Driver Eye Height and Vehicle Performance in Relation to Crest Sight Distance and Length Of No-Passing Zones

I. Vehicle Data

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●THE AASHO handbook, "A Policy on Geometric Design of Rural Highways," states criteria for vertical curve design. The design for stopping distance is based on a driver's eye height of 4.5 ft above the ground and an obstacle 4 in. high, which is presumably the practical case of the smallest obstacle which a driver would want to avoid. This is illustrated in Figure 1.

There is a growing concern among highway designers that, with the emphasis on reduction of over-all height, the driver's eye height may go down and down to the point where the 4.5-ft standard will no longer apply, and design criteria of the crest vertical curves will be invalid. This concern is based on the trend of over-all height, which is derived from Nagler's paper and shown in Figure 2.

At the General Motors Proving Ground, observations have been made of the driver's eye height on representative fleets of passenger cars since 1936; these data were the basis of the choice of 4.5 ft as the design criterion and the continued use of this value in the 1954 issue of the AASHO policy.

In the development of this test procedure, it was found that the average stature dimension to the eye, or seated eye height, of a group of males was approximately 28½ in. above a rigid seat, and that in 1936 the average seat cushion was depressed 2 in. under the passenger load.

Independent measurement of a considerably larger group of people by another agency in General Motors verified this stature dimension.

The test procedure and the data in this test program are based on 28½-in. stature measurement and a 2-in. seat cushion deflection.

Figure 3 shows percentile distributions of driver's eye height in the fleet of test cars from 1936 through 1957. The fleet includes at least one representative car of each make and model of American passenger car each year. Sports car and foreign car data are not available; competitively, these cars have not been of significance and they have not been included in the engineering car fleet. Whether the number in use is sufficient to merit consideration in highway design is open to question.

It will be noted that there have been what appear to be several phases of styling changes relating to this dimension. The cars from 1936 through 1939 gave median values of eye height of about 57 in. The 1941 styling change, carried through the 1947 models, reduced this to between 55 and 56 in. The next phase appeared on some 1948 cars and disappeared on some 1953 makes. The 1953 cars had a median of 54 in., which is the present AASHO standard. Another phase started with 1954 models and appears to have swept through the industry by 1956; this gave a median driver eye height of about 53 in. A rather significant change appeared in the 1957 styling which reduced the median for that year to 51 in.; data on 1958 models are not yet complete, but it may be assumed that the fleet median may be somewhat lower than in 1957.

In discussing these styling phases, it must be noted that the basic styling trend shown in Figure 2 is established by customer desires. Each step is adopted as related component design matures, and the steps are not reached simultaneously by all manufacturers. Even a styling feature achieving a high degree of customer acceptance, such as panoramic windshields, takes up to three years to sweep through the industry. Consequently the effect of any general change develops over several years in terms of the curves of Figure 3.

Of even greater apparent significance than the immediate effect of the long-range trend is the influence of seat cushion depression. This has always varied from car to car, and amount of depression and the range of variation have increased to the extent that a technique of measuring seat cushion depression was developed and established on a routine basis at the Proving Ground on the 1956 models. In passing, the development of a test technique which gives reproducible and realistic results is not as simple as it first appears.

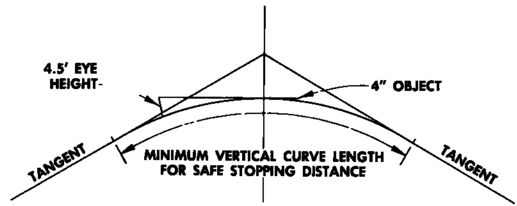

Figure 1. AASHO design heights of eye and object for vertical curves.

Figure 4 shows percentile curves of the depression of a specific point on the seat cushions of 1956 and 1957 cars under an average passenger load. The median value of seat cushion depression was 4. 5 in. in 1956 and 4. 2 in. in 1957. This modifies the driver's eye height on the 1956 and 1957 cars as indicated in Figure 5; this reduces the median eye height on the 1957 cars from a value of slightly below 51 in. on the old procedure to an adjusted value of 48½ in. The over-all change in driver's eye height from 1936 to 1957 is shown on Figure 6. The median height has changed from about 57 in. to 48. 5 in.

To estimate how much lower the driver's eye height may go in volume production passenger cars is difficult. Just as in any design trend, this depends upon customer acceptance and design skill, in this case in developing smaller machinery to fit in the space between the ground clearance line and the line of the depressed seat cushion. If the median eye height observed since 1937 were plotted as a function of time and the curve extrapolated, in the year 2060 the driver's eyeballs would be rubbing the pavement surface. This would not meet widespread customer acceptance, and it is certain that the trend will not continue that long.

