REPORT OF DEPARTMENT OF HIGHWAY DESIGN

R W CRUM, *Acting Chairman*

REPORT OF PROJECT COMMITTEE ON RELATION OF CURVATURE TO SPEED, C N CONNER, *Chairman*

SAFE SIDE FRICTION FACTORS AND SUPERELEVATION DESIGN

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SYNOPSIS

In Part I about 900 road tests are reported, dealing with curvature, superelevation and the speed at which side pitch is first felt If it is assumed that an ample margin of safety against skidding exists when a vehicle moves around a curve at the minimum speed at which side pitch is felt by driver or passenger, the tests indicate that vehicles may safely travel around curves at speeds which require side friction, in addition to superelevation, represented by factors of 0 16 up to and including a vehicle speed of 60 miles per hour, with a reduction of 0 01 for each increase of speed of 5 miles per hour Insufficient tests were made to accept this trend for speeds greater than 70 miles per hour The side pitch was first felt at lower speeds on wet pavements as against dry pavements, and when vehicles with individual front wheel suspension were used as against vehicles with standard front axles

The proposal is made in Part II that highways be superelevated to counteract where possible all centrifugal force for a speed of three-quarters of the assumed design speed, with the following results as compared to superelevating to counteract all centrifugal force for all of the assumed design speed aid to slower moving vehicles without penalizing faster moving vehicles, a safer highway when all traffic moves slowly due to pavements made slippery by ice, etc , no effect on future redesigns to reasonably higher speeds, and greater uniformity in the design of curves of widely different radii

PART I—SAFE SIDE FRICTION FACTORS

The increasing number of motor vehicle accidents in the last decade has focused attention on the need for emphasizing safety in the design and construction of highways as well as for encouraging safe driving Relatively sharp curves were always considered hazardous, but little thought was given to an accurate determination of the speed at which a motor vehicle could negotiate a particular curve with safety The flattest curves possible were constructed commensurate with the topography and available funds It was assumed that a motor vehicle operator would slow down for sharp curves especially if curve warning signs were installed

This method was satisfactory when prevailing speeds were low, but with increasing speeds more refinement in curve design became necessary Operators found it easier and sometimes necessary to flatten curves by cutting corners and the accident rate mounted Superelevation came into general use The speed with which a vehicle could negotiate a superelevated curve without the aid of friction could be calculated The policy adopted generally was to superelevate to counteract all centrifugal force for some assumed speed, generally

35 to 50 miles per hour, and adopt a practical maximum superelevation relying on friction to counteract all centrifugal force not taken care of by superelevation It was realized that most vehicles would travel at speeds greater than that assumed for superelevation and it was expected, rightfully, that friction would take care of the excess centrifugal force, only there existed but a vague conception of how much friction could be utilized with safety Many tests on skidding characteristics have been made, notably those by Prof R A Moyer,[1] but much difference of opinion existed regarding the amount of friction which might be considered safe at different speeds

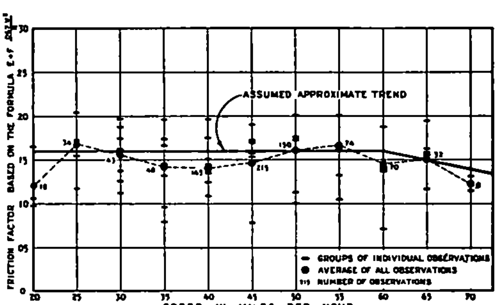


Figure 1. Average Side Friction Factor When Side Pitch Is Noticed

In the spring of 1935 the U S Bureau of Public Roads issued a brochure on "Safe Speeds on Curves" and invited road tests to be made with standard motor vehicles Instructions for measuring curvature and superelevation were included as well as a definition of what is to be considered maximum safe speed under normal driving conditions This definition is "Safe speed on a curve is the minimum speed at which the centrifugal force, created by the movement of a vehicle around the curve, causes the driver or passenger to feel a side pitch outward" Skidding occurs at much higher speeds and it was felt, therefore, that an ample margin of safety against skidding would be present at the speeds at which side pitch is first encountered

