STUDY ON ROAD VISIBILITY IN THE CONTEXT OF ROAD SAFETY

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Abstract

Road safety is a pressing problem in all countries of the world, road accidents, and the main cause of serious injury and loss of human life, constituting a challenge in the field both from a social and economic point of view. The relationship between design geometry and crash rate is complex and not fully understand. Little information is available in the international literature on the relationships between design geometries and the number of road accidents, although it has been clearly demonstrated that very restrictive geometries, such as very short sight distances or tight (small radius) roadway curves, that are in significantly higher accident rates and certain combinations of factors causing unusually serious accidents. Road safety depends on many factors, one of the most important sight distances. The study aims to highlight the factors that contribute to the determination of sight distances, i.e. to increase road safety, given that there are no such studies in Romania. The study is carried out with the help of a specialized calculation software, Civil Site Design, software developed in Australia that allows road designers to work faster and smarter. The Civil Site Design application is developed by Civil Survey Solutions Australia, works on top of BricsCAD, AutoCAD, AutoCAD Civil 3D platforms and offers advanced functionalities for road design at Romanian standards.

Keywords: visibility, road safety, sight distances

1 Introduction

The sight distance available on a road should be sufficiently great to allow a vehicle travelling at or near the design speed to stop before reaching a stationary object in its path. The main factors leading to a car crash are the environment, the vehicle and the driver. Of these factors, the most important is the human factor. Some studies have looked at the safety of driving maneuvers [1] and changes in driver eye height [2, 3], considering the driver's ability to see and control the environment from the driver's seat. Sight distance is an important indicator for ensuring driver safety and is an important basis for evaluation in highway safety engineering. On mountainous motorways, where there are steep gradients and small radii visibility is poor, which can lead to traffic accidents. George Kanellaidis et al. pointed out that the three-dimensional road alignment, as a very important component in highway design, has not yet been practical in highway geometry design [4]. The calculation of sight distance is complex, involving drivers, vehicles, roads, and the environment. The driver's eye height depends on the model of the cars, the average height of the driver, and the driving behaviour [5]. The traffic and road safety on vertical crest is related always to have sufficient visibility (D) for the driver, this visibility is generically called safety sight distance, and is used to make a stopping maneuver or an overtaking maneuver (on two-lane highways) [6].

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Inadequate sight distance can lead to a higher number of accidents because it is related to the reaction and decision that must be made by the driver to manage and cope with any unforeseen circumstances or objects that the driver may encounter on the road [7, 8]. In order to use sight distance as a calculable parameter for geometric road design, the height of the driver's object and the height of the obstacle must be taken into account. Eye height also affects speed variability, at least in certain situations. Lane position variability was similarly affected by eye height, with drivers deviating in their lane more when seated at the high eye height [9].
The paper considers the determination of the sight distance (implicitly if the condition imposed by the Romanian standard PD 162-2002 [10] concerning its minimum value is verified) according to different values of the radius of the convex vertical curve, the height of the driver's eye, the height of the obstacle, traffic lane and the speed.
The aim of the work is to study the sight distance in different situations and thus road safety and also to update the information and standards in Romania.

2 Case study

In the present work, the study of the sight distance on highways with two lanes of traffic/direction, with a design speed of 100 km/h, 120 km/h and 140 km/h was considered. For each speed the eye height was varied from 1.00 m to 1.35 m. The study was done for an obstacle height less than the height of the median barrier, because above a higher height the sight distance is checked.According to the Romanian standard, the minimum sight distance for 100 km/h is 150 m, for 120 km/h is 200 m and for 140 km/h is 325 m. The study was done only for a highway area, not for other categories of roads and it was not possible to measure the visibility distance in situations where it is greater than that recommended by Romanian standards for speeds. The graphical representations highlight both the horizontal curve area, where the sight distance was not checked (km 16+350 - km 17+050), and the horizontal alignment area, in situation plane and convex vertical curve in longitudinal profile.
The present study was developed on a 3.15 km section of highway (km 14+200 - km 17+350), consisting of a curve to the left (km 16+223.24 - km 17+325.87) and a horizontal alignment of 2.023 km length, using CIVIL SITE DESIGN software (software for road design), Figure 1.

