

STUDY ABOUT THE INFLUENCE OF THE ROAD'S ANGLE CUT SLOPE IN A "T" INTERSECTION

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ABSTRACT:

The context in which this study is conducted is represented by the need to improve road safety at T-intersections, which can be visibility-critical locations and of the risk of accidents. Therefore, this study is important to identify and solve potential problems related to sight distance in road intersections. Case studies on sight distance in intersections are an effective way to assess the impact of the factors that influence it on road safety. Currently, the three-dimensional study allows us to analyze the visibility in detail according to the standards and obtain the sight distance both in tabular format and the graphic representation of the sight distance. The visibility triangle is defined as the spatial region formed by the path of the vehicle traveling along the main road and the vehicle traveling along the side road intersecting leading to the conflict point. The area of the visibility triangle depends on the prescribed sight distances, which must be observed based on the travel speeds of the conflicting paths. In this three-dimensional analysis, the sight distance at the intersection between a national road and an access road to a quarry, in the "T" variant, was studied. In this study, the sight distance checks were made in the "T" shaped intersection according to AND 600, with the help of the 3D model and the Civil Site Design software. Also, the influence of the angle cut slope on the sight distance from the intersections was studied considering 2 slope inclinations namely 1:2 and 1:4.

1. INTRODUCTION

Visibility in road design is an extremely important aspect for road traffic safety, several factors such as lighting, adequate signage or abundant vegetation can have a negative impact on drivers' visibility. The traditional design method, the orthogonal representation of the road on three projection planes (situation plane, longitudinal profile and profile), can no longer satisfactorily meet the requirements of modern road traffic: high densities, relatively high speeds and intersections.

The Intersection Visibility Study is a detailed analysis of the factors that influence drivers' ability to see and be seen at critical points in the road infrastructure. By addressing this topic, the aim is to identify practical and effective solutions for improving road safety and preventing accidents in busy intersections. The study clarifies essential concepts related to intersection sight distance, such as the required sight triangle, stopping and starting distance. Likewise, factors that influence visibility, such as lighting, weather conditions, road conditions and the presence of obstacles, were identified and analyzed.

In the specialized literature, considerations regarding the sight distance are presented for the situation in which drivers have to cross over a main road from a secondary road controlled by stops, safely.

In road design, a major factor is represented by the intersection visibility triangle, a triangle that illustrates the driver's field of vision in an intersection and the decision point on the adjacent main road.

The latest AASHTO conclusions on visibility triangles are based on the studies of Harwood, Mason and Brydia (2000) which considered the field observation of the behavior of drivers in intersections with controlled stopping on secondary roads.

According to specialist studies, drivers have problems estimating the speed and distance of traffic approaching intersections when they are in the intersection, on the road, and have to make secondary decisions regarding the crossing (Harwood, Mason and Brydia, 2000). Greater sight distances in intersections correspond to a reduced accident rate (David & Norman, 1979; Harwood et al., 2000).

Improving safety at intersections can be achieved by implementing solutions such as roundabouts, reduced speed limits, appropriate signage, as well as surveillance cameras to monitor driver behavior and reduce the risk of accidents (Petcu Mihai Dragos, 2023), (AASHTO, 2011), (Petcu Claudia et al., 2024).

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Stopping distance is required at any point along the road so that drivers have sufficient visibility ahead to stop. Knowing the stopping distance at all points on the road, including near intersections, is important to reduce the number of accidents (Engineering_Policy_Guide, 2024), (Burlacu F.A. et al., 2018).

Studies have been done that highlighted the visibility triangles and their importance (Khattak et al., 2003). (Tsai et al., 2011). compared the field of view obtained from an observer and the required sight triangle.

In intersections, the causes of accidents are multiple, but failure to yield the right of way is one of the most important, being most often due to reduced visibility (Mussone et al., 2017). There are other opinions (Charlton, 2003), such as if the sight distance is shorter in intersections, then the driver is more cautious, which leads to fewer accidents. Other factors that are important in intersections are: roadway condition, vertical and horizontal signaling condition, illuminated drainage (Respondek, 2019), (Burlacu F.A. et al., 2016). Other elements that can obstruct visibility are: parapets, signs and road signs (Natalia Brycht, 2020).

