GEOMETRIC DESIGN OF DRIVEWAYS UPDATE

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ABSTRACT

NCHRP Project 15-35, Geometric Design of Driveways, is currently underway. After considering a number of possible options, the project oversight panel decided to focus project resources on the following issues related to driveway connections with public roadways.

1. Identify vertical geometry that will cause the underside of a vehicle to drag.
2. Determine the effects of different vertical geometries on the speeds and exposure times of vehicles entering driveways.

To examine the first issue, the research team measured and analyzed the underclearance dimensions of selected vehicles, and measured existing driveways with obvious scrapes from vehicle underbodies. For the second issue, the research team measured speeds and elapsed travel times of vehicles entering driveways with either relatively flat, moderate, or steep grades. The findings are expected to help answer some of the questions raised by those concerned about deceleration and speed differential of vehicles entering a driveway, or concerned about pedestrians' and bicyclists' exposure to turning vehicles. This paper discussed the current state of the project.

INTRODUCTION

One of the concerns that roadway designers must address is designing the connections of driveways to the public roadway. In 1959, the Executive Committee of the American Association of State Highway Officials (AASHO) ordered the printing of a guide for driveways on major highways. This document promulgated general principles and control dimensions, and mentioned geometric controls such as driveway radius, angle, gradient, and sight distance. Since then, a few research projects and the Institute of Transportation Engineers' Guidelines for Driveway Location and Design (1987) have addressed some aspects of driveway design.

In May 2005, an NCHRP panel announced an upcoming research project to study the geometric design of driveways, noting "The design of driveways has had little comprehensive research and no national design guide since the last AASHO guide published in 1959, which is now out of print." Besides the relative scarcity of recent research, other considerations include the different and sometimes conflicting perspectives among the various groups that occupy the area where the driveway connects with public roadways, as displayed in Exhibit 1.

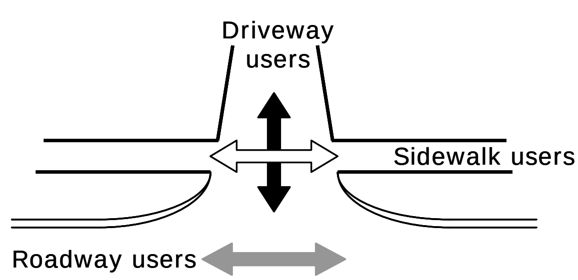


EXHIBIT 1 Conflicting Perspectives Among User Groups

OVERVIEW OF THE PROJECT

The project was divided into two phases, with each phase comprised of different tasks. The project was structured so that the findings from the first four tasks of the project (Phase 1) would be presented in an interim report.

The interim report included reviews of driveway-related literature, responses to a survey of state transportation agencies about their driveway design practices, and comments solicited from interest groups. From the information gained in these initial tasks, the contractor listed driveway geometric design elements and performance measures. The interim report discussed the need for research on these elements, and proposed topics for the project oversight panel to consider for additional research.

The original advertisement to solicit a contractor for the project called for the project oversight panel to define the scope of Phase 2 research, after which the contractor would perform the research and prepare a driveway design guide. Highlights from the interim report are presented in the following paragraphs.

Literature Review

About 90 documents that pertained to some aspect of driveway design were reviewed. Most of the documents were related to the operation of motor vehicles. Several more-recent publications, however, also covered pedestrian and Americans with Disabilities Act (ADA) requirements. Topics covered in the literature review included user characteristics, safety, driveway entry geometry, driveway angle, setbacks for on-site storage, right turn lanes, vertical alignment, coordinating bus stops and driveways, and access location and spacing.

Survey of Transportation Agencies

Sixteen state transportation agencies and one local agency responded to the survey. Most agencies reported that their driveway design standards or practices differed according to development density, land use type, or roadway characteristics. Most had an access management code or policy. For commercial and residential driveways, there was a slight preference for the curved entry-edge transition over the flared or tapered treatment as the design of first choice.

None of those responding allowed a direct connection with an unpaved driveway; a plurality of respondents required paving the driveway all the way to the right-of-way line. Reported problematic issues included those related to driveway grades, and to the entry-edge transition.

Driveway Geometric Design Elements

A number of driveway design factors were identified and related to the range of users (including bicyclists, motorists, and pedestrians), to vehicles, to the public roadway, and to the surrounding environment. The designer often has some influence over some 60 factors (listed in Exhibit 2), but about 30 of these factors (listed in Exhibit 3) are usually beyond the control of the driveway designer.

