DRIVEWAY STUDY

A STUDY OF URBAN

DRIVEWAY APPROACH GEOMETRICS

TSD-G-107-69

TRAFFIC and SAFETY DIVISION

DEPARTMENT OF STATE HIGHWAYS
STATE OF MICHIGAN

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

DRIVEWAY STUDY

A STUDY OF URBAN DRIVEWAY APPROACH GEOMETRICS

TSD-G-107-69

Prepared By

Standards Unit
Geometrics Section
Traffic and Safety Division

May 1969

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

PREPARED BY GEOMETRICS SECTION

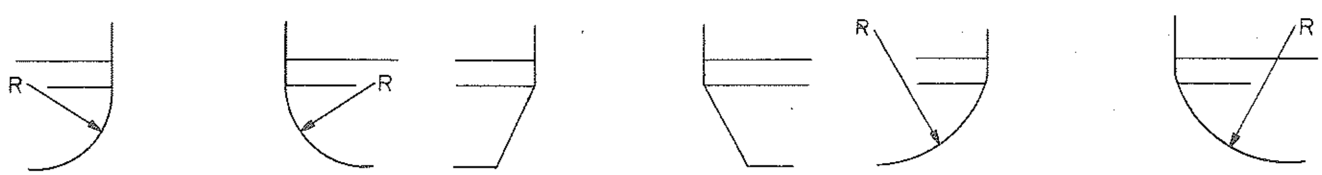
Traffic Geometrics Engineer . . . . . . R. A. Rigotti
Standards Engineer . . . . J. J. Kanillopoolos
Study Engineer . . . . R. C. Haeusler Jr.

Contributor to the Report:

Leigh A. Chizek
Traffic Engineer

INTRODUCTION

At present, Michigan Department of State Highways design standards include two types of urban commercial driveway approaches. The first type is the curb return or full-arc type which makes use of a 90-degree circular curve arc to connect the highway curb line with the driveway edge. The second type is what is referred to as the straight-sided or straight-taper drive approach. A third type, not yet included in design standards, is what might be called a partial-arc driveway. This type, although similar to the full-arc type, has a radius greater than the distance from curb line to sidewalk which allows tangency at the edge of the highway but not at the edge of the driveway. Figure 1 below illustrates the three types.



Full-arc or curb return type

Straight edge or straight taper

Partial-arc

Figure 1

PURPOSE

The purpose of this study was to develop certain basic operational facts involving vehicles making right turns into urban driveways. It was hoped that this information would determine which type of driveway approach should be standardized at commercial establishments in the proposed revision of "Standards and Procedures for Driveways".

CONDUCT OF THE STUDY

Five typical driveway approaches in Lansing and Grand Rapids were studied. The layouts are shown in Figures 5 to 11. Two were straight-edged (Logan Center in Lansing and K-Mart in Grand Rapids), two were full-arc radius type (Meijers in Lansing and Frandor in Lansing), and the fifth was a partial-arc radius type (Jolly-Cedar Plaza in Lansing). The locations were all selected at shopping centers to ensure a sufficient number of samples.

At each location, the right-turn entrance from the highway into the driveway was studied with some locations being channelized with traffic cones in order to force a minimum turning path so that the effect the edge configuration had on the turning movement could be determined. This would also simulate use of the driveway with an exiting vehicle reducing the available width. In two locations (Frandor and Logan), permanant driveway divider islands existed and at two others (Jolly-Cedar and K-Mart), a line of rubber traffic cones was placed to provide channelization. The fifth location (Meijers) was of such nature that entering motorists normally turned hard right, following closely the edge of the driveway, and therefore no cones were used. The location of the line of cones was determined by plotting the minimum P (Passenger) vehicle turning path on a scale drawing of the driveway and adding 2.0" clearance. To determine the effect that the cones had on the data obtained, identical studies were run at two of the locations (K-Mart and Jolly-Cedar) without cones.

The specific data obtained were:

1. Entering Speed. This was the speed at which vehicles traveled over a calculated path between two timing marks while entering the drive.
2. Vehicle Position in Lane Before Entering the Driveway. This was determined by comparing the average position of the right front tire of a turning vehicle with the tire position of a straight through vehicle. This would indicate the tendency of an entering vehicle to encroach on the adjacent street lane.
3. Striking the Curb. At each location the number of vehicles striking the curb while entering the drive was recorded.

The appendix should be consulted for a more complete description of how the data was obtained.

CONCLUSIONS

The speed data for vehicles entering under channelized conditions is inconclusive. It appears that vehicles entering full-arc or partial-arc drives travel faster, but additional locations should be studied to confirm this. There was a significant increase in entering speed when the full driveway width was available (i.e., divider channelization removed).

The placement data indicates that for the locations with outside lane widths of about 12 feet (plus curb and gutter), the entering vehicles moved closer to the curb than straight through vehicles. Curb-striking data indicated that for straight-sided drives, approximately one-fourth of the entering vehicles struck the curb. The incidents at the full-arc (curb return) types were negligible.

RECOMMENDATIONS

1. Curb return driveway approaches, either full-arc (90° segment) or partial-arc (less than 90°), should be used in preference to straight-sided types.
2. The data considered in this report is insufficient to determine those cases in which the full-arc type should be used instead of the partial-arc type. It is recommended, however, that the partial-arc type with a radius of 15 feet be used for urban commercial driveway approaches when the distance from the highway curb face to the edge of sidewalk is 15 feet or less. Where the face of curb to edge of sidewalk distance is greater than 15 feet, the full-arc type should be used.

Subsequent to completion of this study, consideration was also given to the cost of constructing curbed driveways of the three basic configurations. The appendix contains a brief report based on current unit prices which reveals the cost of full-arc or partial-arc drives to be less than the straight-edge type.

ANALYSIS

The data obtained at each of the five locations is reviewed and analyzed in the following sections.

Speed Data

The driveway entering speed data for the five locations using cones or having an island divider is shown graphically as cumulative percentage curves in Figure 2. The average values for each speed curve and the percent speed reduction from 35 MPH are shown in Table 1. A reduction from 35 MPH is used in order to approximate urban conditions.

LOCATION	DRIVEWAY TYPE	AVERAGE ENTRANCE SPEED (MPH)	PERCENT SPEED REDUCTION FROM 35 MPH
Logan	73° straight edged	6.36	82
K-Mart	60° straight edged	7.44	79
Jolly-Cedar	15' partial arc	8.23	76
Meijers	25' full arc	8.93	74
Frandor	15' full arc	8.98	74

TABLE 1

It appears that entering speeds are generally higher for the full- and partial-arc types; however, study of additional locations is necessary to prove this conclusively. Additional locations should include smaller radius (5'-10') full-arc types.

The driveway entering speeds at Jolly-Cedar Plaza (partial-arc type) and K-Mart (straight-edge type) are depicted by the curves in Figures 3 and 4, respectively. In both cases, the entering speeds increased when the cones were removed. For Jolly-Cedar Plaza, the increase was 47.6% and for K-Mart, the increase was 21.0%. Figures 7 and 9 show the average vehicle paths followed at K-Mart and Jolly-Cedar for this "no cone" condition. It appears that the speed increases are the result of the flatter paths followed at the two locations. The path angle changed from essentially 90° to 42° at Jolly-Cedar Plaza and from 90° to approximately 70° at K-Mart. The flatter path at Jolly-Cedar was due to the fact that the drive was at the far end of the shopping center and most all the motorists desired a more central parking place.

Figures 19A through 24A depict six gasoline stations studied by Billion and Scheinbart.* As part of their study, the driveway entering speeds for vehicles following the arrow-paths were determined. The high, low and average entering and through highway speeds are given in Table 2. Station No. 5 is sufficiently narrow in width to force a minimum turning path and with its 90° sides is quite similar to the Logan driveway. The average entering speed (6.3 MPH) likewise compares favorably with the Logan driveway. For Stations 1 through 4 and 6, vehicles could maximize the turning radius and/or cross the driveway at a smaller angle, which makes it difficult to compare results. The average speeds for Stations 1 through 4 and Station 6 are higher than for Station 5.

* "A study of ingress and egress at gasoline service stations on rural state highways without control of access". C. E. Billion, Irving Scheinbart, Highway Research Board proceedings, 1956, V. 35, P. 618-660.

Station	Type of Entrance	Highway Speed (MPH)			Entrance Speed (MPH)		
		High	Low	Aver.	High	Low	Aver.
1	45° Straight Edged	43	20	32.2	20	4	8.7
2	60° Straight Edged	66	25	45.6	25	6	13.1
3	See Figure 21A	50	18	34.7	30	6	15.6
4	30° Straight Edged	59	22	39.5	28	5	15.1
5	90° Straight Edged	54	27	38.4	10	3	6.3
6	Large Radius	54	20	39.6	17	3	10.6

This data taken from Billion and Scheinbart, "Service Station Ingress and Egress".

TABLE 2

Placement Data

The average placements of the right front tire, at the instant the vehicle begins to turn into the driveway, are indicated in Table 3. These values were taken at the beginning of the timing zone. Negative differences in the last column imply that the average turning vehicle was closer to the curb than the average through vehicle. The positive difference implies the opposite.

Location	Highway lane width (face of curb to edge of next lane)	Average position of right front tire for through vehicles (feet from curb face)	Average position of right front tire for right turning vehicles (feet from curb face)	Difference between through and turning vehicles (feet)
Logan Center (St.Edge)	14'-2"	6.1	3.9	-2.2
Jolly-Cedar (Partial Arc) (with cones)	13'-3"	5.6	4.9	-0.7
Jolly-Cedar (without cones)	13'-3"	5.6	4.4	-1.2
Frandor (Full Arc)	8'-9"	3.3	4.0	+0.7

TABLE 3

The positive difference at Frandor (last column) was probably the result of the narrow lane width. The total half-roadway width of 17'-6" accommodated two lanes of vehicles. Figures 5 through 11 show entering vehicle paths which were plotted using the average placement values at each of the three reference stations. The inside edges of the paths correspond to the right rear vehicle tire and the outside edges, the left front. Frandor, Meijers and Jolly-Cedar indicate vehicle paths which conform quite closely to the shape of the driveway edge.

Curb Striking Data

A tabulation of occurrences of turning vehicles hitting the driveway curb is given by Table 4. The curb was hit in all cases by the right rear tire.

Location	Number that hit curb	Total number of vehicles	Percent of total
K-Mart (St. Edge) with cones	25	93	26.9%
Jolly-Cedar (Partial Arc) with cones	1	46	2.2%
Logan Center (St. Edge)	9	43	21.0%
Meijer's (Full Arc)	0	79	0.0%
Frandor Center (Full Arc)	0	55	0.0%

TABLE 4

The entering path diagrams (Figures 5 through 11) correlate well with the curb-striking data. Figures 5 (Logan) and 6 (K-Mart) indicate the vehicle turning path to be very close to the junction of the street and driveway curb.

