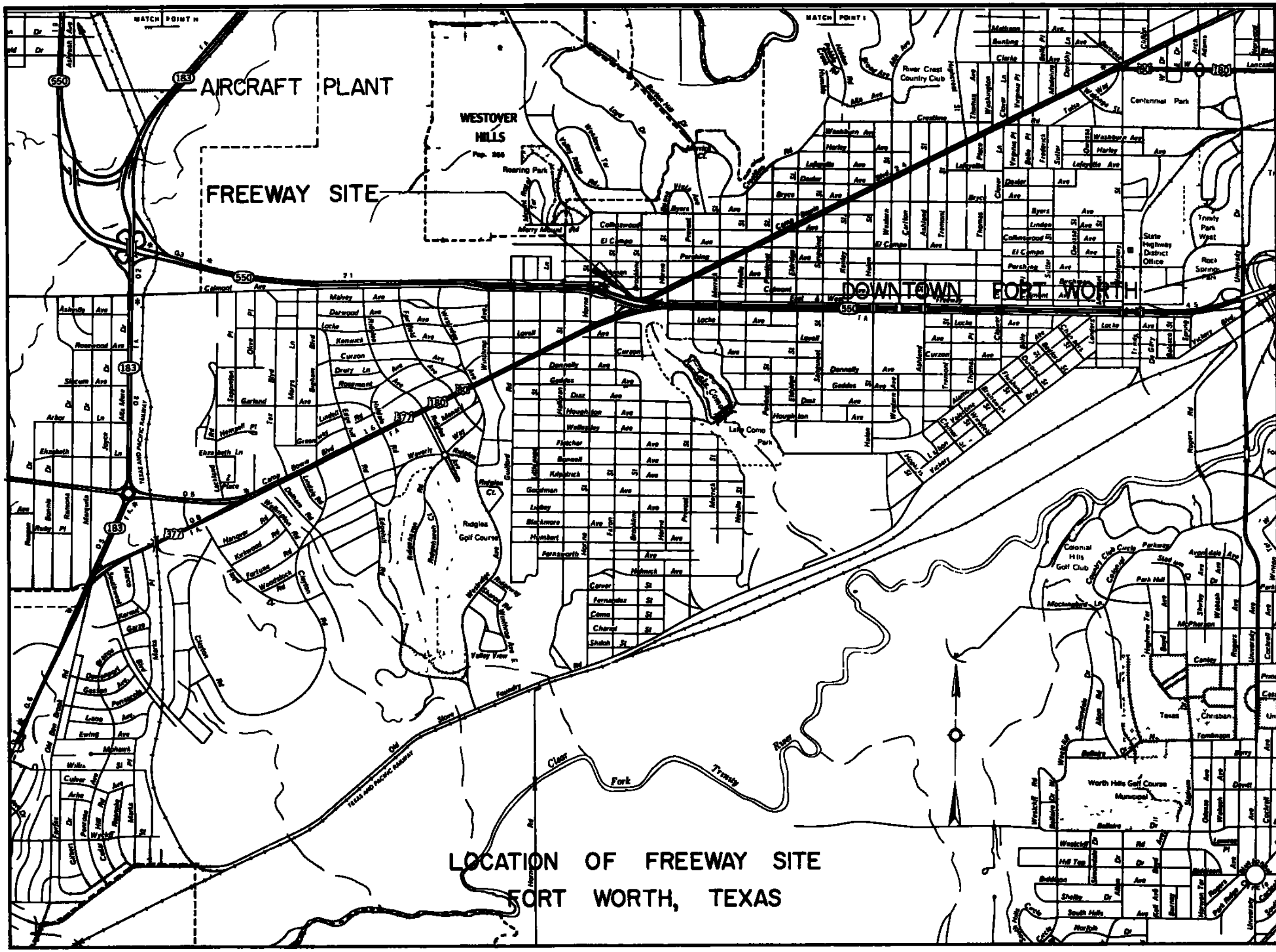

AIRCRAFT PLANT
FREEWAY SITE
WESTOVER HILLS
DOWNTOWN FORT WORTH
River Crest Country Club
Centennial Park
Lake Como Park
Ridglea Golf Course
Colonial Hills Golf Club
Worth Hills Golf Course Municipal
Clear Fork Trinity River
TEXAS AND PACIFIC RAILWAY
LOCATION OF FREEWAY SITE
FORT WORTH, TEXAS

Figure 19.

of the hours were grouped together for analysis. This grouping and the averages resulting from the combination of hours are shown in Table 4. For certain figures the data for the peak 5-min period were extracted but the majority include one or more full hours. This 5-min extraction was made to show the operation at near capacity conditio

The number of commercial vehicles observed in this study was too small for accura analysis, and so it has been omitted from all computations except Table 4.