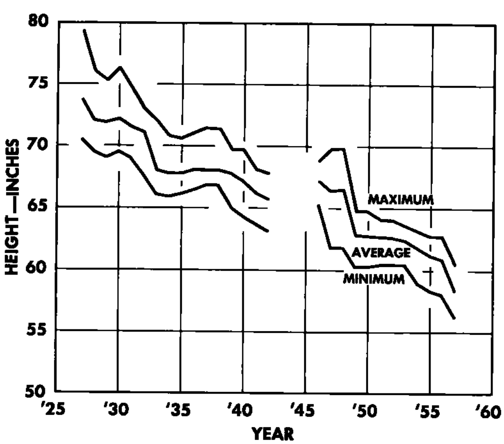

Figure 2. Car over-all height (car loaded).

A tabulation of median eye heights from Figure 3 and 5 and of average over-all height from Figure 2 indicates that the driver's eye is approximately 10 in. below the highest point on the car.

In the "Automotive News" of September 16, 1957, Victor Raviolo, special

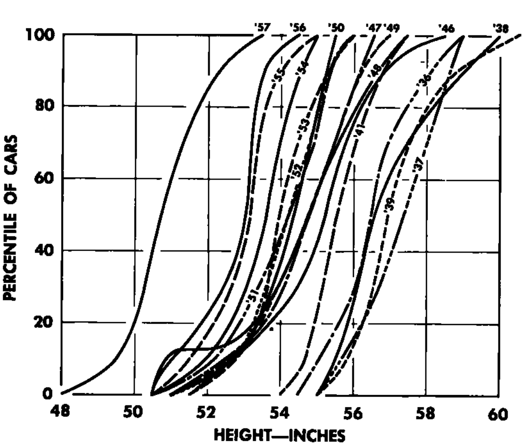

Figure 3. Driver's eye height to ground (defined according to visibility test procedure).

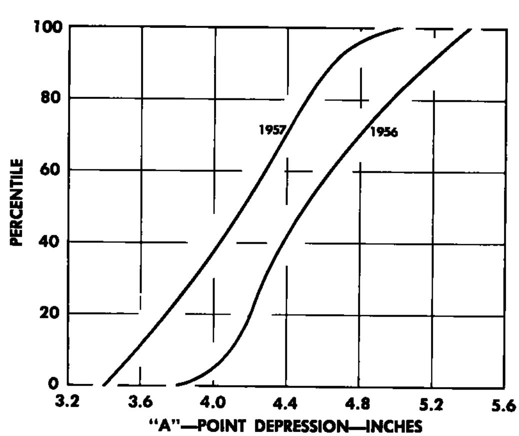

Figure 4. Front seat "A"—point depression percentile distribution.

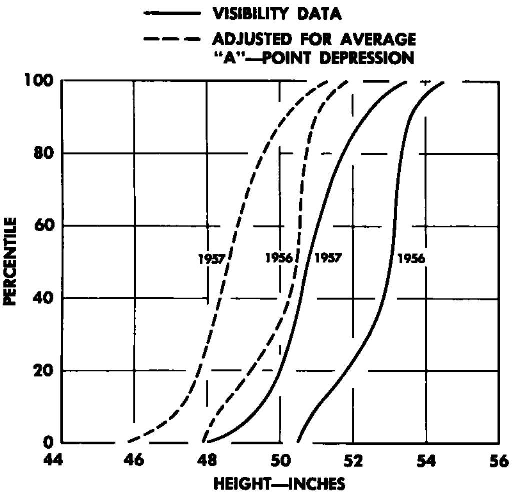

Figure 5. Driver's eye height to ground (defined according to visibility test procedure).

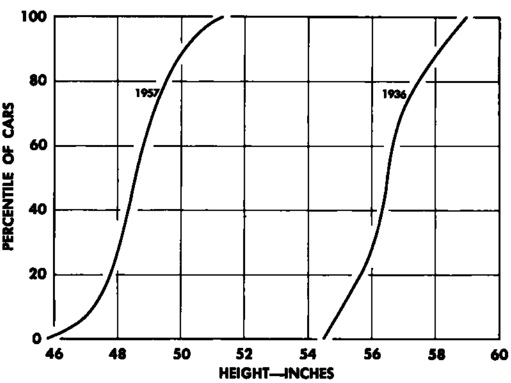

Figure 6. Driver's eye height to ground (defined according to visibility test procedure).

the minimum 1957 value. The evidence suggests that the trend of lower driver eye heights on passenger cars of large volume production is nearing an end.

It must be remembered that there are nearly 60 million cars on the road now, that these cars were designed to be operated on the existing highways, and that all future designs will contemplate satisfactory operation on the highways existing then. Highway designers need not be concerned about radical departures from current automotive designs in terms of satisfactory operation on the highway network; the customers will take care of that problem automatically.

