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Analysis of the influence of longitudinal inclines on horizontal road traffic signs

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Abstract
This article examines the effect of the values of the longitudinal inclines of the road in relation to the location of horizontal road traffic signs. In a simple analysis, baseline scenarios were evaluated to demonstrate results that can be helpful in assessing the design of horizontal road traffic signs. As this is a broad topic, only the recommendations resulting from the test values are listed at the end of the text. The implementation of horizontal traffic signs in the right section of the road can be an important factor in improving road transport safety.

Key words
horizontal traffic signs, view, longitudinal inclines, safety, pedestrian crossing, place for crossing

1 Introduction

Horizontal traffic signs are applied on reinforced road surfaces, which is very important for the safety of traffic on the road. The application of the traffic signs is carried out according to the previous proposal, prepared by the designer of the construction, and approved by the relevant state administration bodies, according to the valid legislation. For example, in the Czech Republic, for the safe movement of pedestrians, horizontal road traffic sings are made with paint either for pedestrian crossings on the road, or places for crossing, which are identified by places adapted for pedestrians to cross the road. Both of these options differ in the markings themselves. While the pedestrian crossing is made up of transverse bands with a width of 0.5 m, the place for crossing is marked with only interrupted transversal lines of a width of 0.125 m. The visibility of pedestrian crossing and place for crossing from a moving vehicle are obviously different.

Vertical traffic signs marking a pedestrian crossing may be poorly recognizable, or completely obscured in unfavourable visibility conditions. In real-life situations, the marking of a pedestrian crossing by a vertical road sign is often covered or hidden by a solid obstacle, such as a parked vehicle, a standing bus or lorry, vegetation, etc. The place for crossing is visible only by seeing the horizontal traffic signs, or a person using the crossing.

When designing the location of horizontal traffic signs, the design elements of the relevant road are rarely evaluated. This is often the case when designing signs on existing roads. A typical example is the addition of a pedestrian crossing in the built-up parts of a village or community.

2 Sight views

The driver's view of horizontal traffic signs from the vehicle cabin is dependent on the following parameters:

- speed of the approaching vehicle
- pedestrian crossing length, crossing points, the width of the road
- longitudinal profile of the road
- directional road solution
- unplanned obstacles on the road
- solid obstructions on the road
- technical parameters of the vehicle (speed, braking distance, driver's eye height, etc.)
- properties and type of horizontal road signs material
- health condition of the driver and the person on the crossing
- use of reflective elements
- psychological impact of the surrounding area
- wind conditions
- vehicle transit time (day / night)

as well as other influences…

Not only in Czech national standards, the location of the horizontal road traffic signs for the pedestrian crossing is solved in the form of a viewpoint for stopping. The parameters for the calculation vary according to the experience of the country in which the viewpoints are verified, but the principle is the same. Examples of pedestrian crossing signs are shown in the following figure.

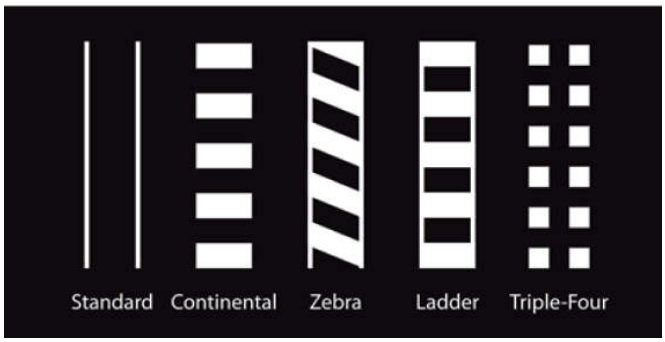

Figure 1: Examples of the horizontal road traffic signs for the pedestrian crossing [1]

2.1 Auxiliary parameter

For the purpose of analysis, the angle between the lines drawn from the driver's eye to the beginning and end of the horizontal traffic markings was marked by the author as the angle of view of the horizontal traffic signs, the so-called **"viewing angle"**. The driver's eye height was chosen to be 1m above the road surface, and the height of the horizontal road markings on the road surface.