Reports on nearly 900 road tests were received In all but one set of observations passenger vehicles were used Weights of vehicles varied widely, but low and medium priced cars were in the majority In one set of observations, a one-half ton truck was used Most of the tests were run on high type pavements of various kinds, but some tests were run on low cost bituminous types It was not convenient to tabulate the results in accordance with different types of pavements Tires in all stages of wear were used but no especially old and smooth tires were reported Reports were received from very widely separated sections of the country

The side friction factor for each test was calculated from the well known formula $E + F = \frac{067\ V^2}{R}$ in which E represents the superelevation slope, F the side friction factor, V the velocity of the vehicle in miles per hour, and R the radius of the curve in feet

The results were grouped into speeds in multiples of 5 miles per hour so that no test was tabulated for a speed more than 2 miles per hour different than the observed speed The results of the tests which could be utilized were used to plot a few curves in all of which the ordinates represent the side friction factor and the abscissae the speed in miles per hour

Figure 1 shows the curve platted using all observations Each horizontal dash represents the average for that speed of the reports of one observer or set of observers Each solid circle represents the average for that speed of all observations The figure near each solid circle

[1] Skidding Characteristics of Automobile Tires on Roadway Surfaces and Their Relation to Highway Safety by Prof R A Moyer, Iowa State College of Agriculture and Mechanic Arts Bulletin 120 Also Proc Highway Research Board, Vols 13 and 14

represents the number of observations used for computing each average Some variation from the mean is obvious but practically all averages of the reports of one observer or set of observers are greater than 0 10 and less than 0 20 The assumed trend is represented by the heavy line It assumes a side friction factor of 0 16 up to and including a speed of 60 miles per hour and a friction factor 0 01 less for each increase in speed of 5 miles per hour above 60 These are the figures used in subsequent calculations though they appear to be slightly higher than the trend represented by the broken line The choice of a slightly

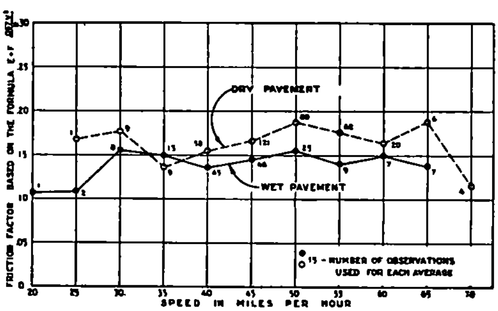


Figure 2. Average Side Friction Factor When Side Pitch Is Noticed. Dry vs Wet Pavements

higher factor is justified by the fact that the results of one set of observations, low in value and large in number unduly influenced the averages The observations for speeds greater than 60 miles per hour were so few in number that many additional tests are needed to confirm the assumed trend for the higher speeds The trend for the higher speeds is assumed for convenience in developing Part II of this discussion

The trend represented by the curve is practically horizontal For the same speed range almost all tests made to determine skidding characteristics as distinguished from safe friction result in decided downward trends in the side friction factor-speed curves with increasing speed, but no similar trend is apparent in these tests There appears to be no reason why the trends should be similar because skidding is affected principally by the character and condition of tires and surface of pavement whereas side pitch is affected principally by the construction of the vehicle particularly the distribution of weight and the character of springs and suspension Except for icy pavements side pitch will be felt generally at speeds much lower than those at which skidding impends so that only a fraction of the friction required to prevent a vehicle from sliding outward at impending skidding is required to prevent

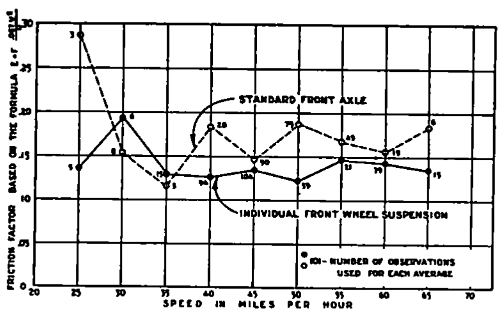


Figure 3 Average Side Friction Factor When Side Pitch is Noticed. Standard Front Axle vs. Individual Front Wheel Suspension

the same vehicle from sliding outward at the lowest speed at which side pitch is noticed A very rough pavement may have some bearing on side pitch in that it may set some parts of the vehicle in motion which may be synchronous with the motion caused by centrifugal force, but other characteristics of pavement surface should have no bearing on side pitch The margin of safety at any speed may be represented by the difference between the friction factor at impending skid and the friction factor when side pitch is first noticed Since the skidding factor curve drops with increase in speed and the side pitch factor curve remains approximately horizontal, it is evident that for the method used herein for the determination of safe side friction factors, the margin of safety is less on curves designed for and negotiated at higher speeds than on curves designed for and negotiated at lower speeds

