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These **Digests** are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed and prior to publication of the project report in the regular NCHRP series, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may obtain, on a loan basis, an uncorrected draft copy of the agency's report by request to: NCHRP Program Director, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418

Recommended Modification of Superelevation Practice for Long-Radius Curves

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 1-14, "Influence of Combined Highway Grade and Horizontal Alignment on Skidding," by D.F. Dunlap, P.S. Fancher, R.E. Scott, C.C. MacAdam, and L. Segel, Highway Safety Research Institute of the University of Michigan, Ann Arbor, Michigan.

THE PROBLEM AND ITS SOLUTION

Various factors have contributed to the rise in the number and severity of highway accidents, with attendant loss of life, injury, and property damage. As a result of greater than normal accident experience at several downgrade curve sites, Project 1-14 was initiated to deal with the particular portion of the over-all accident problem involving skidding on highway sections containing the combination of horizontal curvature and vertical grade. The objective was to develop guidelines for highway geometrics and pavement surface characteristics to ensure adequate vehicle control during anticipated maneuvers on such highway sections.

Based on the combined findings from (a) an extensive analysis of accident data, (b) computer simulation studies, and (c) an in-depth field investigation of two high-accident sites, the HSRI researchers have concluded that drivers are not likely to lose control of their vehicles on curve-grade sites unless they are attempting to perform severe maneuvers on slippery road surfaces with fair to poor tires. The AASHTO design procedures - as described in *A Policy on Geometric Design of Rural Highways, 1965* (GDRH) and *A Policy on Design of Urban Highways and Arterial Streets, 1973* (DUHAS) - provide a practical method for arriving at reasonable geometric designs for sites with combined horizontal curvature and vertical grade, provided (1) the selected values of superelevation are large enough to result in adequate pavement surface drainage and (2) the pavement skid resistance is sufficient for anticipated vehicle

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maneuvering. However, misinterpretation of the AASHTO design procedures has resulted in design and construction of long-radius curves with inadequate superelevation for surface drainage that contributes to an extraordinary wet-weather accident rate at this type of site.

The report recommends compliance with the design superelevation values for various degrees of curvature and design speeds found in Tables III -7 to -10 in (GDRH) and attention to roadway geometry, signing, and maintenance practices to reduce severe maneuvers on curves. It also contains a proposed procedure for determining pavement skid resistance requirements for curves. The recommendations for increasing superelevation and for reducing severe maneuvers at curve sites are based on the combined findings of mathematical simulation studies, rather extensive accident data, and a pavement surface drainage analysis, and thus should be implemented immediately during the design of new highway sections and improvement of existing high-accident sites. The procedures for determining specific pavement skid-resistance requirements for curve sites have not as yet been correlated with accident experience.

FINDINGS

To examine the factors that influence safe operation of modern passenger automobiles on highway sections having combined curvature and grade, the research was divided into the following major interrelated tasks: (a) accident data analysis, (b) mathematical vehicle simulation analysis, (c) pavement drainage analysis, and (d) field site investigations. Project findings are reported by these tasks.

Accident Data Analysis

Accident records from the Ohio and Pennsylvania Turnpikes were examined for influences of curvature and grade, both separately and in combination. This was accomplished by acquiring accident data by milepost location and combining it with geometrics data. The Pennsylvania Turnpike data cover a 2½-year period starting in 1966, consisting of 9,822 accidents. The Ohio Turnpike data also begin in 1966, but cover a 4½-year period and 5,553 accidents. Information from toll records was sufficient to compute traffic exposure for each point on the two highways. The over-all accident rate on the Ohio Turnpike was 96 accidents per 10^8 vehicle-miles; the corresponding rate for the Pennsylvania Turnpike was 148. Analysis of the accident data shows that the Pennsylvania Turnpike accident rate is not dependent on grade, but does increase with increasing degree of curvature. Accident rates on the Ohio Turnpike are not influenced by grade, except at the steepest downgrades. However, as shown in Figure 1, the accident rate associated with curves of about 1° on the Ohio Turnpike is more than twice the over-all rate.

