CONCLUSIONS

It has been shown that there are significant relationships between tire-pavement friction and tire-pavement noise. Near-field noise data obtained by the procedures developed in this research have spectral characteristics related to the skid resistance of PCC pavements. Over the wider range of asphalt concrete surfaces included in this study, however, poor agreement was noted between the spectral characteristics and pavement friction.

Far-field noise data at 64 and 80 km/h show definite relationships with skid resistance. The most significant variable in these relationships is blank-tire skid resistance. This finding indicates the important effect of pavement macrotexture on far-field tire noise in that blank-tire skid resistance is most strongly affected by pavement macrotexture (11). Increasing skid resistance and increasing macrotexture are seen to produce increased levels of far-field noise.

ACKNOWLEDGMENT

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Pavement Edges and Vehicle Stability: A Basis for Maintenance Guidelines

RICHARD A. ZIMMER AND DON L. IVEY

The repair of pavement edge geometry adjacent to unpaved shoulders is a maintenance activity that requires continuous effort on the part of all state and local agencies. Although it is generally accepted that these roadway discontinuities have some effects on vehicle stability and thus on facility safety, these effects have never been comprehensively quantified. A comprehensive treatment of this problem is presented that was developed by using research conducted previously by the California Department of Transportation and Systems Technology, Inc., and adding a testing program to supplement and extend the earlier work. Recommendations are made for the use of this information to establish maintenance guidelines. Appropriate use of this information by highway engineers can, in time, have a major impact on reducing accidents affected by pavement edges. This can be accomplished by reducing unnecessary maintenance and spending available maintenance funds on areas that have real safety significance.

The repair of deteriorated pavement edges and unpaved shoulders adjacent to pavement edges is a maintenance activity that requires continuous effort by all state and local highway agencies. Although it is generally accepted that pavement edges of excessive height have an effect on vehicle stability and thus on facility safety, this effect has never been comprehensively quantified.

The research described in this paper--the analysis of available literature and the testing program--allows a realistic evaluation of the effect of pavement edges on automotive safety and further defines the effect of certain critical driver and vehicle factors so that the urgency of the need for maintenance can be accurately assessed.

Pavement edges can represent a significant problem in vehicle control. In some cases the problem can be worsened and even made critical by inappropriate forms of caution on the part of drivers (see Figure 1). What may happen in such a critical situation can be described as follows:

1. A vehicle is under control in a traffic lane adjacent to a pavement edge where the unpaved shoulder is lower than the pavement elevation.
2. Because of driver inattention or distraction or for some other reason, the vehicle is allowed to move or is steered into a position in which the right side wheels are just off the paved surface. The right side wheels are now to the right of the pavement edge on a surface elevation below that of the main lane.
3. The driver then carefully tries to steer gently back onto the paved surface without reducing speed significantly.
4. The right front wheel encounters the pavement edge, which prevents it from moving onto the pavement. The driver further increases the steer angle to make the vehicle regain the pavement. The vehicle still does not respond. At this point there is equilibrium between the cornering forces to the left acting on both front tires and the pavement edge force to the right acting as shown in Figure 1a.
5. The critical steer angle is added by the driver, and the right front wheel mounts the paved surface. Suddenly, in less than one wheel revolution, the edge force has disappeared and the right front cornering force may have doubled as a result of increases in the available friction on the pavement and increases in the right front wheel load caused by cornering (Figure 1b).
6. The vehicle yaws radically to the left, pivoting about the right rear tire, until that wheel can be dragged up onto the paved surface. The excessive left-turning yaw continues, too rapid in its development for the driver to prevent penetrating the oncoming traffic lane (Figure 1c).
7. A collision with oncoming vehicles or spin-out and vehicle roll may then occur.

Although this phenomenon does occur on highway facilities, in many cases the same result, vehicle loss of control, may occur without the effect of a pavement edge. A loose or muddy shoulder can have the same effect if the driver overreacts when trying to regain the paved surface. Frequently, a pavement edge of modest height is blamed when excessive steering input is the cause.

LITERATURE SURVEY

The qualitative effect of pavement edges, or so-called lip drop-off, has been understood to some degree for many years. In the Traffic Accident Investigator's Manual (1), published by Northwestern University and originally compiled by Baker, the following statement is found: "Lip drop-off is simply a low shoulder at the edge of a hard pavement. It is important when the shoulder is more than three inches below the pavement...." Based on a telephone conversation with Baker in September 1982, it was determined that this conclusion was reached by informal testing at Northwestern University as early as 1959.

Ivey and Griffin (2) dealt with surface discontinuities including pavement edges in a paper published in 1975. Based on 15,968 accidents in the North Carolina accident file, there was an overrepresentation of the key words associated with a shoulder or pavement edge drop--i.e., dropped, soft, curb, and edge. A Delphi study included in this report ranked pavement edge-shoulder drop-off among the top accident-related pavement disturbances.

A series of tests reported by Nordlin (3) in the mid-1970s included a range of automobile sizes and edge drop conditions from 1.5 to 4.5 in. Nordlin concluded that there was no significant safety hazard for vehicles in mounting edges up to 4.5 in. This work did not include testing of the scrubbing situation, in which the offside tire scuffs along the pavement edge before the steering input causes it to mount the edge. This scrubbing action is the most critical situation. In further testing at the California Department of Transportation (Caltrans), Stoughton (4) observed the effect of a broken asphaltic concrete pavement edge and muddy shoulder on vehicle stability. The tests included small, medium, and large passenger cars and a pickup truck driven at speeds up to 60 mph. Again, pavement edge drops of 1.5, 3.5, and 4.5 in. were tested. Stoughton reached the following primary conclusion: "The pavement drop-offs had little effect on vehicle stability and controllability in all tests." Again, the scrubbing situation was not tested.

Klein et al. (5) produced a report in 1976 that included analyses of accident data, questionnaire surveys, and a variety of both open-loop and closed-loop tests. In closed-loop tests, naive drivers were used. Special efforts were made to achieve the edge scrubbing condition. In tests of edge drops up to 4 in. high, loss of control was encountered at the higher speed levels, generally more than 30 mph.