Three sets of observers made comparative test runs on wet and dry pavements The results are shown in Figure 2 When testing for skidding characteristics smaller side friction factors for wet pavements should be expected, but there appears to be no reason for expecting this when testing for initial side pitch The tests, however, result in lower side friction factors for all speeds for which a reasonable number of observations are available The unexpected result may be attributed to the fact that the average observer is likely to be more alert on wet pavements and imagine he feels side pitch at lower speeds than those at which side pitch actually occurs

Three sets of observers made test runs to compare the action of vehicles with standard front axles with the action of vehicles in which the front wheels are individually suspended The results are shown in Figure 3 and indicate lower side friction factors for cars with individual front wheel suspension for all speeds for which a reasonable number of observations are available The observers were probably influenced by body roll but whatever the cause, the side friction existing at the minimum speed causing driver and passengers to feel side pitch, real or apparent, is assumed to be the amount which may be used with safety The effect of front wheel suspension, therefore, is to lower the average side friction factor assumed to be safe

PART II—SUPERELEVATION DESIGN

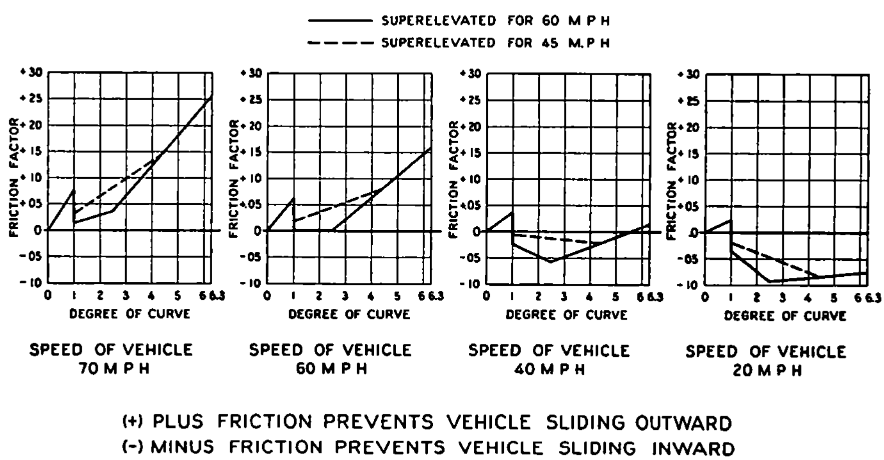
Most highway organizations at the present time design and construct curves with enough superelevation, wherever possible, to counteract all centrifugal force when a vehicle travels at an assumed speed on the highway All sharp curves for which the calculated superelevation slopes required to counteract all centrifugal force are equal to or greater than a practical maximum are constructed with this practical maximum superelevation slope Side friction is relied on to counteract all centrifugal force not taken care of by the superelevation

It is proposed that curves be constructed with only enough superelevation to counteract all centrifugal force when a vehicle travels at three quarters of the assumed design speed of the highway rather than at the assumed design speed Let us examine the effects of this proposal on vehicles traveling at various speeds

Figure 4 shows the friction, represented by the friction factor, required by a vehicle rounding various curves at various speeds on a highway designed for 60 miles per hour A positive factor represents friction required to prevent a vehicle from sliding outward and a negative factor represents friction required to prevent a vehicle from sliding inward Solid lines show the factors when the superelevation is designed to counteract all centrifugal force wherever possible when a vehicle travels at the assumed design speed of the highway Dashed lines show the factors when the superelevation is designed to counteract all centrifugal force wherever possible when the vehicle travels at three quarters of the assumed design speed