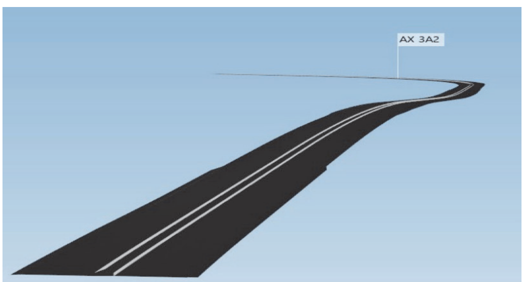

Figure 1 Route studied in perspective (km 14+200 - km 17+350)

A schematic drawing of the transverse profile of the studied motorway section is shown in Figure 2 and the measurement of the sight distance according to the CIVIL SITE DESIGN software is shown in Figure 3.

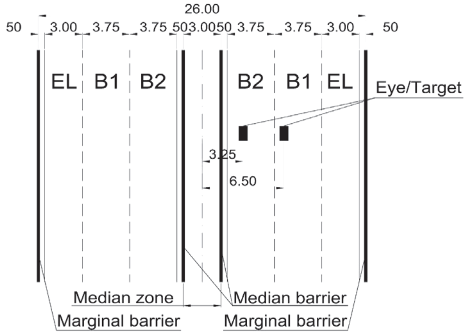

Figure 2 Highway transversal section - schematic drawing

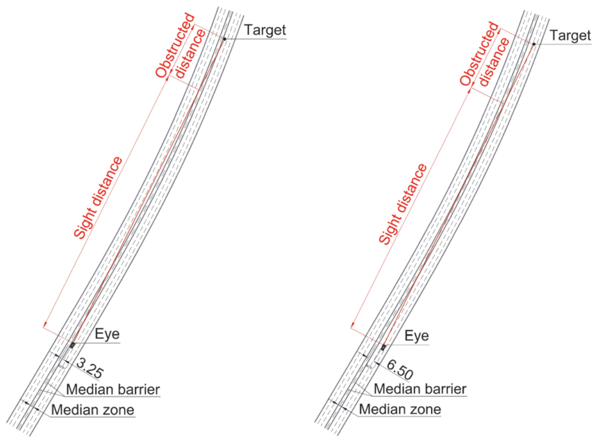

Figure 3 Sight distance measurement according to CIVIL SITE DESIGN software for traffic lane B1 and traffic lane B2 respectively

The curve in the situation plane is made up of: a clothoid (L = 200 m), a curve (C = 700 m) and a clothoid (L = 200 m). On the curve area (from the situation plan) there is a 1% slope, and on the alignment area (from the situation plan) there is a convex vertical curve with a radius of 10000 m and a concave vertical curve with a radius of 20000 m (the route was designed for a speed of 120 km/h, according to Romanian standards), (Figure 4). On the vertical alignment the visibility problems are on the convex vertical curve area, which is studied. On the studied route, there is a median barrier with a height of 0.75 m.
In Figure 5, Figure 6, Figure 7 and Figure 8 the studies are shown only for traffic lane B2, but for traffic lane B1 the graphs are similar. Sight distance as a function of kilometre position and driver eye height, for V = 100 km/h, in traffic lane B2, $h_{obstacle}$ = 0.0 m, for the horizontal curve is shown in Figure 5.