Another important discovery made by Klein is shown in Figure 2, which illustrates the steering-

Figure 1. Loss of vehicle control caused by driver's attempt to return to the roadway.

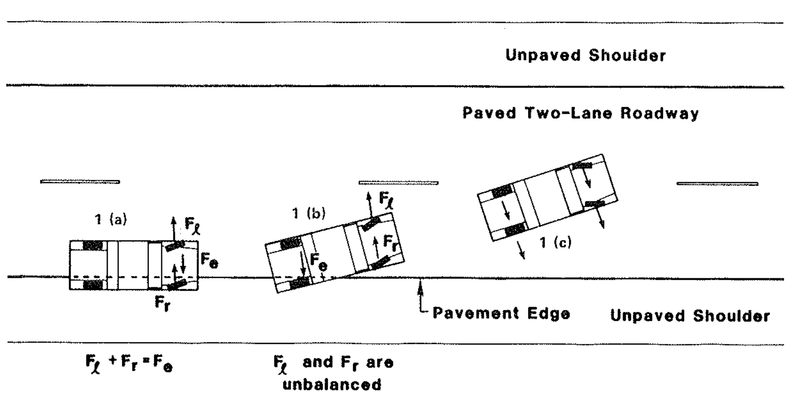
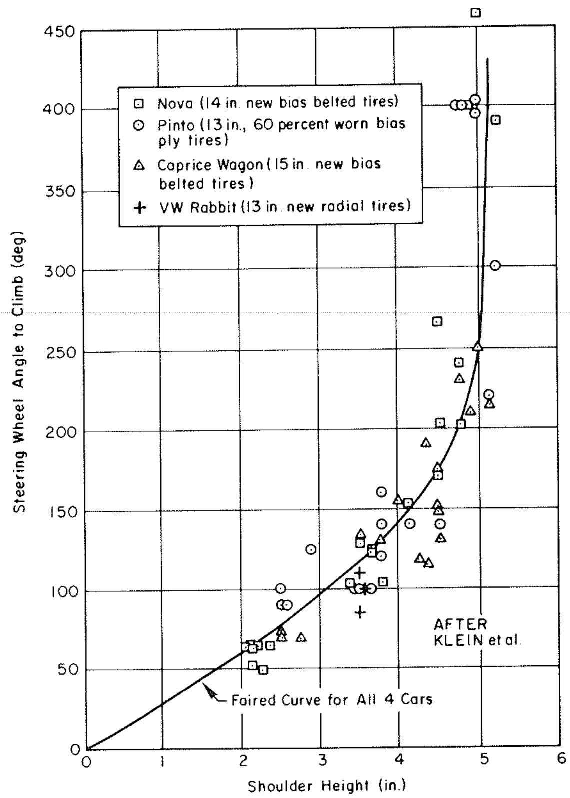


Figure 2. Steering-wheel angle required to climb various edge heights from edge scrubbing condition.



wheel angle required to climb various edge heights from the scrubbing condition (5). The curve in Figure 2 could potentially be used to describe the safety of the maneuver in that the initial relatively linear range (in Figure 2, from 0 to 3 in.) is reasonably safe. As the curve becomes curvilinear, the maneuver becomes significantly more difficult. As the curve starts a precipitous rise, again approaching a straight line, the difficulty of the maneuver becomes extreme.

Klein presented the most analytically appealing and experimentally comprehensive work done on this subject. The main limitation is that he tested only one, albeit the most critical, pavement edge geometric condition--that of an extreme 90 degree angle with little edge rounding. The limitations in scope of the two principal studies--the noninclusion of the edge scrubbing condition in the study by Nordlin and the inclusion of only one pavement edge geometry in the study by Klein--made the present study necessary. The testing plan was designed to complement and extend the earlier studies.

TEST PROGRAM

A comprehensive test program was developed to evaluate the effects of edge conditions based on a variety of drop-off heights, vehicles, tires, drivers, speeds, and positions. The conditions chosen do not represent every conceivable situation involving an edge condition. This would produce an extremely large and unwieldy test matrix. The variables for the initial full-scale testing program were chosen as representative of those typically found on the highways today, which would extend the information already developed by Nordlin (3) and Klein (5).

Edge Height and Shape

To obtain a sufficient number of data points without allowing the test matrix to become too massive, three shoulder-to-pavement heights were chosen--1.5, 3, and 4.5 in.--along with a construction tolerance of ±0.25 in. measured at intervals of 10 ft.

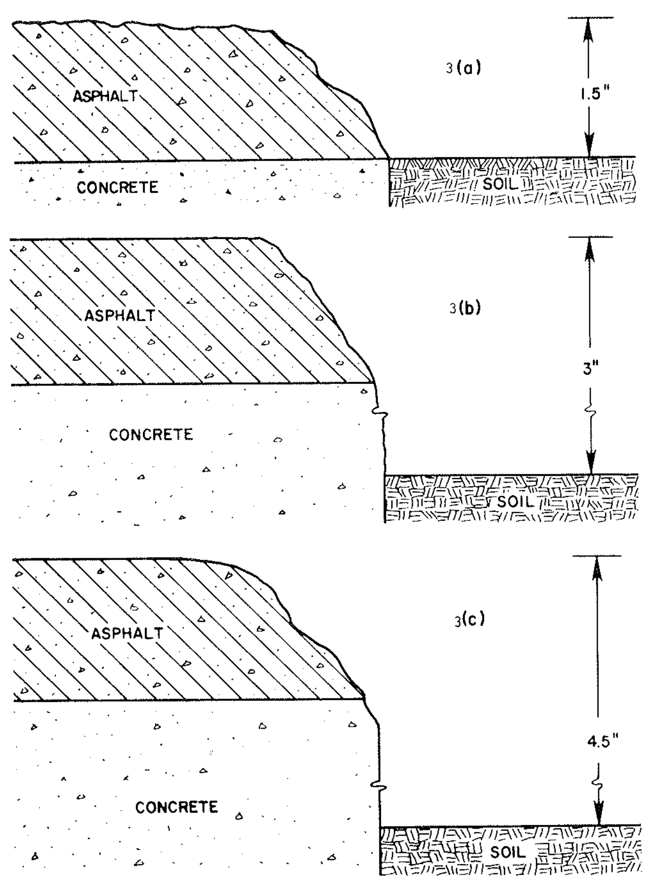
To evaluate these heights, a 500-ft test course was constructed at the Texas Transportation Institute (TTI) Proving Grounds adjacent to an existing concrete runway. To produce a soil shoulder, the vegetation and topsoil were first removed from the runway edge over approximately a 20-ft width. Next, a sandy loam was added, graded for drainage, and finally rolled. With the soil at the level of the existing concrete, a 1.5-in. pad of asphalt, 12 ft wide and 500 ft long, was applied to the concrete. This produced an asphalt-soil interface with a 1.5-in. height.

