An excel file to calculate the look through in short curving tunnels – version 3

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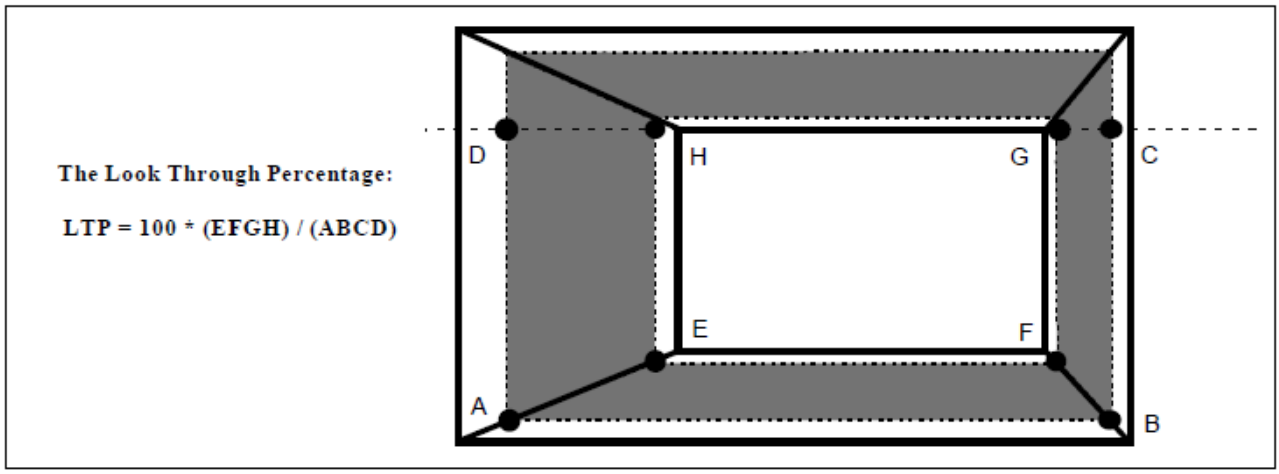
Introduction

CR 14380: 2003 "Lighting applications - Tunnel lighting" defines the "Look through Percentage", LTP as shown below.



The points ABCD are located at the apparent entrance portal, which is a cross-section in the tunnel in a plane at a certain distance behind the entrance portal.

Similarly, the points EFGH are located at the apparent exit portal, which is a cross-section in the tunnel at a certain distance in front of the exit portal. The idea behind these apparent portals is that daylight penetrates some distance into a tunnel at both ends.

CR 14380: 2003 also defines a vehicle and a cyclist as rectangular objects that are placed in the apparent entrance portal.. The relevant measures for these objects are the percentages of their areas that are seen in backlight against the apparent exit portal.

These measures involve an observer, whose location influences the values.

This report describes an excel file that calculates the measures for short curving tunnels. The curve may be in the horizontal plane or the vertical plane or both. The road leading up to the tunnel can have its own curves. The continuation of the road after the tunnel is irrelevant.

The input/output of the excel file is shown in figure 1, while a diagram used as an illustration is shown in figure 2.

The input values are those in a red font. They are all geometrical measures and include the location of the observer relative to the road passing through the tunnel, radii of the curve of the section of the road in front of the tunnel, the dimensions of the tunnel, the locations of the apparent entrance and exit portals, radii of the curve of the tunnel and the road inside the tunnel, and the above-mentioned objects.

The output values are in a black font and include the LTP and the percentages for the two objects.

The diagram shows in perspective the entrance portal, the apparent entrance portal, the rectangle defined by the points ABCD, the apparent exit portal containing the points EFGH, the two objects and the observed.

Additionally, the diagram also shows the lines between the tunnel surfaces in order to improve the visual understanding.

The perspective is such that the observer is the point of the perspective, while all projections are onto the plane of the entrance portal.

In this perspective it is possible to judge the LTP and the percentages of the two objects in a visual manner, and thereby inspect the influence of the lay-out of the road and the tunnel.

The diagram shows only those parts of the elements that are inside entrance portal and, therefore, visible for the observer through the entrance portal.

In this connection, the author thinks that the CR 14380: 2003 has the implicit assumption that the apparent entrance portal is fully visible through the entrance portal.

If so, reductions of the projection of the apparent entrance portal may not really be permissible, and should be avoided. After all, reductions of this nature may cause a raise of the LTP value - indicating better visibility, while the truth is that some of the apparent entrance portal is obscured.