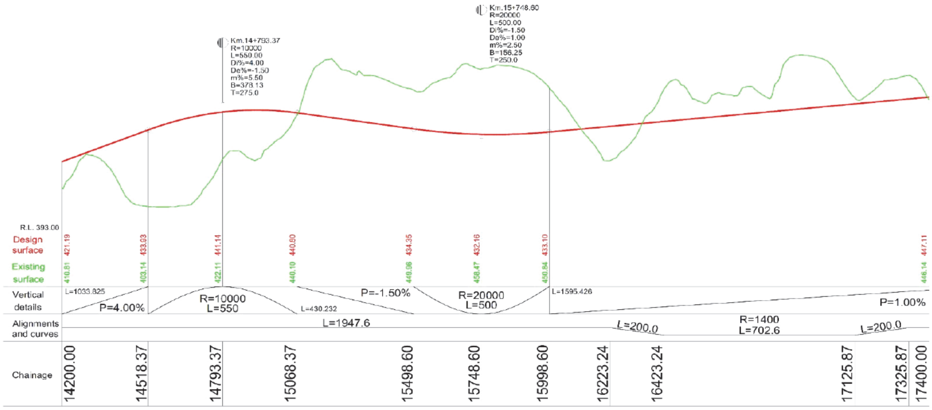

Figure 4 Longitudinal profile of the studied route (km 14+200 - km 17+350)

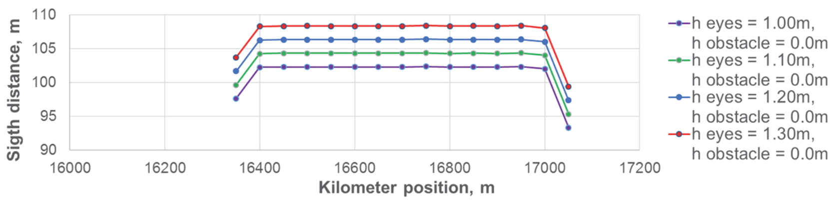

Figure 5 Sight distance as a function of kilometre position, for V = 100 km/h, traffic lane B2, h $_{obstacle}$ = 0.00 m - horizontal curve

Between km 16+350 and km 17+050, for h obstacle = 0.00 m, the sight distance increases with the height of the driver's eye by 2% - 7% for V = 100 km/h.

Sight distance as a function of kilometre position and driver eye height, for V = 120 km/h, in traffic lane B2, h $_{obstacle}$ = 0.00 m, for the horizontal curve is shown in Figure 6.

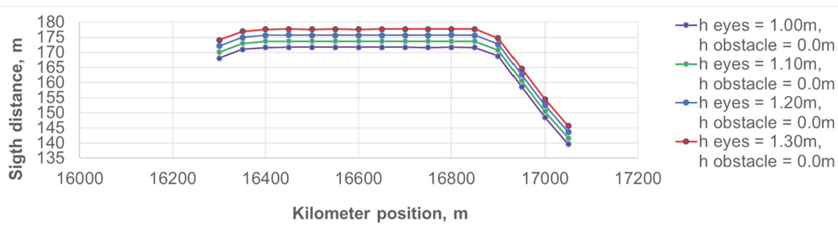

Figure 6 Sight distance as a function of kilometre position, for V = 120 km/h, traffic lane B2, h $_{obstacle}$ = 0.0 m - horizontal curve

Between km 16+350 and km 17+050, for h obstacle = 0.00 m, the sight distance increases with the height of the driver's eye by 1% - 5% for V = 120 km/h.

Sight distance as a function of kilometric position and driver's eye height, for V = 140 km/h, in traffic lane B2, h $_{obstacle}$ = 0.00 m, for the horizontal curve is shown in Figure 7.

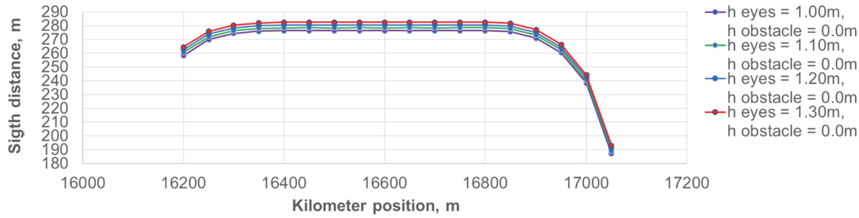

Figure 7 Sight distance as a function of kilometre position, for V = 140 km/h, traffic lane B2, h $_{obstacle}$ = 0.00 m - horizontal curve

Between km 16+350 and km 17+050, for h obstacle = 0.00 m, the sight distance increases with the height of the driver's eye by 1% - 4% for V = 140 km/h.
The satisfaction of the criteria for the sight distance (expressed in percentages according to the minimum sight distance according to the Romanian standard PD 162-2002), for traffic lane B2, h $_{obstacle}$ = 0.00 m, for the horizontal curve is shown in Figure 8.