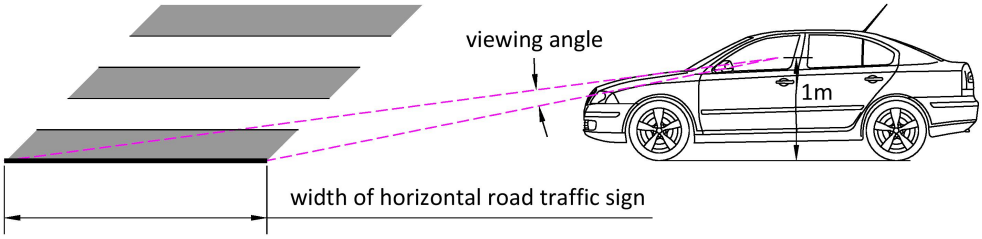

Figure 2: Viewing angle, [source: author]

3 Interdependence of design parameters

The pattern of horizontal pedestrian crossing signs or crossing points is a very important factor when designing their placement. The essence of the article is to find other contexts that influence the improvement of transport safety. For the purposes of the analysis, a graphical plot of the pedestrian crossing width and the approach distance of the approaching vehicle reflect the design speeds according to the standard ČSN 73 61110.

3.1 The relationship between the width of the horizontal road signs and the longitudinal incline of the road

In real-life situations, vehicle speed is a variable quantity, as is the length and width of the horizontal traffic signs on the road. While there are rules for designing parameters defining certain limits in the proposal, there are many cases of non-compliance with these parameters. For example, the vehicle speed is often higher than that considered in case model calculations. In ČSN 736110, the maximum pedestrian crossing times and place for crossing are specified. However, pedestrian crossings controlled by a light signalling device may be longer. However, the signalling device may not always work, or it is an existing pedestrian crossing, which has been proposed according to invalid regulations. This is an area for assessing its safety, basically to evaluate non-standard parameters.

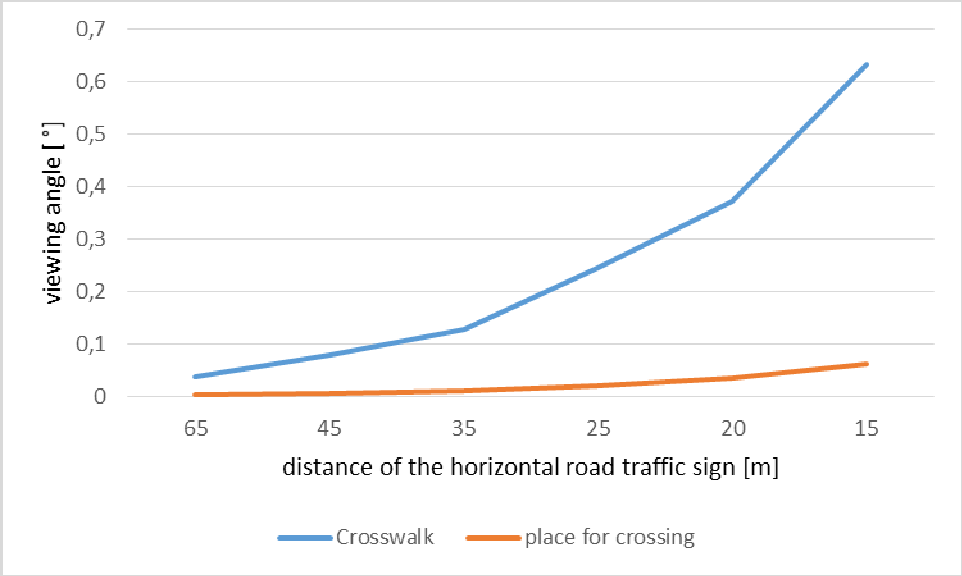

Figure 3: Dependence between distance and viewing angle

The graph only indicates the expected fact. The larger the distance between the driver of the incoming vehicle and the horizontal traffic signs, the lower the angle of view. In other words, the higher the design speed of the vehicle on the road, the lower the viewing angle. The higher the design speed, the longer the car's braking distance. From these contexts, it can be stated that the pedestrian crossing width or the place for crossing could be determined not only by the intensity of the pedestrian traffic, but also, for example, depending on the speed of the approaching vehicle.

3.2 Influence of the longitudinal incline of the road

In another model case, the influence of the longitudinal incline of the road on the angle of view on the horizontal traffic sings was performed. A graphical method with precise parameters was used. In order to simplify the task, we took into account the values for stopping, according to ČSN 73 6110, i.e. 35 m for the design speed on the 50 km/h road.