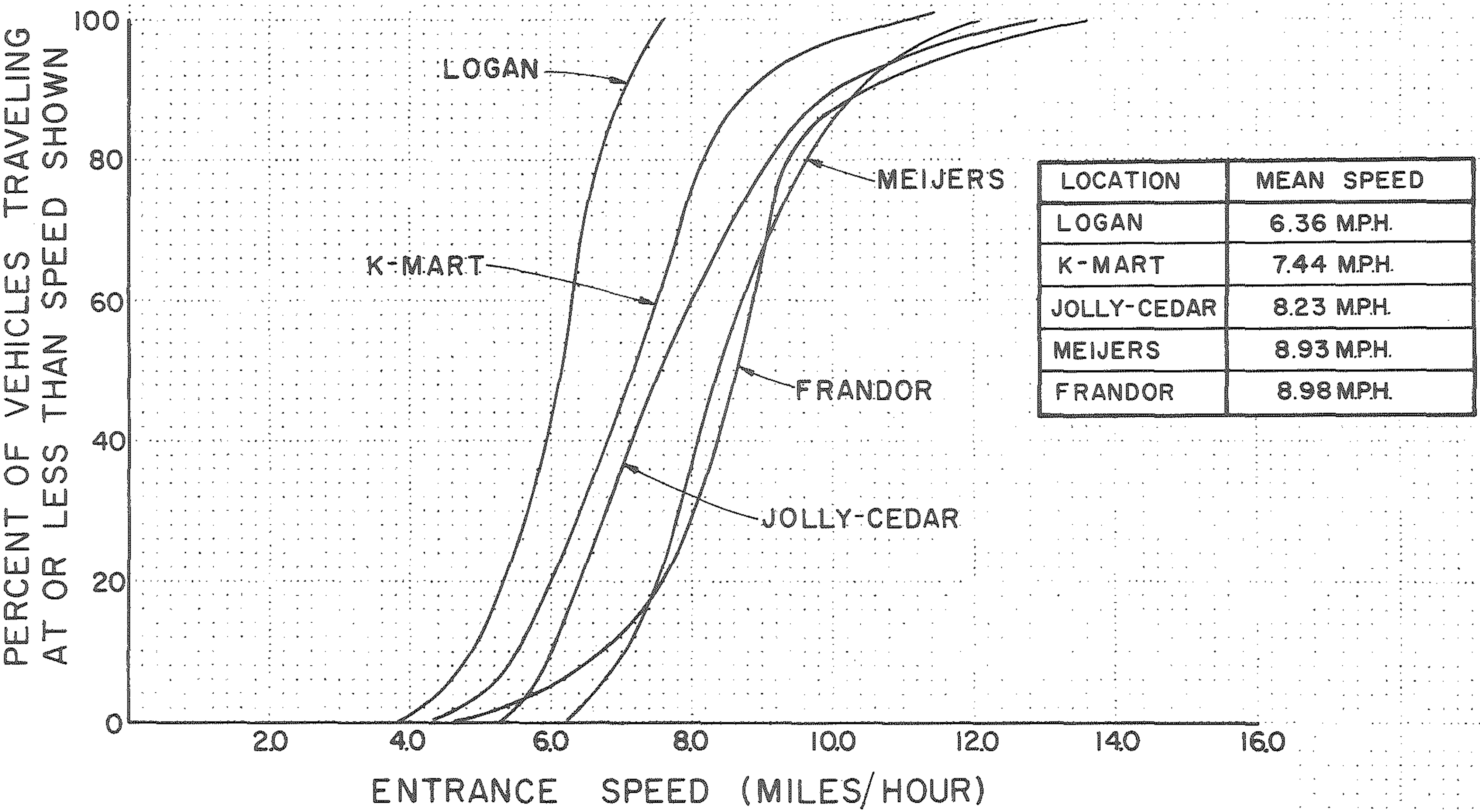
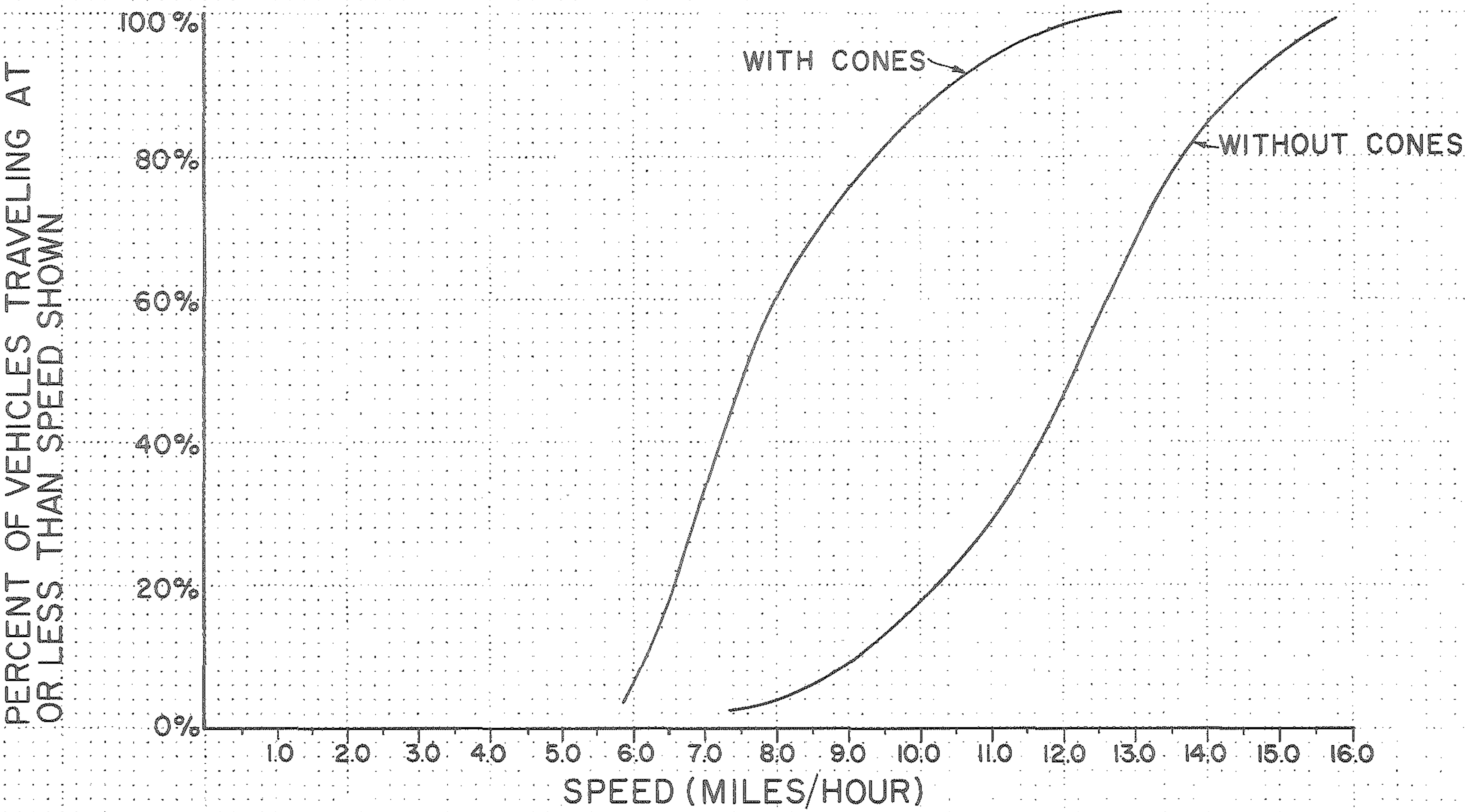

PERCENT OF VEHICLES TRAVELING AT OR LESS THAN SPEED SHOWN
100
80
60
40
20
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
ENTRANCE SPEED (MILES/HOUR)
LOGAN
K-MART
MEIJERS
FRANDOR
JOLLY-CEDAR
LOCATION | MEAN SPEED
LOGAN | 6.36 M.P.H.
K-MART | 7.44 M.P.H.
JOLLY-CEDAR | 8.23 M.P.H.
MEIJERS | 8.93 M.P.H.
FRANDOR | 8.98 M.P.H.

FIGURE 2

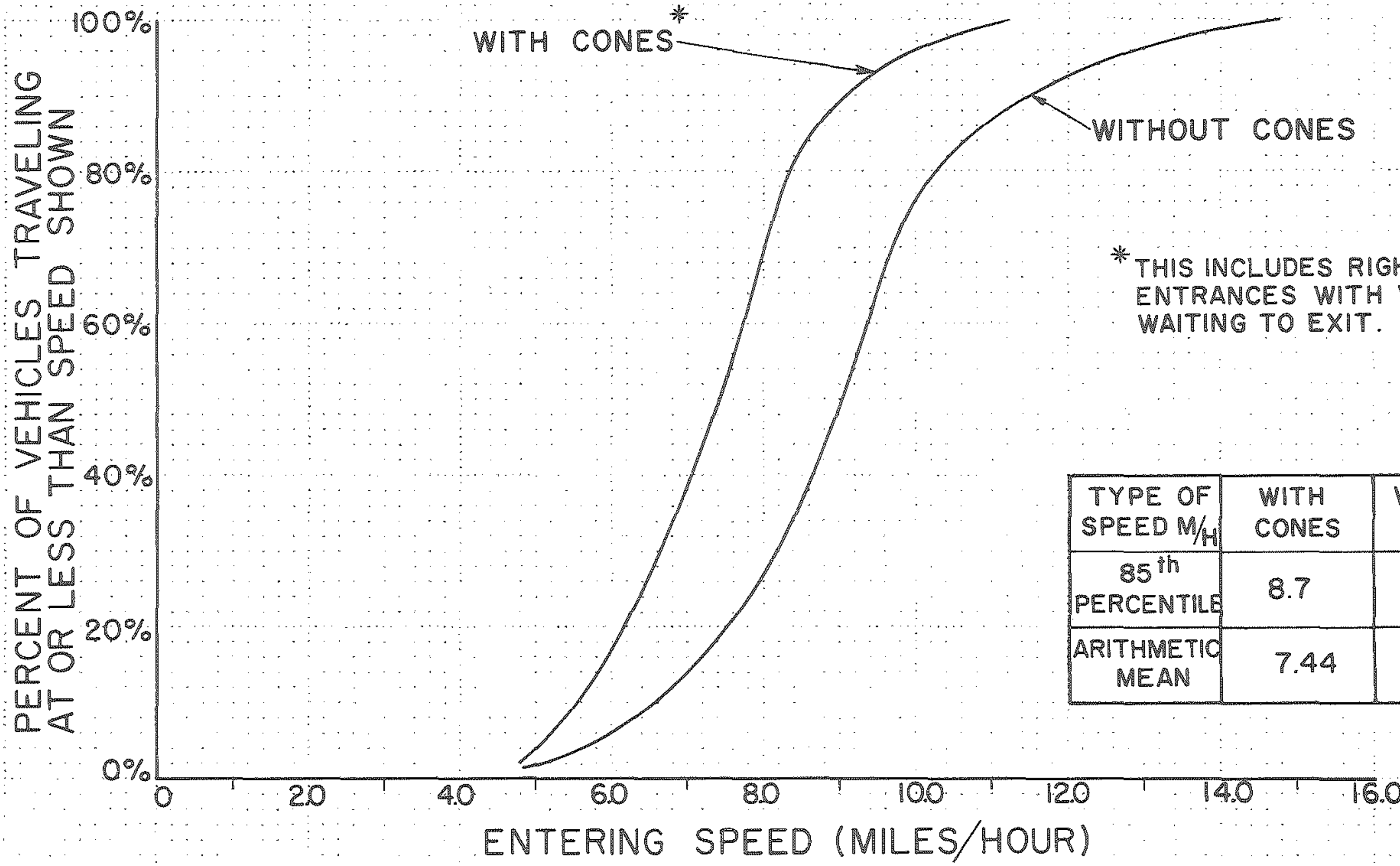


JOLLY-CEDAR PLAZA

TYPES OF SPEED	WITH CONES	WITHOUT CONES
85th PERCENTILE	9.85	14.20
ARITHMETIC MEAN	8.23	12.15
MEDIAN	7.91	12.30

FIGURE 3

K-MART (GRAND RAPIDS)