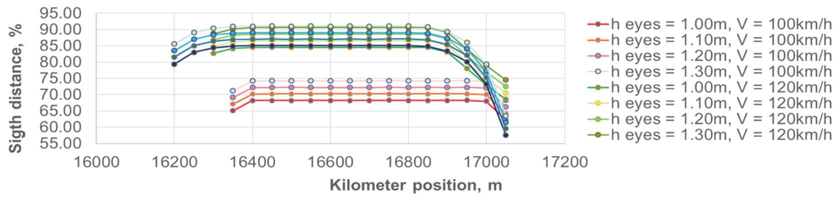

Figure 8 Satisfaction with the criteria for sight distance according to the Romanian standard PD 162-2002, for traffic lane B2, h $_{obstacle}$ = 0.00 m - horizontal curve

The minimum limit values for sight distance according to speed, as laid down in PD 162 -2002, can be met more easily for V = 140 km/h.
The values of the visibility distances on the two traffic lanes were compared, in order to observe where the visibility is better and implicitly if it is influenced by the traffic lanes. The sight distance as a function of kilometre position and position on the highway, respective traffic lane, V = 140 km/h, for h $_{obstacle}$ = 0.00 m is shown in Figure 9, and for h obstacle = 0.40 m is shown in Figure 10.

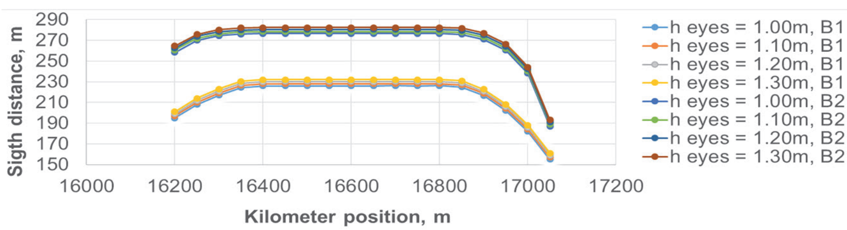

Figure 9 Sight distance as a function of kilometre position and traffic lane, for V = 140 km/h, h $_{obstacle}$ = 0.00 m - horizontal curve

The sight distance for V = 140 km/h is 17% - 19% less in traffic lane B1 than in traffic lane B2 for obstacle h = 0.00 m.

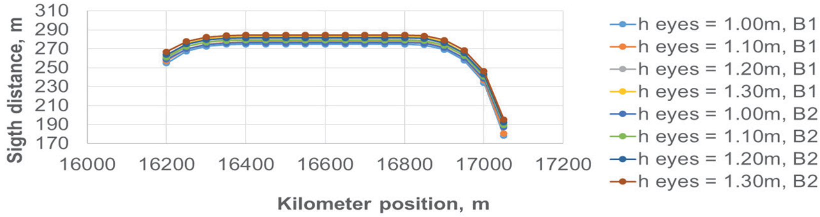

Figure 10 Sight distance as a function of kilometre position, for speed 140 km/h, $h_{obstacle}$ = 0.40 m - horizontal curve

The sight distance for V = 140 km/h is 1% - 2% less in traffic lane B1 than in traffic lane B2 for $h_{obstacle}$ = 0.40 m.
The sight distance as a function of the kilometric position and the height of the driver's eye, for V = 120 km/h and $h_{obstacle}$ = 0.00 m, on the vertical convex curve - horizontal alignment is shown in Figure 11.