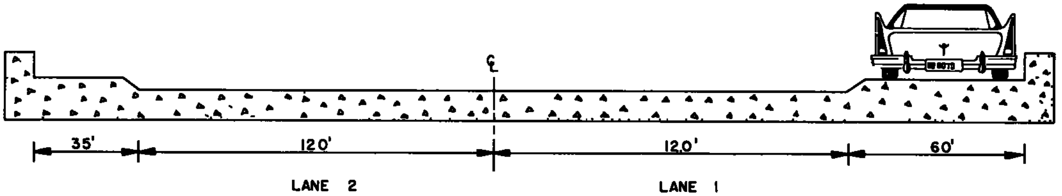


Figure 20. Cross-section of freeway bridge.

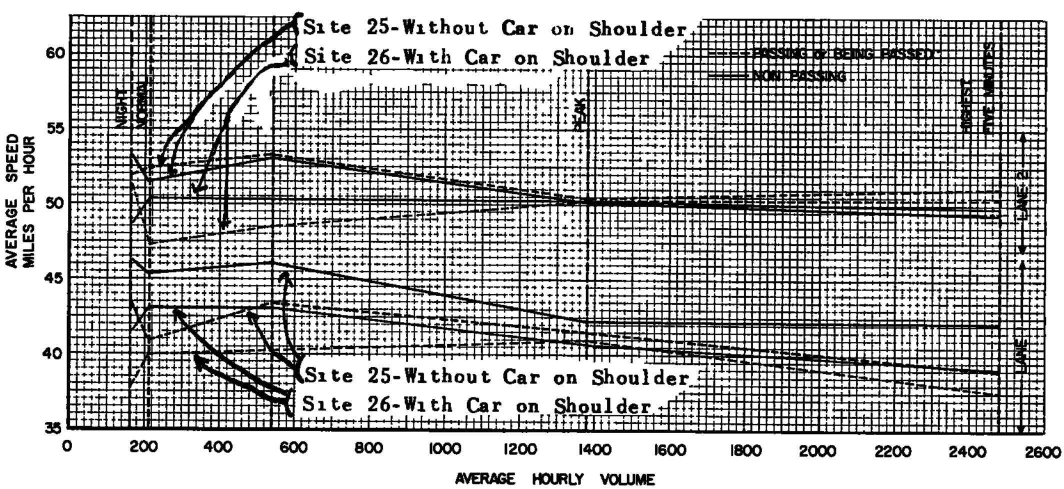
Speed

Cumulative speed curves and the 85 percentile speeds for the various volume conditions and vehicle maneuvers were arranged so that comparisons could be made between the two shoulder conditions. The general effect of the parked car seems to have been to reduce speeds. It was also evident that speeds were lower in the right lane than they were in the left lane (9).

Speed Volume

Figure 21 shows the average speed plotted in relation to the hourly traffic volumes for the two shoulder conditions. Speeds in Lane 1, the right lane, are less than they are in Lane 2. This difference seems to be increased by the presence of the vehicle on the shoulder, as volumes increase. This increased influence is more pronounced for passing and being passed vehicles than for non-passing vehicles, which indicates that a car in the right lane decreases its speed when it is "sandwiched" between a car on the shoulder and a car in the left lane. The effect on speeds by the vehicle on the shoulder is somewhat similar for both lanes for lower volumes, but as volumes increase, the effect on the left lane decreases.

There is a general convering of the speeds at the peak hour, with vehicles in the left lane traveling at a speed of about 50 mph and those in the right lane at about 41 mph. Speeds in the left lane continue to be fairly constant through the peak 5-min volume;



speeds in the right lane tend to decrease and show a wider variation between passing and non-passing vehicles.

Lateral Placement

The lateral placement of the vehicles is shown in Figures 23A and 23B. The distribution of vehicles within the lanes and the percentage are shown by the height of the bars. Each lane is plotted separately so that the percentages in each lane will add up to 100 percent. Volumes are not the same in each lane. Figure 22 shows the lane volume distribution for the various volumes studied. The percentage of the traffic in the right lane decreases steadily as the total volume increases. The effect of the car on the shoulder was to increase the percentage of vehicles in the left lane at all volume conditions, indicating that regardless of the volume some vehicles moved from the right lane to the left lane because of the vehicle on the shoulder.

This movement became less pronounced as volumes increased, partly because it became more difficult to find a gap in the left lane to move into, and partly because vehicles traveling in a more dense stream of traffic did not become aware of the vehicle on the shoulder until after it was too late to take any action.