Several factors were examined relative to their association with accident rate and grade and curvature. The most significant was pavement surface condition. Tables 1 and 2 give the distribution of accidents by surface conditions for each stratum of curvature and grade. Wet-pavement accidents are definitely over-represented on curves of about 1°. The proportion of single-vehicle to multi-vehicle accidents is generally similar to that for wet-pavement and single-vehicle accidents on curves of about 1°. Both types of accidents are likely to be associated with the loss of control due to inadequate tire-pavement friction. This observation is supported by the higher incidence of "primary cause" entries implicating defective (worn) tires on 1° curves than on the remainder of the Ohio Turnpike.

Computer Simulation Analysis

Simulation and analytical studies of a wide variety of vehicle, tire, road surface, geometric, and maneuver combinations were conducted to determine operating conditions that can lead to loss of control and the onset of skidding. The Highway Vehicle Object Simulation Model (HVOSM)[1] was used to perform this parametric study. A small sedan, an intermediate sedan, and a station wagon were used. Maneuvers considered were normal cornering with forward acceleration, lane change, and lane change plus braking, all on various curves and grades. The results are presented in terms of the maximum velocity above which loss of control will occur for the given set of conditons.

The simulation findings (Fig. 2) show the influence of pavement skid resistance and curvature on V_{CR} (safe speed for normal cornering with forward acceleration to maintain constant speed) and V_{LOC} (maximum initial speed from which a combined lane change plus braking can be performed without loss of control) for a baseline set of conditions in which a typical sedan with half-worn tires is operated on a curved road with a grade of -6 percent and a superelevation of 0.0156 ft/ft. It can be seen that for the given set of conditions, curvature is indicated as having a large influence on V_{CR}, but the influence of skid resistance is much smaller. However, when the more severe maneuver of passing and braking is performed, the model indicates that pavement skid resistance is the primary factor influencing V_{LOC}. For example, a pavement SN_{40}-value of 40 is indicated to ensure that V_{LOC} is greater than 70 mph for a 3° curve. An SN_{40}-value of 20 appears adequate to ensure safe normal cornering speed (V_{CR}) of 70 mph on the same curve. With bald tires, substantially higher pavement skid resistance would be needed to safely perform either of the described maneuvers.

It was also shown by the simulation work that reasonable variations in grade have little influence on V_{LOC}. The lane change plus braking maneuver appears to be so severe that grade, curvature, and superelevation are removed from primary influence. Curvature and superelevation were found to have a noticable influence on the critical speed (V_{LOC}) for a lane change maneuver without braking.

Pavement Drainage Analysis

Drainage of the pavement surface is an important consideration in pavement cross-section design in that water depth has a critical influence on the friction available at the tire-pavement interface and thus on the safe operation of vehicles. Tire hydroplaning is commonly considered to be the primary adverse effect from excess water on a pavement. In actuality, complete hydroplaning, even with smooth tires, is probably a rare occurrence. The vast majority of wet-weather skidding accidents undoubtedly occur as the result of water depths well below those needed for complete hydroplaning. This degradation of tire-pavement friction as the consequence of the presence of water is generally referred to as partial hydroplaning.

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[1] McHenry, R.R., and DeLeys, N.J., "Automobile Dynamics - Motions for Use in Studies of Braking Systems and of the Driving Tasks." *Rep. No. VJ-2251-V-7,* (Aug. 1970). Cornell Aeronautical Laboratory.