	Shared Elements, Surroundings	
1	Illumination	
2	Conspicuity	(to visually detect an element at a distance)
3	Sight obstructions	
	Driveway	
4	Width	(maximum and minimum; sufficient for ped. refuge)
5	Lanes	(number, width)
6	Median in driveway:	(absence or presence)
7	width	
8	type	(raised, flush, depressed)
9	nose-end recessed from edge of through-rd.	
10	Cross slope, cross slope transition runoff	
11	Horizontal alignment, curvature	
12	Connection depth (throat length)	
13	Traffic controls or other potential impediments to inbound traffic (inc'l entry gate)	
14	Paving length	(applicable where dirt driveway)
15	On-site turn-around capability	(where backing into roadway is undesirable)
16	Driveway edge	(edge drop off, barrier)
17	Space for nonmotorized users	(e.g., pedestrian movement parallel to driveway)
18	Driveway border treatments	(sideclearance, sideslope)
19	Grade	(maximum and minimum)
20	Change of grade (grade breaks)	
21	Vertical curve design criteria	
22	Drainage (separate from intersection drainage)	
23	Other special situations	(e.g. railroad crossing, trail, bridle path, etc.)
	Sidewalk-Driveway Intersection	
24	Sidewalk cross slope (i.e., driveway grade)	
25	Path definition	(e.g., visual, tactile cues)
26	Crossing length (i.e., driveway width)	
27	Angle of intersection with driveway:	
	flat-angle (turn angle $< 90^{O}$); right-angle (turn angle $\approx 90^{O}$); sharp-angle (turn angle $> 90^{O}$)	
28	Bearing of sidewalk relative to street:sidewalk diverging from, parallel to, or converging with the street	
29	Grade of sidewalk (i.e., driveway cross slope)	
30	Vertical profile of pedestrian route	(abrupt elevation change: max. 1/4")
31	Sidewalk-driveway interface treatment:detectable warnings for visually impaired (e.g., truncated dome)	
		(only at certain locations, inc'l. a signalized crossing; refer to guidelines)
	Roadway-Driveway Intersection	
32	Angle of intersection with street:	
	flat-angle (turn angle $< 90^{O}$); right-angle (turn angle $\approx 90^{O}$); sharp-angle (turn angle $> 90^{O}$)	
33	Cross slope of street and shoulder, considered with driveway grade	
34	Curb threshold treatment	(rolled, vertical lip, counterslope, continuous)
35	Curb-termination treatment	(abrupt end, drop-down, returned)
36	Entry transition shape	(e.g. radius, flare/taper, straight, etc.)
37	Entry transition-shape dimensions	(radius, flare dimensions)
38	Channelization of right turn from street into driveway	
39	Channelization of right turn from driveway into street	
40	Channelization in the driveway: triangular island to prohibit in and out left-turns	
41	Channelization in street - street median prohibits all left-turns in/out of driveway	
42	Channelization in street - street median prohibits one but not both left-turns	
43	Drainage: confining the gutter flow	
44	Drainage: inlet type and location	
45	Clearance from utility appurtenances	
46	Pavement surface deformity	(corrugation, potholes)
	Traffic Controls (for driveway vehicles)	
47	Stop controls	
48	Signal controls	
49	Turn restrictions	
50	One-way operation	
	Roadway in vicinity of the Driveway	
51	Right-turn lane attributes:	(absence or presence)
52	right-turn lane deceleration, storage length	
53	right-turn lane entry transition shape	
54	right-turn lane offset	
55	Left-turn lane attributes:	(absence or presence)
56	left-turn lane deceleration, storage length	
57	left-turn lane entry transition shape	
58	left-turn lane offset	
59	Number of driveways per site	
60	Driveway spacing from upstream access connection	
61	Driveway spacing from downstream access connection	

EXHIBIT 2 Driveway Elements the Designer May Have Some Control Over

	Shared Elements, Surroundings	
1	Land use	
2	User and vehicle mix and composition	
3	Temporal variation: season, day of week, time of day	
4	Weather and weather effects	
	Roadway-Driveway Intersection	
5	Elevation difference between roadway surface and abutting property	
	Roadway in vicinity of the Driveway	
6	Width of roadway	
7	Lanes	(number, width)
8	Lane type	(travel, HOV, bicycle, turn, parking)
9	Cross slope (travel lanes, shoulders)	
10	Horizontal alignment of roadway	
11	Vertical alignment of roadway	
12	Sight distance restrictions	
	User characteristics - Bicyclist	
13	Bicyclist perception-reaction process, time	
14	Speed	
15	Braking capability	
16	Sight distance need	
	User characteristics - Pedestrian	
17	Pedestrian perception-reaction process, time	
18	Speed	
19	Sight distance need	
20	Special needs groups	General - children, elderly
21		Impaired (e.g., mobility, visually)
22		Legal mandates - disabled
	User characteristics - Vehicle, Driver	
23	Driver perception-reaction process, time	
24	Speed	
25	Deceleration characteristics (typical)	
26	Braking capability (limiting)	
27	Sight distance need	
28	Vehicle width	
29	Vehicle length	
30	Vehicle turning radius	
31	Vehicle front overhang, wheelbase, rear overhang, and ground clearance dimensions	

EXHIBIT 3 Driveway Elements the Designer Usually Has Little Control Over

Research Issues

The following 14 key geometric or geometry-related elements were identified, and performance measures were developed for each.