Therefore, the excel file presents a warning, whenever a parts of the apparent entrance portal is obscured. The warning appears below the diagram of figure 2 and reads “Warning: The apparent entrance portal is not fully visible through the entrance portal”.

This puts some constraint on the location of the observer relative to the road outside of the tunnel, and in particular to the curve of the section of the road that leads up to the tunnel. However, the warning may be ignored if only a small part of the apparent entrance portal is obscured.

The projection of the apparent exit portal may be reduced by the tunnel surfaces. As an example, the road surface may obscure some of the apparent exit portal when the tunnel curves down.

There could be a similar effect for the entrance portal and the apparent portals, when the section of the road leading up to the tunnel curves down. In view of the above, this should not be accepted, but is not evaluated by the excel file as the above-mentioned warning appears at less strong curves down.

Location of the observer		
Height above the road surface	1,2	meter
Distance to the right of the centre line	1,0	meter
Distance to the entrance portal	80	meter
Curves of the road in front of the tunnel		
Radius of upwards curve	0	meter
Radius of curve to the right	0	meter
(negative values produce opposite curve)		
(zero produces no curve)		
Dimensions of the tunnel		
Height of the tunnel	7,0	meter
Width of the tunnel	7,0	meter
Length of the tunnel	100	meter
Location of apparent entrance and exit portals		
Apparent entrance portal (CR 14380 recommends 5,0)	5,0	meter
Apparent exit portal (CR 14380 recommends 10,0)	10,0	meter
Curves of the tunnel		
Radius of upwards curve	0	meter
Radius of curve to the right	0	meter
(negative values produce opposite curve)		
(zero produces no curve)		
Vehicle at the apparent entrance portal		
Height (CR 14380 recommends 1,6)	1,6	meter
Width (CR 14380 recommends 1,4)	1,4	meter
Distance to the right of the centre line	1,75	meter
Cyclist at the apparent entrance portal		
Height (CR 14380 recommends 1,8)	1,8	meter
Width (CR 14380 recommends 0,5)	0,5	meter
Distance of the centre to the right of the centre line	3,0	meter
Percentages		
Look Through Percentage	42	%
Vehicle backlight	54	%
Cyclist backlight	0	%

Figure 1: Input/output of the excel file.