TYPE OF SPEED M/H	WITH CONES	WITHOUT CONES
85th PERCENTILE	8.7	10.8
ARITHMETIC MEAN	7.44	9.00

FIGURE 4

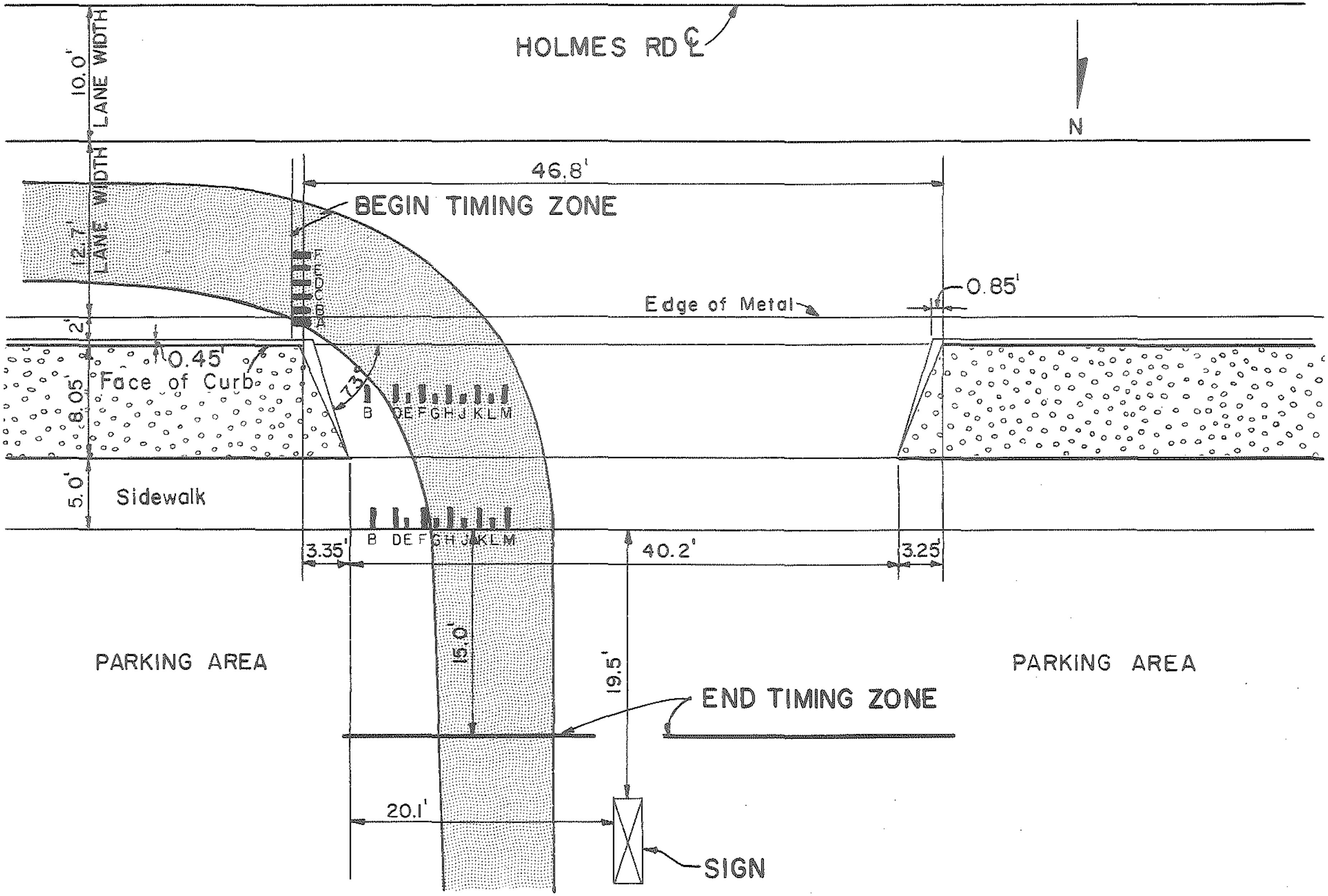


FIGURE 5 LOGAN SHOPPING CENTER

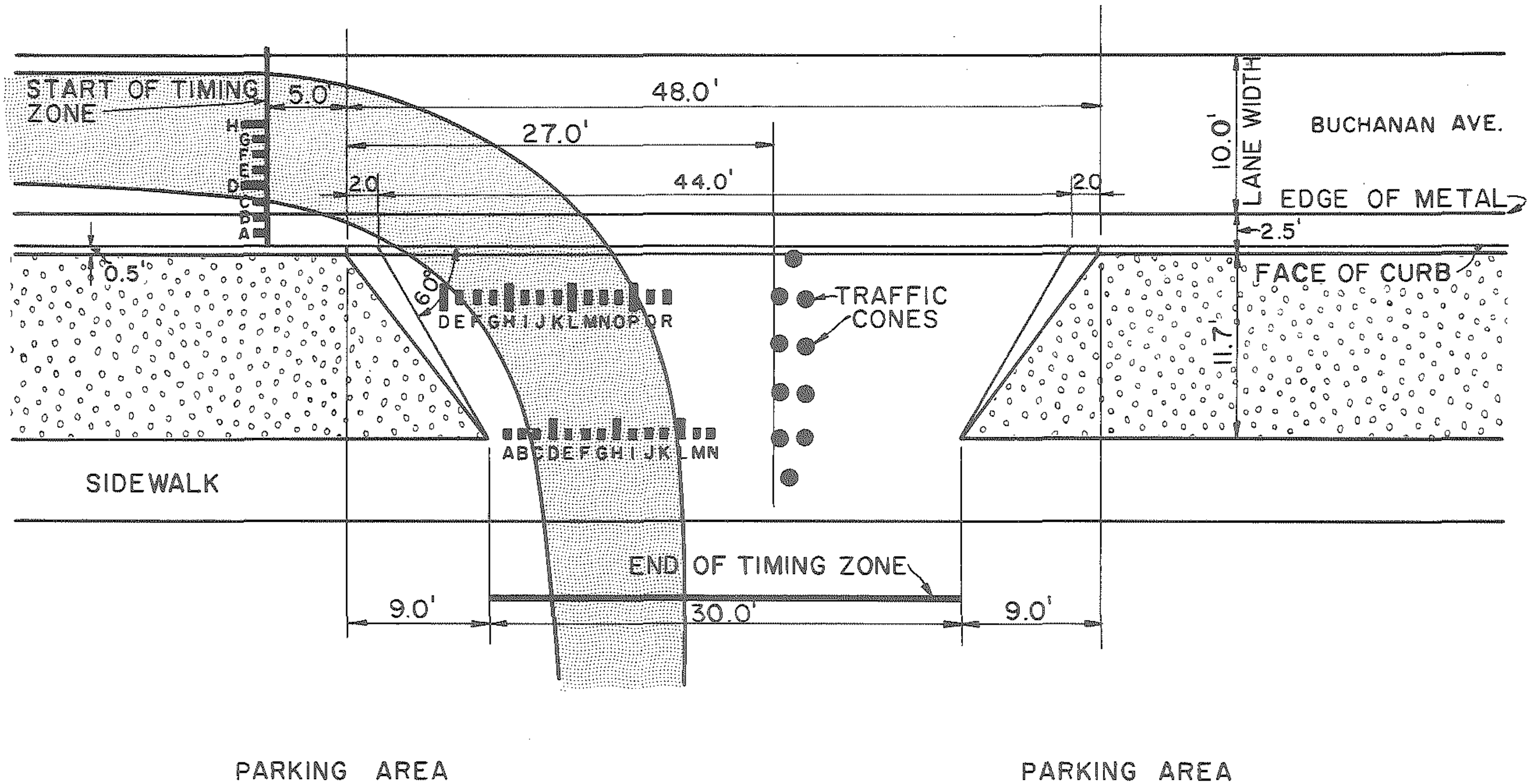


FIGURE 6 K-MART GRAND RAPIDS

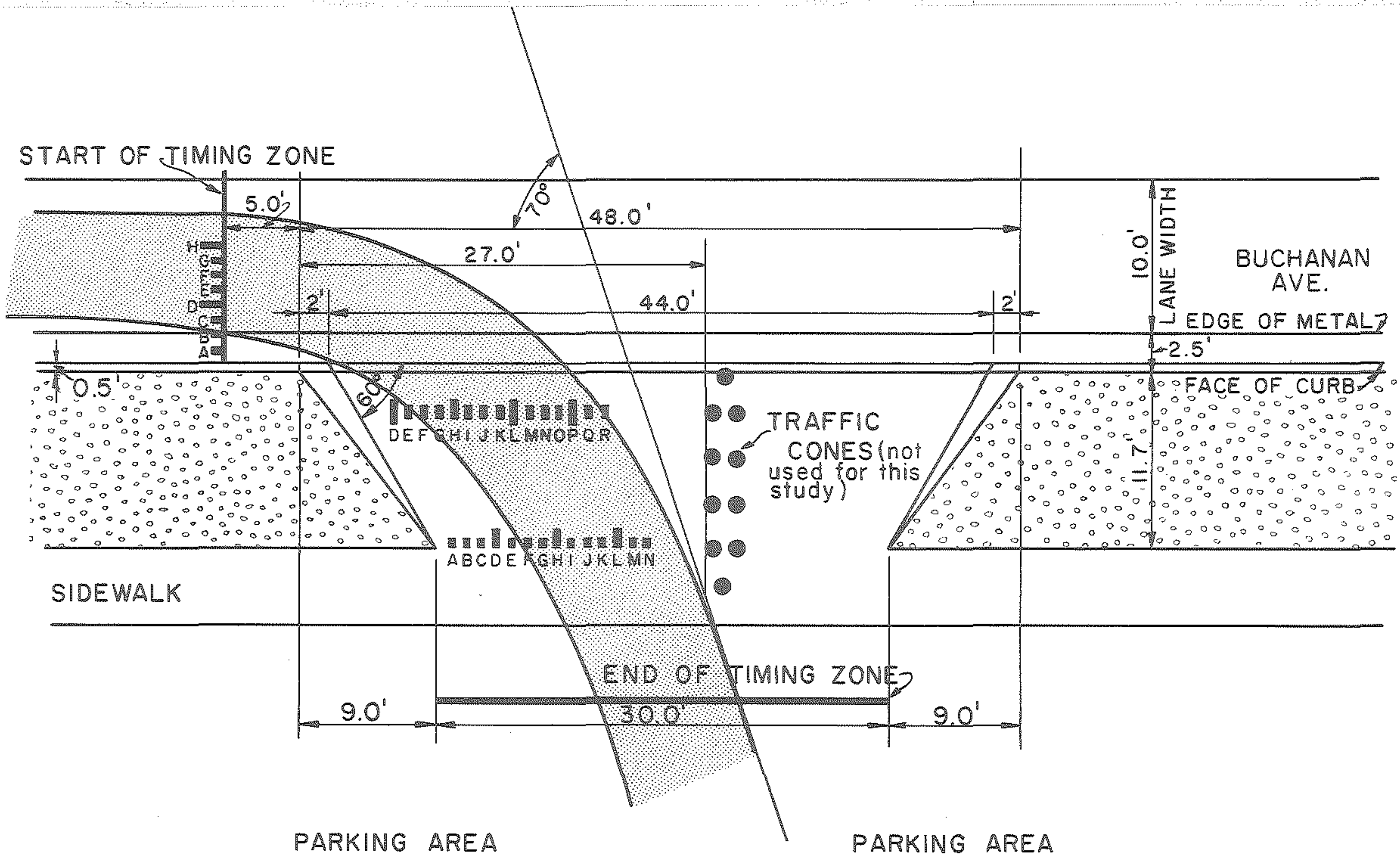


FIGURE 7 K-MART GRAND RAPIDS
NO CONES

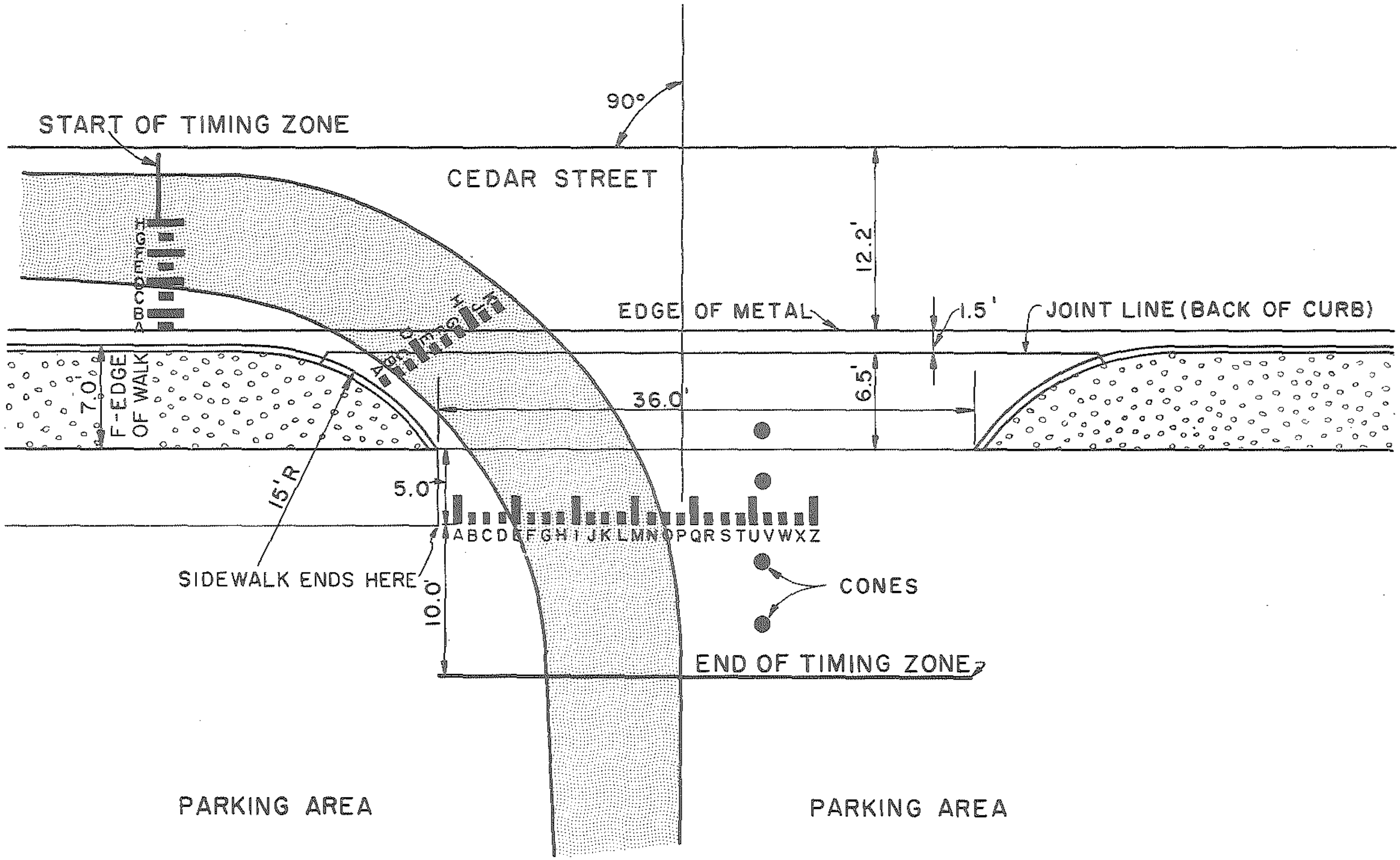


FIGURE 8 JOLLY-CEDAR PLAZA

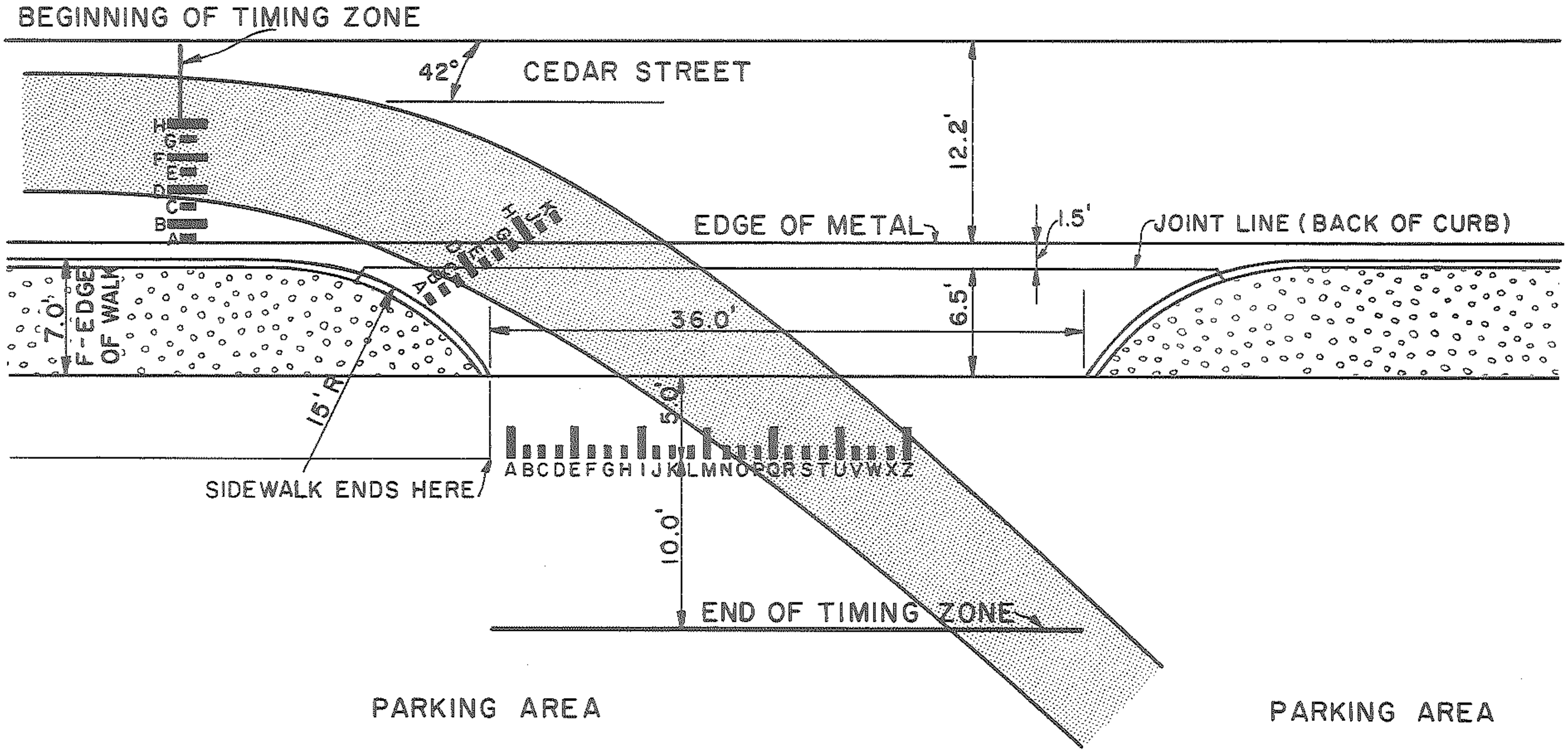


FIGURE 9 JOLLY-CEDAR PLAZA NO CONES

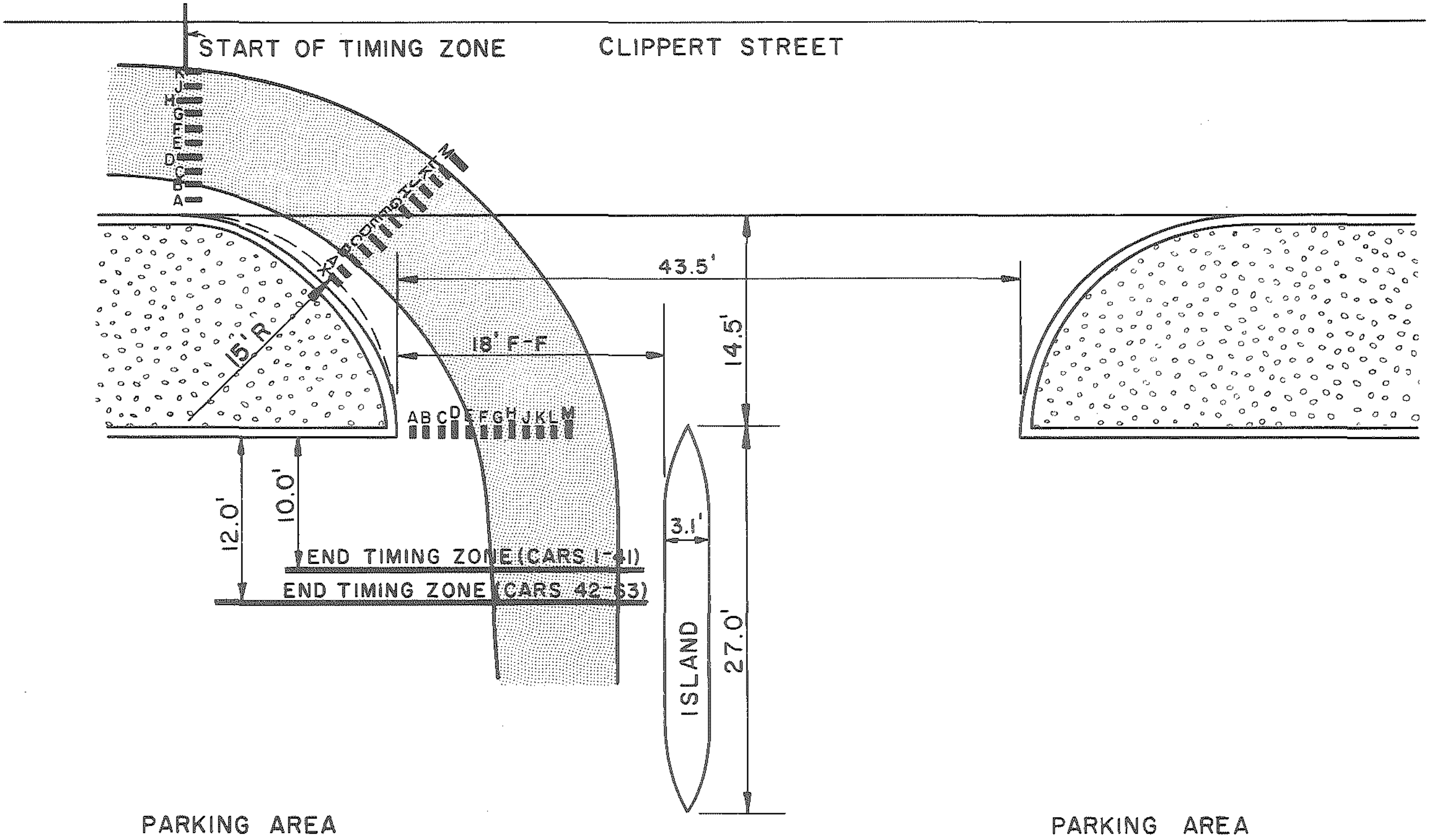


FIGURE 10 FRANDOR SHOPPING CENTER

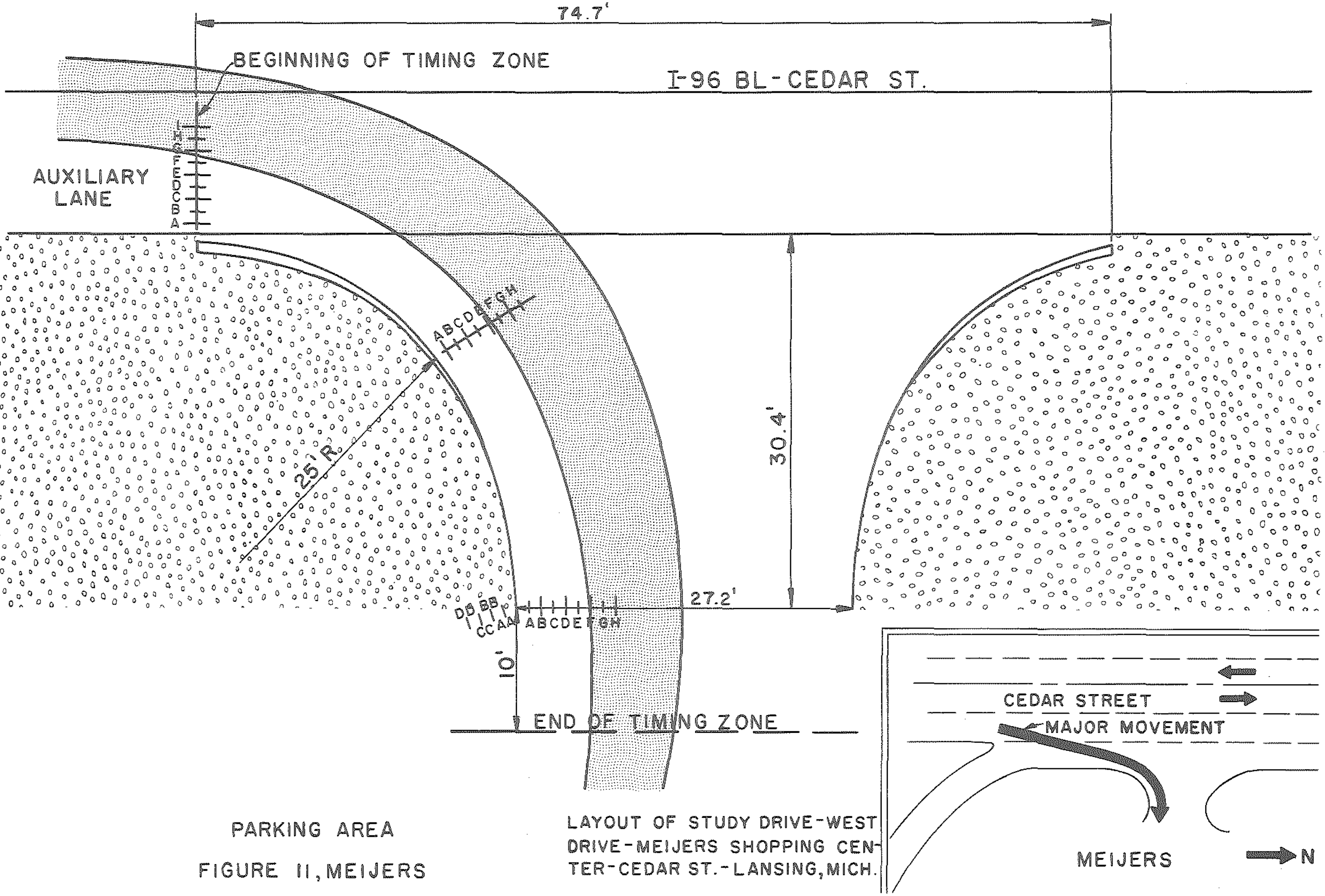


FIGURE 11, MEIJERS

LAYOUT OF STUDY DRIVE-WEST DRIVE-MEIJERS SHOPPING CENTER-CEDAR ST.-LANSING, MICH.

APPENDIX A

DEVELOPMENT OF DATA

The following description indicates how the data was obtained in the field and reduced to a meaningful form in the office.

SPEED DATA

Entering speeds were determined using stop watches and a timing zone laid out between two keel marks. The zone began in the street at the point where the entering vehicle initiated its turn into the driveway. The end of the time zone was placed in the driveway or parking lot where the vehicle had completed its turn and its wheels were straightened. The zones were set up to obtain only the driveway entering speed and not the approach or parking lot speeds. The timing zones are indicated for all the locations on Figures 5 through 11.

As entering vehicles were free to choose any desired path between the timing marks, it was necessary to determine vehicle placement or position. This allowed a fairly accurate (± 1 foot) determination of the actual vehicle path length within the timing zone. Vehicle placement was determined by photographing the entering vehicles as they