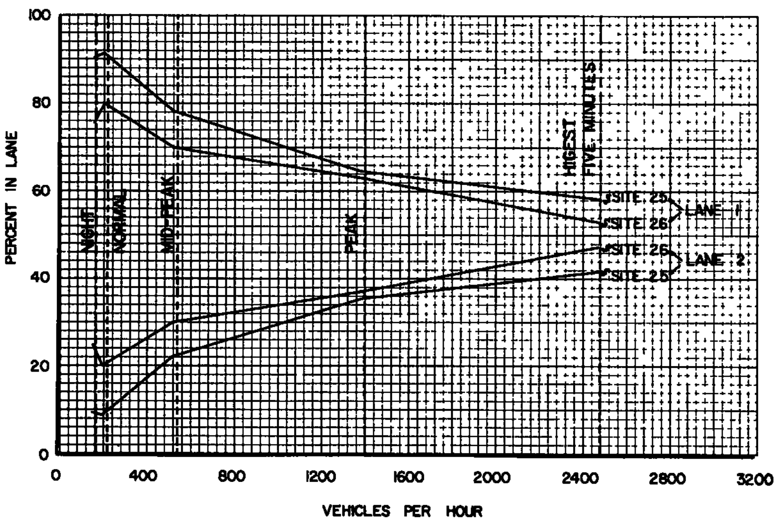


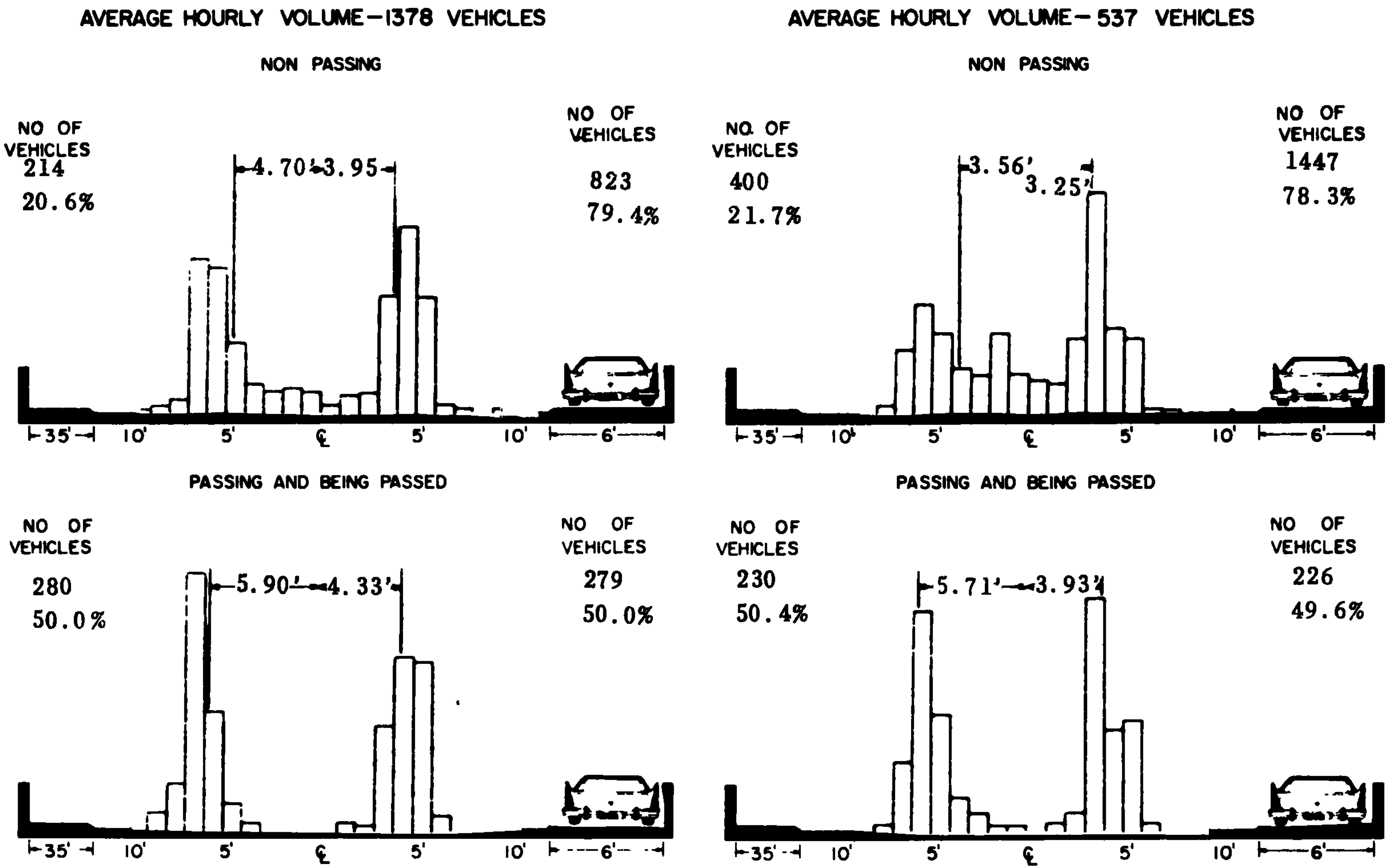
Figure 22. Percent of vehicles in lanes 1 & 2 vs. volume.