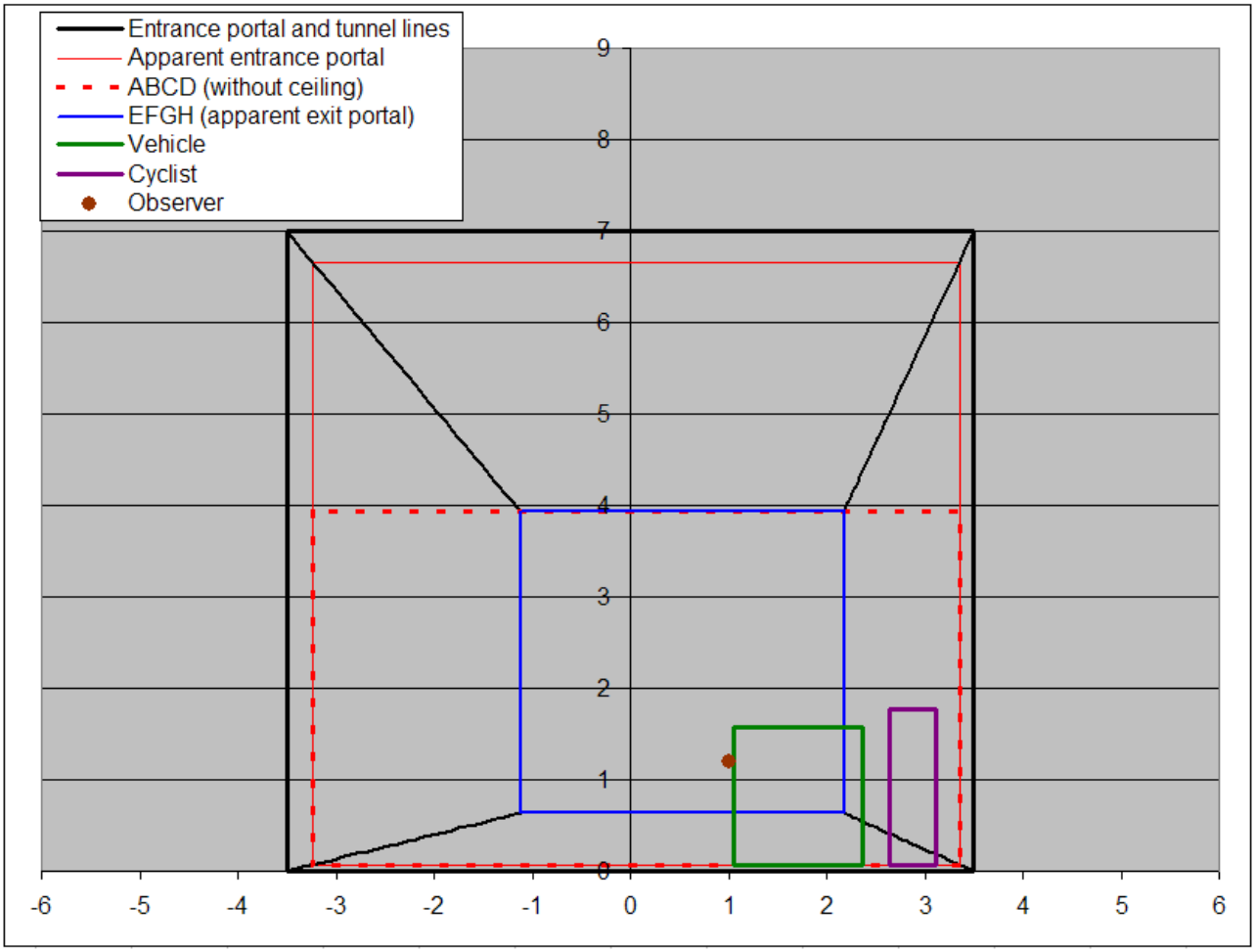


Figure 2: Diagram used for illustration.

The principles of the calculations are accounted for in the following.

1. The observer and the road leading up to the tunnel entrance

The observer is described by means of his eye location, including the height above the road, the transverse location to the right of the centre line of the road and his distance from the tunnel entrance portal. These measures are indicated in the input.

The road leading up to the tunnel may have a circular curve up, down or no curve in the vertical plane. The cases are indicated by respectively a positive value of the radius of curve, a negative value or the value 0. The radius is measured to the centre line of the road.

The road can also have a circular curve right, left or no curve in the horizontal plane. This is indicated in the same manner. The radius is measured to the surface of the road.

As explained in the following, these curvatures have the single action of moving the observer.

2. The tunnel

The tunnel is described by means of its height, width and length.

Figure 3 shows a top view of the tunnel with an apparent entrance portal and an apparent exit portal. These are placed at certain distances from respectively the entrance and exit portals to be given in the input. Refer to CR 14380: 2003, which recommends distances of respectively 5 and 10 m.

Figure 3 also illustrates that the tunnel - together with the road passing through it - can have a curve, in this case to the right. The options are as for the road in front of the tunnel and are to be given in the input. The curvatures are individual for the sections in front of the tunnel and within the tunnel. The location of change is at the tunnel entrance.

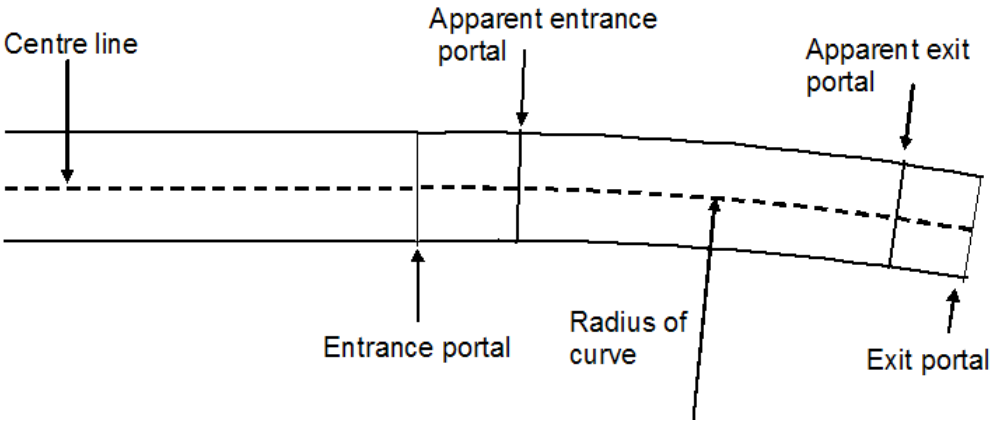


Figure 3: A road that passes through a short tunnel with a curve.