The effect on a vehicle traveling at the assumed design speed of the highway is shown in the second diagram which represents the friction in addition to superelevation required to resist centrifugal force when a vehicle travels at 60 miles per hour When the curves are superelevated for 60 miles per hour no friction is required up to curves of 2 6 degrees, after which required friction increases rapidly to the maximum safe friction When the curves are superelevated for 45 miles per hour a moderate amount of friction is required for the flatter curves, the amount increasing gradually to curves of 4 4 degrees The abruptness of the change from no friction to maximum friction is thus softened considerably and greater uniformity in the design of curves of different degree is effected There seems to be little uniformity in a design in which almost all curves are superelevated to the practical maximum and in which a vehicle rounding one curve requires the maximum safe side friction to keep it on the pavement and in rounding the next curve requires no friction whatsoever required friction on any curve affected by it to an amount greater than that represented by a factor of 0 14 which is assumed to be safe for 70 miles per hour

The effect on vehicles traveling at speeds less than the assumed design speed is shown in the third and fourth diagrams which represent the friction required to resist centrifugal force when a vehicle travels at 40 and 20 miles per hour respectively When the curves are superelevated for 60 miles per hour the vehicles require negative friction to prevent them sliding down the slopes. In effect the great number of vehicle operators who travel at speeds less than



Friction 4 Required Side Friction Factor Assumed Speed 60 M P.H.

The effect on a vehicle traveling at excessive speed is shown in the first diagram which represents the friction required to resist centrifugal force when a vehicle travels at 70 miles per hour, 10 miles per hour in excess of the assumed design speed The friction required on the sharper curves is, of course, greater than is considered safe, reaching a factor of 0 25 for the sharpest permissible curvature of 6 3 degrees The alternate proposal does not affect these sharper curves While it increases the friction required on the flatter curves the alternate proposal does not increase the total the assumed design speed are penalized When the pavement is covered with ice most vehicle operators will reduce speed and the necessity for requiring negative friction to stay on the pavement is often annoying and sometimes dangerous When the curves are superelevated for 45 miles per hour the required negative friction is reduced

Let us now examine the effects of the proposal on the theoretical safe speeds with which vehicles may travel on curves of various degrees

The lower diagram in Figure 5 shows the amounts of superelevation slope required for various degrees of curvature for an assumed design speed of 60 miles per hour The superelevation represented by the solid line will counteract all centrifugal force when a vehicle travels at the assumed design speed up to the point where a practical maximum superelevation slope of 1¼ inches to the foot is required The superelevation represented by the dashed line will counteract all centrifugal force when a vehicle travels at 45 miles per hour up to the point where the same practical maximum

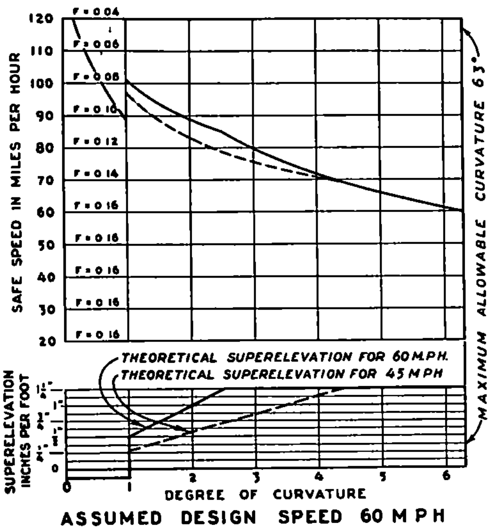


Figure 5. Safe Speed on Curves

superelevation slope is required For curves sharper than those represented by these limiting points increasing amounts of side friction are required to counteract centrifugal force On curves of 6 3 degrees vehicles traveling at 60 miles per hour will require the practical maximum superelevation plus the safe maximum side friction represented by a friction factor of 0 16 to counteract centrifugal force Curves sharper than 6 3 degrees therefore should not be considered safe for vehicles traveling at speeds of 60 miles per hour and greater

The break at a curvature of one degree is indicative of the fact that curves flatter than one degree are not superelevated generally and the outer lane or lanes of a crowned pavement are, in effect, superelevated negatively about one eighth inch to the foot

The upper diagram in Figure 5 shows the theoretical safe speeds at which vehicles may travel on these curves based on the formula

$$E + F = \frac{067\ V^2}{R}$$

in which E represents the superelevation slope, F the friction factor considered safe for the speed, V the speed in miles per hour, and R the radius in feet The safe friction factors are taken from the assumed trend mentioned in Part I of this discussion, namely, 0 16 for speeds up to and including 60 miles per hour and a reduction of 0 01 for each increase in speed of 5 miles per hour