Research on methods for predicting pavement water depth as a function of rainfall rate and pavement geometrics has been conducted by the Texas Transportation Institute, the Road Research Laboratory of England, and Goodyear Tire and Rubber Co. From a review of this research, it is concluded that road width and cross slope are the primary roadway factors affecting pavement drainage, with grade and texture being of secondary importance. Increasing the road width increases the runoff distance and thus leads to increased water depths. Increasing the cross slope leads to lower water depths. Increasing the grade, on the other hand, increases both slope and runoff distance. The former leads to lower water depths and the latter to greater depths; the net result is essentially zero. For a rainfall rate of 0.25 in./hr, a cross slope of 0.0156 ft/ft, and using the (British) Road Research Laboratory formula, the computed maximum water depths for a crowned tangent section (12-ft drainage width) and a 1° curve with shoulder drainage across the roadway (34-ft drainage width) are 0.028 in. and 0.046 in., respectively. This indicates that the wet-weather tire-pavement friction available for emergency maneuvers on the curve is substantially less than on the tangent section when the same cross slope is used.

Field Site Investigations

Two sections of highway with high accident rates were subjected to an in-depth evaluation to determine accident causation factors. One of the selected sites was on the Ohio Turnpike. The other was located on I-95 near Fredericksburg, VA, near an interchange with US 1. During the investigations methods were developed for evaluating high-accident sites and for recommending corrective measures.

The Ohio Turnpike site is a 1° curve to the right in the westbound lane between mileposts 166.4 and 166.7. The roadway is on a 60-ft fill on a downgrade varying from 2% to 3%. No interchanges or service plazas are within three miles, and there are no signs near the site. The effective road width for drainage considerations is 34 ft, including two 12-ft-wide traffic lanes plus a 10-ft paved shoulder, all having a cross slope of 0.0156 ft/ft. Prior to June 1970 the pavement was portland cement concrete. Although the skid resistance at the site was not recorded, locked-wheel skid trailer measurements made in the fall of 1969 on similar pavements in the same general area of the turnpike gave SN_{40}-values averaging 31 in the travel lane and 38 in the passing lane. The site was resurfaced with asphaltic concrete in June 1970. In the fall of 1971, the SN_{40}-values at the site averaged 40 in the travel lane and 53 in the passing lane.

From January 1, 1966, to June 30, 1970, there were 34 recorded accidents at this site and the accident rate was computed as 665 per 10^8 vehicle-miles. The average accident rate for the entire Ohio Turnpike was 96 per 10^8 vehicle-miles for this same period. From July 1, 1970, to May 1, 1973, there were 21 recorded accidents at the site, with an accident rate of 559 per 10^8 vehicle-miles. Prior to resurfacing, 79 percent of the accidents at the site occurred under wet-pavement conditions. After resurfacing, this proportion was 62 percent. These percentages are both much higher than commonly occurs along the turnpike, which averages 18 percent for all tangent sections. Although tire conditions were not always noted on the accident reports, defective tires (generally one or more with inadequate tread depth) were noted on 16 of the 55 accident reports and, more significantly, 14 of the 16 were also associated with wet pavements. Of the 40 wet-pavement accidents, 34 (85 percent) involved a single vehicle.

An evaluation of the Ohio Turnpike high-accident site indicates that the major problem is inadequate tire-pavement friction during wet weather. Suggested remedial measures include:

1. Improve pavement drainage by increasing cross slope.
2. Improve drainage beneath the tire by pavement grooving, open-graded surface course, or a very course surface texture.
3. Improve pavement wet-weather skid resistance by addition of surface with large, sharp, polish-resistant aggregate.

The I-95 site in Virginia is in the southbound lane near Fredericksburg between the exit and entrance ramps of a diamond-type interchange with US 1. It is located on a 1° curve to the right on a downgrade varying from 2.6 percent to 3.1 percent. The cross slope is 0.0156 ft/ft, and the effective drainage width is 24 ft, consisting of two 12-ft traffic lanes. The paved shoulder on the high side drains away from the traffic lanes. The pavement surface is portland cement concrete. The entire site was longitudinally grooved in June 1972. Skid trailer measurements made in a longitudinal direction were about the same prior to and after grooving. The SN_{40}-values average 52 in the travel lane and 59 in the passing lane.