1. Cost and constructability
2. Visual and tactile cues (to identify the sidewalk path and driveway) and pedestrian route accessibility
3. Driveway width (as perceived by bicyclists and pedestrians)

4. Driveway entry plan-geometry effects on turning vehicles (related to driveway width, as perceived by motorists)
5. Driveway throat design
6. Driveway border design
7. Channelization
8. Sidewalk cross slope (driveway grade)
9. Driveway grade (sidewalk cross slope) and vertical alignment
10. Roadway-driveway threshold treatment
11. Driveway visibility
12. Auxiliary lanes for right-turn entry movements into driveways
13. Drainage of surfaces occupied by user groups
14. Spacing between driveways

Based on the adequacy of current information and the perceived importance of each element, the need and desirability for further research was also presented. After an analysis and discussion of these issues, the interim report suggested that the project oversight panel consider the following five topics for research.

1. Analysis of driveway influenced crashes
2. Visual and tactile cues to identify the pedestrian route across the driveway
3. Effects of driveway plan-geometry on turning vehicles
4. Driveway triangular islands
5. Driveway vertical alignment guidelines

The interim report contained work plans for these five topics suggested for further research. It gave reasons for conducting research on each of the five, proposed methodologies, noted factors that might affect success, and provided preliminary cost estimates.

The project oversight panel met with the contractor to discuss possible research topics, and after discussing various options, directed the contractor to perform research activities related to the design of the vertical alignment of driveways during Phase 2 of the project. Specifically, the plan called for the contractor to:

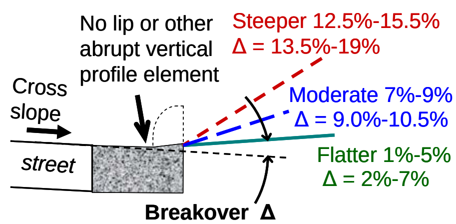
1. based on measurements of selected vehicles, determine the grade change at which vehicles drag;
2. based on measurements of driveways with visible scrape marks, determine what driveway profiles cause the undersides of vehicles to drag; and
3. assess the effects of certain profile differences on the speeds and elapsed travel times of vehicles entering a driveway.

Exhibit 4 lists these activities, along with a brief description of them as they evolved over the course of the project.

DETERMINING THE GRADE CHANGE AT WHICH VEHICLES DRAG

To determine the change in vertical profile at which the underside of the vehicle will drag, one makes x- and y-coordinate measurements of the critical points on the underside of a vehicle that will define a profile or silhouette of the vehicle's underside. Then one conducts a geometric analysis to determine the least change in profile grade that will impinge the underside of the vehicle. Exhibit 5 displays the geometry of this analysis.

EXHIBIT 4 Summary of Project Research Objectives

Objective	Description of Work	Additional Information
1. Determine the crest and sag grade changes at which a static vehicle drags the underside.	Measure the underclearance of three or four selected vehicles. The contractor analyzed five (one additional) vehicles. Measurements for the pickup truck and trailer were obtained from manufacturers' literature. All others were measured by the contractor.	P-car: Chevy Camaro, Corvette Ford F-150 pickup w/trailer Class A diesel motor home Tractor w/10-bay beverage trailer
2. Determine what actual driveway profiles cause the undersides of vehicles to drag.	Measure driveways that have a visible indicator of a vertical alignment problem. The contractor found driveways with scrape or gouge marks on the pavement surface, near where the driveway intersects the street, then measured the driveway profile.	
3. Assess the effects of profile changes (roadway cross slope – driveway grade) at roadway-driveway interface and driveway grades on the speed and elapsed time of vehicles turning left and turning right into a driveway.	The contractor located a pool of driveways similar in many respects, but with different grades, then measured speeds and elapsed times of vehicles turning into the driveways. The driveway were assigned to the following three grade groups: • steeper grades (12.5%-15.5%, breakover 13.5%-19%) • moderate grades (7%-9%, breakover 9%-10.5%) • flatter grades (1%-5%, breakover 2%-7%)	 The speeds and elapsed times for vehicles turning right and turning left in to the three driveway grade groups were compared to determine what effect grade has. This is related to both the exposure of turning vehicles to crashes due to speed differential, and exposure of sidewalk users to turning vehicles.

There are two modes in which the underside of a vehicle can drag or hangup. One mode occurs when the road profile creates a sharp vertical crest, which causes the underside of the vehicle between the front and rear axles to drag on the pavement surface. The other mode occurs when the road profile creates a sharp vertical sag, which causes the underside of the vehicle either to the front of the front axle or to the rear of the rear axle to hang up. Exhibit 6 displays both of these conditions.