The proposed alternate would have no effect on a possible future redesign of the highway for a higher speed In Figure 5 it is evident that the theoretical safe speed of no curve affected by the proposed alternate is reduced to less than 70 miles per hour so that a redesign for 70 miles per hour could be made without affecting the curves whose radii need not be increased In fact appreciable changes would not be caused by the adoption of the proposed alternate if a redesign to 75 miles per hour were made The extent of the reduction in theoretical safe speeds on the flatter curves is illustrated by the fact that this speed is reduced from 89 to 83 miles per hour on a 2 degree curve

Figure 6 is similar to Figure 5 and shows similar relationships for assumed design speeds of 30, 40, 50, 60, and 70 miles per hour The same avoidance of change where the theoretical safe speed is not considerably greater than the assumed design speed is manifest so that the alternative method for superelevating curves will not affect future changes to higher assumed design speeds

From the foregoing it may be concluded that designing superelevation to counteract all centrifugal force when a vehicle travels at three quarters of the assumed design speed instead of at the assumed design speed results in the following·

1 —Aiding slower moving vehicles without penalizing faster moving vehicles

should be safe for the assumed design speed The unexpected is always dangerous so that if a driver is encouraged to speed up on a few successive comparatively flat curves the danger point will be the beginning of the next sharp curve· This does not imply that a deliberate attempt should be made to sharpen curves The alternative reduces superelevation only on the relatively flat curves for which the theoretical safe

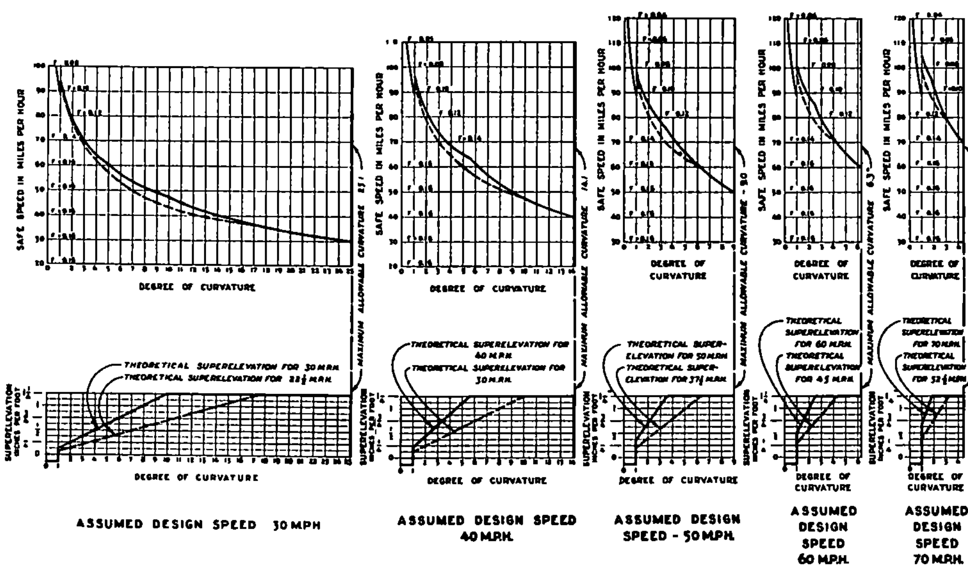


Figure 6 Safe Speed on Curves

2 —A safer highway when all traffic moves slowly due to pavements made slippery by ice, etc

3 —No effect on future redesigns to reasonably higher speeds

4 —Greater uniformity in the design of curves of widely different radii

The assumed design speed of a highway should be the maximum reasonably uniform speed which would be adopted by the faster driving group of vehicle operators, once clear of urban areas The various factors which go into the choice of this design speed need not be discussed here However, the aim in designing any section of highway should be a balance in design All features

speeds are considerably greater than the assumed design speeds Wherever possible long flat curves should be preferred to tangents and short sharp curves Nothing adds more to the pleasing appearance of a highway than long, flowing, graceful alignment However, if the design results in a succession of flat curves a higher design speed may be assumed An exceptional sharp curve in this section may be signed for a lower speed