From December 18, 1964, to June 26, 1972, 133 accidents were recorded in a region extending 1,000 ft beyond the beginning and ending of the exit and entrance speed-change lanes. Of this number, 45 (34 percent) involved wet pavement. Although tire conditions were not always noted on the accident reports, worn tires were indicated in 9 (7 percent) of the accidents. An analysis of accidents by the Virginia Department of Highways before and after grooving shows that there were 23 reported accidents at the site during the 12-month period before grooving, and 16 during the 12-month period after grooving. This 30 percent reduction in reported accidents during a comparable period indicates that available tire-pavement friction was improved by the grooving even though longitudinally measured locked-wheel skid resistance was unchanged.

Site geometry and/or signing can produce driver indecision that results in unusual acceleration, braking, and cornering maneuvers. This increased driver demand, combined with borderline pavement surface drainage and skid resistance, is likely to result in above-average wet-weather accident experience at the site. The geometric features of the I-95 site in Virginia that contribute to unusual maneuvers are location of the interchange on a curve and grade, steep curvature and grade of the exit and entrance ramps, and superelevation less than recommended in AASHTO geometric design policy. Due to the number of signs associated with the interchange, the bridge railing, embankments, and roadside vegetation, there is a continuous sight distance problem throughout the side.

An evaluation of the Virginia high-accident site indicates that the problem was a combination of above-normal driver demand and inadequate tire-pavement friction during wet-weather. The suggested remedial measures for the Ohio Turnpike are all applicable to this site. It should be noted that one of the suggestions (pavement grooving to improve drainage beneath the tire) was applied to the site with a reduction in accident experience. The report also contains several specific suggestions for improving signing, sight distance, and interchange ramp geometry.

Although two downgrade-curve sites with unusually high accident rates were indentified and investigated, the over-all findings of the study do not indicate that AASHTO geometric design procedures for horizontal curves need to be modified for application to highway sections with combined horizontal curvature and vertical grade. However, there is substantial evidence that lack of conformance with AASHTO recommendations for superelevation on curves of about 1° is probably the rule rather than the exception on many miles of Interstate highways. The primary consequences of less than recommended superelevation on multi-lane curves are degradation of available tire-pavement friction during precipitation and reduction in the margin of safety that may be required by a motorist due to such factors as worn tires, a severe maneuver, or unusual vehicle load distribution.

APPLICATIONS

Due to the safety implications of project findings and the fact that they are based on both computer simulation studies and accident analysis, the following actions should be taken:

1. Review and clarification by AASHTO of pavement surface drainage and superelevation portions of GDRH and DUHAS.
2. Evaluation and modification as appropriate by all highway agencies of current design practices with regard to superelevation of long-radius curves on multi-lane highways.
3. Evaluation and modification as appropriate by all highway agencies of geometric design, signing, and maintenance practices to minimize severe maneuvers at curve sites.
4. Adoption of standardized method for evaluation of high-accident sites and identification of remedial measures.

AASHTO Procedures

The following excerpt from page 162 of GDRH recognizes the importance of pavement surface drainage and appears to be the basis for the use of 0.0156 ft/ft as acceptable cross slope to satisfy drainage requirements:

> *Sharpest Curve Without Superlevation.* The minimum rate of cross slope applicable to traveled ways is determined by drainage requirements. Consistent with the type of highway, amount of rainfall, snow, and ice, the values usually accepted range from 0.008 foot per foot for high type rigid surfaces to approximately 0.02 for low type flexible surfaces .... Here these values are the extreme. In more general use are the values from 0.01 to 0.015. A value of 0.012 is about average and, for discussion purposes, is used herein as a single intermediate value representative of the general range for uncurbed pavements. Steeper cross slopes are needed on curbed pavements to minimize the spread of surface water flow.