Figures 24A and 24B show vehicle placement plotted against traffic volumes and indicate the most conclusive effect of the car on the shoulder. The effect of the vehicle is particularly pronounced in the right lane and at lower volumes. As volumes increase, the effect of the stopped vehicle decreases. For all conditions as volumes increase the vehicle placement moves closer to the center of the lane, and also, for all conditions, the average placement for both the left and right lane lies closer to the center of the lane than to the outer edge of the pavement.

The shape of the curve for the non-passing vehicles in the left lane with the car on the shoulder indicates that, at lower volumes, vehicles were moving from the right lane to the left lane to allow a greater lateral distance to the stopped vehicle. This substantiates Figure 22, which shows a greater percentage of vehicles in the left lane when the car was stopped on the shoulder.

CONCLUSIONS

The vehicle stopped on the 6-ft shoulder did have an effect on traffic, but as traffic volumes increased the effect decreased. Differences in behavior in both speed and lateral placement were detected, with the lateral placement being most noticeably affected.


AVERAGE HOURLY VOLUME—1378 VEHICLES
NON PASSING
NO OF VEHICLES
214
20.6%
4.70'
3.95'
NO OF VEHICLES
823
79.4%
35'
10'
5'
℄
5'
10'
6'
PASSING AND BEING PASSED
NO OF VEHICLES
280
50.0%
5.90'
4.33'
NO OF VEHICLES
279
50.0%
35'
10'
5'
℄
5'
10'
6'
AVERAGE HOURLY VOLUME—537 VEHICLES
NON PASSING
NO. OF VEHICLES
400
21.7%
3.56'
3.25'
NO OF VEHICLES
1447
78.3%
35'
10'
5'
℄
5'
10'
6'
PASSING AND BEING PASSED
NO OF VEHICLES
230
50.4%
5.71'
3.93'
NO OF VEHICLES
226
49.6%
35'
10'
5'
℄
5'
10'
6'

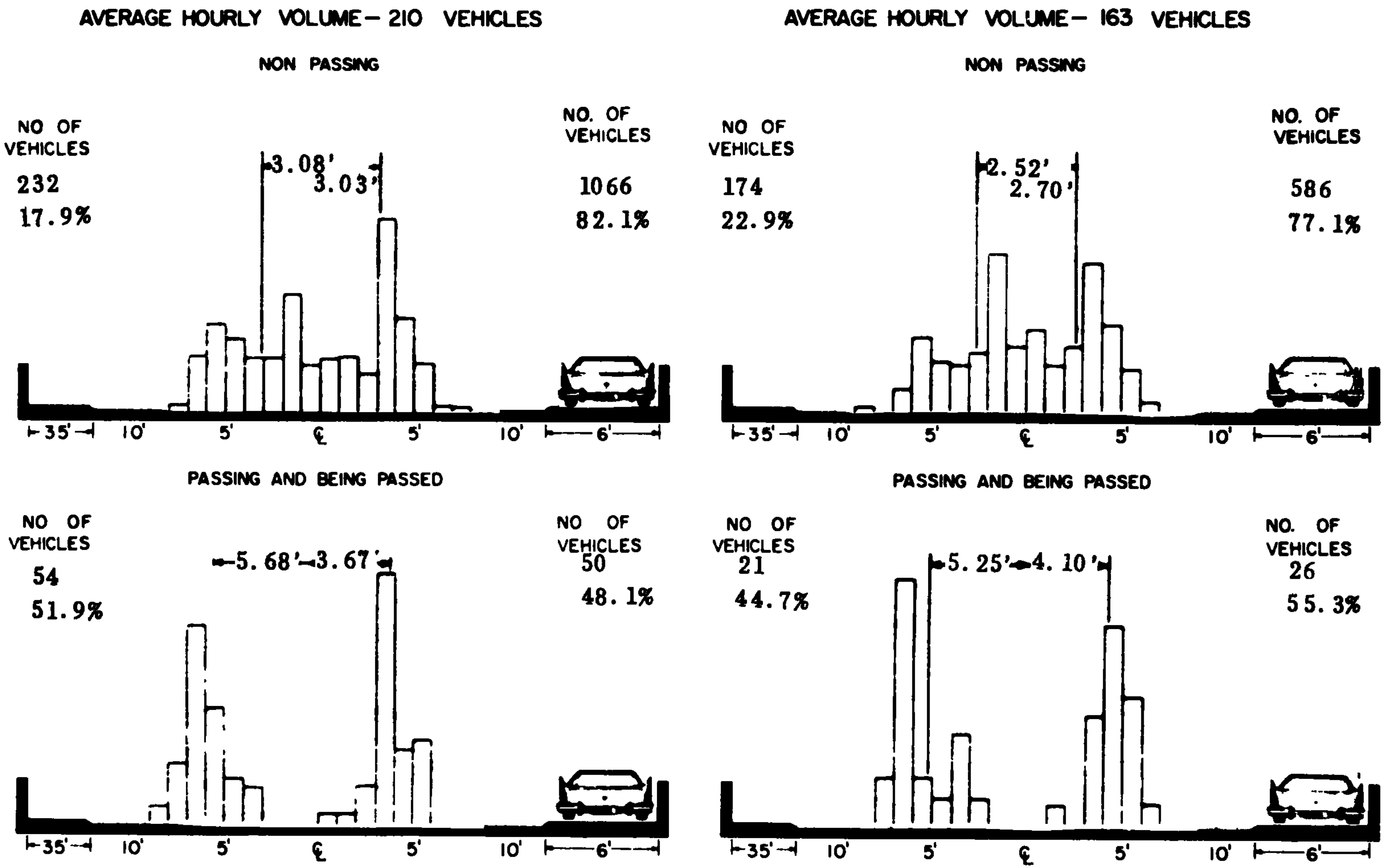
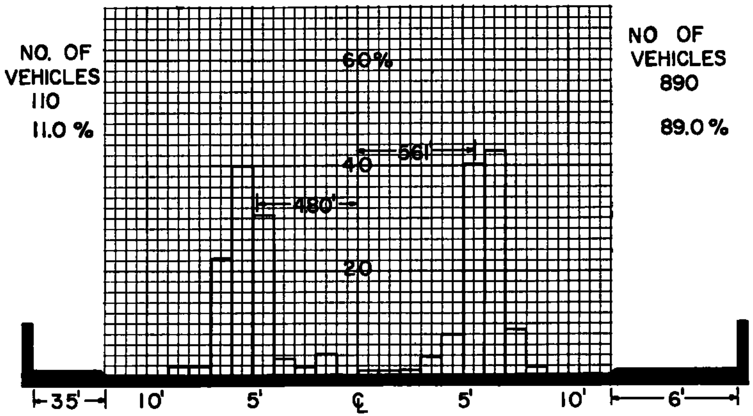