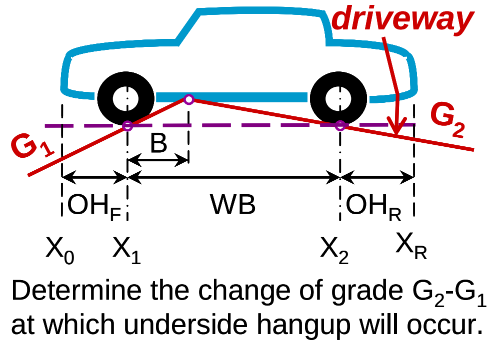


EXHIBIT 5 Vehicle Underclearance Geometry

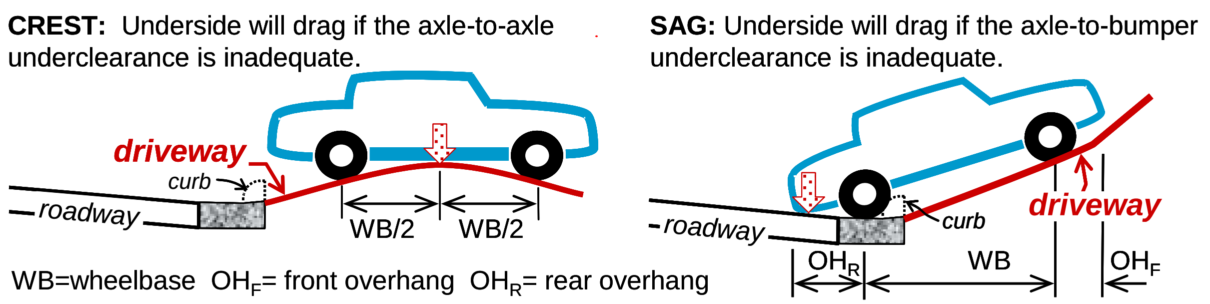


EXHIBIT 6 Two Modes of Vehicle Underside Dragging

Selecting and Locating Vehicles

The project panel directed the contractor to measure the underclearance dimensions of at least three vehicles. The project panel specified that the vehicles to be measured include a small automobile and a Class A motor home ("diesel pusher"), and the contractor suggested a pickup truck pulling a trailer and a beverage delivery truck.

To locate vehicles to measure, the contractor contacted nearby automobile dealers, beverage distributing companies, and recreational vehicle dealers. The underclearance of one automobile was measured on a dealer's lot, and another was measured on a dealer's showroom floor. The beverage delivery truck was measured inside the distributor's warehouse. The motor home was measured on a dealer's lot. Dimensions for the pickup truck and trailer were obtained from manufacturer's literature.

Measuring Vehicle Underclearances

To measure the underside in hard-to-reach areas, a technician fabricated a specially designed measuring jig. This jig, shown in Exhibit 7, consisted of a black rigid flat base, a silver vertical rod at each end of the base, and an orange rigid parallel bar with bushings on each and that allowed the bar to slide up and down on the two vertical rods. To measure the vertical clearance at any given spot, two people slide the rigid parallel bar up to contact the underside of the vehicle, then make a measurement from the ground up to the top of the rigid bar.

EXHIBIT 7 Measuring Vehicle Underclearance

Vehicle Underclearance Measurement Findings

Exhibit 8 shows the resulting x- and y-coordinates of the points that define the underside profile of one of the measured vehicles. From these measurements, the profile or grade change at which the vehicle would drag in both crest and sag conditions was computed. Note that these measurements represent a static condition. The measurements do not account for the effects of additional static loading on the vehicle (such as weight of the passengers or cargo), or for the vertical displacement which may result from the dynamic forces on the vehicle in motion. In actual driving conditions, one would expect underside dragging to occur at grade changes that were somewhat less than those described in Exhibit 9, which shows the calculated grades at which underside dragging would occur.