From the subsequent Tables III-6 and III-9, it seems apparent that for a highway having a design speed of 80 mph the maximum curvature for a normal crown section should be 0°14' and that the superelevation for a 1° curve should be 0.048 ft/ft when maximum superelevation is selected as 0.10. Pages 350 and 351 DUHAS contain information indicating the need for an increased rate of cross slope on multi-lane pavements, but no specific mention of superelevation on curves. The procedures appear to concentrate on drainage of crown sections and do not give adequate attention to surface drainage of curves. There is no specific recognition of the influence of length and slope of drainage path on water depth. The Project 1-14 report contains an analysis of the influence of such factors as precipitation rate, texture, drainage length, and slope on pavement surface drainage and, consequently, on safe vehicle maneuverability. It also recommends procedures for quantification of these influences that can be considered during the review and revision of the previously mentioned AASHTO publication.

Highway Agency Superelevation Practices

As indicated under "Findings," there is a general lack of conformance with AASHTO recommendations for superelevation of long-radius curves. Compliance with the AASHTO recommended superelevation values for various degrees of curvature and design speeds would substantially improve pavement surface drainage, particularly on long-radius curves. Each highway agency should examine its current design practices in this regard to prevent the design and construction of potentially hazardous curve sections in the future.

Reducing Driver Demand

Equally important to providing adequate pavement drainage and other surface characteristics for safe maneuverability is the necessity for reducing severe maneuvers. Factors such as signing, sight distance, roadway discontinuities, traffic density, and driver responsiveness interact in quite complex manners to influence the types and severity of maneuvers undertaken at a site. At one of the high-accident sites investigated during this project, several geometric and signing factors seemed to combine to produce a greater than normal proportion of severe maneuvers and thus contributed to the accident rate at the site. It is important, therefore, to conform to existing design guidelines in GDRH and DUHAS, as well as those on traffic control devices and maintenance. In evaluating new designs, a design review process could be used to define a running record of maneuver demand throughout the length of the roadway and thus reduce the potential for high-accident sites in the future.

Existing High-Accident Sites

It is emphasized that the study findings do not contend that all long-radius curves on multi-lane highways are hazardous locations. The study does indicate that during wet-pavement conditions the margin of safety and maneuverability is less on many long-radius curves built with lower-than-AASHTO-recommended superelevation rates than on tangent sections and on sharper curves. As a result, the accident potential is increased at these sites. The actual accident experience will depend on the amount of the reduction in the margin of safety, the degree of maneuver severity, and other traffic factors. The procedures developed during this study for the detailed site investigations will be useful for determining possible remedial measures applicable to existing high-accident sites. The procedures can be used to investigate other existing long-radius curve sites to evaluate accident potential and thus determine corrective actions to prevent the development of a high-accident site.

From an applications standpoint, the suggested procedure for investigation of existing sites has undergone some field evaluation in that the Highway

Design and Safety Committee of the Virginia Department of Highways has reviewed the agency report. The Committee has concurred in the findings and suggested remedial measures for the I-95 site at its interchange with US 1, and has recommended immediate implementation of several of the measures. Others will be considered during planned upgrading of I-95 to a six-lane facility.

TABLE 1

ACCIDENT EXPERIENCE BY SURFACE CONDITION,
OHIO TURNPIKE

	ACCIDENTS			
		PERCENT		
DEGREE OF CURVATURE	NUMBER	DRY	WET	OTHER*
0°0'	3,317	61.5	18.5	20.0
0°1' to 0°21'	619	56.7	27.6	15.7
0°22' to 0°43'	621	54.4	32.2	13.4
0°44' to 1°5'	616	34.9	53.4	11.7
1°6' to 1°27'	96	60.4	27.1	12.5
1°28' to 1°49'	73	56.2	32.9	11.0
1°50' to 2°11'	78	55.1	21.8	23.1
2°12' to 2°33'	133	47.4	21.8	30.8
All	5,553	56.7	25.4	17.9
GRADE, PERCENT				
+1.5 to +2.4	649	57.5	22.2	20.3
+0.7 to +1.4	547	55.9	23.6	20.5
-0.6 to +0.6	2,879	59.9	24.8	15.2
-1.4 to -0.7	642	52.8	25.7	21.5
-2.4 to -1.5	708	49.4	29.2	21.3
-3.5 to -2.5	83	36.1	49.4	14.5
All	5,553	56.7	25.4	17.9

*Consists largely of snow/ice conditions.