The edge was left unmodified, as it was installed, to provide a typical edge condition or shape with approximately a 1.5-in. radius. Figure 3a shows the nominal shape of this edge and the slight variations that occur over the length of the test course.

On completion of the 1.5-in. test runs, the soil was cut down 1.5 in. and regraded to produce a 3-in. edge height condition with the same asphalt shape as the 1.5-in. condition and a vertical face 1.5 in. below that, as shown in Figure 3b. The 4.5-in. condition was produced in the same way by removing 1.5 in. of soil and regrading, as shown in Figure 3c.

To gain some insight into edge shape, at the 4.5-in. condition the first half of the course was

Figure 3. Edge profiles.



modified (see Figure 4) to produce a sharper edge with approximately a 0.75-in. radius. By using an epoxy base paving material, with aggregate similar to the asphalt pavement, the required edge was finally produced by grinding to the desired contour and texture. The final edge type tested is the 45 degree slope shown in Figure 5. Informal testing on similar edges had shown the potential of this geometry to reduce the disturbance to a traversing vehicle. The unmodified test course is shown in Figure 6 in the 4.5-in. rounded edge condition and in the 6-in. 45 degree edge condition.

Vehicles

Passenger automobiles and a pickup truck were tested. To evaluate the effect of weight, suspension system, and wheel size, a minicompact, an intermediate-sized automobile, and a full-sized automobile were tested along with a standard-sized pick-up. The vehicles ranged in weight from 1,668 to 4,713 lb and in wheel size from 12 to 15 in. (see Figure 7). Each vehicle was set up to manufacturer's specifications with respect to the suspension and steering system before testing and was periodically inspected during the course of the testing. Each vehicle was equipped with a roll bar and racing lap and shoulder belts to provide an added margin of safety for the test drivers.

Tires

To determine the effect of tire construction, the intermediate- and full-sized sedans were tested with both bias ply and radial tires. The other two vehicles were tested with only radial tires. Only full-tread tires were considered in this testing because smooth or damaged tires could be considered a special case for future investigation. In all cases the tire inflation was adjusted to recommended cold pressures just before testing.

Drivers

Closed-loop tests are those in which the driver is free to steer or brake as needed to maintain stability. Driver skill level is notoriously difficult to assess. To evaluate the effect of skill level, four drivers were chosen:

1. A professional who teaches high-performance driving techniques;
2. A semiprofessional, a technician who occasionally performs as a test vehicle driver;
3. A typical male, a construction supervisor with no special driving skills; and
4. A typical female, a technician with no special driving skills.

Only driver 1 drove the complete matrix of tests, because it was felt that professional skills were required for any tests involving a potentially hazardous situation. Driver 2 performed all tests except those for the 4.5-in. drop-off. Drivers 3 and 4 made a selected number of runs at the 1.5- and 3-in. edge heights.

Test Speeds

To evaluate the effect of vehicle speed, for each test condition runs were made at 35, 45, and 55 mph. These values were chosen to cover the spectrum of speeds that may be encountered in a typical edge recovery situation.

Figure 4. Profile of modified 4.5-in. edge.

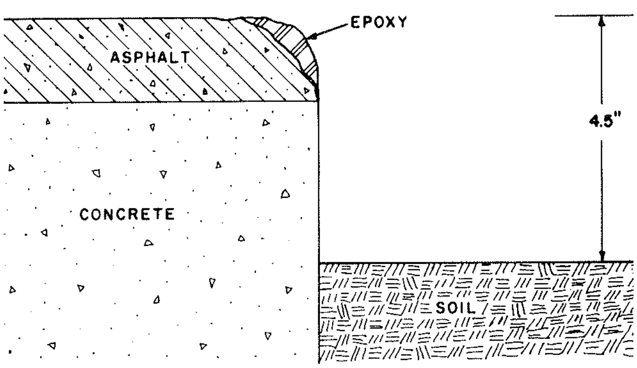


Figure 5. Profile of modified 45 degree edge.

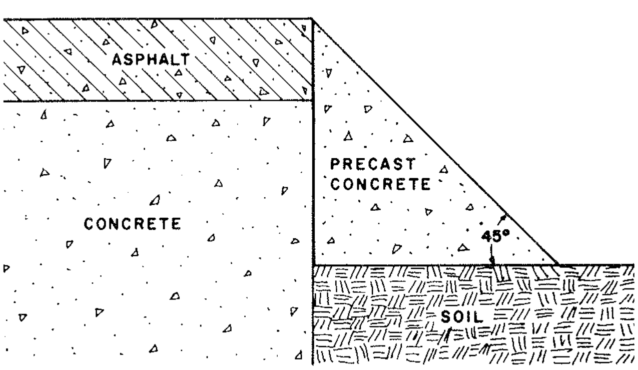


Figure 6. Unmodified test course: (top) minicompact cars on 4.5-in. rounded edge and (bottom) full-sized automobile on 6-in. 45 degree edge.