TENTATIVE CONCLUSIONS

If it is assumed that an ample margin of safety against skidding exists when a vehicle moves around a curve at the minimum speed at which side pitch is felt by driver or passenger, road tests indicate that vehicles may safely travel around curves at speeds which require side friction in addition to superelevation represented by factors of 0 16 up to and including a vehicle speed of 60 miles per hour with a reduction of 0 01 for each increase of speed of 5 miles per hour to counteract centrifugal force The number of tests at speeds greater than 60 miles per hour were insufficient to confirm the assumed trend for these speeds Some differences between individual sets of observations and the mean indicate that additional tests at all speeds would be useful

It seems advisable to design superelevation to counteract all centrifugal force, wherever possible, of vehicles traveling at about three quarters of the assumed design speed of the highway The sharpest curves for the assumed design speed are not affected Slow moving vehicles are aided without penalizing fast moving vehicles Possible future redesign of the highway for higher speed is not affected Greater uniformity in design of curves of widely different radii results

DISCUSSION ON FRICTION FACTORS AND SUPERELEVATION

MR E R HAILE, JR, *U S Bureau of Public Roads,* The assumptions that the minimum speed at which a side pitch outward is felt by the occupants of the vehicle is the maximum safe speed at which the average driver can negotiate a curve, and that there is an ample margin of safety against skidding at that speed are valid only within a narrow range of speeds (near 45 miles per hour)

At speeds under 45 miles per hour, the margin of safety is unnecessarily large, and at speeds over 45 miles per hour, the margin of safety is too small Figure 1 shows the maximum side friction factor considered safe by the average driver at various vehicle speeds as determined from a small number of observations

Since it is estimated that less than one-fourth of the drivers have most of the accidents, the average driver is essentially a *safe* driver Consequently, his judgment should bear considerable weight in the determination of a safe speed

An examination of Figure 1 suggests the following remarks

At low speeds, the side friction factor, F, may be as high as 0 30 and still allow some margin of safety; because skidding does not occur under normal conditions until F reaches about 0 50 This margin is ample at low speeds when the car can be slowed down or stopped in a short distance At high speeds because skidding may occur when F = 0 35 the side friction factor should not exceed 0 10 in order to provide a sufficient margin of safety A larger margin is necessary because of the greater difficulty in steering, the greater distance required for reducing speed and the greater danger of fatal accident in cases of emergency. This margin is important, because excessive speed, say 10 per cent higher than the safe speed, results in a friction factor 30 to 40 per cent greater than the safe value

The writer's method of determining safe speed is to observe the average speed of all the drivers who, upon entering the curve, begin to encounter difficulty in keeping their vehicles under control and reduce their speed This does not imply that such drivers are on the verge of skidding, but only that they want to provide an ample margin of safety It is essential that only those who reduce speed be noted, because it is probable that those who were going slowly and did not reduce speed were traveling under the maximum speed they would consider safe for the curve

An analysis of the definition of safe speed based on "initial side pitch," upon which the road tests described in Mr Barnett's paper were made, shows that the side pitch causing a given degree of discomfort should occur at the same value of F whatever the speed of the vehicle or the slipperiness of the pavement, therefore, the lower values of F obtained for speeds over 60 miles per hour (Fig 1) and for wet pavements (Figs 1 and 2 of Mr Barnett's paper) are due to the imagination of the observer

The fairly wide variation in values of F at which the initial side pitch was felt (Barnett, Fig 1) is due to the variety of conceptions of "initial side pitch " Each observer has to set up his own standard criterion for safe speed that is not generally used by drivers A more common criterion for safe speed is whether or not the vehicle is under control

The method of determining maximum safe speed by observing the "speed con-

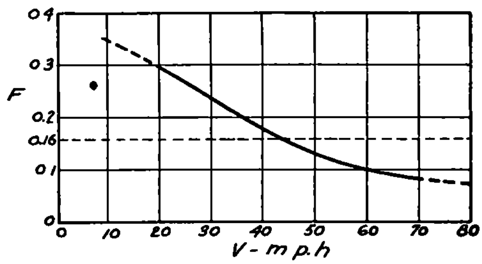


Figure 1 Note· F=0 16 Is Not Much Different from the Graph for Design Speeds 35 to 50 m p h.