TABLE 2

ACCIDENT EXPERIENCE BY SURFACE CONDITION,
PENNSYLVANIA TURNPIKE

	ACCIDENTS			
		PERCENT		
DEGREE OF CURVATURE	NUMBER	DRY	WET	OTHER*
0°0'	4,479	53.3	29.5	17.2
0°1' to 0°43'	569	51.7	29.2	19.2
0°44' to 1°49'	1,595	38.1	51.2	10.8
1°50' to 2°33'	1,310	38.4	43.5	18.1
2°34' to 3°22'	1,136	43.8	35.6	20.6
3°23' to 4°12'	434	39.4	42.4	18.2
4°13' to 4°59'	75	48.0	30.7	21.3
5°00' to 6°00'	224	55.8	33.0	11.2
All	9,822	47.1	36.2	16.7
GRADE, PERCENT				
+2.5 to +3.5	1.615	49.8	32.3	17.9
+1.5 to +2.4	1,016	46.4	36.0	17.6
+0.7 to +1.4	1,007	50.1	36.0	13.9
-0.6 to +0.6	2,158	46.4	40.0	13.6
-1.4 to -0.7	1,009	51.7	30.5	17.8
-2.4 to -1.5	1,198	46.4	37.4	16.2
-3.5 to -2.5	1,819	41.8	37.7	20.5
All	9,822	47.1	36.2	16.7

*Consists largely of snow/ice conditions.

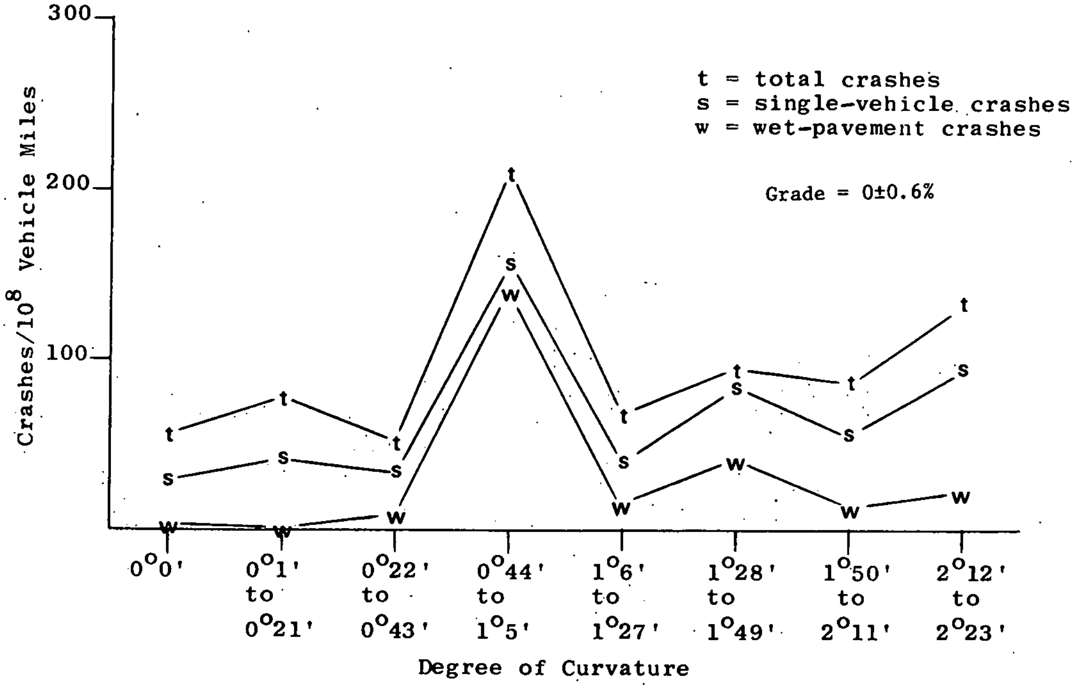

Figure 1. Expected relationship between curvature and crash rate; Ohio Turnpike data.