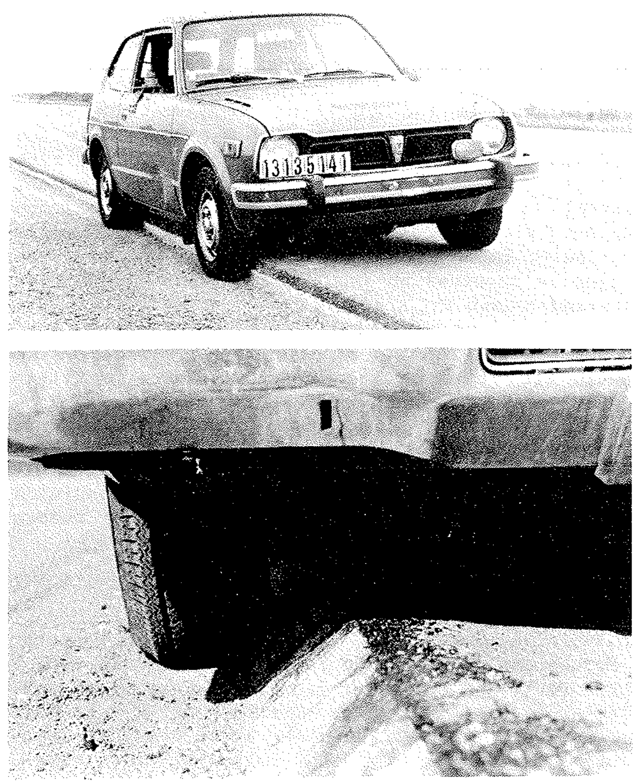


Figure 7. Description of vehicles used in study.

SIZE	MINI COMPACT	INTERMEDIATE	FULL SIZE	PICKUP TRUCK
YEAR	1977	1974	1977	1976
MAKE	HONDA	CHEVROLET	PLYMOUTH	FORD
MODEL	CIVIC	NOVA	GRAND FURY	F150 CUSTOM
Weight(a) FRONT	L 519, R 514	859 883	L 1347, R 1323	1259 1289
Weight(a) REAR	L 306, R 329	773 731	1019 1024	872 889
TOTAL	1668	3246	4713	4309
ENGINE DISPL.	75.5 CID	250 CI	440 CI	390 CID
SHOCK ABSORBERS	TELESCOPING	TELESCOPING	TELESCOPING	TELESCOPING
SUSPENSION	STRUT	BALL JOINTS	BALL JOINTS	KING PINS
POWER STEERING	NO	NO	YES	YES
STEERING RATIO	18.2:1	36:1	21.2:1	21.8:1
BRAKE TYPE/POWER	FT DISC REAR DRUM/NO	DRUM/NO	FT DISC REAR DRUM/YES	FT DISC REAR DRUM/YES
AIR CONDITIONER	NO	NO	YES	YES
TIRE SIZE	P155/80R12	P195/75R14	P225/75R15	L78-15
AND TYPE	GOODYEAR TIEMPO	GOODYEAR POLY STEEL	GOODYEAR VIVA	GOODYEAR POLYGLAS
AVE. TREAD DEPTH	LF 9/32 RF 9/32	LF 11/32 RF 11/32	LF 10/32 RF 10/32	LF 11/32 RF 11/32
	LR 9/32 RR 9/32	LR 11/32 RR 11/32	LR 10/32 RR 10/32	LR 11/32 RR 11/32
RECOMMENDED TIRE PRESSURE	FRONT 24	FRONT 24	FRONT 30	FRONT 30
	REAR 24	REAR 24	REAR 30	REAR 36
WHEELBASE	86.5"	111.25	122	132.75
FRONT TRACK	51.5"	59.25	63.875"	65
REAR TRACK	50.75"	59.5	63.625"	64.5
MILEAGE	70122	07077	78651	65270
MINIMUM GROUND CLEARANCE mm	5.25"	6.25"	7.25"	8.75"

(a) Weight Less Driver and Instruments

Vehicle Positions

Once a vehicle has left the roadway and has a wheel or wheels on the shoulder, several methods of returning to the roadway are possible. Three of these methods were investigated during the study.

The first is the scrubbing condition, in which the driver allows the vehicle to move laterally toward the roadway at a very slow rate until a tire contacts the roadway-shoulder lip. At that point lateral motion stops and the tire is in intimate contact with the roadway edge (scrubbing) while continuing to travel forward. To mount the edge the driver is required to input an increasing amount of steering toward the roadway.

In the second condition, the right front and rear wheels are well on the shoulder while the other two wheels are still on the roadway. The driver then steers to the left at a comfortable level to produce a lateral velocity high enough to preclude any continuous scrubbing condition as the vehicle returns to the roadway. In the third condition, the vehicle returns to the roadway as in the second condition except that all wheels are on the shoulder before the return maneuver is initiated.

Subjective Rating System

In addition to the photographic and electronic data, a system was developed to allow the driver to report the severity of each test run immediately after completing it. This system consisted of a numerical ranking from 1 (no detectable effect) to 10 (complete loss of control). The following list, referred to as a severity code, was prepared to assist the drivers in assigning a number to their impressions:

1. Undetectable;
2. Very mild;
3. Mild;
4. Definite jerk;
5. Effort required;
6. Extra effort;
7. Tire slip (slight lateral skidding);
8. Crossed centerline and returned;
9. Crossed centerline, no return; and
10. Loss of control (spin-out).

Even though this system is subjective and tends to vary from driver to driver, it proved a good indicator when confined to any one driver's reactions to the entire matrix of tests. This rating value was later used as the dependent variable in sorting by computer on various combinations of conditions.

DISCUSSION OF RESULTS

To evaluate the effect of the three edge heights on two modes of returning to the roadway (scrubbing and a smooth return), average severities were obtained by using the professional driver. Only this driver was used for these data because he completed the entire test matrix.

Figure 8 shows the average values for each of the conditions when the vehicle smoothly returns to the roadway from a position in which it is about half on the earth shoulder and half on the pavement. Clearly, there is little difference between either vehicles or edge heights (3 versus 4.5 in.).