Figure 4 gives a further illustration of the curvatures within the tunnel.

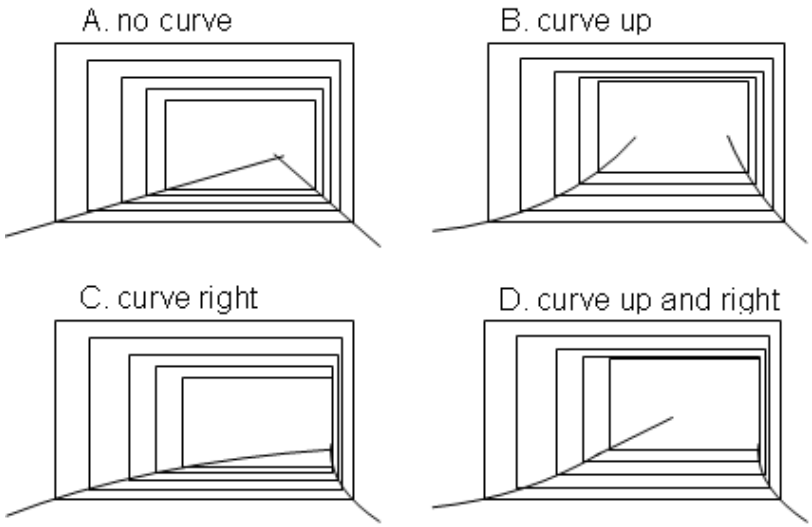


Figure 4: Illustration of the curvatures.

With no curve (figure 4A), the tunnel continues straight out. The ground may be horizontal or it may have a steady slope.

With a curve up (figure 4B), the tunnel takes up part of a vertical loop. With a curve to the right (figure 4C), the tunnel takes up part of a circular track in the plane of the ground.

The case is more complex with a curve up and also right (figure 4D). The tunnel stays on a circle with the indicated radius for the curve to the right as seen from above, while the slope gets more and more steep with the indicated radius for the curve up. The radii are measured to the centre line of the road through the tunnel.

This can be compared to a winding staircase, where the steps are arranged to make the staircase more and more steep.

There are other ways to arrange simultaneous curves in two planes, but the one that has been used seems the more practical. In particular, the tunnel and the road inside the tunnel get no tilt in the lateral direction.

In practice, only relatively small angles of curve, up to perhaps 15°, are interesting, as the there is otherwise no or very little look through to the apparent exit portal. Because of this, the actual way to arrange curves in two planes makes little difference.

3. Calculation of the LTP

The apparent entrance portal is projected on to the plane of the entrance portal as shown in figure 5.

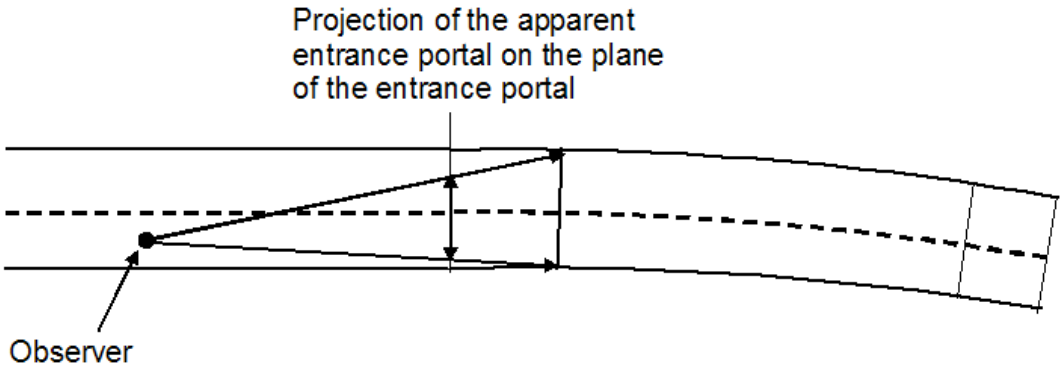


Figure 5: Projection of the apparent entrance portal on the plane of the entrance portal.

The width and height of this projection is determined, and the area is calculated as the product.

Additionally, the apparent exit portal is projected on to the plane of the entrance portal as shown in figure 6, and the area of this projection is calculated in the same manner. The LTP value is then calculated as the ratio of the two areas multiplied by 100.