Example 1—Assume Design speed = 70 m p h Radius of curve = 1824 ft Traffic distribution—see Figure 3B

Speed	Under 25	25-35	35-45	45-55	55-65	Over 65	70
Per cent from Fig 3B	5	29	37	22	6	1	neg
F when E = 100 (Banked for 3/4 x 70)	– 077 (and more)	– 067	– 041	– 008	+ 032	+ 055 (and more)	+ 080
F when E = 059 (Banked for 40 m p h)	– 036 (and more)	– 026	– 0	+ 033	+ 073	+ 096 (and more)	+ 121
Per cent when road is icy (From Fig 3C)	14	76	10	—	—	—	—

as to how severe a lurch should be called the "initial side pitch " Upon analyzing "side pitch," it is discovered that there is no property of a curve that can cause it The lurch is primarily a consequence of a short spiral, because where the spiral is sufficiently long, no side pitch is felt The only evidence an observer in the car has that there is a large friction factor developed is the apparent tilting of the vehicle outwards through an angle whose tangent is F, except in the case of the driver, who has to exert a force on the steering wheel to maintain the curvature He limits his speed on account of this difficulty in steering, instead of because of any "initial side pitch " This demonstrates the inappropriateness of using a sidered safe by the average driver" or "the speed at which he begins to encounter difficulty in keeping his vehicle under control" is superior to the method described in the paper in which "initial side pitch" is the criterion, because it will more accurately predict the speeds that will be used and because it provides a larger margin of safety at high speeds than at low speeds, in contrast with the method described in the paper, which provides a smaller margin at high speeds than at low speeds

It is proposed that curves be superelevated to counteract all centrifugal force, wherever possible, for the average speed of all the vehicles on the highway

(instead of for the design speed, or three-quarters thereof)

In some cases the average speed may equal three-quarters of the design speed However it may be nearly as high as the design speed, in which case most of the vehicles will encounter a positive side friction factor if the curve is superelevated for three-quarters of the design speed Again, it may be less than three-quarters of the design speed, in which

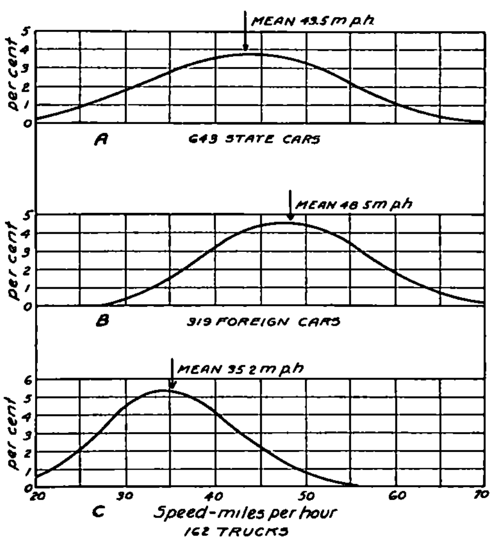


Figure 2 Percentage of Vehicles at Different Speeds.

case most of the vehicles will encounter a negative friction factor Example 1 illustrates this case It feels normal to a driver to experience a slight centrifugal force outward when driving around a curve, but it is disconcerting to feel a force in a direction contrary to normal It compels him to guide his steering wheel outward to avoid heading to the inside of the curve, with danger of collision If icy, the road is unsafe for friction factors in excess of minus 0 05

The writer has observed the speeds of vehicles on several trunk highways in Pennsylvania and Maryland on eight different days at different seasons of the year In each case, the portion of the road over which the vehicles were clocked was about a mile in length, on tangent, with gently rolling profile, grades mostly under 3 per cent, sight distances over 1000 feet, no cross roads, pavement dry, on weekdays in daylight, with traffic so light that a fast vehicle was seldom delayed in passing a slow vehicle, and with no traffic patrolmen in evidence The data are shown in Figures 2 and 3

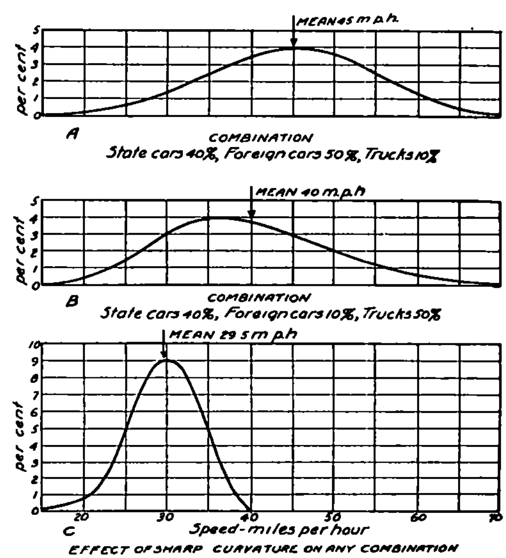


Figure 3 Percentages of Vehicles at Various Speeds for Different Combinations of Traffic and Effect of Sharp Curves