Road incline -10 to +10%. The considered width of horizontal road signs was chosen from 2-5 m.

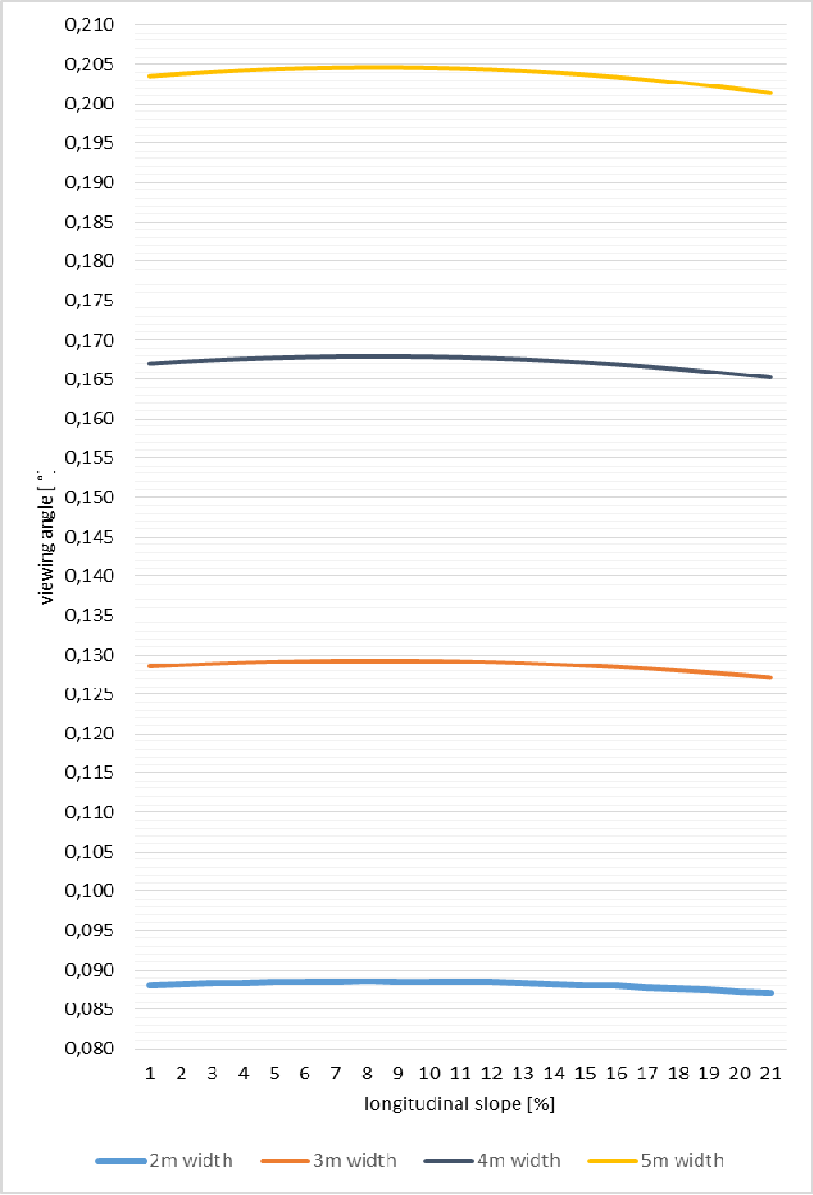

Figure 4: Wieving angle for different values of the width of the horizontal road traffic signs

The resulting measurement results in the assumed straight line between the width of the horizontal road traffic signs and the range of the viewing angle from the vehicle cabin. The wider the road traffic signs is, the greater the angle of change. However, if the values of the longitudinal incline of the road range from 0 % to +10 %, the value of the viewing angle decreases more slowly than when there is a dip or downward slope in the road. Decreases in view from zero to 10 % amounts to 15 %. It is also possible to read that the value of the viewing angle for the individual longitudinal inclines of the road to the horizontal traffic marking with a width of 5m is 231% higher than for marking of a width of 2 m.

3.3 Influence of rounding of the height polygon of the road with a flat arc

Let's take a look at the values of the viewing angle in the situation of a vehicle passing through a convex arc. Within the scope of the simplification, the values of the radius and the length of the projection for the design speed of 50 km/h according to ČSN 73 61110, i.e. the value of the radius of the convex arc 1000 m and the viewpoint of the stop at 35 m.