Vegetation and surrounding objects can obstruct sight lines in intersections, making it difficult for drivers to see oncoming vehicles. Abundant vegetation and objects such as roadside poles or billboards can create additional hazards, and measures such as periodic trimming of vegetation and strategic placement of objects are essential to improve safety (MUTCD, 2023).

The impact of slopes on visibility is an essential aspect in road and urban infrastructure design. Slopes, by their very nature, can create visual obstructions that affect the perception of drivers and pedestrians, thereby increasing the risk of accidents. It is important that the height and angle of the slopes are carefully evaluated to minimize these obstructions. For example, a slope that is too high or too steeply angled can significantly block visibility, especially in critical areas such as intersections. Vegetation planted on slopes must be properly managed so as not to contribute to visibility problems.

Regulated pruning and slow-growing plant selectors can help maintain optimal visibility. In addition, it is crucial to avoid placing large objects on slopes, such as billboards or other structures, which may obstruct visibility (ITE, 2016), (TRB, 2012).

When approaching an intersection, the driver of the vehicle must have an unobstructed view of the entire intersection, of the other users, of the steering elements and the branches of the intersection for sufficient lengths, to allow the anticipation and avoidance of potential collisions (AND 600, 2017).

When traffic on the secondary road is controlled by the STOP sign, the driver on the secondary road must have sufficient sight distance to be able to safely depart from the stop line, assuming the worst case, in which the oncoming vehicle the main road enters the field of vision when the stopped vehicle starts moving. Sight distance in intersections is the minimum sight distance required for the driver to safely enter the intersection so that he can break and then stop before the point of collision.

In the context of accelerated urbanization and the continuous increase in the number of vehicles on public roads, effective traffic management and ensuring road safety become imperative.

Intersections, as critical points of transportation networks, present unique challenges in this regard. Sight distance in a T-intersection plays a vital role in preventing accidents and smoothing traffic. This paper proposes to analyze the factors that influence the sight distance and to develop recommendations for its optimization, thus contributing to the increase of traffic safety and efficiency. As one of the most important aspects of intersections in the context of road safety, these road confluence points are frequent places where accidents occur. In this sense, the risk factors include reduced visibility, inadequate speed, faulty signaling or the lack of it, as well as behavior that does not comply with the traffic rules. Improving road safety at intersections can be achieved by implementing solutions such as roundabouts, reduced speed limits, appropriate signage, as well as surveillance cameras to monitor driver behavior and reduce the risk of accidents.

2 CASE STUDY

By analyzing the literature and identifying gaps in current knowledge, the research provides a solid foundation for the development of new theories and predictive models to explain how various variables, such as intersection geometric characteristics, the presence of visual obstructions, and environmental conditions, influences the sight distance.

To carry out this case study, the intersection was analyzed taking into account the starting and approaching visibility triangle in accordance with AND 600 (Figure 1). The intersection is located on DN A national road at km 131+962, at the intersection with the access road to Quarry B. In the plan, there is a curve with a radius of 115m on the main DN A road. The connecting radius of the secondary road with DN A is 12m. The width of the traffic lanes, both the current ones of DN A, as well as the width of the left turn lane is 3.50m. Figure 1 shows the intersection studied in perspective.



Figure 1. The intersection studied in perspective

In longitudinal profile, the studied route is designed according to STAS 863-65. Figure 2 shows the longitudinal profile on the DN A national road where the slopes are between 0.5% and 5.50%. Near the intersection, at approximately 120m, there is a convex vertical connecting curve designed with a radius of 800m. Figure 3 shows the longitudinal profile of the access road to Quarry B, with two slopes, namely in the intersection area it is 0.5%, and after the vertical connecting curve the slope is 10.5%.