Since none of the observations were made within commuting distance of a city, and none were made on Sundays, commuters and idling pleasure cars are not included

If the proposed highway is between widely separated cities, the curve (A) in Figure 3 gives a probable distribution of traffic, and if it is between nearby cities where short haul trucking is profitable, the center curve (B) gives a probable distribution The lower curve (C) of Figure 3 shows how the traffic is slowed down by sharp curvature Snowfall, icy surface, and to some extent darkness have a similar effect in reducing the average speed of vehicles

In this example, the average speed is 40, which is less than $\frac{3}{4} \times 70$ Notice how the majority of vehicles are favored, especially if traveling slowly in icy weather, when the curve is superelevated for 40 miles per hour When and if the average speed of vehicles ever attains about 52 miles per hour, then the superelevation can be increased to 0 100 (with a wedge course), and the road will be safe for 70 miles per hour without any changes in alignment

The proposed method of superelevating curves for the average speed is more satisfactory than the method of arbitrarily superelevating for three-quarters of the design speed, except in those cases where topography and other conditions permit the chosen design speed to be four-thirds of the average speed of all the vehicles

PROF R A MOYER, *Iowa State College* In general, I agree with the author in regard to the standards in superelevation and curvature which he recommends I cannot agree entirely with the recommendations of Mr Haile, that we should base our design standards on what drivers will do on curves of our present highways because on many curves in our roads of today, a marked reduction in speed is necessary as compared to the general speeds prevailing on the straightaways Many drivers are not prepared or are not willing to drive at this reduced speed and, therefore, will take the curves as fast as they can with a very small margin of safety At the time that we conducted our tests on curves, measuring steering angles, slip angles, coefficients of friction and other factors related to the critical speeds on curves, we encountered many drivers who were taking the curves at higher speeds than those at which we were willing to drive in our tests This was because we operated at speeds at which we knew we could keep the car on the right side of the road within a 9-ft traffic lane whereas the other drivers operating at excessively high speeds were rarely, if ever, on their own side of the road and within the 9-ft lane for the full length of the curve If curves are designed properly the driver should have little difficulty in keeping on his side of the road

I believe that the maximum safe speed on a curve, the speed for which the curve should be designed, should be very nearly the same as the maximum safe speed permissible on the straightaway or at which the majority of drivers are operating on the straightaway, because we should not introduce the unexpected to surprise the driver It is a hazardous practice to design the straightaways for 60 or 70 miles an hour but require a reduction in speed to 40 or 50 miles an hour on a part or on all curves Today there are certain designers who recommend that the maximum coefficient of friction which should be used in arriving at design standards for curves, should be 0 03 or 0 04 In my opinion, that is excessively low because our tests showed that we can and do depend more on friction than on superelevation to drive safely on curves The maximum superelevation which may be used in localities where snow or ice covered roads are encountered is about $1\frac{1}{4}$-inches per ft This is equivalent to a slope of 1 in 10 or a coefficient of friction of 0 10 Now the maximum coefficient of friction that can normally be developed on highway curves is about 0 30, with 0 50 and as high as 0 60 for the exceptional driver The value of 0 16 which the observers found to be safe and which permitted a fairly comfortable ride on curves, is in my opinion a reasonable value to adopt as a standard in curve design It is true that many drivers will develop a much higher coefficient of friction on our curves today than the 0 16 recommended in this report, but that fact in itself does not warrant the use of a higher coefficient in the design of curves in the future

A question which the author did not discuss but which I believe is of paramount importance to highway engineers today is—"What are the speed standards which should be adopted in the design of the various classes of highways of the future?" This is a question worthy of the most careful study to which all interested parties should contribute In many states there is agitation among enforcing officials to restrict speeds to 40, 50, or 60 miles an hour In certain other states, highway engineers are designing highways for speeds of 80 and 100 miles an hour Isn't it possible that both groups are wrong? Upon the answer to this question centers much of the safety of our highways and the extent to which funds for highway construction may be used most effectively