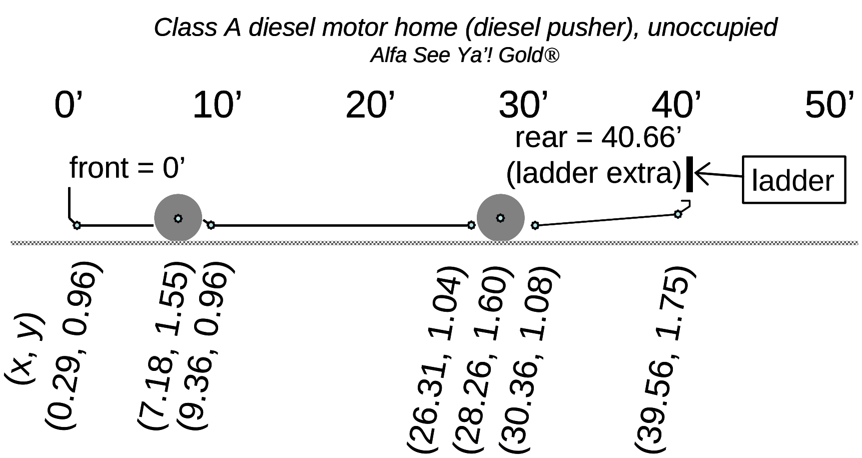


EXHIBIT 8 Measured Coordinates of Vehicle Undersides

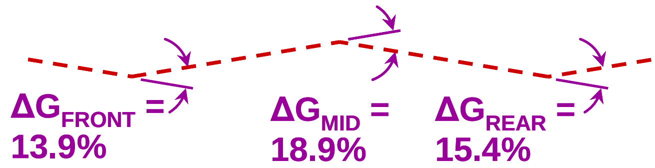


EXHIBIT 9 Calculated Profile Change at Which Dragging Occurs

IDENTIFY DRIVEWAY PROFILES THAT CAUSE VEHICLES TO DRAG

Visible scrape marks on the surface that result from the dragging of vehicle undersides can be clear indicators that the profile geometry of an existing driveway is too abrupt. The project panel directed the contractor to measure the profiles of driveways with scrape marks that the contractor encountered during the course of conducting the research.

Some of these driveways were measured by one person with a 24-inch digital level, while others were measured by two-person crew with land surveying equipment. Typically, two profiles were measured. For instance, for driveway with visible scrape marks on the entry side, the entry-side edge and the driveway centerline were profiled. One of the driveways with visible scrape marks that the contractor measured is shown in Exhibit 10. Exhibit 11 shows one of the profiles drawn from measurements made at a driveway with visible scrape marks. The various profiles will be examined to identify the least-abrupt profiles that caused dragging.

EXHIBIT 10 Example of a Driveway with Visible Vehicle Underside Scrape Marks

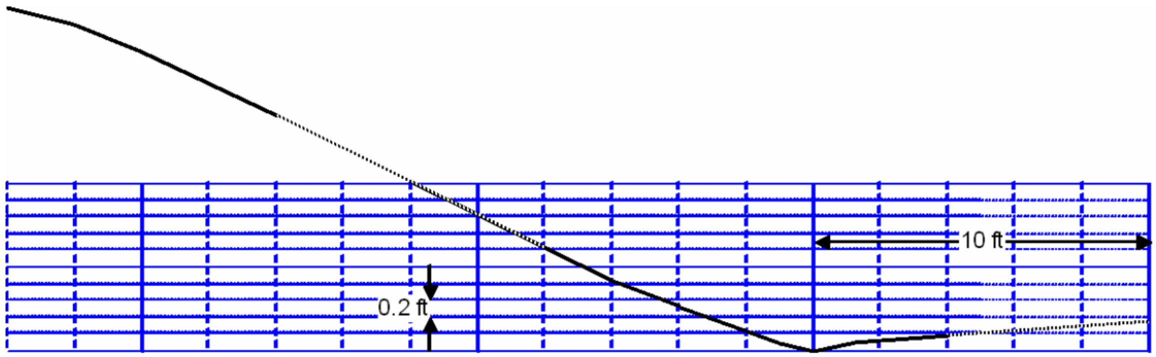


EXHIBIT 11 Example Profile of a Driveway with Visible Scrape Marks

SPEEDS AND ELAPSED TIMES OF ENTERING VEHICLES

In order to study the speeds and elapsed travel times of vehicles entering driveways of different grades, the researchers determined that the sites selected should possess attributes that are representative of a broader population of driveways. To the extent possible, the driveways studied should have similar attributes in order to reduce the variability among the attributes of the sites at which the data would be collected. However, the researchers recognized that it was highly unlikely to find sites having the same widths, entry shapes, and shape dimensions. One factor that could increase the similarity among the sites, in terms of characteristics such as volume and speed of traffic on the through street, would be to select some driveways along the same street or on similar arterial roadways in the same part of a city.

Establishing Site Selection Criteria

The initial criteria the researchers developed for identifying potentially suitable driveways for data collection evolved during the course of the research. Some of the criteria choices were affected by what traits were being frequently encountered. The following criteria helped identify a pool that is typical of those driveways serving small- to medium-sized commercial and professional office developments that became quite common in the latter part of the 1900s along suburban multilane arterial roadways.