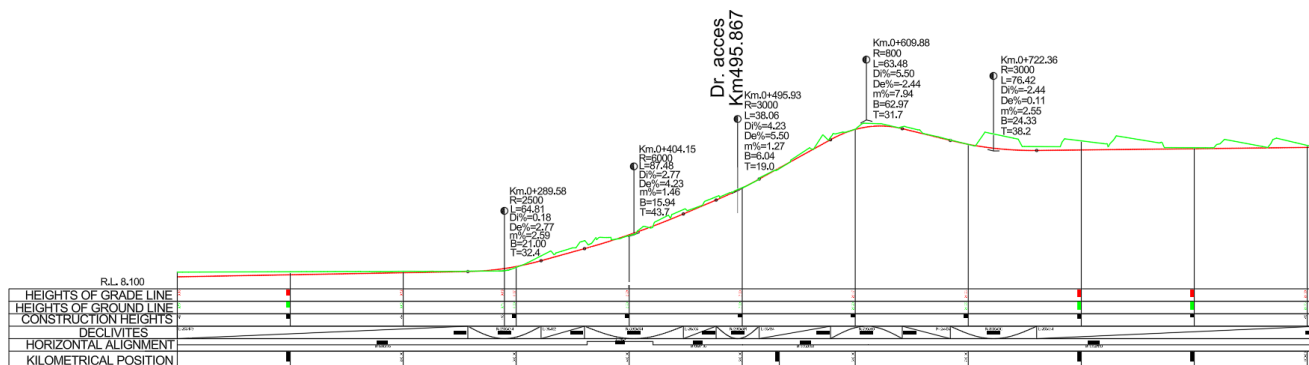


Figure 2. Longitudinal profile DN A

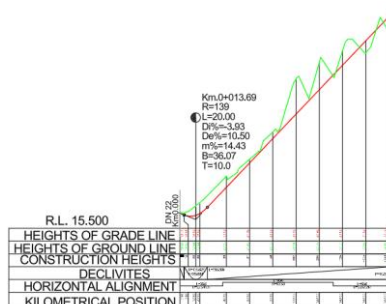


Figure 3. Longitudinal profile for the access road to Quarry B

2.1 Criterion - STOP at a speed of 60 km/h

The sight distance is composed of two distances, a decision distance and a stopping distance, according to AND 600. The stopping distance for the speed of 60 km/h is 85m, the decision distance for the speed of 60 km/h is 195m. The required sight distance in the intersection for the speed of 60 km/h, on the main road, is 280m.

Figure 4 shows the sight distance (% of the sight distance according to AND 600) depending on the kilometer position and the slope of the slope, on the left side of the intersection. It is observed that for the slope of 1:4 the sight distance is greater than for the slope of 1:2 and increases with the kilometer position, and for the last 2-kilometer positions this is satisfied.

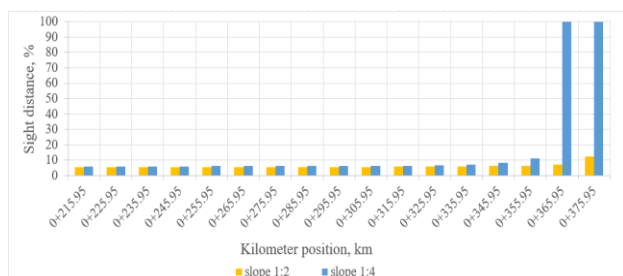


Figure 4. Sight distance as a function of slope on the left side

A 3D model of the studied intersection is shown in Figure 5 and the sight distances for the slope of 1:2 for both sides is plotted.

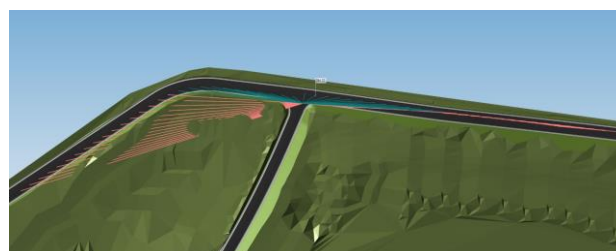


Figure 5. Sight distance perspective for 1:2 slope

Figure 6 shows a perspective of the studied intersection, but this time with a slope of 1:4. Compared to the other perspective, from Figure 5 an increase in the sight distance on the left side is observed.