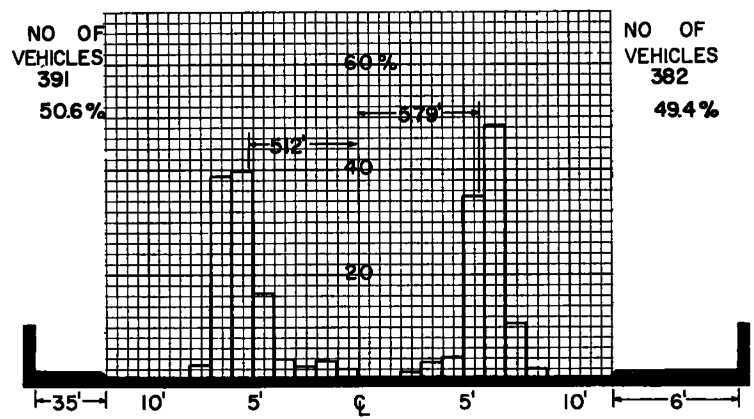
Figure 23A. Lateral placement of vehicles by lane - Site 26 (with vehicle).

AVERAGE HOURLY VOLUME—1378 VEHICLES

NON PASSING

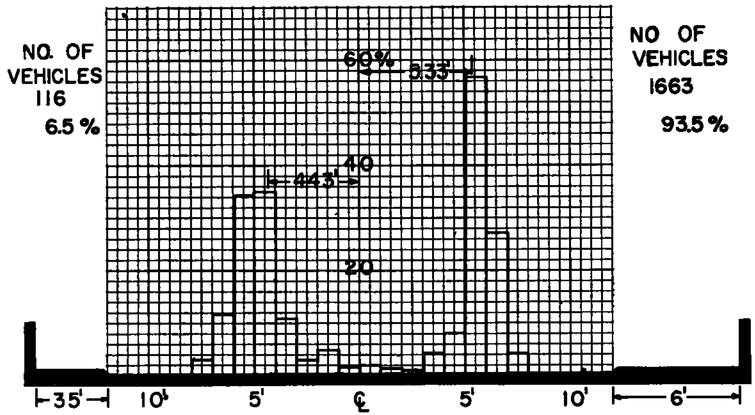


PASSING AND BEING PASSED