passed over each of three sets of graduated paint or tape stripes on the pavement. Typical photographs of entering sequences are shown by Figures 1A through 18A. The placement marks were set at approximately the beginning, the mid-point and just before the end of the timing zone. They were spaced one foot apart and designated by letters of the alphabet (see Figures 5 through 11). In the office, the photographs were reviewed and the position of the right front tire in relation to the three sets of placement marks was recorded. Using scale drawings of the driveway, the three position points were connected with a smooth curve which was extended to the beginning and ending time zone marks. This was a plot of the path followed by the right front tire. The path length was then measured within the timing zone using a map mileage measuring wheel. Finally, the entering speed was determined by dividing the path length by the stop watch time.

To ensure that motorists entered the driveway at a self-selected speed, only single isolated vehicles or the first vehicle in a platoon of vehicles were used as samples. It was felt that any following vehicles would be forced to adjust their speed to that of the lead vehicle and would therefore be an invalid sample. At the Frandor driveway, where a traffic signal existed, only those vehicles approaching and entering the drive on a green signal phase were used.

PLACEMENT DATA

The placement data study made use of the tabulated placements of the right front tire which were determined for the speed study.

CURB STRIKING DATA

This information was determined by reviewing the photographs and counting the number of vehicles striking the curb. The photographs proved an invaluable aid in this respect.