Figure 6. Sight distance perspective for 1:4 slope

In Figure 7 the sight distance is represented on the right side, where we notice that the sight distances coincide regardless of the slope, in this case we will refer to the longitudinal profile in Figure 2 where a convex connection on the main road DN A is observed which obstructs the visibility on the right at this intersection. Because of this, the sight distance does not vary according to the slope of the slope.

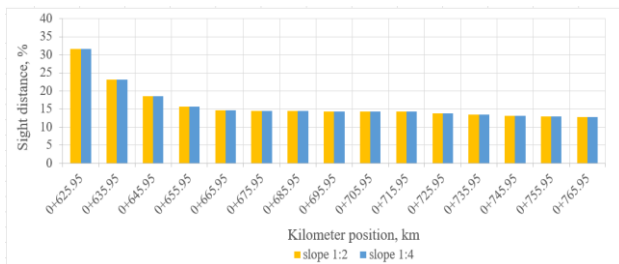


Figure 7. Sight distance as a function of slope on the right side

2.2 Criterion - STOP at a speed of 50 km/h

The stopping distance for the speed of 50 km/h is 65m, the decision distance for the speed of 50 km/h is 155m. The required sight distance in the intersection for the speed of 50 km/h on the main road is 220m. Figure 8 shows sight distance according to the shape of the slope on the left side.

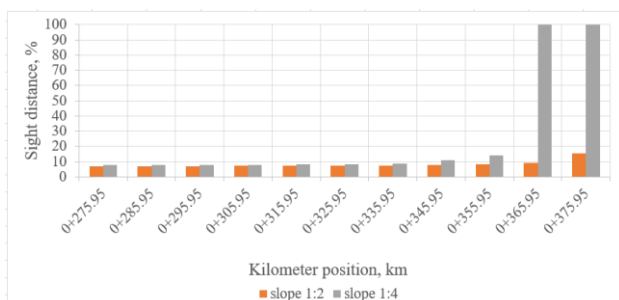


Figure 8. Sight distance according to the shape of the slope on the left side

Figure 9 shows sight distance perspective for 1:2 slope.

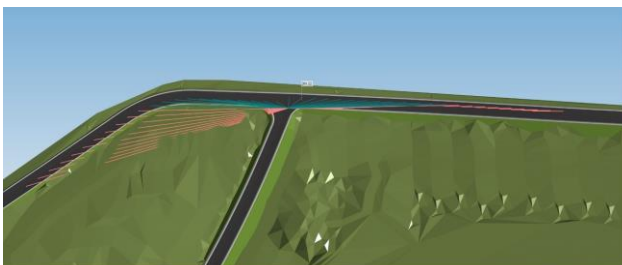


Figure 9. Sight distance perspective for 1:2 slope

Figure 10 shows a perspective of the studied intersection, but this time with a slope of 1:4. Compared to the other perspective, from Figure 9 an increase in the sight distance is observed on the left side.



Figure 10. Sight distance perspective for 1:4 slope

In Figure 11 the sight distance, on the right side, can be seen to be identical for the 1:2 slope and the 1:4 slope. In this case we will refer to the longitudinal profile on the main road where it is observed that the convex connection between the slopes on DN A obstructs the visibility on the right side in this intersection. Because of this, the sight distance does not vary according to the slope of the slope.

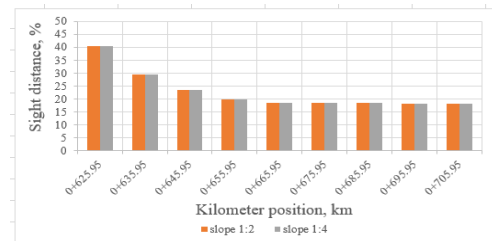


Figure 11. Sight distance as a function of slope on the right side

2.3 Criterion - STOP at a speed of 40 km/h

The sight distance when stopping for a speed of 40 km/h is 50m. The sight distance of 50m is required in the intersection for the speed of 40 km/h on the main road.