Figure 9 shows the same series of tests for a different prereturn condition. In this case the right wheels are in intimate contact with the pavement edge (the scrubbing condition) before the return to the pavement is attempted. Once again the

Figure 8. Comparison of vehicle performance in nonscrubbing condition at 35, 45, and 55 mph.

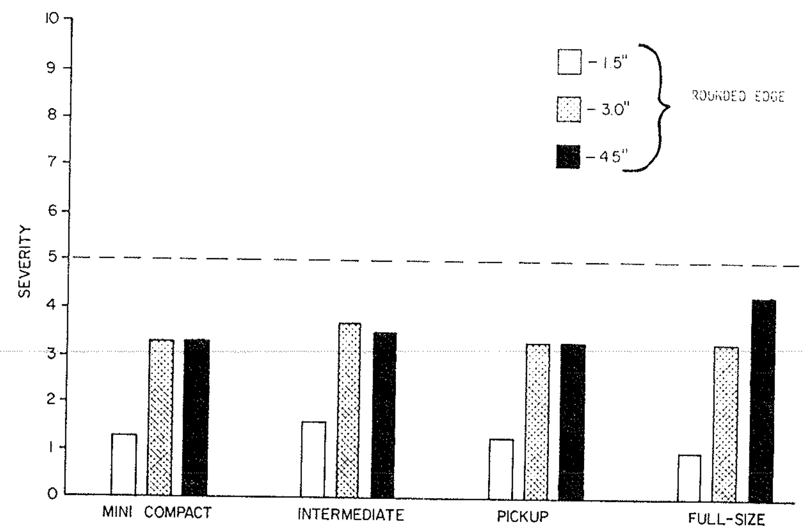
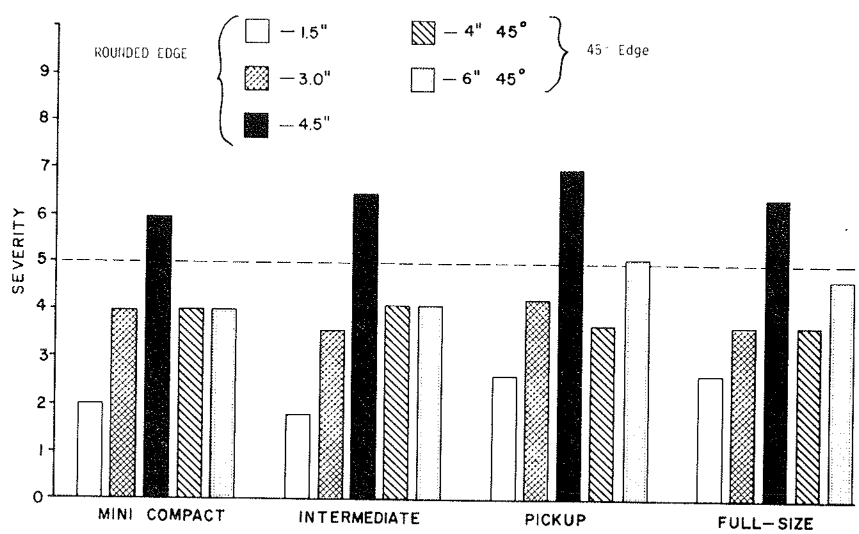


Figure 9. Comparison of vehicle performance in scrubbing condition at 35, 45, and 55 mph.



difference between the vehicles is quite small. But the effect of edge height on the rounded edge is pronounced in the case of the 4.5-in. height: Figure 9 shows the severity of the return maneuver for all vehicles at this edge height extending into the upper half of the graph--i.e., the critical severity range. There is a marked reduction in severity for the 4- and 6-in., 45 degree edges compared with the rounded edges.

To determine the effect of driver skill level, average severity levels were obtained from three drivers (the professional, the semiprofessional, and the untrained male). Data from all vehicles at each test speed for the 3-in. edge height were summarized. The average values for each driver under each prereturn condition were fundamentally equal.

Because both bias and radial tires were tested on the intermediate- and full-sized vehicles, it was possible to make a comparison by using the similar conditions of each test speed, the professional driver, and the intermediate-sized vehicle at the various edge heights. Only the scrubbing condition was considered in this comparison because it involves tire construction much more than the other two conditions. The modified 4.5-in. edge (0.75-in. radius) was also used in this comparison. The bias ply was found to produce slightly higher severity levels than the radial at all edge heights.

Finally, the effect of the speed at which the vehicle returned to the roadway was considered (see Figure 10). Only the runs made by the professional driver were evaluated to maximize the scope of the comparison. In addition, only the scrubbing condition was considered because it has been shown to lead to the most hazardous conditions.

The test results for all vehicles were averaged. As Figure 10 shows, within each edge-height condition a nearly linear increase in severity occurs as the speed increases. As before, the 4.5-in. edge height is a potentially unsafe condition, even at the 35-mph speed. It should also be noted that 45 and 55 mph exceed the critical speeds found by Klein (5). In the case of a 6-in., 45 degree edge, a condition approaching a severity rating value of 5 occurs as the vehicle speed approaches 55 mph.

Steering Angle

Steering-wheel movements required to perform a specific maneuver is one of the most graphic means of developing an appreciation of the difference between a relatively safe and a potentially hazardous condition. The difference between the maneuvers for 3-in. and 4.5-in. edge heights is shown in Figures 11 and 12. Figure 11 shows the results of a typical run made by the professional driver at 55 mph in the intermediate-sized vehicle. In this run, the driver returns to the pavement over a 3-in. drop height. Figure 12 shows the results of a run made under the same conditions but at the 4.5-in. edge height. Notice the extreme arm movements of the driver at 4.67 and 5.75 sec in Figure 12.

Figure 10. Averaged test results for all vehicles in scrubbing condition at 35, 45, and 55 mph.