FRANDOR
SHOPPING CENTER
LANSING, MICHIGAN

Fig. 1A

Fig. 2A

Fig. 3A

JOLLY-CEDAR
PLAZA
LANSING, MICHIGAN

Fig. 4A

Fig. 5A

Fig. 6A

MEIJER
THRIFTY ACRES
LANSING, MICHIGAN

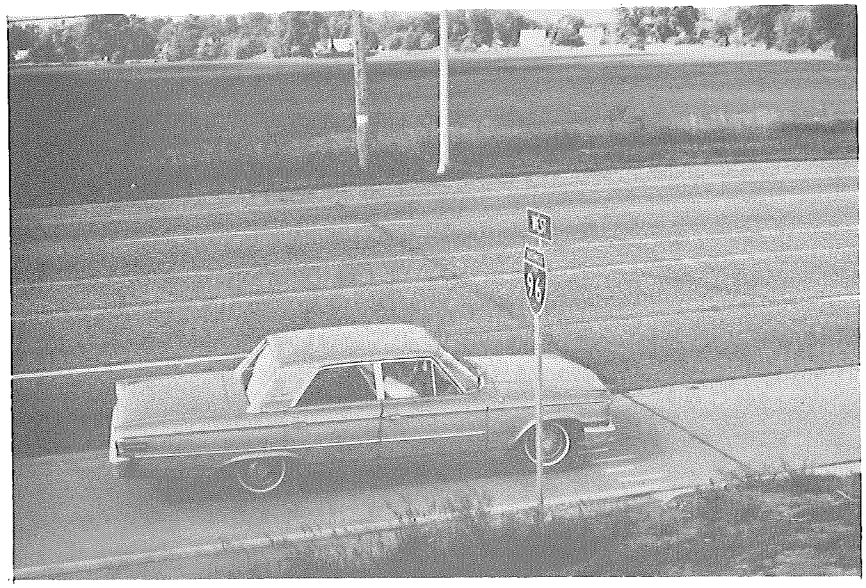


Fig. 7A

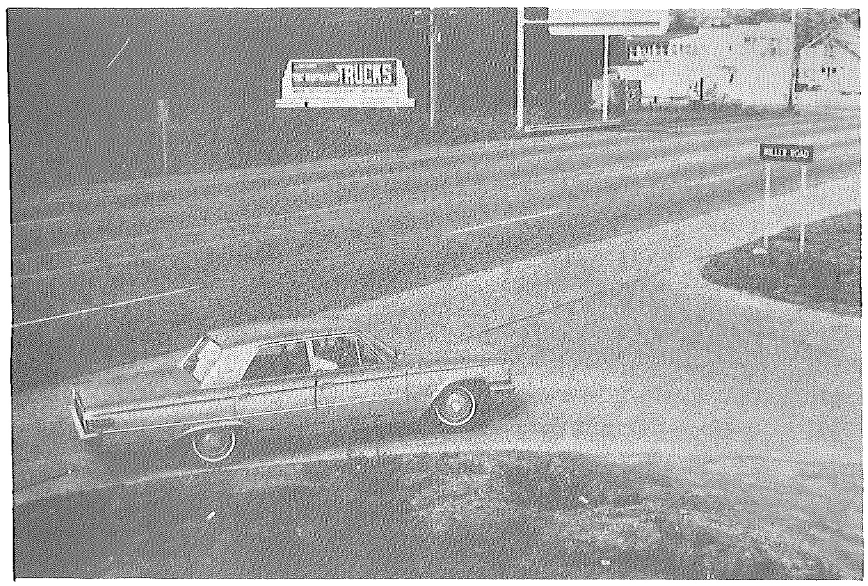


Fig. 8A

Fig. 9A

LOGAN CENTER
LANSING, MICHIGAN

Fig. 10A

Fig. 11A

Fig. 12A

K-MART
GRAND RAPIDS, MICHIGAN