It is necessary to specify – according to AND 600 for speeds lower than 50 km/h there is no decision distance, so the STOP 40 km/h criterion is no longer composed of the sum of the two visibilities prescribed and used in the previous criteria. Figure 12 shows the variation of visibility as a function of speed and the shape of the slope in the intersection on the left side. Figure 13 shows the variation of visibility as a function of speed and the shape of the slope in the intersection on the right side.

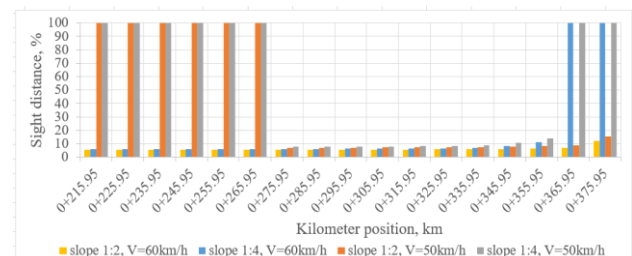


Figure 12. Sight distance as a function of speed and slope shape, on the left side

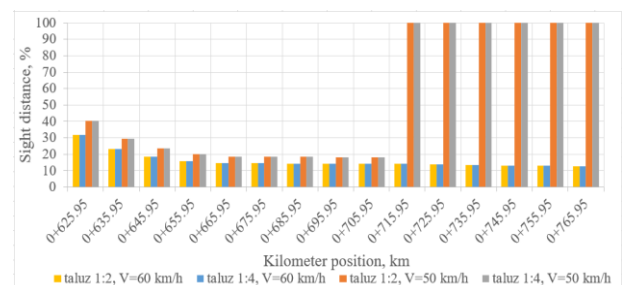


Figure 13. Sight distance as a function of speed and slope shape, on the right side

2.4 Criterion – Maneuver at a speed of 60 km/h

The study continues with the check of visibility when stopping and maneuvering. This criterion checks the non-traffic intersection signaled with the Give way sign. The criterion

considers that both participants are in motion and their trajectories meet in one of the conflict points of the intersection. The position of the participant on the secondary road is for the case where the minimum stopping distance of 35m is respected, according to AND 600 – the speed on that section is 30km/h. In the software this check criterion is identified as AND_600, the speeds at which these checks were made are 60km/h, 50km/h, 40 km/h and 30 km/h.

The criterion is composed of two sight distances, one for stopping and one for maneuvering, according to AND 600. The decision distance for stopping at a speed of 60 km/h is 85m, the decision distance for maneuvering at a speed of 60 km/h is 235m. The required sight distance in the intersection for the speed of 60 km/h, on the main road, is 320m.

In Figure 14 we can see the improvements in the drivers' field of vision due to the variation in the shape of the slope in the intersection, on the left side. It is observed that for the intersection with slope of 1:4, the visibility increases and for the last kilometer position (0+475.95) the sight distance is satisfied.

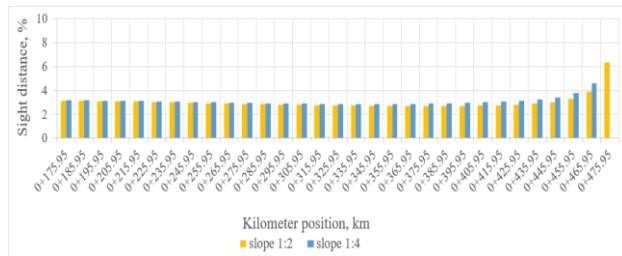


Figure 14. Sight distance according to the shape of the slope on the left side

Figure 15 shows a perspective of the studied intersection, but this time with a slope of 1:4.

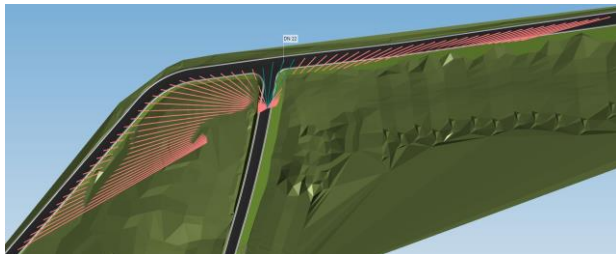


Figure 15. Sight distance perspective for 1:2 slope

In Figure 16 the sight distance is represented on the right side.