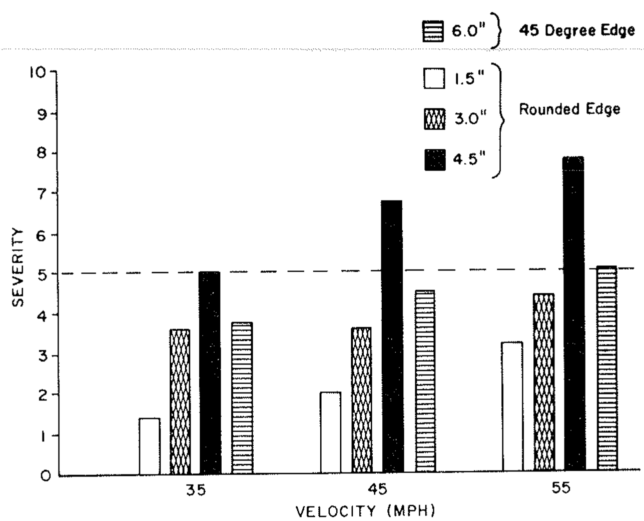
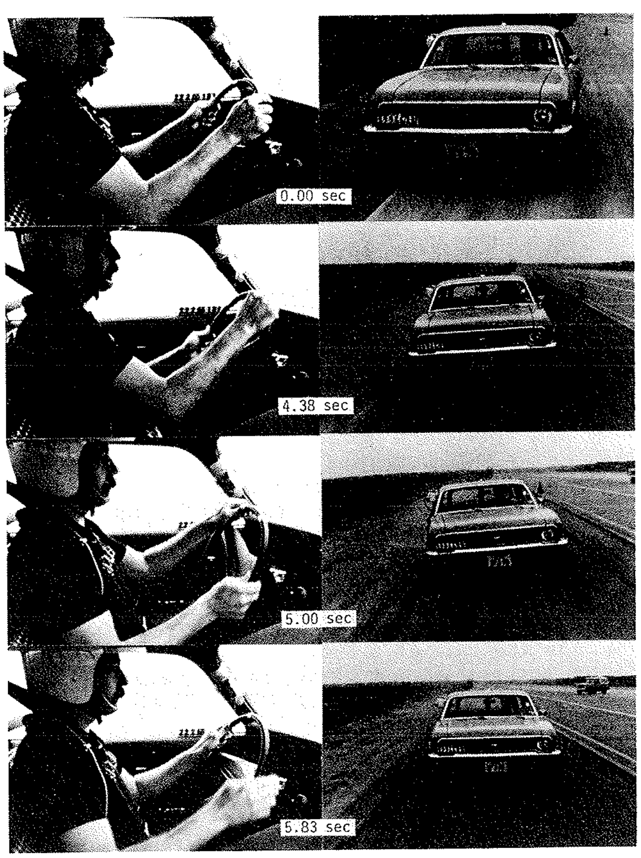


Figure 11. Steering-wheel maneuvers by professional driver in scrubbing condition: 3-in. edge height, intermediate-sized vehicle, at 55 mph.



The amount of lateral acceleration generated after returning to the roadway to avoid entering the oncoming lane of traffic has a significant effect on safety. Figure 13 shows the average lateral acceleration developed over the three speed ranges by the four test vehicles at the various edge heights. The two conditions of prerecovery position are considered. Driver opinion levels obtained from Kummer and Meyer (6) are indicated on the chart. A level of lateral acceleration greater than 0.3 g is considered excessive. This would be a potential limitation imposed on themselves by most drivers, who may not attempt to develop all of the available friction to remain in their lane of traffic. The scrubbing condition produced quite high values--0.7 to 0.8 g--for the 4.5-in. edge, which proved to be near the maximum available friction levels because lane violations and slipouts did occur.

The results of the non-scrubbing-condition test runs compare favorably with the edge mounting work done by Nordlin (3). No loss of control of the test vehicle and no lane encroachment up to and including the 4.5-in. edge height occurred in Nordlin's study or in the research reported here.

The influence of the edge shape is brought out by comparing the results of this study with the results of a study by Klein (5), who used a smooth, near vertical concrete surface for an edge with a 0.5-in. radius at the top. This edge produced similar steering angles for the return maneuver from a scrubbing condition at the 4.5-in. height. Klein reported a steering angle of 9 degrees compared with the 7 degrees observed in this study. The large difference shows up at the lower heights, where 2.5 and 5 degrees were required on the sharp edge at the 1.5- and 3-in. heights compared with the 1.5 degrees needed on the more rounded asphalt edge used in this project.