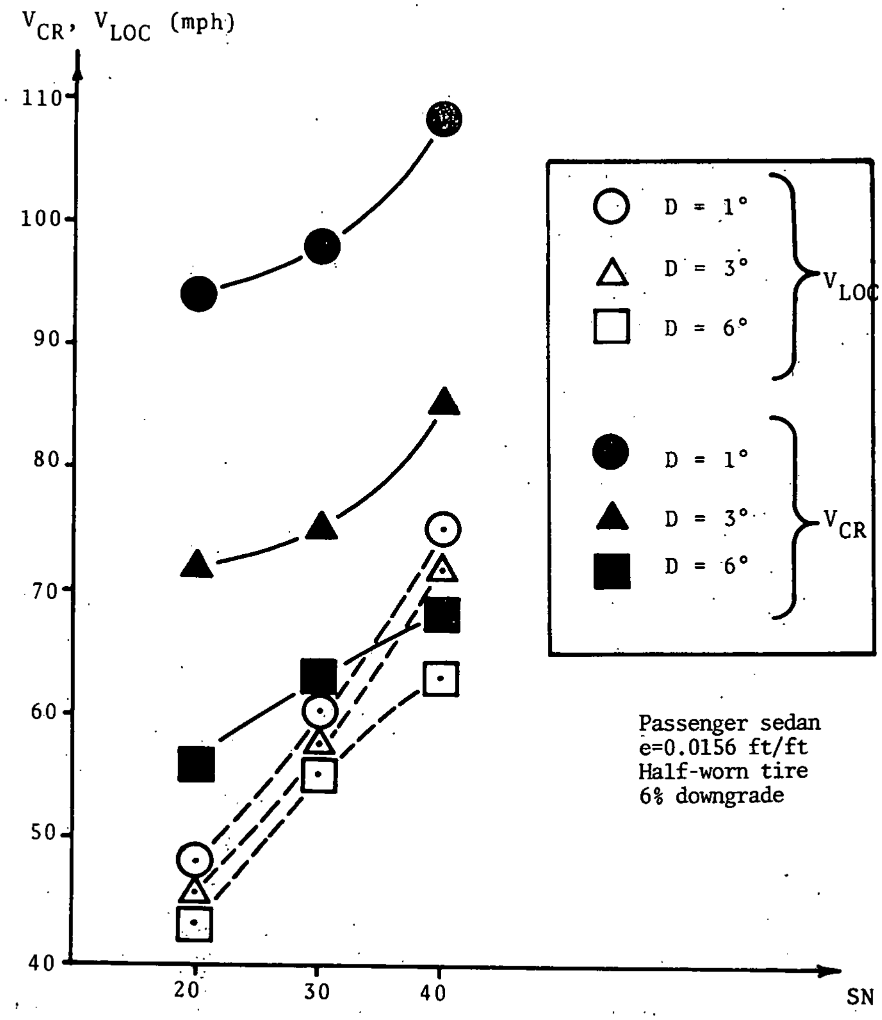

Figure 2. Curvature and SN effects on V_{CR} and V_{LOC}.