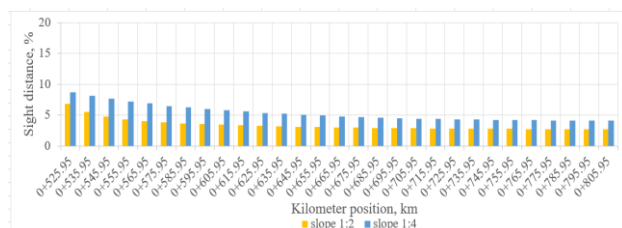


Figure 16. Sight distance according to the shape of the slope on the right side

Figure 17 shows the visibility perspective when the slope of the slope is 1:4. Compared to the other perspective, from Figure 15 an increase in the sight distance on the left side is observed.

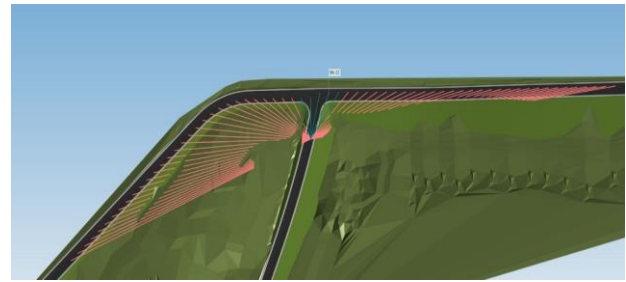


Figure 17. Sight distance perspective for 1:2 slope

2.5 Criterion – Maneuver at a speed of 50 km/h

In Figure 18, the sight distance is represented on the left side where we observe the variation depending on the slope. It is observed that for the intersection with slope of 1:4, the visibility increases and for the last kilometer position (0+475.95) the sight distance is satisfied.

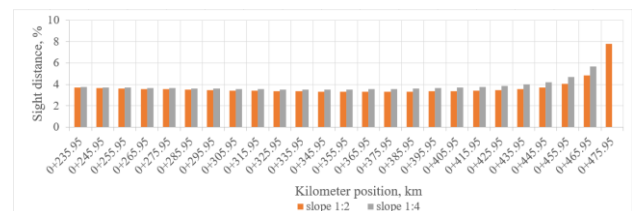


Figure 18. Sight distance according to the shape of the slope on the left side

According to the perspective in Figure 19 of the sight distance for the model with a slope of 1:2 it is observed that inside the visibility triangle the red lines signal that the sight distance is obstructed by the slope and different forms of the land near the intersection.

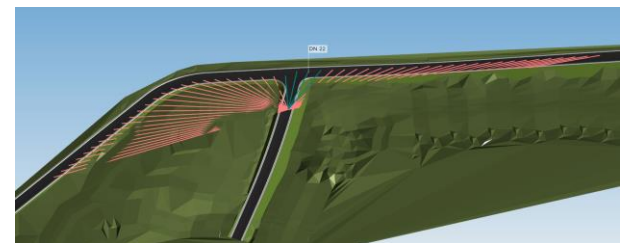


Figure 19. Sight distance perspective for 1:2 slope

In Figure 20, the sight distance is represented depending on the inclination of the slope on the right side.

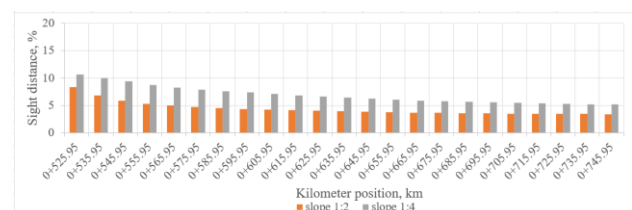


Figure 20. Sight distance according to the shape of the slope on the right side

Figure 21 shows a perspective of the studied intersection, but this time with a slope of 1:4.