WITH CONES

Fig. 13A

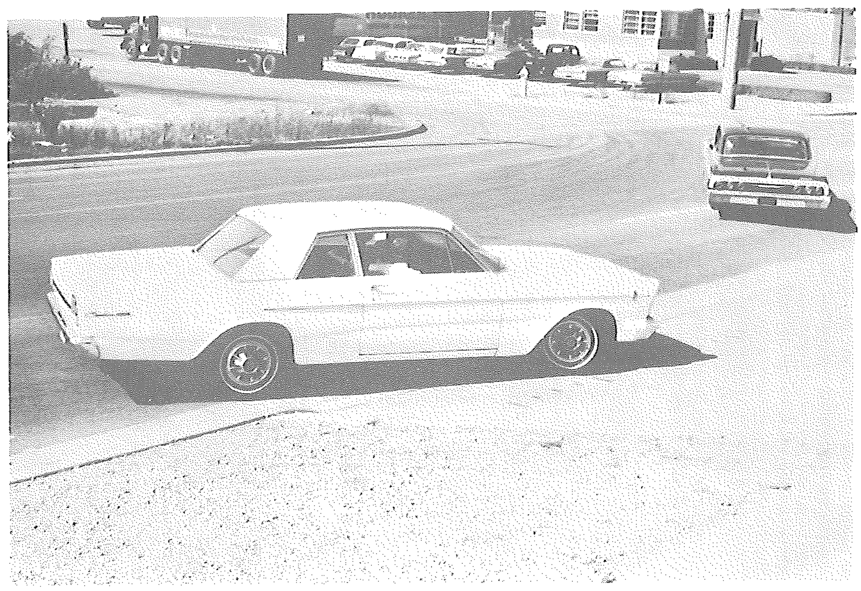


Fig. 14A

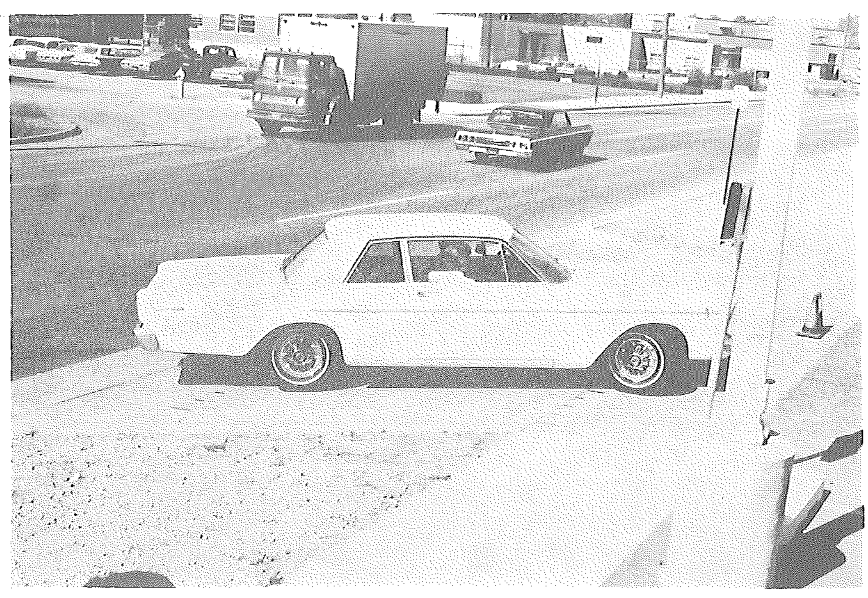


Fig. 15A

K-MART
GRAND RAPIDS, MICHIGAN

WITHOUT CONES

Fig. 16A

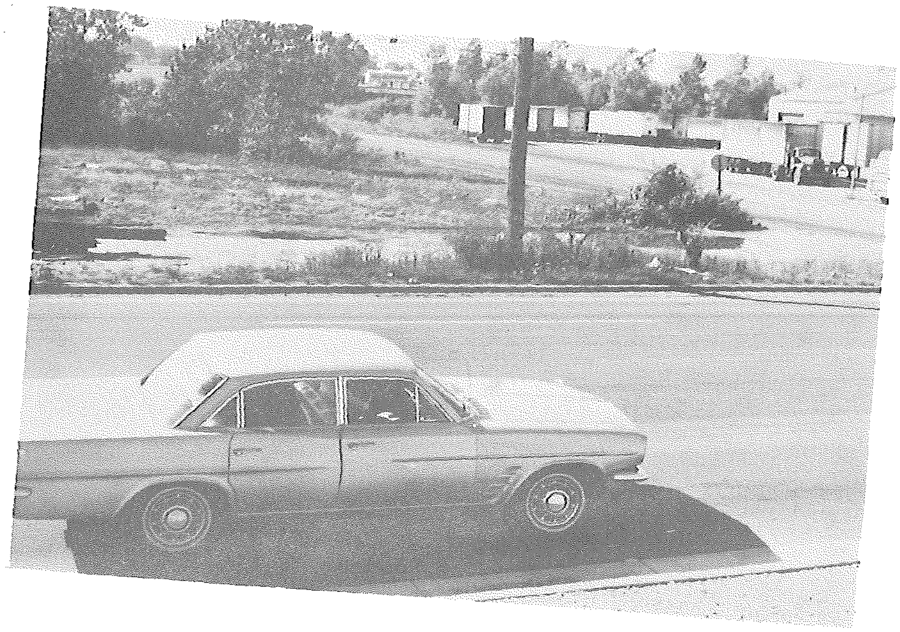


Fig. 17A

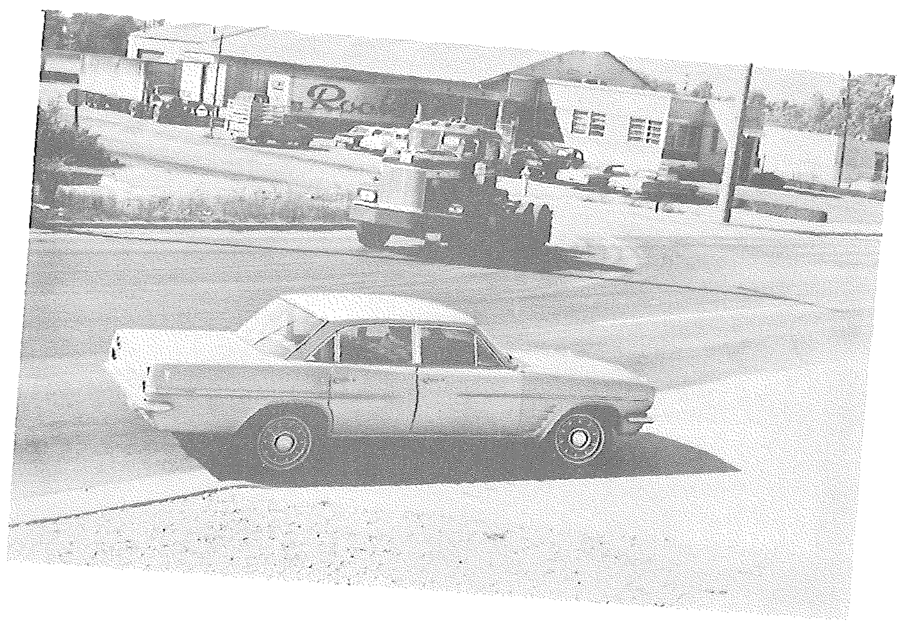
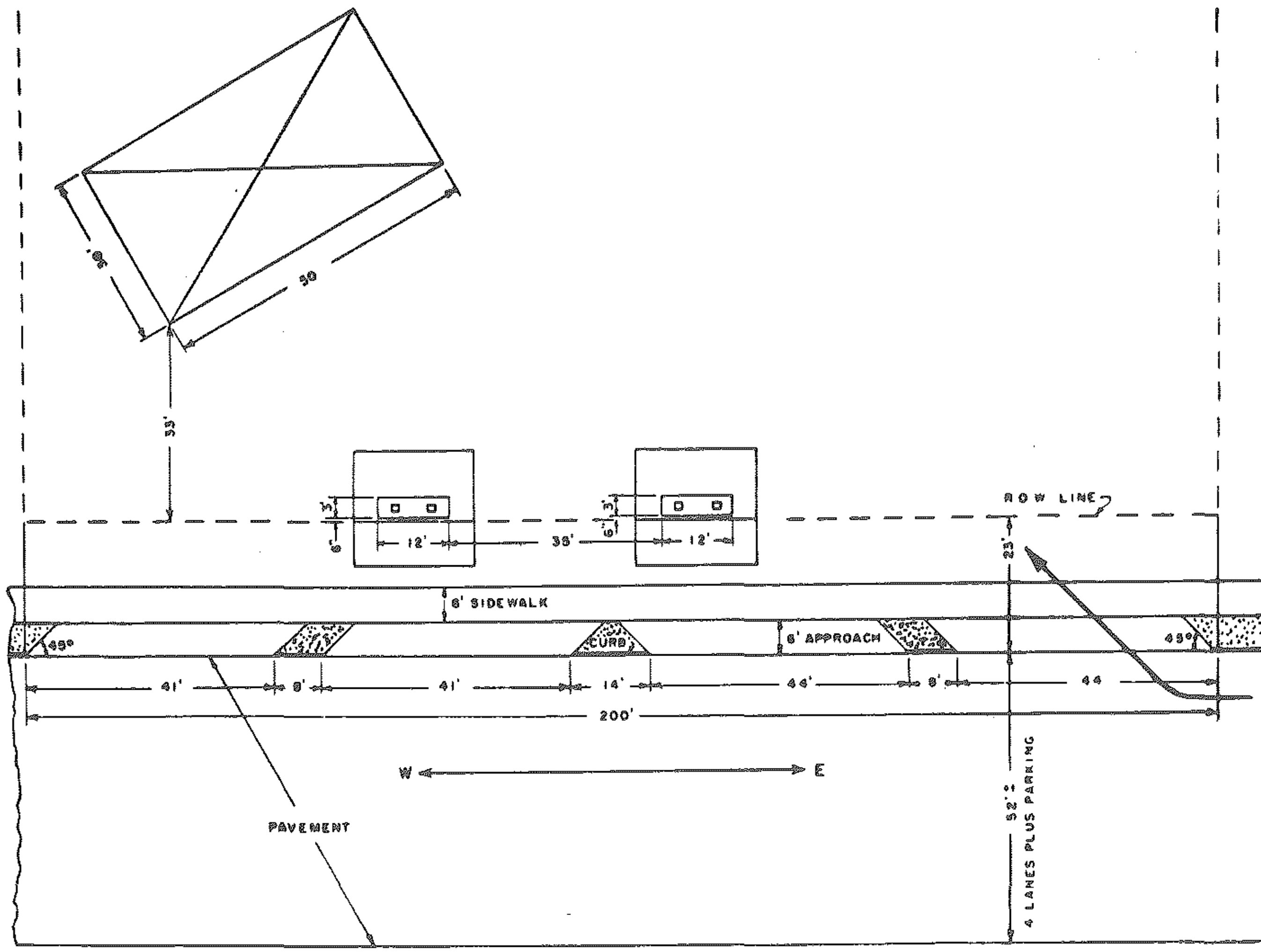
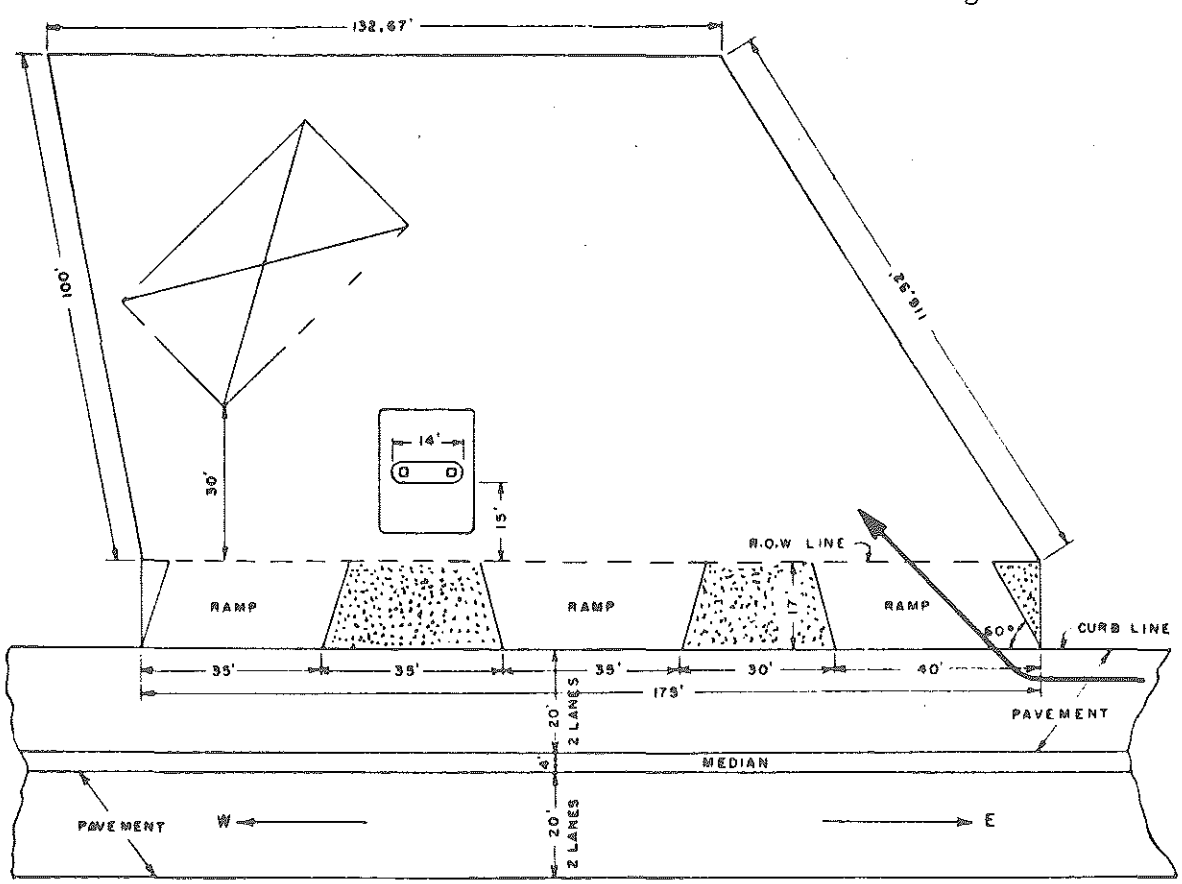


