PROMOTING HIGHWAY SAFETY BY THE ELIMINATION OF RIGHT ANGLE TURNS

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Since the year 1900 there has been a very great development in the theory and practice of road design and construction. The engineer and those who have been placed in charge of the highway program in our progressive communities have had a very large part in this forward movement. The engineer has shown the way, and those to whom he has had to look for financial support, and in some localities political support, have swung, sometimes slowly it is true, into line, until today we see everywhere, in all our states, a rounding out of a comprehensive and complete network of paved and improved highways, the results of this cooperation of engineers, road authorities, and road builders.

“Every farmer upon an improved road” was at first a slogan loudly and steadfastly promulgated, but the fallacy of this ideal has gradually been borne in upon the minds of those who have been dealing with roads until today it is recognized that all roads are not of equal importance. A certain number of roadways are carrying such heavy concentrated traffic as to fall into the class which is very much before the public today, known as the superhighway. There is another group of roadways which carries heavy traffic more local in its origin which is classed as the primary state trunk line system. The other roads of lesser traffic value are classed as secondary roads, also known as the county and township systems.

In working up the design of the highway, it should be a requirement that traffic conditions of the present and as predicted for the future be taken into consideration. A design based only on present-day traffic conditions will fall far short of giving maximum service as future traffic comes upon it. There is bound to be an increase in traffic on all roads, and this increase must be provided for in the design.

The original roads of the country developed from woodland trails to traveled ways. A great many of our present-day improved highways are but the utilization of these old trails, brought up to present-day requirements by some grading and surfacing. The real automobile road which is intended to serve the present and future must in its design and its construction deviate to a greater or less extent from these old trail locations.
Horizontal Curves

Considering only that part of the design of the present road structure which has to do with making safe for travel those places where the roadway must turn to the right or to the left, we will investigate what has been done and what is being proposed for the improvement of curvature with respect to

- Horizontal alignment
- Vertical alignment
- Sight distance
- Superelevation
- Widening
- Heavy traffic intersections

In the day of horse-drawn traffic, the 90° angle, which is so prominent in those parts of the United States which have been laid out under the survey methods of the United States Land Office, was not objectionable nor dangerous, but today under our present fast traffic operations any sharp curve, and the 90° turn in particular, becomes a genuine hazard to those who travel the highway.

In hilly country where there is a continuous succession of grades and curves, sharper curves are allowable than in level country where roads tend to have long tangents. There is a natural tendency for the driver to speed up on the long, straight tangent, and likewise there is also the natural tendency of the driver to use slower speeds in the hill country. The sharp curve at the end of a tangent, perhaps just over a slight rise, is a real danger and should be reduced in the greatest amount possible. Curves should, at the ends of the tangent stretch, be made just as flat as conditions will permit. Do not use sharp curves at the bottom of a steep grade. Sharp curves at the head of a valley as the road winds through are allowable, whereas sharp curves around a jutting rock are a great source of danger.

The horizontal curve where there is no limiting condition should, from the standpoint of safety, be cut down to a curve of 5 degrees; and if the conditions permit, the curve might be made flatter yet as a precautionary measure against the undoubted higher speeds of the future. There is no uniformity of practice in our adjoining states, but investigation discloses that horizontal curves are being constructed with curvatures limited from 5 to 11 degrees or with radii limited from 300 to 1,000 feet. It appears to be the general practice to hold the curvature down as near 5 degrees as possible, each curve being studied with respect to its own local conditions. There is in the 5° curve, in addition to safety to the traveling public, an economy and a saving in expenditure for pavement.
Construct the flatter curves now and be relieved of the necessity at some time in the future of having to go through the work of a second relocation, legal condemnations, and reconstruction of the curve to take care of faster and denser traffic.

**Vertical Curves**

The vertical alignment should be a rolling grade following the surface of the ground within the limitations required by drainage, local controlling points, and the maximum allowable rate of grade.

A minimum sight distance between any two points 5 feet above the road surface should be not less than 500 feet, and, where the vertical curve is combined with a horizontal curve, the sight distance, in the cause of safety, could well be lengthened to 600 or 700 feet. The inner side of such curves should have all brush, timber growths, and banks cut back to give a clear sight distance across the curve of not less than 600 feet. An automobile traveling at a speed of 40 to 45 miles per hour, which is not unusual, requires, under general average conditions of brakes and roadway, not less than 200 feet of distance in which to slow down to a safe emergency stop.

**Superelevation**

Within limits, all horizontal curves should be superelevated. Present practice in adjoining states is well agreed upon the necessity of the use of superelevation. Michigan, Ohio, and Illinois at present have a superelevation requirement for all curves. Indiana superelevates on curves from 1° up. Other states have varying practice, but all must come to the use of the superelevation eventually.