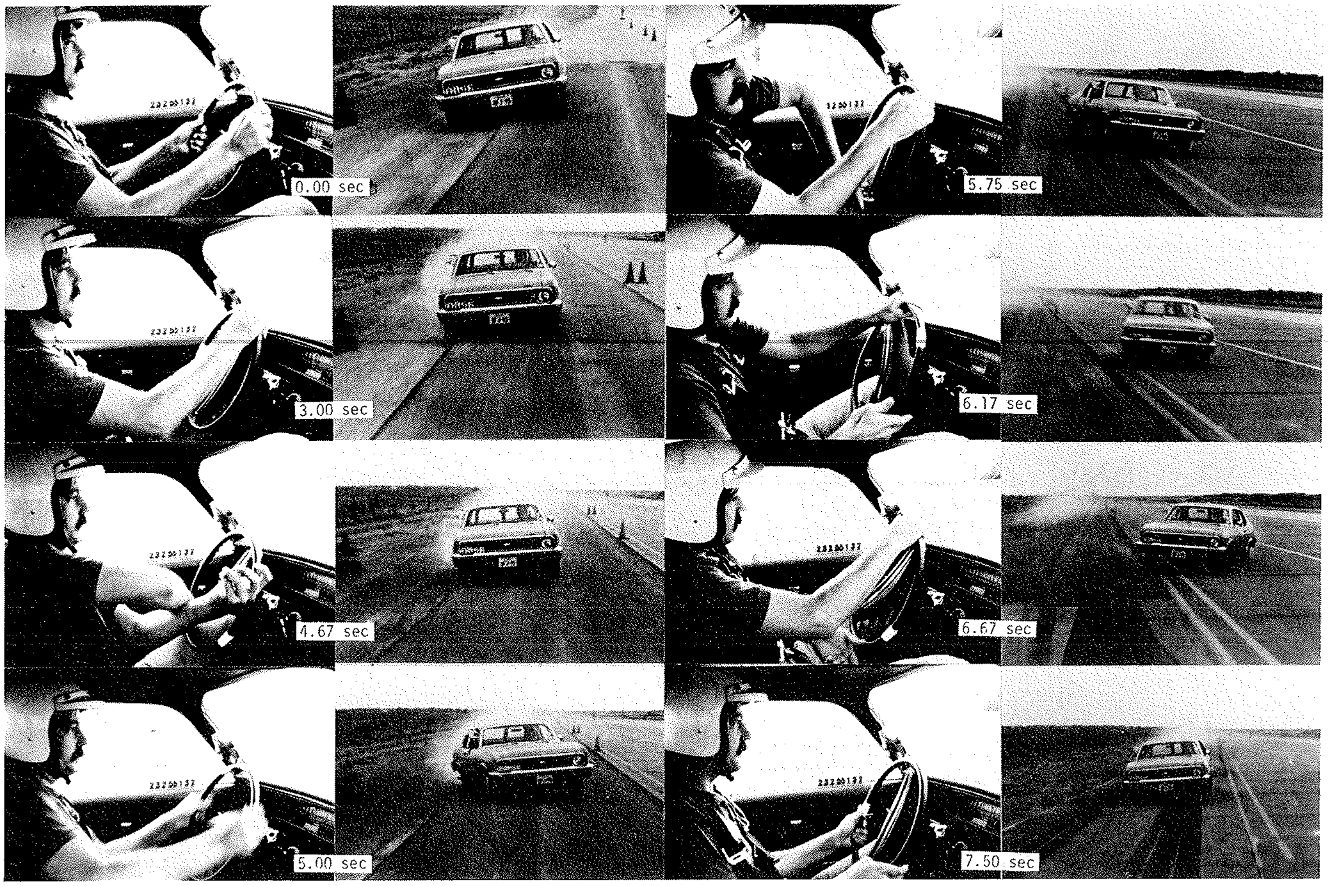
LIMITATIONS OF THE TEST PROGRAM

Although the choice of vehicles would seem to be adequate to define a fairly wide spectrum of vehicle-handling characteristics, this has not been experimentally verified. To evaluate objectively the spectrum of vehicles covered, parameters such as inertial properties, spring stiffness, and tire cornering stiffness should be defined. Other factors, such as vehicle loading and the effect on vehicles other than four-wheeled automobiles, were not considered. The effect of differential tire pressures, especially low pressures on one or more rear tires, was not specifically investigated, although it is anticipated that anything that enhances oversteering would be more critical in a scrubbing edge maneuver. It should also be noted that the subjective rating technique was attempted with only four subjects. This is a limitation, although it was surprising how consistent the ratings were within that group. Although it has not been possible to prove, by using vehicle accident statistics, whether the scrubbing situation is in fact a contributor to a significant number of accidents, in an effort to be conservative that test condition is thought to be a reasonable indicator for use in the development of maintenance guidelines.

SUMMARY AND CONCLUSIONS

The results of the study are summarized in Figure 14, where relative degree of safety, in terms of the subjective severity levels defined previously, is plotted versus change in longitudinal edge elevation. Three curves are shown, one for each pavement edge profile shape: Shape A is the sharp edge tested by Klein, shape B is the rounded edge shown in Fig-

Figure 12. Steering-wheel maneuvers by professional driver in scrubbing condition: 4.5-in. edge height, intermediate-sized vehicle, at 55 mph.



ure 3, and shape C is the 45 degree edge shown in Figure 4b.

The terms used to describe relative degrees of safety can be defined as follows:

1. Safe indicates that, no matter how impaired the driver or how defective the vehicle, the pavement edge will have nothing to do with a loss of control. (This includes the influence of alcohol and other drugs and any other infirmity or lack of physical capability.) The term includes the subjective severity levels 1 through 3.
2. Reasonably safe indicates that a prudent driver of a reasonably maintained vehicle would experience no significant problem in traversing the pavement edge. The term includes subjective severity levels 3 through 5.
3. Marginally safe indicates that a high percentage of drivers could traverse the pavement edge without significant difficulty. A small group of drivers might experience some difficulty in performing the scrubbing maneuver and remaining within the adjacent traffic lane. The term includes subjective severity levels 5 through 7.
4. Questionable safety indicates that a high percentage of drivers would experience significant difficulty in performing the scrubbing maneuver and remaining within the adjacent traffic lane and full loss of control could occur under some circumstances. The term includes subjective severity levels 7 through 9.
5. Unsafe indicates that almost all drivers would experience great difficulty in returning from the pavement edge scrubbing condition and loss of control would be likely. The term includes subjective severity levels 9 through 10.

Figure 14 represents an effort to summarize all research and testing results available for interpretation, including the testing by Caltrans, Systems Technology, Inc., and TTI. It was necessary to use subjective judgment in constructing this figure, based on the preceding definitions of safety. The figure is subject to the limitations previously stated and represents average vehicle and speed conditions. Atypical vehicles, vehicle loadings, tire conditions, and speeds could result in significant shifts in the positions of the curves.

Figure 14 could have direct application to maintenance recommendations. For example, consider the point on the shape B curve where the curve crosses line 1--i.e., at the 2.5-in. elevation change. This height might indicate a need to prepare for maintenance before the edge level increases to the point where the curve crosses line 2--at 3.5 in. For shape A edges, maintenance would be somewhat more critical: maintenance activities are indicated at a height between 2.0 and 3.0 in., roughly corresponding to the crossing of lines 1 and 2.

The advantage of avoiding shape A is also apparent in Figure 14. If shape C can be constructed, either during the original construction or as a maintenance activity, the need for edge maintenance could be significantly reduced. It is thought that these curves can be used as a guide for the maintenance of pavement edges and that they indicate the desirability (based on determinations of cost-effectiveness) of gradually moving toward edge shape C. Shape C may also result in significant gains in the reduction of edge deterioration.