TABLE III-6

Maximum Curvature for Normal Crown Section

Design speed, mph	Average running speed, mph	Maximum degree of curve	Minimum curve radius, feet	Resulting side friction factor f with adverse crown	
				At design speed	At running speed
30	28	1° 21′	4.250	.026	.024
40	36	0° 48′	7,160	.027	.024
50	44	0° 32′	10,810	.027	.024
60	52	0° 23′	14,690	.028	.024
65	55	0° 20′	17,360	.028	.024
70	58	0° 18′	19,100	.029	.024
75	61	0° 16′	21,220	.030	.024
80	64	0° 14′	24,590	.029	.023

From: "A Policy on Geometric Design of Rural Highways - 1965," p. 167. AASHO (1966).

TABLE III-9

Values for Design Elements Related to Design Speed and Horizontal Curvature

D	R	V=30 mph			V=40 mph			V=50 mph			V=60 mph			V=65 mph			V=70 mph			V=75 mph			V=80 mph		
		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet		e	L-Feet	
			2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane		2-lane	4-lane
0° 15′	22918′	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	240	240
0° 30′	11459′	NC	0	0	NC	0	0	NC	0	0	RC	175	175	RC	190	190	RC	200	200	.022	220	220	.024	240	240
0° 45′	7639′	NC	0	0	NC	0	0	RC	150	150	.024	175	175	.027	190	190	.029	200	200	.033	220	220	.036	240	240
1° 00′	5730′	NC	0	0	RC	125	125	.023	150	150	.032	175	175	.035	190	190	.039	200	200	.044	220	220	.048	240	240
1° 30′	3820′	RC	100	100	.021	125	125	.033	150	150	.046	175	190	.052	190	220	.058	200	260	.065	220	310	.071	240	350
2° 00′	2865′	RC	100	100	.028	125	125	.042	150	150	.058	175	230	.066	190	290	.074	220	330	.082	260	390	.089	290	440
2° 30′	2292′	.021	100	100	.034	125	125	.051	150	180	.069	190	280	.077	220	330	.086	260	390	.094	300	450	.099	330	490
3° 00′	1910′	.025	100	100	.040	125	125	.059	150	210	.079	210	320	.087	250	380	.094	280	420	.100	320	480	.100	330	500
3° 30′	1637′	.029	100	100	.046	125	140	.067	160	240	.087	230	350	.093	270	400	.099	300	450	.100	320	480	.100	330	500
4° 00′	1432′	.033	100	100	.051	125	160	.073	180	260	.093	250	380	.098	280	420	.100	300	450	D max=3.0°			D max=3.0°		
5° 00′	1146′	.040	100	110	.061	130	190	.084	200	300	.099	270	400	.100	290	430	.100	300	450						
6° 00′	955′	.046	100	120	.070	150	220	.092	220	330	.100	270	410	D max=4.5°			D max=4.0°								
7° 00′	819′	.053	100	140	.077	160	240	.098	240	350	D max=5.5°														
8° 00′	716′	.059	110	160	.084	180	260	.100	240	360															
9° 00′	637′	.064	120	170	.089	190	280	.100	240	360															
10° 00′	573′	.068	120	180	.093	200	290	D max=8.5°																	
11° 00′	521′	.073	130	200	.097	200	310																		
12° 00′	477′	.077	140	210	.099	210	310																		
13° 00′	441′	.080	140	220	.100	210	320																		
14° 00′	409′	.083	150	220	.100	210	320																		
16° 00′	358′	.089	160	240	D max=13.5°																				
18° 00′	318′	.093	170	250																					
20° 00′	286′	.097	170	260																					
22° 00′	260′	.099	180	270																					
24° 00′	239′	.100	180	270																					
		.100	180	270																					
		D max=25.0°																							

emax=0.10

D—Degree of curve
R—Radius of curve
V—Assumed design speed
e—Rate of superelevation
L—Minimum length of runoff of spiral curve
NC—Normal crown section
RC—Remove adverse crown, superelevate at normal crown slope
Spirals desirable but not as essential above heavy line.
Lengths rounded in multiples of 25 or 50 feet permit simpler calculations.

From: "A Policy on Geometric Design of Rural Highways - 1965," p. 170. AASHO (1966).

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