Superelevation may be computed by use of the equation

\[ e = \frac{V^2}{15R} \]

where

- \( e \) = superelevation in feet per foot of width
- \( V \) = velocity in miles per hour
- \( R \) = radius of the curve in feet

The full theoretical rate as computed for high velocity on sharp curves should not be used. There is some resistance to skidding offered by the friction of tires on pavement. The driver automatically slows down somewhat when coming into a sharp curve. The full superelevation would be uncomfortable and possibly dangerous for slow moving traffic. The maximum slopes or the superelevations per foot of pavement which are not uncomfortable and not dangerous to slow traffic lie between \( \frac{3}{4}" \) and 1" per foot. Superelevation up to \( 1\frac{1}{2}" \) per foot is used in some of the states on very sharp curves of 300' radius or less.
Two methods are in use for constructing this superelevation.

a. By revolving the pavement surface about the center line as an axis, thus raising the outer edge and lowering the inner edge.

b. By revolving the pavement surface about the inner edge as an axis.

The first method carries the center line of the pavement at the established grade, the outer edge being raised by one-half the superelevation requirement and the inner edge being depressed by a like amount. This method causes drainage difficulties in flat country and presents a poor appearance, the sag on the inner side of the curve being very objectionable under certain combinations of layout.

The second method carries the inner edge of the pavement at grade, the outer edge taking the entire rise. There are no drainage troubles in flat country and there is no sag on the inner side of the curve. This method is recommended as being the better practice.

The change or transition from the normal crown section of the tangent to the banked plane section of the superelevation must be gradual.

For the simple circular curve the warped sections should begin 50 to 100 feet before reaching the P.C. of the curve, and the maximum superelevation should be reached at 50 to 75 feet inside the curve. Full superelevation is carried around the curve until the run-off point is reached at 50 or 75 feet on the curve ahead of the P.T. point, the run-off distance back to normal being the same as used in entering the superelevated section.

For a spiral easement into the central circular curve, the superelevation of the warped section should be run in with the spiral, full superelevation being reached at the end of the spiral, the full superelevation being carried through the central curve, and the run-off back to normal being taken through the spiral at the end of the curve. If the curve is run in as a double spiraled curve, the superelevation should start with the spiral and attain full elevation at 1/2 to 3/4 of the spiral length, the run-off back to normal being the same.

The change from normal crown section to full superelevation section should be as gradual as conditions will permit. Too sharp a rise or fall gives the appearance of a hump or sag in the pavement. When two right or two left-hand curves are separated by a short tangent, the superelevation should be carried right through the entire tangent to avoid the appearance of a sag in the outer half of the pavement between the two curves.
Curve Widening

Curves should be widened, especially where the curvature is sharp. It is advisable to widen the curve for the reason that the rear wheels do not follow in the track of the front wheels, hence a greater width of roadway is occupied by the car on the turn than on the tangent. Psychologically the driver of a car moving at high speed demands more room for clearance on a curve. The amount of widening should increase with the degree of the curve. There is no uniformity of practice among the states, but curve widening lies between the extremes of 8' for 30° curves and 2' for 5° curves.

Widening may be attained by placing the maximum required at the center inside edge of the pavement for a circular curved center line, then computing the distance back along the edge of the pavement to where the circumference line of the lune of widening becomes tangent to the edge of the normal section and running in this edge of the pavement as a simple curve of longer radius than the curve of the center line. The better practice, however, is to spiral both the outer and the inner edges of the pavement. The widened section on the inside is provided by the inside spiral being on a longer curve than is the outer spiral.

Heavy traffic intersections must each be studied for the particular local conditions and requirements. Good practice suggests that the pavement as it approaches the intersection be widened. If the traffic is not too heavy, a solid crossing with edge curves of 100' radius will suffice. Where traffic is denser, a “Y” connection, with connecting curves of 500' or 1,000' radius will facilitate traffic. For very heavy traffic intersections it is even advisable to build a central park with a full circle for traffic on a 500' radius, all traffic moving to the right. These traffic circles are at present being developed at heavy traffic intersections near our larger cities.

All curves should be marked with the standard caution and warning signs placed sufficiently far back from the curve so that the motorist moving at high speed has time to slow down before he comes into the curve. Luminous signs should be placed for night warning at the most dangerous points and, if the curve is of more than ordinary danger, a flasher signal should be installed.

All these measures mean additional costs in the building of the roadway, but money carefully spent in the cause of safety is money well spent. The engineer’s and road contractor’s duty in accident prevention should be recognized, and they should use all the effort and means available in the promotion of safety. The public expects this and will not begrudge funds for such work if it is well done.