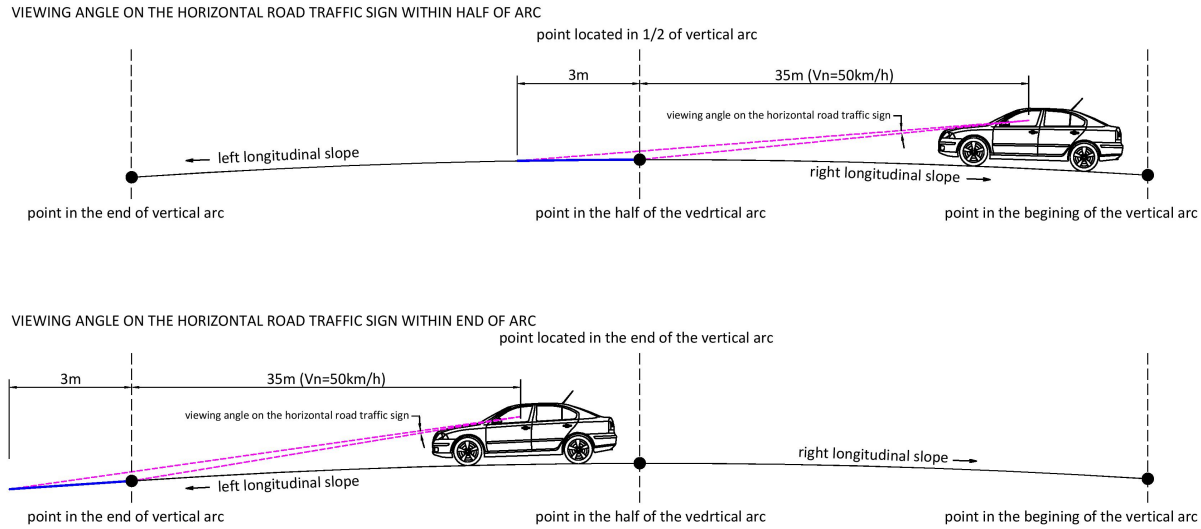

Figure 5: Wieving angle explanation

The angle of view of the horizontal traffic markings varies in each section of the vehicle trajectory. For example, only situations with pedestrian crossing with a width of 3m in the middle of the arc, and beyond the last point of the arc, according to the previous schematic image, were plotted. The following values were measured:

Table 1: Viewing angle values for horizontal traffic sign width 3m in the half of vertical arc with radius 1000m

Vn=50km/h		longitudinal slope on right side							
		-1	-2	-3	-4	-5	-6	-7	-8
longitudinal slope on left side	-1	0,0829	0,0685	0,0571	0,0496	0,0443	0,0424	0,0425	0,0431
	-2	0,0685	0,0571	0,0496	0,0443	0,0425	0,0425	0,0431	0,0431
	-3	0,0570	0,0496	0,0443	0,0425	0,0425	0,0431	0,0431	0,0428
	-4	0,0496	0,0433	0,0424	0,0425	0,0431	0,0431	0,0428	0,0426
	-5	0,0442	0,0425	0,0425	0,0431	0,0431	0,0428	0,0426	0,0425
	-6	0,0424	0,0425	0,0431	0,0431	0,0428	0,0426	0,0425	0,0425
	-7	0,0425	0,0431	0,0431	0,0428	0,0426	0,0425	0,0424	0,0424
	-8	0,0430	0,0430	0,0428	0,0426	0,0424	0,0424	0,0424	0,0425

Table 2: Viewing angle values for horizontal traffic sign width 3m in the half of vertical arc with radius 700m

Vn=50km/h		longitudinal slope on right side							
		-1	-2	-3	-4	-5	-6	-7	-8
longitudinal slope on left side	-1	0.0782	0.0616	0.0465	0.0335	0.0242	0.0165	0.0103	0.0066
	-2	0.0615	0.0466	0.0336	0.0242	0.0166	0.0103	0.0066	0.0053
	-3	0.0464	0.0335	0.0242	0.0165	0.0103	0.0066	0.0053	0.0061
	-4	0.0335	0.0242	0.0166	0.0103	0.0066	0.0053	0.0061	0.0060
	-5	0.0242	0.0165	0.0103	0.0065	0.0053	0.0061	0.0060	0.0062
	-6	0.0165	0.0103	0.0065	0.0053	0.0061	0.0060	0.0062	0.0063
	-7	0.0103	0.0065	0.0050	0.0061	0.0066	0.0065	0.0063	0.0060
	-8	0.0065	0.0049	0.0061	0.0066	0.0065	0.0065	0.0060	**0.0058**