Fig. 18A



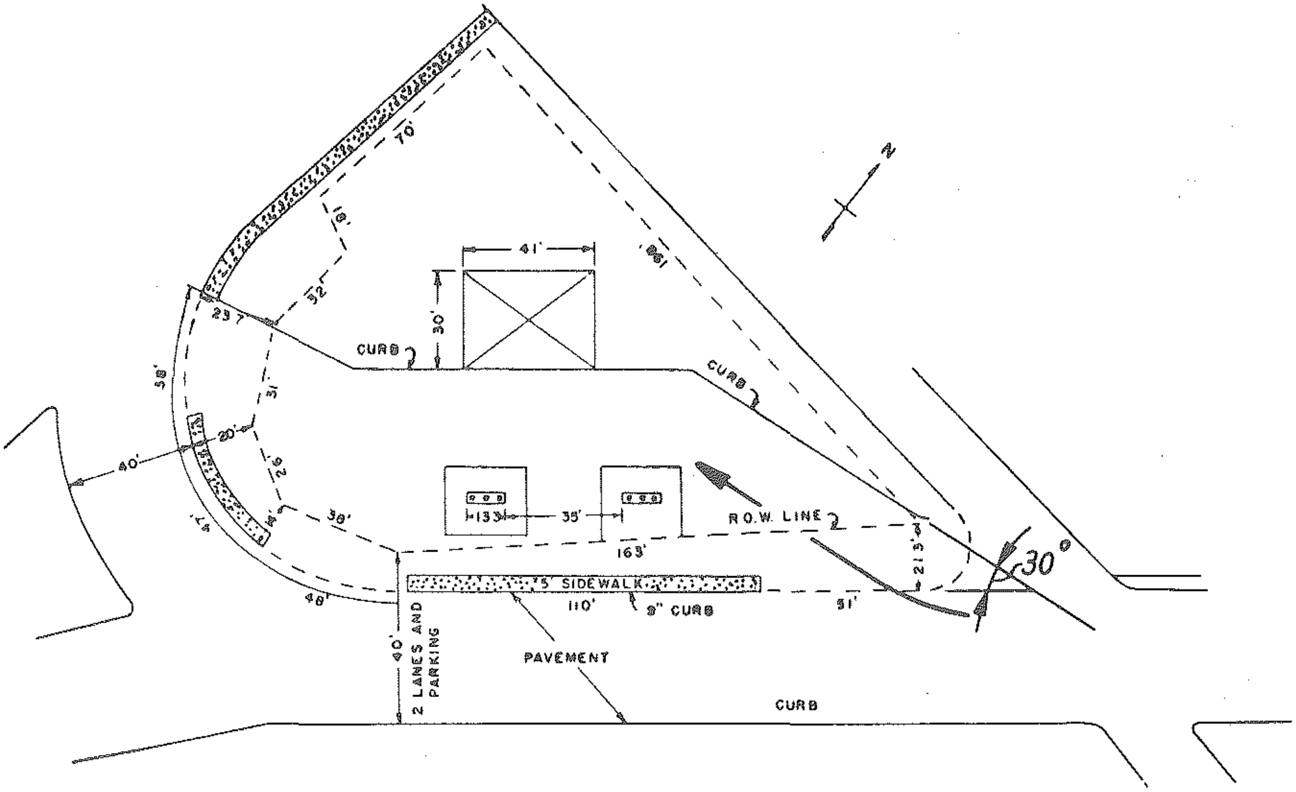
Layout of Station 1

Figure 19A



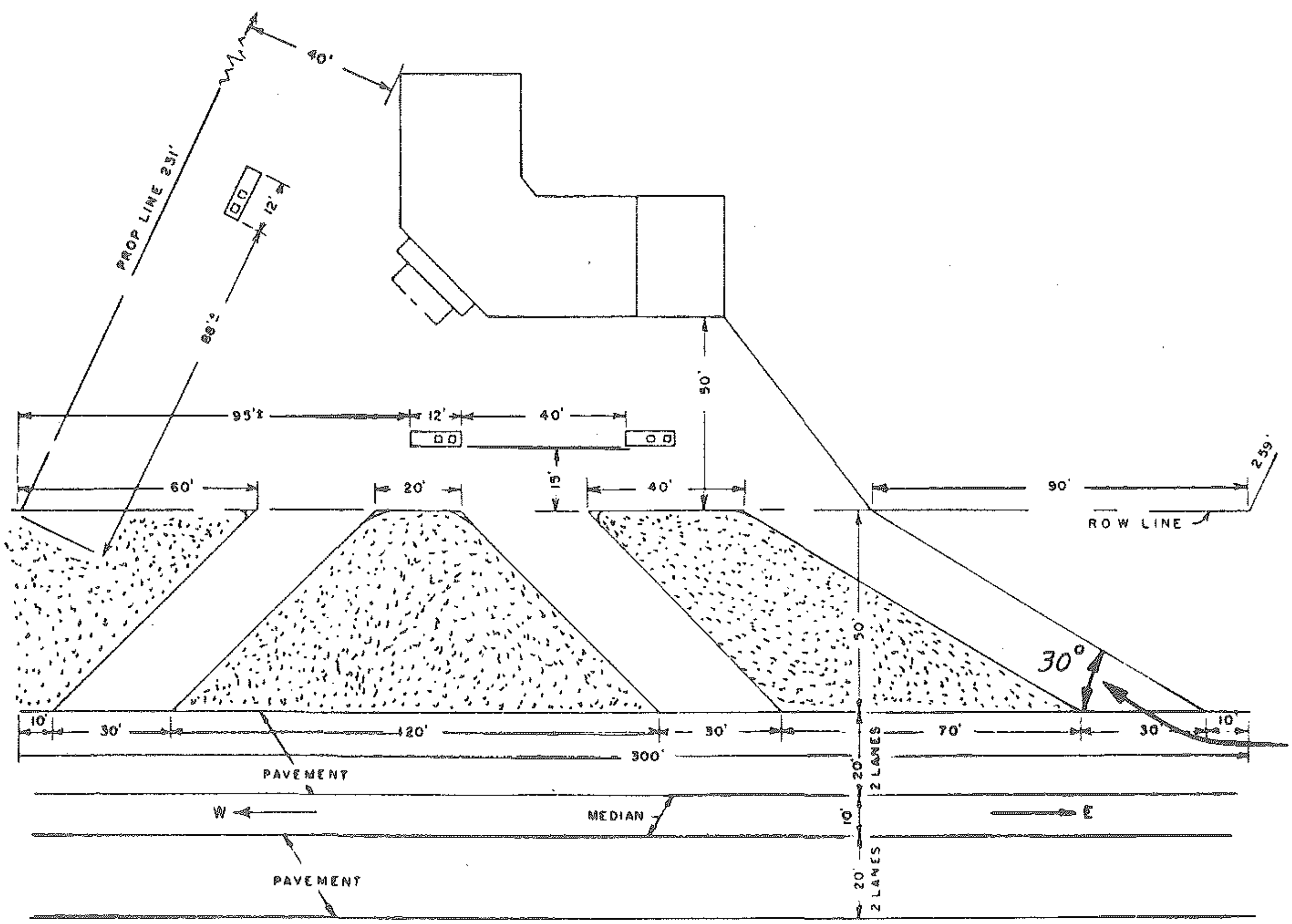
Layout of Station 2

Figure 20A



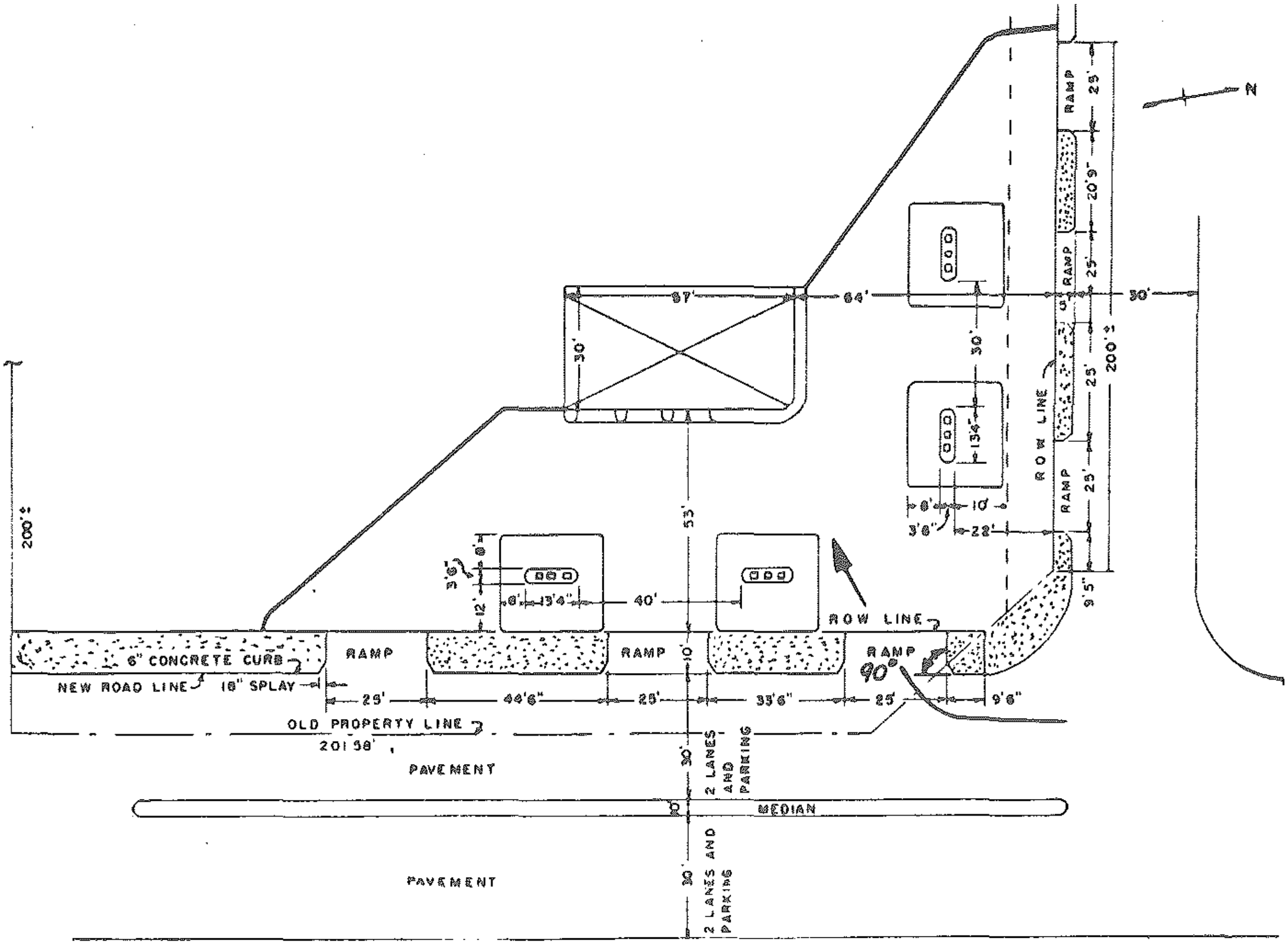
Layout of Station 3

Figure 21A



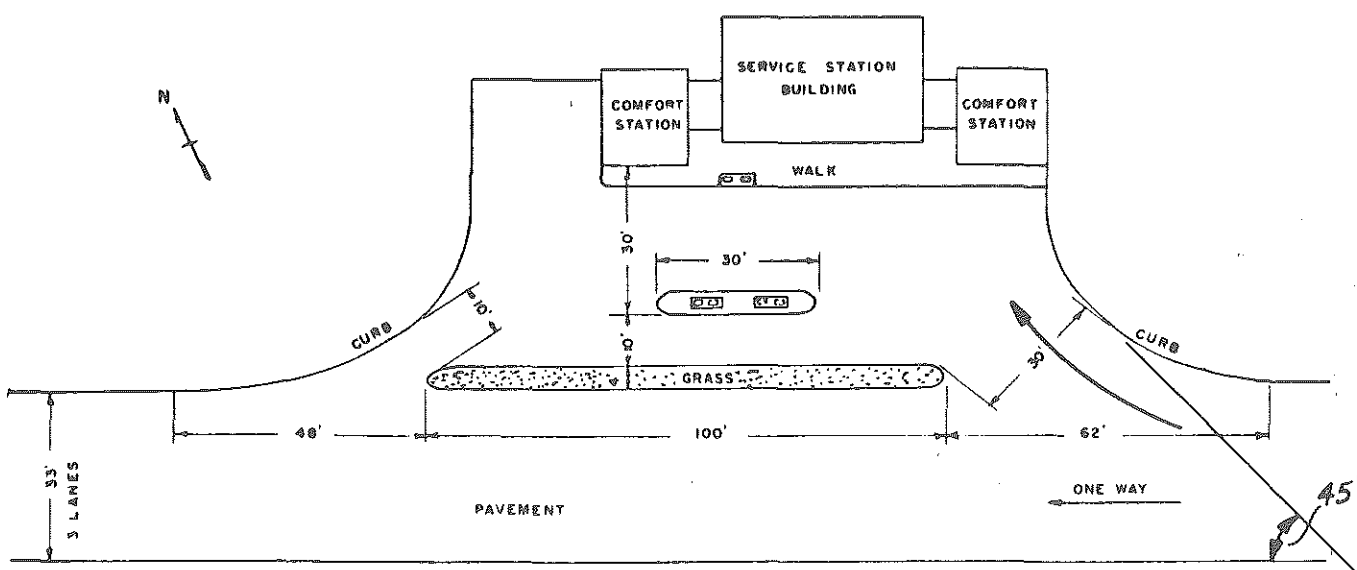
Layout of Station 4

Figure 22A



Layout of Station 5

Figure 23A



Layout of Station 6

Figure 24A

APPENDIX B

Cost Analysis of Urban Residential Driveway Approaches

The data gethered from field studies (A Study of Urban Driveway Approach Geometrics) suggests that a vehicle will enter a full-arc or partial-arc driveway faster, thus moving out of the through roadway traffic flow with minimum interference to following vehicles. A vehicle will also have less tendency to swing out into an adjoining lane before entering the driveway -- a movement that causes conflicts in traffic flow. In addition, the returning radius better delineates the driveway (particularly at night or in inclement weather) so the driver can adjust his speed far enough in advance of the driveway and will not have to make erratic maneuvers to exit from the roadway. Therefore, based on operational considerations, it can be concluded that the full-arc or partial-arc approach should be utilized for all driveways.

However, the question of how this proposed change affects construction costs must be considered before a final recommendation can be determined. The costs can be divided into two items; (1) curb and gutter and (2) concrete or bituminous pavement.

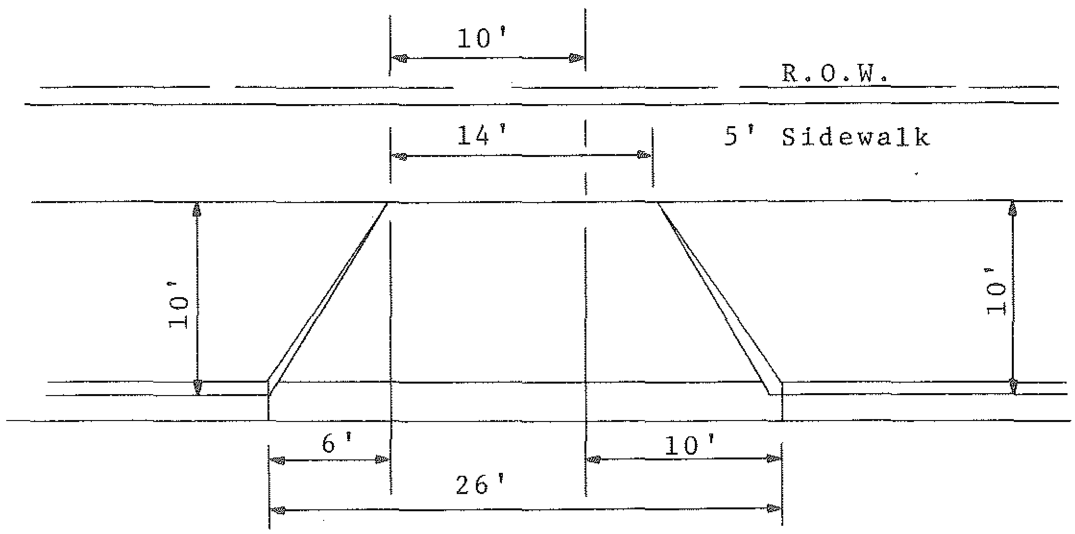
Since contractors bid curb and gutter on a lineal footage basis, it is difficult to estimate the increased cost of the curb and gutter portion of the driveway when the modified curb opening (which is required with the full-arc or partial-arc radius approach) is used instead of the curb cut opening required with the straight-taper approach. The contractor's bid prices reflect a number of considerations, which include location in the state, size of project, time allowed to complete the contract and the affected number of driveways and intersections included in the project. Recent contracts show costs for Detail 8 curb and gutter vary from $2.93 per lineal foot for 6,218 feet to $3.03 per lineal foot for 8,000 feet. For Detail 10 curb and gutter, the costs varied from $2.80 per lineal foot for 48,000 feet to $3.25 per lineal foot for 1,222 feet. In the case of Detail 8 curb and gutter, a higher unit price was paid on a larger project than on the smaller project. This is opposite to what is normally expected, but illustrates how other considerations can affect the contractor's bid price. To determine the