General Traits

1. The site has space to accommodate people and equipment collecting the data, with a clear line of sight to the driveway entry
2. The driveway is not built to appear like a street (note: this tends to exclude driveways to large commercial developments, such as large shopping centers)
3. Through-street posted speed limit is either 35, 40, or 45 mph
4. The driveway has sufficient volume to make the time spent in data collection productive

Plan View Design

5. Driveway is either 2 or 3 lanes wide
6. The driveway does not have pavement markings that would conflict with the standard marking the contractor installs at each site
7. Driveway throat length (connection depth) is not less than 23 feet (ft), measured from face of curb

8. Driveway entry shape is curved (i.e, not tapered/triangular) with a radius of from 13 to 20 ft
9. Driveway intersects street at or close to a 90^{O} angle
10. Both the driveway and the through-street are fairly straight where they connect
11. Driveway connects to a multilane street
12. The width of the through-street outer lane from curb face to lane line is between 10.5 and 12.5 ft (e.g., no shoulder, bike lane, or auxiliary right-turn lane)
13. The through-street has a separate left-turn lane or a two-way left-turn lane (TWLTL)

Vertical Alignment
14. No vertical lip at the roadway-driveway interface
15. The driveway does not slope markedly downward from the through-street into the site
16. The street grade is relatively flat, not steep

Operations - Driveway Interaction with Other Traffic
17. Driveway is not signalized
18. Driveway traffic operations are not often affected by a nearby traffic signal, such as the backup queue from a nearby signalized intersection
19. Enough separation so driveway traffic is not often affected by any other driveway or street

Selecting Suitable Sites

Searches for suitable data collection sites were made in parts of six states. Recognizing that the only way to obtain a perfect set of data collection sites would be to fund and construct the driveways specifically for this project, the researchers exercised judgment to evaluate potential driveway sites. Visual inventories were made along many miles of roadway in a number of cities. At promising sites, the researchers measured attributes such as width and entry radius. The process eventually identified a list of driveways with relatively similar characteristics. The selected driveways were grouped into one of the three categories shown in Exhibit 12.

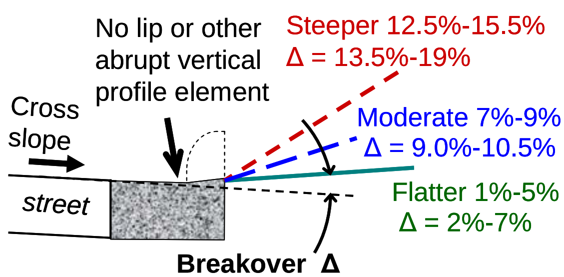


EXHIBIT 12 Driveway Groups

- The steeper driveways have grades up from the gutter line of 12.5% to 14.5%, with changes of grade between roadway cross slope and the driveway grade (i.e., breakover grade) ranging from 13.8% to 18.6%.
- The moderate-grade driveways have grades up from the gutter line between 6.0% and 8.7%, with breakover grades ranging from 9.0% to 10.5%.
- The flatter driveways have grades up from the gutter line between 1.6% and 4.7%, with breakover grades ranging from 3.7% to 6.5%.

All of the 12 driveways chosen for data collection serve small to medium-sized commercial or office tracts abutting suburban arterial roadways. The sites selected in Austin, Texas were all along the same arterial roadway. The sites selected in Tulsa and in the suburb of Broken Arrow, Oklahoma were all in the southeast part of the metropolitan area, where Tulsa and Broken Arrow abut. One site was in Fayetteville, Arkansas. An example site is shown in Exhibit 13.

EXHIBIT 13 Example Driveway Study Site

Questions About Driveway Profiles

Each of the sites was tagged with both quantitative and qualitative descriptors, such as the land-use activity, or the dimensions of the driveway. To define the profiles, the contractor initially had used surveying equipment to read the elevations of the observed break points along the profiles of each driveway. The project panel expressed concern that the contractor may have not taken elevation readings at intervals spaced closely enough to truly capture the profiles of the driveways. To check this, the contractor resurveyed some of the driveways, taking readings at closely spaced intervals. Exhibit 14 compares one of the profiles generated from the initial survey and from the "checking survey". To illustrate how the information from the initial survey can be compared with the later re-survey, the original profile of the Arvest driveway determined from shots made only at the observed breakpoints was reported as a street cross slope of 1.2% and a driveway grade of 12.6%, creating a breakover angle of 13.8%. From the re-survey with closely-spaced shots, the street grade was 1.15%, the driveway grade was 12.52%, with a resulting breakover grade of 13.67%. These resurveys indicated that the profiles constructed from the initial surveys (calculated grade) were very close to the profiles made from the more detailed follow-up checking surveys (actual elevation).

Data Collection Procedures

The contractor used contact closure switches to record the speeds and elapsed travel times between successive sensors as vehicles turned right or turned left into the driveway. Exhibit 15 displays these patterns. Data for vehicles turning right into a driveway were collected separately from left turn entry data.