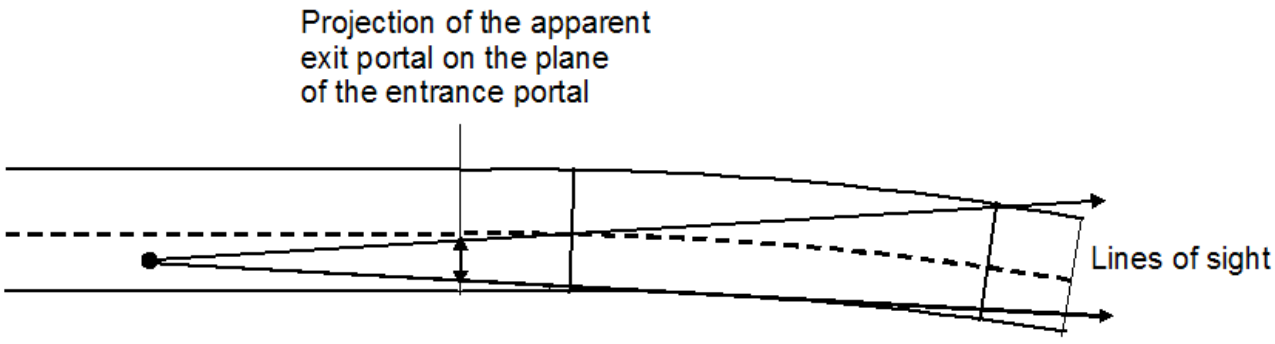


Figure 6: Projection of the apparent exit portal on the plane of the entrance portal.

In case the projection of the apparent entrance portal is not fully within the entrance portal, only the part that is inside is taken into account. This happens, if the observer is placed outside of the road or at extreme height positions. More important, however, this happens easily, if the observer is moved because of curve of the road in front of the tunnel.

4. Calculation of the backlight percentage of objects

The objects are placed as silhouettes on the road surface in the plane of the apparent entrance portal and are projected on to the plane of the entrance portal. It is then easy to determine the fractions of the projected areas that are seen on the background of the projected apparent exit portal, and to convert the fractions to backlight percentages.

5. Some details of the calculations

5.1 Co-ordinate system

The co-ordinate system shown in figure 7 is the basis for all calculations carried out by the excel file. All distances along the road are measured along the centre line of the road.

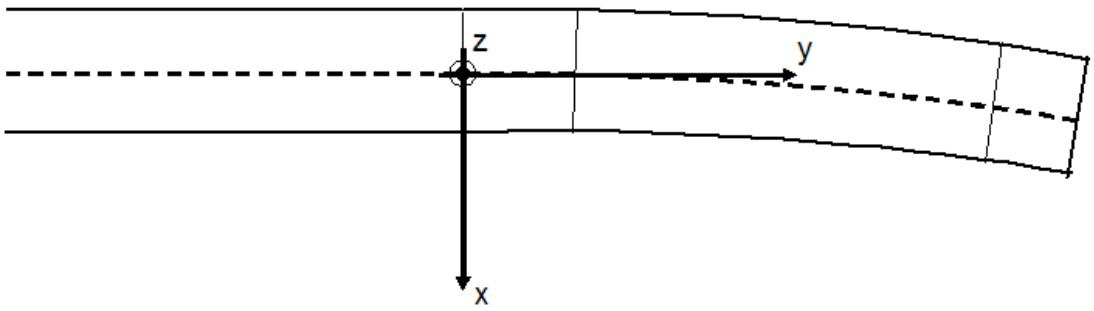


Figure 7: Co-ordinate system used in calculations.

5.2 Obstruction of the view to the apparent exit tunnel by the surfaces of the tunnel

In connection with figure 7 it is to be noted that the line of sight from the observer to the left wall at the apparent exit portal can be assumed to be unobstructed (when the tunnel curves to the right). This is not necessarily the case for the line of sight to the right wall at the apparent exit portal, as the curving wall may hide this location.

This is handled in the way illustrated in figure 8. The projection of the right tunnel wall is calculated for several cross-sections along the tunnel, and the projection that is the most to the left is selected. The actual number of cross-sections is 30, which is ample for an accurate determination of the projection that is the most to the left.