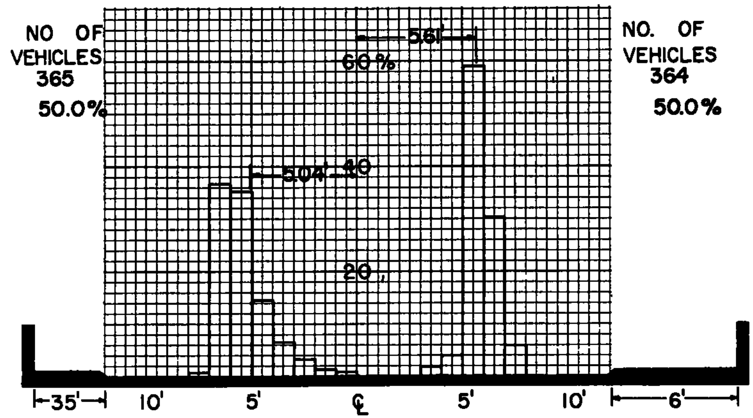


AVERAGE HOURLY VOLUME— 537 VEHICLES

NON PASSING



PASSING AND BEING PASSED



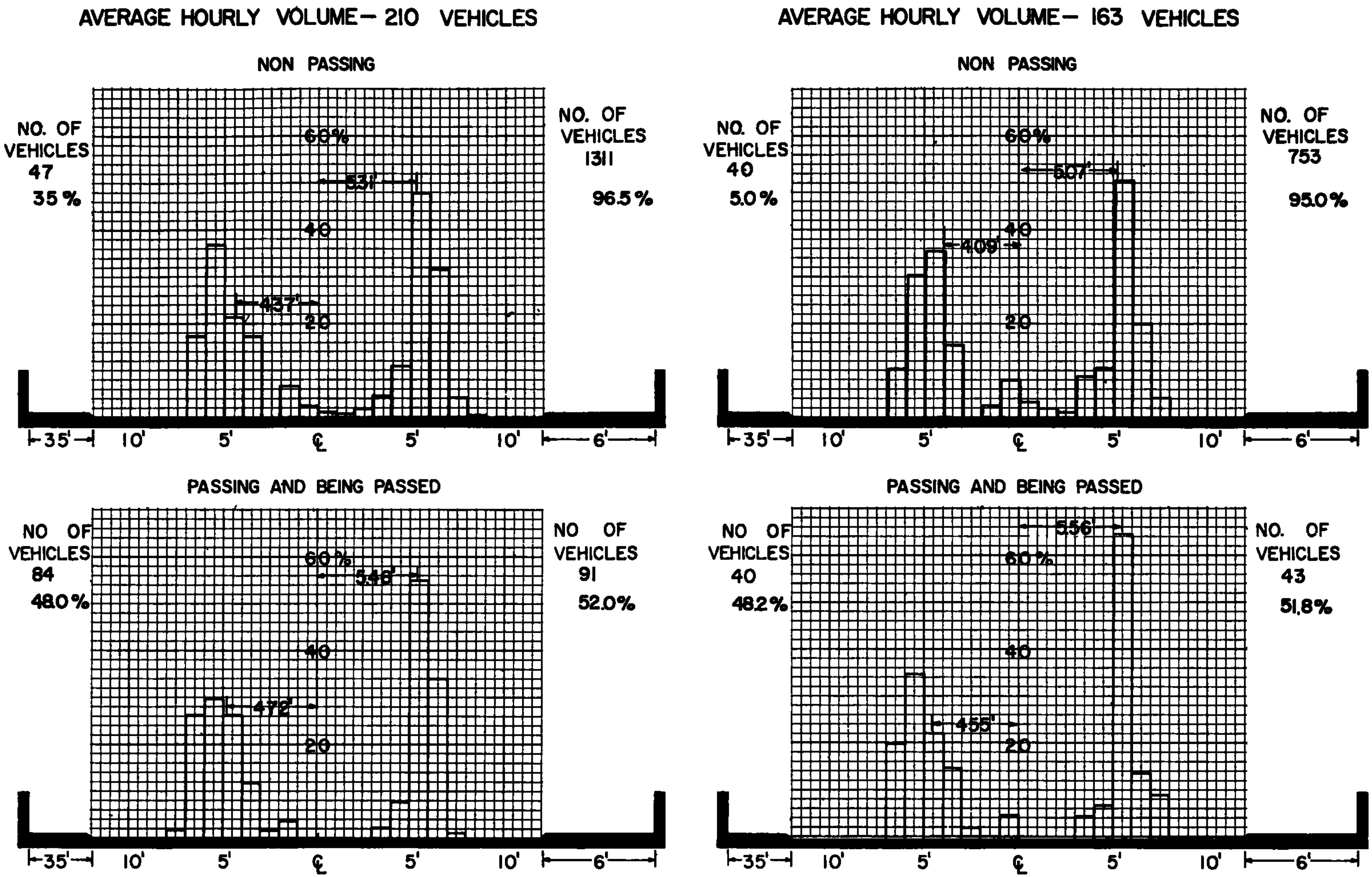


Figure 23B. Lateral placement of vehicles by lane - Site 25 (without vehicle).