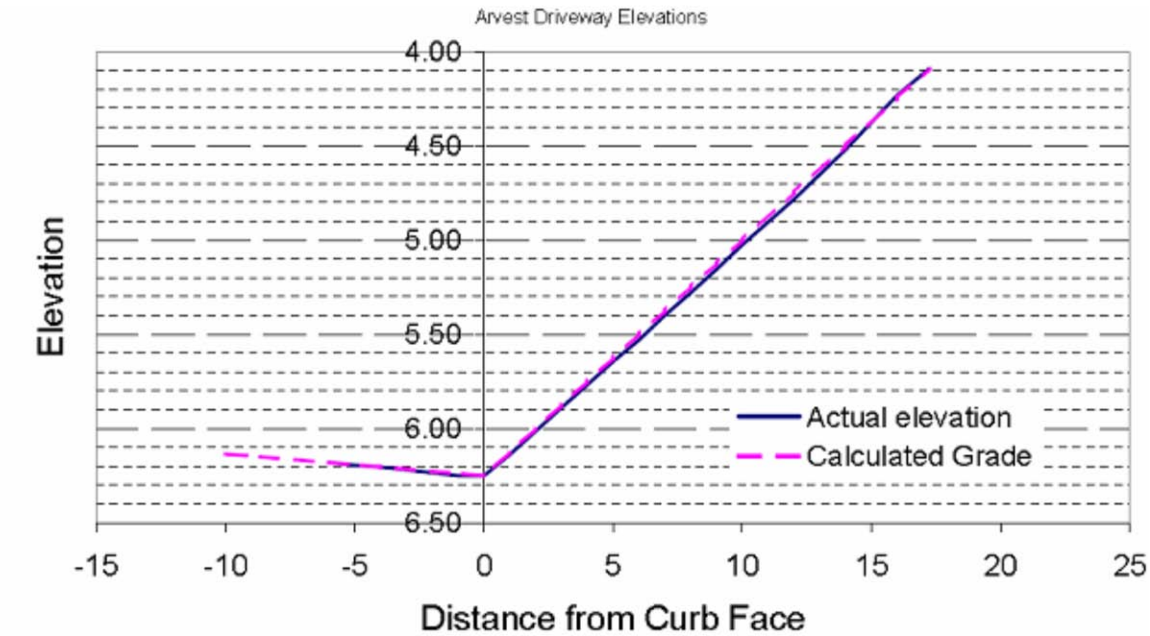


EXHIBIT 14 Example of a Driveway Re-survey

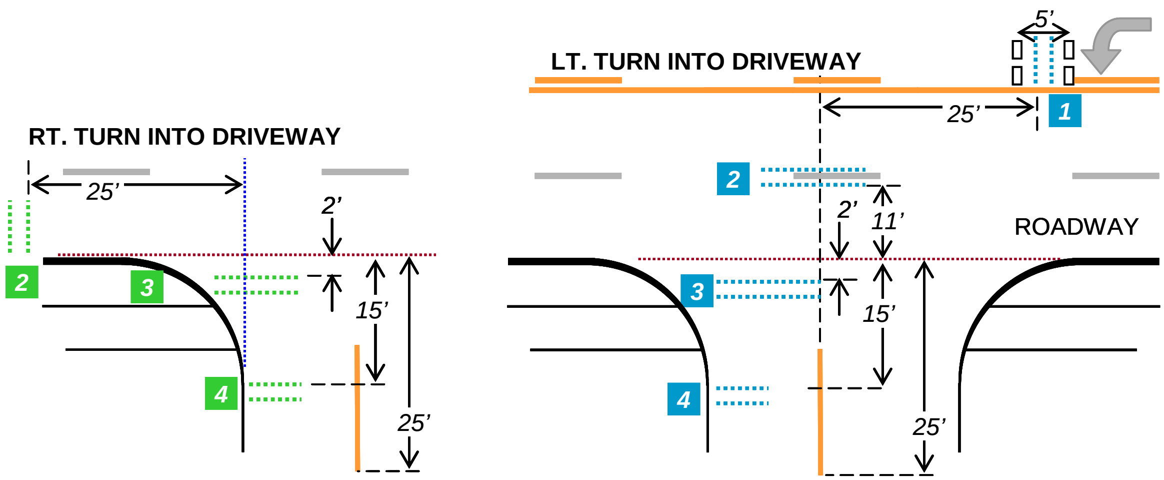


EXHIBIT 15 Sensor Layout Diagrams

Precise measurements were required to establish the location of pairs of contact closure switches. A pair of switches constituted a sensor. The switch ends were connected to a data logger, which in turn was connected to a laptop computer loaded with a program specially designed to receive and store the readings generated in the data logger. A person operating the computer would key the devices to record data when a turning vehicle approached the sensors. Three sensors (i.e., pairs of contact closures switches) recorded the data. These pairs were named Sensors #2, #3, and #4. Initially, sensors were also placed at left turn #1, but due to technical problems, data collection at this position was discontinued. A camcorder was aimed to include Sensors 2 and 3 in the field of view.

Note that the pairs of switches actually recorded the speed of the vector perpendicular to the orientation of the switches, which may in some cases be less than the actual forward speed of the vehicle. The switches at Sensor #3 recorded the speed vector toward pedestrians on the sidewalk.

At one of the Steeper locations, there were numerous marks from the scraping of vehicle undersides at the locations for certain sensors, so the positions of the affected sensors were shifted by two feet.