AASHO policies also treat the criteria of passing sight distances, and the trend toward lower vehicle heights will reduce

assistant to the engineering and research vice president of the Ford Motor Company, is quoted as saying that 51 in. is the approximate ultimate minimum height for volume production passenger cars, and that in 10 years there will be 52-in. sedans, the height of the Thunderbird. He continued by saying that there are two basic problems, entrance and visibility, that must be worked out before then. It is understood that, at a later informal discussion, this minimum was increased to 53 in. as a more practical value.

If it is assumed that this estimate is right and that 10 in. will remain the approximate vertical dimension between the driver's eye and the top of the car, the ultimate minimum eye height would be 43 in. This is about 5.5 in. lower than the median 1957 value, and about 3 in. below

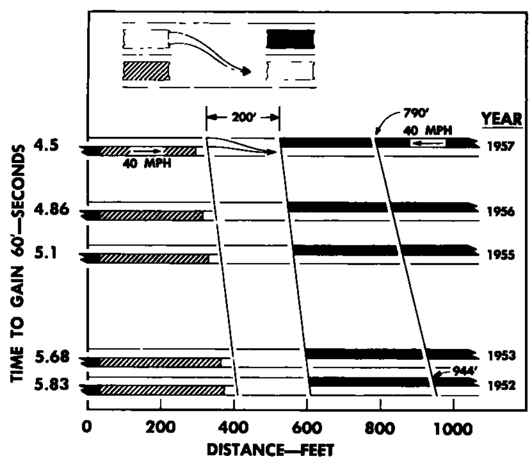

Figure 7. Trend of passing distance average of all cars.

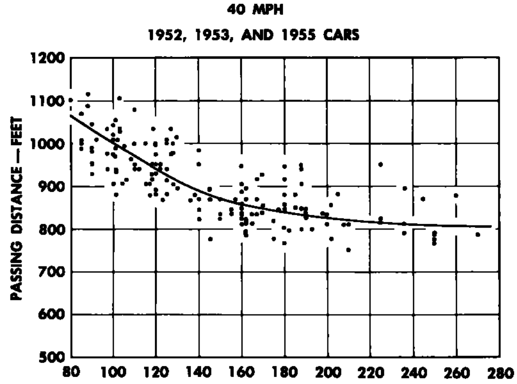

Figure 8. Minimum passing distance versus rated horsepower.

the passing sight distances provided by current design standards. Improved performance has reduced the distance required.

Figure 7 shows the trend of time and distance required to pass a vehicle traveling at 40 mph for the years 1952 through 1957. This shows an improvement in passing ability provided by the superior performance of modern automobiles of more than 16 percent during the period. It is thought that the reduction in passing sight distance provided by the decrease in eye height shown is more than compensated for by improved performance. It has been shown (1) that the rate of reduction in passing distance with increases in rated horsepower falls at the higher values of horsepower (Figure 8). It is anticipated that further reductions in passing distance resulting from greater transmission flexibility will continue, at least until there are 53-in. sedans.

REFERENCE

1. Stonex, K.A., "Lessons Learned by the Proving Ground Engineer in Highway Design and Traffic Control," Proceedings of the Institute of Traffic Engineers (1955).

II. Vertical Curve Design

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● TODAY there is a single, widely used basis for design of crest vertical curves. Several factors and criteria are combined in this design method and consideration of adjustment in any one of these factors properly should entail review of the whole group of items.

Safety and efficiency in highway operation demand uniform and consistent design treatment along the length of any one type of highway. The highway design speed, selected or otherwise determined for given conditions, is the principal means of attaining this end. Design guides and standards have been established for a number of controls and dimensions for the likely range of design speeds. For safety, to permit control of vehicles in an emergency, the designer provides a sufficient length of clear sight distance ahead along every part of the highway. A stopping sight distance has been determined for each highway design speed to be used as this minimum clear sight length. This distance is calculated by joint use of (a) selected values for driver perception and reaction time to begin a stop and (b) friction factors that establish a vehicle braking distance.

Crest vertical curves are designed to be of sufficient flatness to provide this clear sight length as a tangent sight line between driver's eye height and some object on the highway ahead. The parabolic form of vertical curve is used because of marked convenience in design calculation and construction staking. Using selected criteria of height of eye and height of object, it is relatively simple to calculate the length of parabola between any two profile tangents that meet at an apex that will provide the desired clear sight distance. The two height criteria are important items in the whole related series. The height of driver's eye obviously must be a representative value. That for passenger cars was used, since being the lower, it is more critical than that of truck vehicles. The 4.5-ft value was established in the late 1930's and reaffirmed when design policies were reconsidered in 1954.

The height of object is equally important but is much less direct in derivation. The present height of object criterion actually is a compromise value used to bring into balance for convenient design purposes the different sight distance conditions obtained around a horizontal curve and over a crest curve. The 4-in. height now used was selected as a somewhat arbitrary, single value between the zero or pavement surface level and an 18-in. or higher object on the pavement, which the driver nearly always would need to avoid hitting. Use of the 4-in. height permits all design to be based on