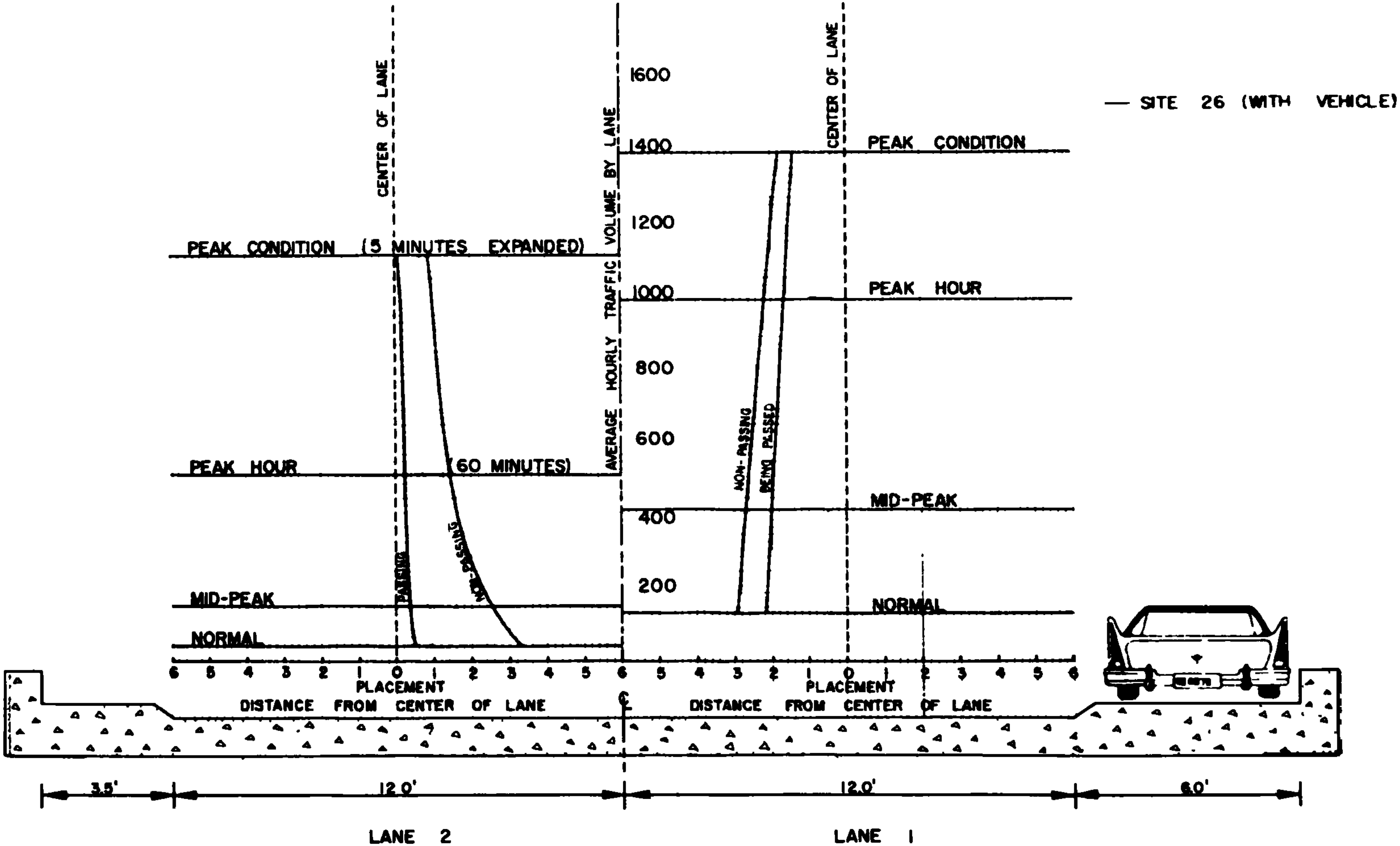


Figure 24A. Placement of vehicles on two-lane freeway bridge in relation to traffic volume with disabled vehicle on six-ft emergency shoulder.