Achieving a More Common Entry Throat Width

To confine the vehicles turning into a driveway to a width at each site that would be similar to the widths at the other sites, and to compensate for variations in the radii among the different sites and for the construction of slightly irregular radii, the researchers used a 15 ft long strip of 4 inch wide yellow pavement marking tape to create a driveway centerline. The yellow pavement marking tape was placed at the greater of either an offset distance of 13 ft from the straight edge of the driveway, or after measuring back from the face-of-curb (FC) edge a distance of 13.2 ft, an offset distance of 14.2 ft from the entry radius. These 13.2 and 14.2 ft distances were chosen to replicate the throat width available 70° into a right turn having a 20 ft radius into a 13 ft wide entry lane (see Exhibit 15).

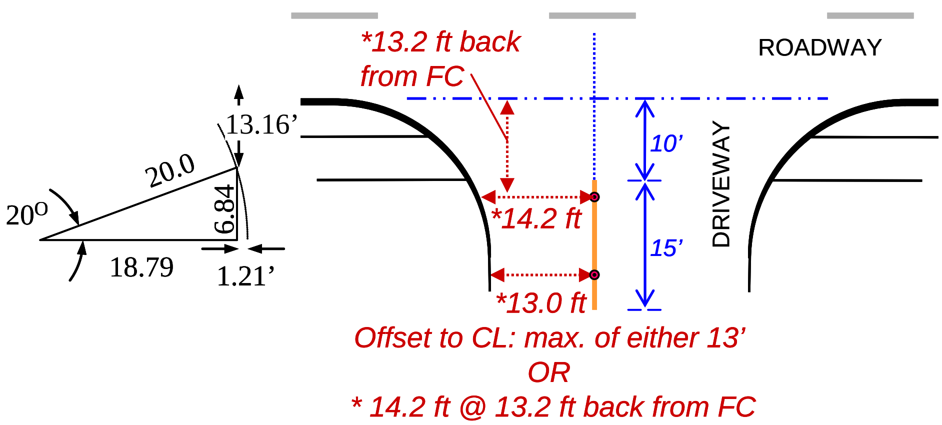


EXHIBIT 15 Throat Width at 70° Through a 90° Right Turn

In addition to the presence of the pavement marking tape, a "blocking vehicle" was situated in the driveway exit lane, to encourage drivers turning into the driveway to stay within the confines of their entering lane. This blocking vehicle parked in the exit lane until such time as another vehicle trying to leave the site pulled behind the blocking vehicle. When this occurred, the blocking vehicle drove away and then quickly returned to the blocking position.

Exhibit 16 shows two people installing the switches at a data collection site. Exhibit 17 shows a site with data collection in progress. Note that the persons operating the laptop computers were partially screened from the view of drivers.

EXHIBIT 16 Installing Sensors

EXHIBIT 17 Data Collection in Progress

Again, right turn data were collected and analyzed separately from the left turn data. The following paragraphs and table show the preliminary findings from one of the three right turn sensors.

Speed at Right Turn Sensor 2

At right-turn Sensor 2, measured on the main roadway just before the driveway, the average speeds for all three groups were similar. The average speed of vehicles about to enter the Steeper driveway was slightly higher than the averages of the other two groups of sites. The Steeper mean speeds were statistically significantly higher than the other two means, with both p-values less than 0.05.

	Flatter	Moderate	Steeper
Sample size N	243	83	240
Maximum speed	22.8	18.0	20.7
75th percentile speed	15.9	15.3	16.1
Average speed	14.1	13.8	14.5
25th percentile speed	12.6	12.5	13.3
Minimum speed	5.1	7.9	5.0
Standard deviation	2.9	2.1	2.4

DRIVEWAY DESIGN GUIDE

Six people contributed to the driveway design guide, including one specialist for those with impaired visibility, and one who specialized in design for those in wheelchairs. The following is an outline of the driveway design guide in its present draft form.

1. Introduction
   - Purpose
   - Organization
2. Terms and Definitions
3. Design Controls
   - The setting
   - The user mix
   - Attributes of motor vehicle traffic
4. Driveway and Access Spacing
   - Briefly state principles
5. Geometric Design Elements
   - Plan and cross section
   - Length
   - Vertical alignment
   - Other
6. Driveway Design Applications

CLOSING

The effort directed toward NCHRP Project 15-35, Geometric Design of Driveways, will produce two deliverables. One, project research will provide information about the effects of driveway gradients on bicyclists, motorist, and pedestrians. The research will better define the driveway profiles that cause vehicles' undersides to drag. The research will also provide better information about the operational effects, specifically the effects of vertical alignment upon the entry speeds and elapsed travel times of vehicles turning right in turning left into driveways. The second deliverable will be a comprehensive guide for the geometric design of driveway connections with roadways. In addition, the literature review, survey of transportation agencies, and input from interest groups led to the identification of other research needs for the future.