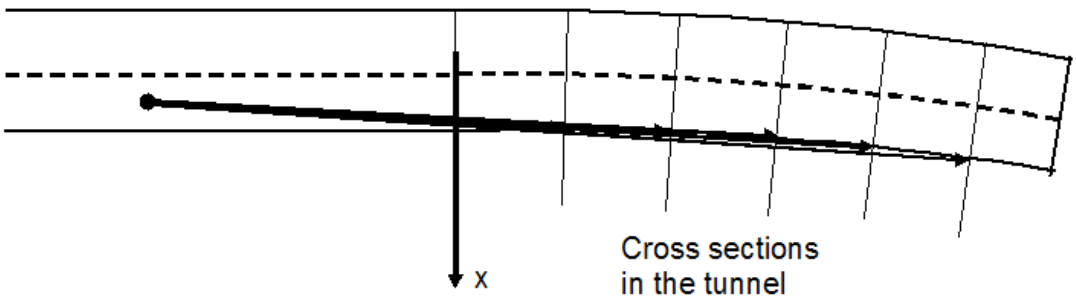


Figure 8: Projection of the right side of the tunnel wall at several cross-sections along the tunnel.

In case the tunnel curves to the left instead of to the right, it is the left wall that may obscure the view to the apparent exit portal. Therefore, the procedure illustrated in figure 8 is actually used for both walls. The same method is applied for the floor and the ceiling in the side view.

5.3 The shape of the projections

The projected areas of the apparent portals are assumed to be rectangular, as only the projected widths and heights are determined. This, however, is not strictly correct when the tunnel curves.

To illustrate that, figure 9 shows a tunnel curving up as seen from the above (A) and from the side (B).

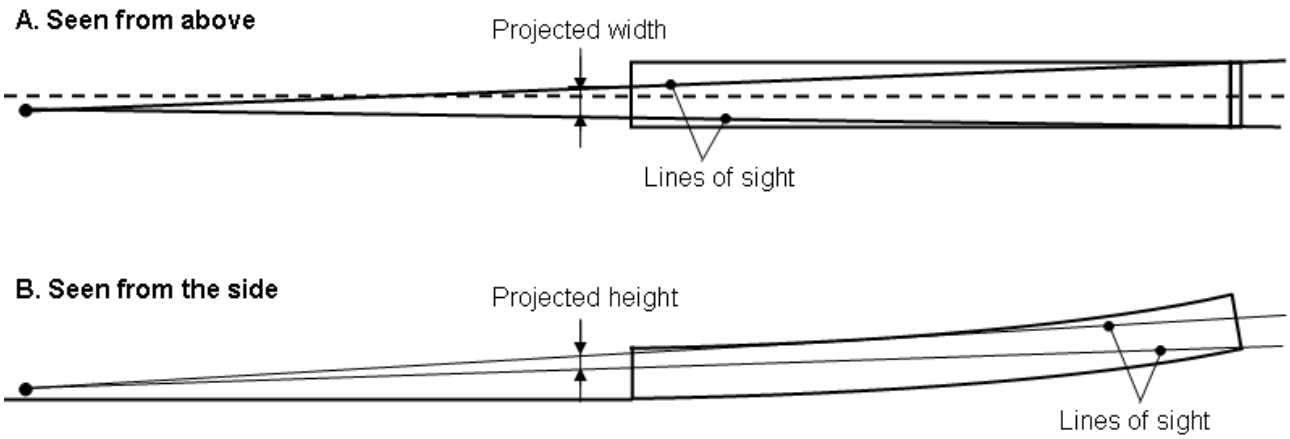


Figure 9: A tunnel curving up as seen from the above (A.) and from the side (B).

The projected width of the apparent exit portal is determined by means of two lines of sight pointing from the observer to two points on the road surface at the apparent exit portal. The points are those visible most to the right, and most to the left. In this case, there is no obstruction from the walls of the tunnel.

The projected height of the apparent exit portal is determined by means of two lines of sight pointing from the observer to two points on the centre line of the apparent exit portal. The points are those visible in the most downward and the most upward directions. In this case, there is no obstruction from the road surface concerning the lower point, while the upper point is limited by the ceiling of the tunnel.

The matter is that the apparent exit portal is tilted backwards because of the upward curve of the tunnel. This brings the upper point a bit closer to the observer, so that the projected area is actually a bit wider at the upper line than at the lower line.

The opposite would be the case for a tunnel curving down. For a tunnel curving right or left, the projected heights would be a bit different at the two sides.

On the other hand, such deviations from a rectangular projection are small for tunnels that leave a reasonably large LTP value. The case illustrated in figure 9 leave an LTP value of approximately 30 % with a difference

between upper and lower widths of only 0,5 %. This would not be visible to the eye in a diagram as in figure 2.

For the projection of the apparent entrance portal, such deviations are much smaller. Therefore, the matter is pointed out, but has been ignored.