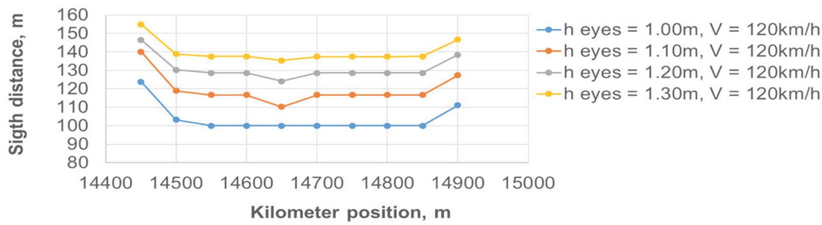

Figure 11 Sight distance as a function of kilometric position, for speed 120 km/h and $h_{obstacle}$ = 0.00 m, on vertical convex curve area – horizontal alignment

Sight distance increases by 8% - 15% with the height of the driver's eye in the area of the convex vertical curve for V = 120 km/h.
The sight distance (expressed in percentages according to the minimum sight distance according to Romanian standards) according to the kilometric position and height of the driver's eye, for V = 120 km/h and V = 140 km/h, $h_{obstacle}$ = 0.00 m, on the area of the vertical convex curve - horizontal alignment is shown in Figure 12.

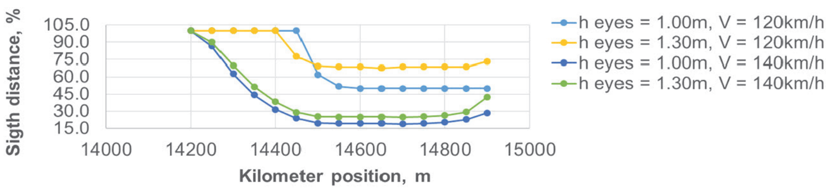

Figure 12 Sight distance as a function of kilometric position, for $h_{obstacle}$ = 0.00 m, on the vertical convex curve area - horizontal alignment

The sight distance increases by approximately 19% with the height of the driver's eye in the area of the vertically convex curve for V = 120 km/h and by approximately 9% with the height of the driver's eye in the area of the vertically convex curve for V = 140 km/h. Sight distance increases by approximately 30% with speed, on the vertical convex curve area, for h_{eyes} = 1.00 m and by approximately 45% with speed, on the vertical convex curve area, for h_{eyes} = 1.30 m.
Sight distance as a function of kilometric position and radius of the vertical convex curve, for $h_{obstacle}$ = 0.00 m and V = 120 km/h - horizontal alignment is shown in Figure 13.

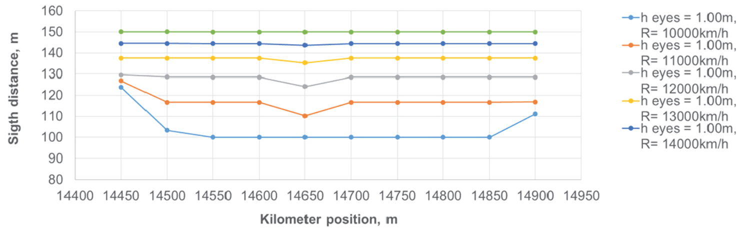

Figure 13 Sight distance as a function of kilometric position, for h $_{obstacle}$ = 0.00 m and different values of vertical convex curve radius

Sight distance depending on kilometric position increases with radius of the vertical curve by 5% - 17%, for h $_{obstacle}$ = 0.00 m.

3 Conclusions

From the case study, it was observed that the sight distance is influenced both on the horizontal curve area and on the horizontal alignment (vertical convex curve) by the height of the driver's eye and the height of the obstacle.
The influence of the radius of the vertical convex curve on the sight distance was also observed in the area of the horizontal alignment.
The graphs in Figures 5, 6, 7 and 8 also hold for obstacle heights lower than the height of the median barrier. It can be seen that the sight distance increases with speed, but the influence of the driver's eye height decreases with increasing speed in the case of the horizontal curve. In terms of sight distance on convex vertical curves, the driver's eye height and speed have a much greater influence than on horizontal curves.
Sight distance is the key to braking safety when the driver encounters obstacles in the process of braking driving, which is closely linked to the safety of life and national assets, which is why studies on determining sight distance is of great importance.
In the few studies in the specialized international literature, it was observed that the visibility distance is influenced by the factors taken into account in this study, but in Romania we have not identified such studies. More variations on: horizontal curve radii values, convex vertical curve radii values and vertical alignment slope values should be considered for the following studies in order to improve the conclusions obtained in this study.

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