Table 3: Viewing angle values for horizontal traffic sign width 3m in the end of vertical arc with radius 1000m

Vn=50km/h		longitudinal slope on the right side							
		-1	-2	-3	-4	-5	-6	-7	-8
longitudinal slope on the left side	-1	0,0646	0,0517	0,0501	0,0500	0,0500	0,0501	0,0501	0,0500
	-2	0,0516	0,0500	0,0500	0,0500	0,0500	0,0500	0,0500	0,0500
	-3	0,0500	0,0500	0,0499	0,0500	0,0500	0,0500	0,0500	0,0500
	-4	0,0499	0,0499	0,0500	0,0500	0,0499	0,0499	0,0499	0,0499
	-5	0,0498	0,0499	0,0499	0,0499	0,0499	0,0499	0,0498	0,0498
	-6	0,0498	0,0498	0,0498	0,0498	0,0498	0,0498	0,0498	0,0498
	-7	0,0498	0,0497	0,0497	0,0497	0,0497	0,0497	0,0498	0,0497
	-8	0,0497	0,0496	0,0496	0,0496	0,0496	0,0497	0,0496	0,0497

Table 4: Viewing angle values for horizontal traffic sign width 3m in the end of vertical arc with radius 700m

Vn=50km/h		longitudinal slope on the right side							
		-1	-2	-3	-4	-5	-6	-7	-8
longitudinal slope on the left side	**-1**	0.0568	0.0343	0.0207	0.0162	0.0161	0.0161	0.0162	0.0161
	-2	0.0343	0.0207	0.0161	0.0161	0.0161	0.0161	0.0161	0.0161
	-3	0.0206	0.0161	0.0161	0.0161	0.0161	0.0161	0.0161	0.0161
	-4	0.0161	0.0161	0.0161	0.0161	0.0161	0.0161	0.0161	0.0161
	-5	0.0161	0.0161	0.0161	0.0160	0.0161	0.0161	0.0161	0.0161
	-6	0.0161	0.0161	0.0160	0.0161	0.0161	0.0161	0.0160	0.0161
	-7	0.0161	0.0160	0.0161	0.0161	0.0160	0.0160	0.0160	0.0160
	-8	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160

From the measured values, it is obvious that the lower viewing angle on the horizontal road sings is, the higher the value of the longitudinal incline of the assessed road. However, it does not differ from set values, and the value is still consistent with the 50 km/h design parameter. It can also be stated that the viewing angle at inclines of - 8 and + 8 % (16 % difference) and - 1 and + 1 % (2 % difference) is almost 13.5 times worse in the case of pedestrian crossing in the middle of the arc.

In the case of placing horizontal pedestrian crossing signs/markings with a width of 3 m and the same incline difference, the viewing angle is only 3.5 times lower. However, it is necessary to mention that the values apply to the standard design parameters of the road. For values of a height arc that does not meet the standard values according to ČSN 73 6110, while maintaining the design speed of 50 km/h, the values are very similar. They are, however, considerably lower, due to the non-observance of the minimum radius for the mentioned speed. In this case, however, the viewpoint parameters deteriorate significantly.

4 Conclusion

From the point of view of the design parameters for road, it is possible to determine the optimal location of the pedestrian crossing during the design of the road itself, or to choose the most suitable place for the pedestrian crossing, taking into account the highway solution of the road. The viewing angles from the vehicle's cabin move at very low values, but their differences are very high. Determining the optimal section for the application of horizontal traffic signs (pedestrian crossings, crossing points, directional arrows, etc.) can help to improve traffic safety. The cases investigated are not only suitable for the new design, but are also applicable to the design of horizontal road signs on existing roads, taking into account their height solutions. However, it is necessary to mention that many other parameters contribute to the design of horizontal traffic signs, and the longitudinal slope of the road is only one of them.

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