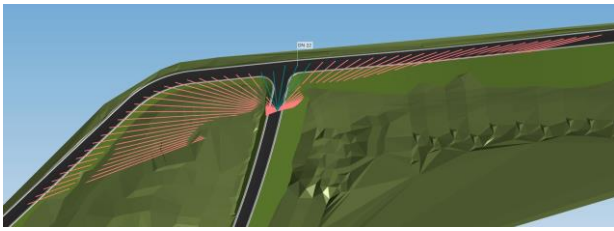


Figure 21. Sight distance perspective for 1:4 slope

2.6 Criterion – Maneuver at a speed of 40 km/h

Criterion The 40 km/h maneuver is based on the stopping distance presented by AND 600. The stopping distance for the speed of 40 km/h is 50m. For this criterion - in the standard, the decision distance disappears, as a result the sight distance is no longer made up of two components, it is considered as the minimum sight distance when stopping. Figure 22 shows sight distance as a function on the shape of the slope in the intersection.

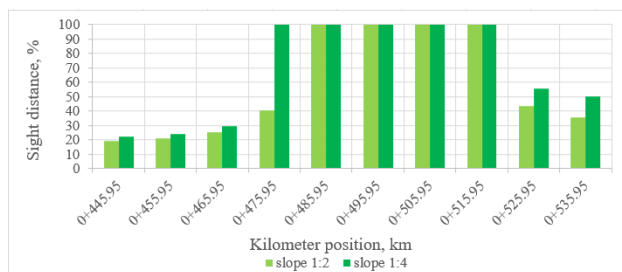


Figure 22. Sight distance depending on the shape of the slope in the intersection

In Figure 23 is present the perspective of the intersection with a slope of 1:2 compared to Figure 24., where the perspective of the intersection with the shape of the slope 1:4 is found.

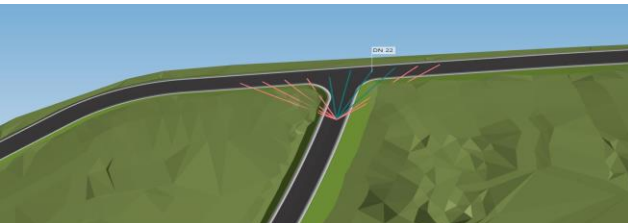


Figure 23. Sight distance perspective for 1:2 slope



Figure 24. Sight distance perspective for 1:4 slope

2.7 Criterion – Maneuver at a speed of 30 km/h

The criterion of the 30 km/h maneuver is based on the stopping distance presented by AND 600. The stopping distance for the speed of 30 km/h is 35m.

In this criterion we specify that the speed of all participants on the main and secondary road is 30 km/h and the minimum stopping distances are the same for all 3 participants considered in this intersection. In Figure 25, the sight distance is shown depending on the shape of the slope for both parts in the intersection.

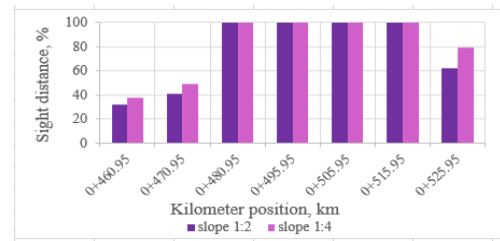


Figure 25. Sight distance depending on the shape of the slope in the intersection

Figure 26 shows the variation of the sight distance according to the speed of movement on the main road, for the left side. Between km 0+215.95 - km 0+265.95 the sight distance is respected for slope 1:2, V = 50 km/h and slope 1:4, V = 50 km/h, and between km 0+365.95-km 0+ 375.95 sight distance is respected for 1:4 slope, V=60 km/h and 1:4 slope, V= 50 km/h.