cost differential between the two types of driveway openings, the Design Division was requested to make a cost comparison. Their conclusion was that the cost of providing either driveway opening was not a major consideration especially when weighed against other factors influencing the contractor's bids on curb and gutter for any given project. Therefore, the same cost per foot was utilized when estimating both treatments.

The driveway approach surface between the sidewalk and the gutter line is the second item that affects costs. Current practice is to provide 7-inch uniform concrete paving when the distance between the sidewalk and gutter line is 10 feet or less. Where this distance is greater than 10 feet, bituminous pavement is used unless no other bituminous pavement is required on the project, in which case concrete would be utilized. The recent cost of 7-inch uniform concrete paving ranges from 80 cents per square foot for 1,800 square feet to $1.15 per square foot for 4,807 square feet. The contractor also takes into account any subbase and drainage requirements, along with any other problems that may arise at a given location. Figure IB shows two residential driveway treatments, along with the cost estimates prepared by the Design Division. The first treatment is a typical urban residential driveway utilizing a straight taper which entails an estimated cost of $350, which included bid items for 7-inch uniform concrete (driveway approach), concrete curb and gutter (for length of gutter pan) and required earth excavation. The second treatment consists of two returning radii incorporated into the 7-inch uniform driveway approach. All other factors were considered by the Design Division to be equal, and the estimated cost was $275. Therefore, a savings of $75 for each typical urban residential driveway can be expected. Similar savings can be expected at commercial driveways because of the reduction in driveway approach area.

Therefore, from this analysis and from field studies, it is concluded that the decision to use the straight taper-type driveway approach based on lower costs is not justified, and the choice of driveway type should be based on traffic flow and operational considerations only.

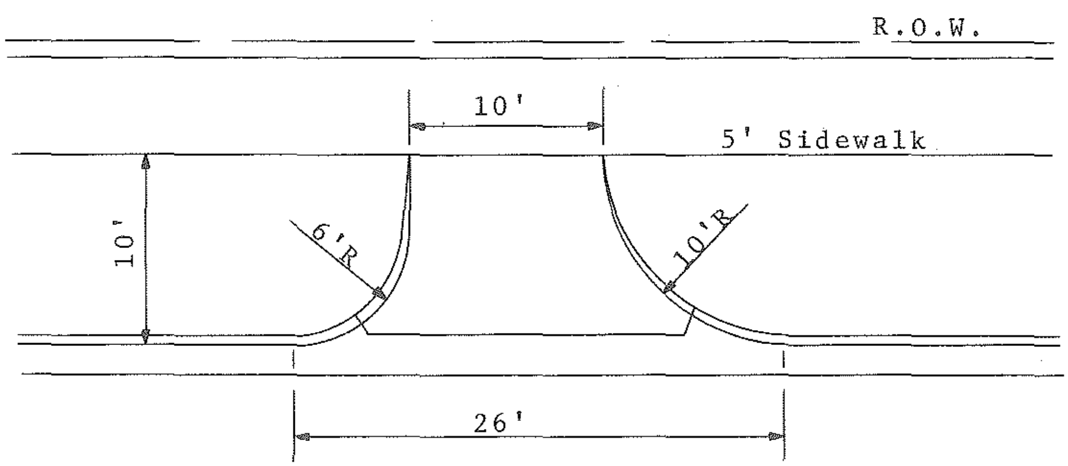
It is recommended that the Department of State Highways specify full-arc or partial-arc approaches for all driveways so that ingress and egress can be controlled more efficiently.

FIGURE IB



CURRENT PRACTICE FOR URBAN RESIDENTIAL DRIVEWAYS

ESTIMATED COST $350.00



PROPOSED TREATMENT FOR URBAN RESIDENTIAL DRIVEWAYS

ESTIMATED COST $275.00

NOTE: COST ESTIMATE PREPARED BY

DESIGN DIVISION ON 1-21-69