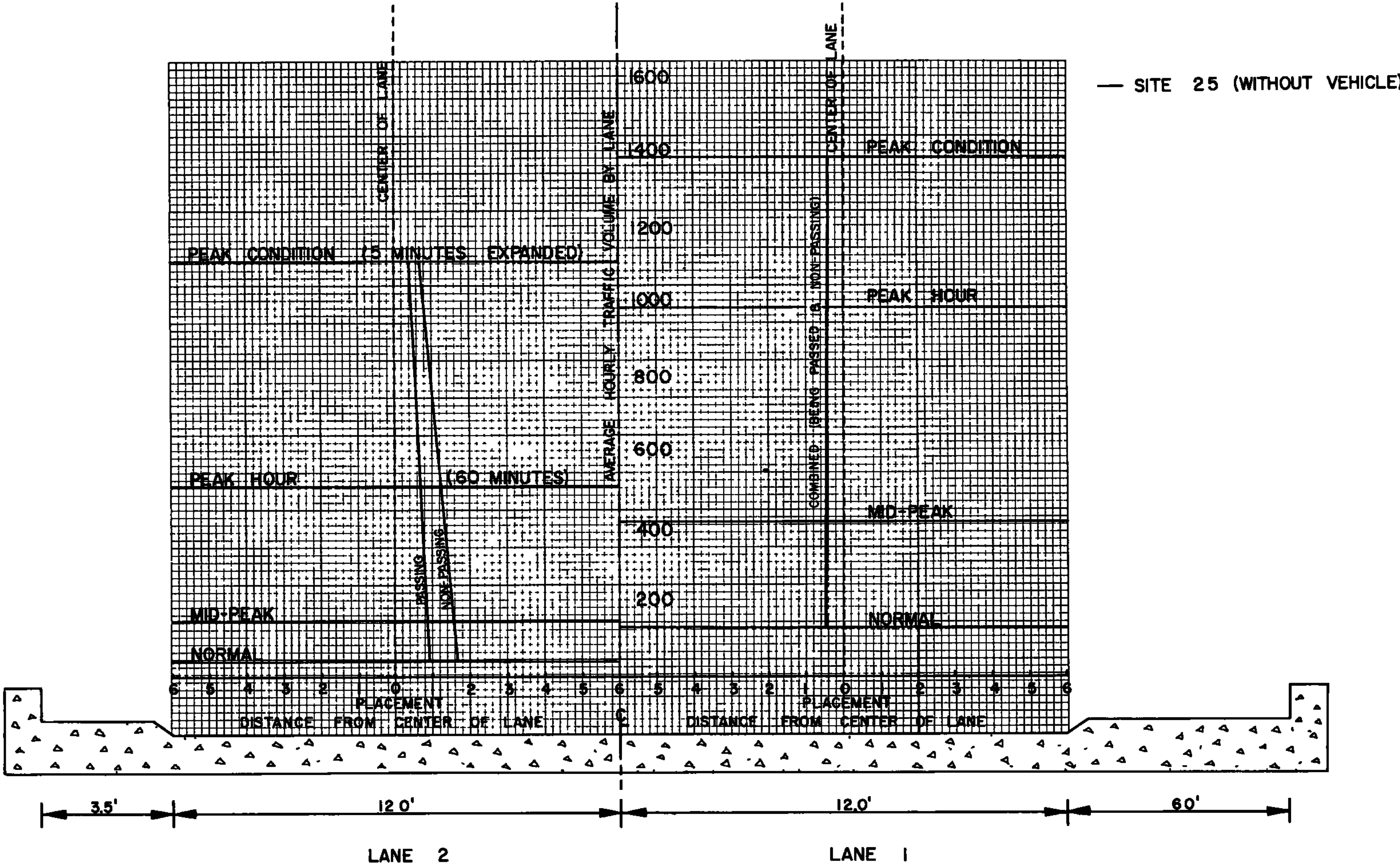


Figure 24B. Placement of vehicles on two-lane freeway bridge in relation to traffic volume without disabled vehicle on six-ft emergency shoulder.

The presence of the vehicle, although it had an influence on traffic, did not seriousl decrease the capacity or noticeably impair the safety of the facility which would indicate that a 6-ft emergency shoulder can accommodate a single stalled vehicle without seriously affecting traffic operation.

The application of the data collected in this study to general freeway operating characteristics is necessarily tied in with the association of these data with those collected at other locations. For this reason, no conclusions have been drawn on this phase of the study. However, the data have been presented in full.

Conditions existing during this study which should be considered in the application of these results are as follows:

1. There was no one visible around the disabled vehicle during the time of the study
2. The disabled vehicle was stopped so close to the bridge rail that it was impossible to open the right door; and
3. The percentage of trucks at this particular location was small, amounting to less than one percent of the vehicles during the peak hour.

ACKNOWLEDGMENTS

This research was performed under the general direction of the Road Design Divisio Texas Highway Department, and was made possible by the cooperation of the U.S. Bureau of Public Roads, which furnished the measuring equipment used and also much expert advice and assistance through representatives from its headquarters, regional and district offices. The project was a coordinated effort of the Road Design Division, the Planning Survey Division, and the Austin, San Antonio, and Fort Worth Districts.

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