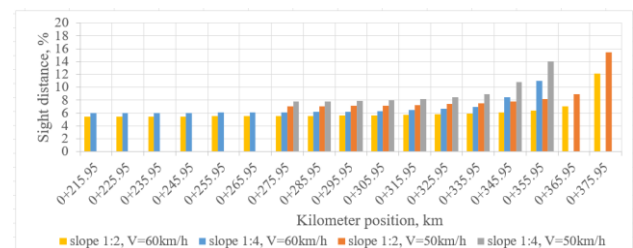


Figure 26. Sight distance as a function of speed on the left side

Figure 27 shows the variation of the sight distance according to the speed of movement on the main road, for the right side.

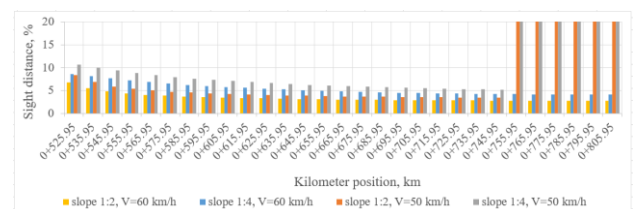


Figure 27. Sight distance as a function of speed on the right side

3 CONCLUSIONS

The study found that visibility at an intersection is an important component of road safety. The necessary checks of these critical points on public roads should become part of the designers' habit in order to create the necessary conditions for traffic participants to perform maneuvers in the vicinity of such an intersection.

The shape of the embankment and nearby terrain can influence sight distance at an intersection, according to the case study.

The Romanian standard does not differentiate between the directions of maneuver in an intersection, it is therefore necessary to further study this issue to increase traffic safety. Due to this study, according to the checked visibility conditions, it is recommended to limit the speed on the main and secondary road to 30 km/h and to place the STOP sign (B2) at the edge of the road platform.

3.1 For the criterion - STOP

- the sight distance as a function of the slope on the left side increases by 9% - 42% for 1:4 slope, compared to the sight distance for 1:2 slope;
- the sight distance on the right side as a function of the slope of the embankment does not vary, but the sight distance varies between 13%-32% of the required sight distance according to AND 600;
- the sight distance on the left-hand side varies according to the slope of the slopes and the speed. The sight distance is in between 7%-14% of the sight distance required for a speed of 50 km/h, and for a speed of 60 km/h the sight distance varies between 5%-12%;
- the sight distance on the right side does not vary depending on the slope of the slopes and the speed, but for 50 km/h the sight distance is included in the range of 20%-46% of the required sight distance and for 60 km/h the sight distance is 14% - 32%.

3.2 For the criterion - Maneuver

- the sight distance as a function of the slope on the left-hand side increases by 2% - 15% for a 1:4 slope compared to the sight distance for a 1:2 slope. The sight distance for the 1:4 slope is checked from kilometer position 0+475.95 and for the 1:2 slope from kilometer position 0+485.95;
- the sight distance as a function of the slope on the right-hand side increases by 21% - 40% for the 1:4 slope, compared with the sight distance for the 1:2 slope;
- the sight distance as a function of slope increases between 11% - 60% on both sides of the intersection for 1:4 slope versus 1:2 slope. For milepost 0+475.95 the sight distance is met for 1:4 talus slope;
- the sight distance across the entire intersection depending on the slope shape varies between 13% - 21%. On the left side of the intersection the sight distance for the 1:4 slope is approximately 9% greater than the value for the 1:2 slope. On the right side of the intersection the sight distance for the 1:4 slope is approximately 16% greater than the value for the 1:2 slope;
- on the left side, the sight distance varies depending on the speed and the sight distance required according to AND 600, as follows: between 3% - 6% of the sight distance required for a speed of 60 km/h; between 4% - 8% for a speed of 50km/h; between 21% - 74% of the sight distance required for a speed of 40 km/h, between 47% - 100% at a speed of 30 km/h.
- on the right side, the sight distance depending on the speed and the sight distance required according to AND 600 varies as follows: between 3% - 8% of at a speed of 60 km/h; at a speed of 50 km/h it is between 4% - 9% of the required sight distance; for 40 km/h the sight distance varies between 38% - 72%; between 65% - 100% of the sight distance required for a speed of 30 km/h.

From the analysis carried out, we can state with certainty that the adoption of a slope solution near intersections with a lower slope creates a longer sight distance.

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