Using data from Michigan's Highway Safety Research Institute, Indiana data, and his own survey questionnaire, Klein (5) has shown pavement edges to

Figure 13. Maximum lateral acceleration and edge height.

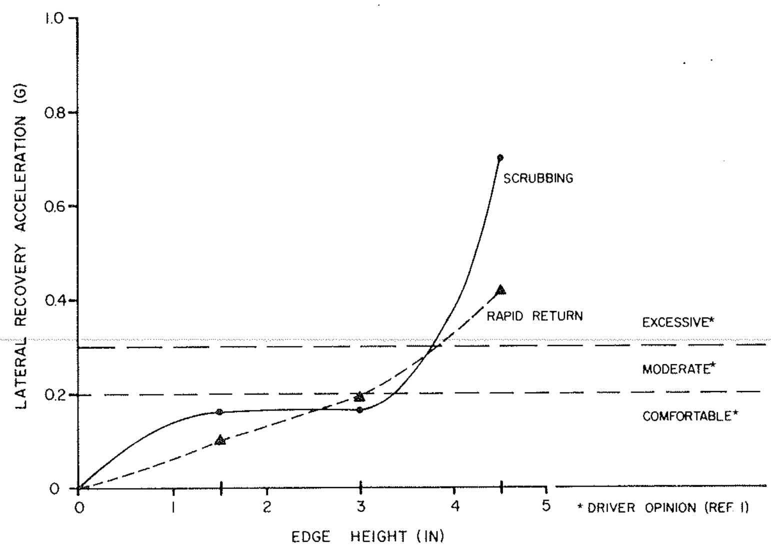
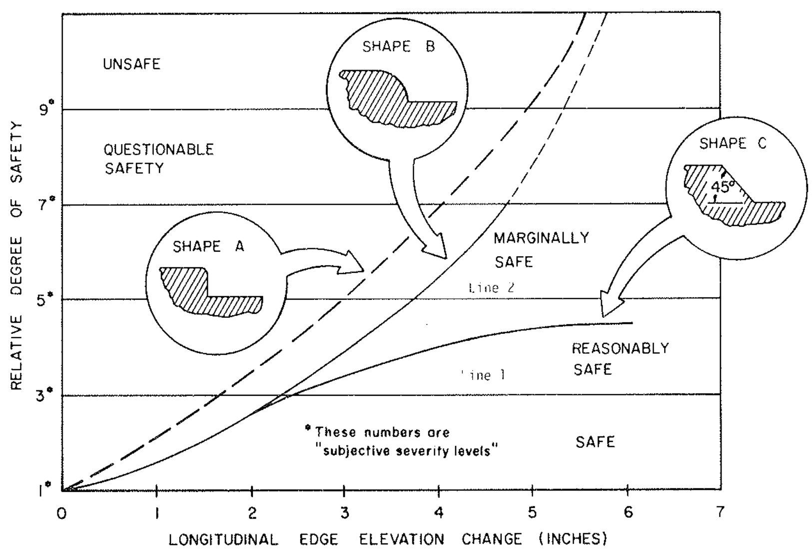


Figure 14. Relationship between edge geometry and safety for scrubbing condition.



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ACKNOWLEDGMENT

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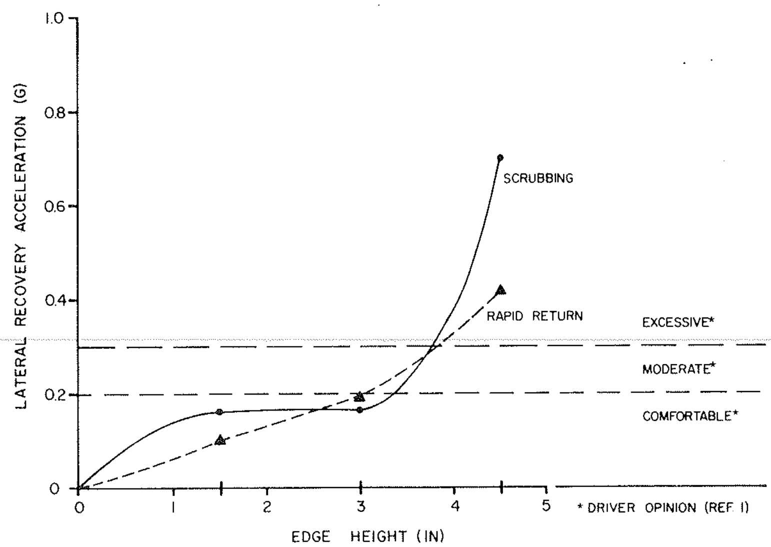
Figure 13. Maximum lateral acceleration and edge height.



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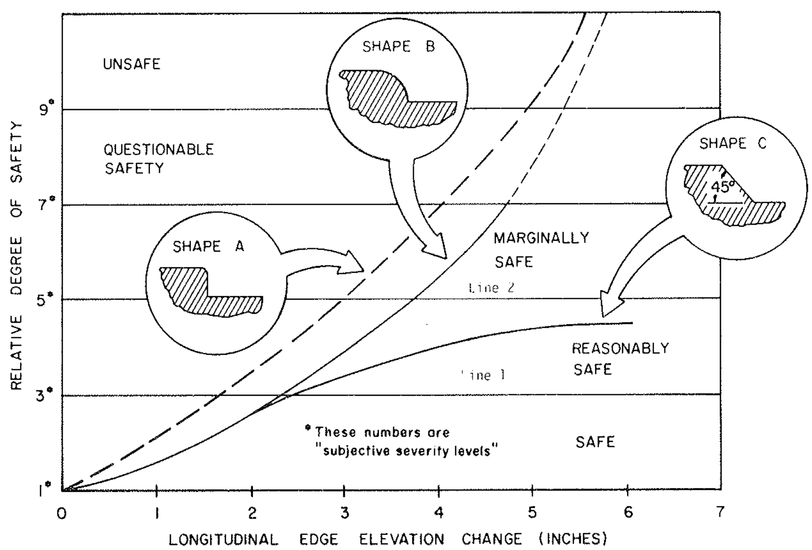

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