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CALCULATION OF REVERSE CURVES IN TRANSPORTATION CIVIL ENGINEERING

Roumen A. Ivanov, Nevena I. Babunska-Ivanova
rang75@hotmail.com, babunska_n@abv.bg

Todor Kableshkov University of Transport
Sofia, 158 Geo Milev Str.
THE REPUBLIC OF BULGARIA

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Abstract: *Knowing the different geometry of the roadways and railways is of great importance for their design and reconstruction. Horizontal alignment, vertical alignment and cross-section are the three fundamental components of roadway and railway geometry. The geometry of the roadway can be of different types–horizontal and vertical curves. The horizontal alignment of the roads consists of straight lines, transition curves, circular arcs, etc. In practice, the geometry of roadways and railways is often a combination of different types of curves used in roundabouts and railway station tracks. Horizontal curves may be reverse, spiral, circular, compound, broken back, deviation, etc. Vertical curves are used to ensure a smooth transition between the tangents of the vertical alignment of roadways and railways. In transportation civil engineering a variety of curves are used. This research presents an approach to calculating the radius of a reverse curve. In the experiment described we show the difference between the officially used formulas and those proposed by the authors. The presented solution and example prove that it is necessary to improve the normative documents in the field of transportation infrastructure. The application of these formulas to an example shows that there is a difference between the two formulas applied for the calculation of the radius of the reverse curve.*

1. ROADWAYS AND RAILWAYS GEOMETRY

In transportation civil engineering a variety of curves are used. For roadway and railway measurements and quality assessment we are using different methods, models, and instrumentation [1,2]. When reconstructing roadways it's necessary to perform measurements to determine the length of straight sections and the radius of the horizontal curves of the road, the degree of curvature, etc. The use of GNSS receivers can automatically give higher accuracy in determining the geometry of the roadway. This technology opens new possibilities for control measurements not only of the roadways, but also of the railways. Photogrammetric, barometric, inclinometric measurements, etc., are performed together with the satellite measurements. Laser scanners are applied intensively for geodetic surveys and mapping [3,4]. The mathematical methods used allow besides the radius of the curves (horizontal and vertical) to also determine the radius of curvature, the longitudinal and transverse slope, the existing road signs in the measured road section, visibility in a curve, width of the roadway, etc. Integrated measuring systems use electronic sensors to obtain the information necessary to determine the geometrical characteristics of the roads–horizontal and vertical radius, grade, etc., derived from sensors (GPS, accelerometers, gyros, odometer, laser scanners, etc.). The appropriate inertial measurement systems and hardware implementations are presented in [5]. In practice, the geometry of roadways and railways is often a combination of different types of curves used in roundabouts and railway station tracks [6,7].

2. REVERSE CURVE CALCULATIONS

2.1 Reverse curve in a straight section

In our case we will discuss passing from one gauge distance to another on railway tracks in a straight section with a reverse curve and without an intermediate straight. After fulfilling the condition is $R \geq V^2$, where V is the speed in km/h, the stretching length L is [8] (Fig.1):

(1) $$L = 2V\sqrt{S}$$

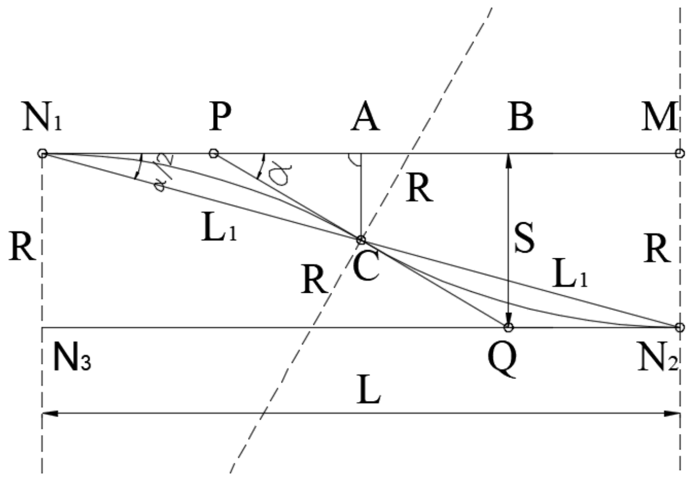

Fig. 1

In this solution from the triangle ACN_1 we found:

(2) $$L_1^2 = (0.5L)^2 + (0.5S)^2$$

The long chord L_1 is calculated using:

(3) $$L_1 = 2R\sin(\alpha/2)$$

and after substituting the values in the formula, we get:

(4) $$(2R\sin(\alpha/2))^2 = (0.5L)^2 + (0.5S)^2$$

Now, we can find the radius R of the given reverse curve:

(5) $$R = ((0.5L)^2 + (0.5S)^2)^{1/2} / (2\sin(\alpha/2))$$

The angle α is obtained using the relationship:

(6) $tg(\alpha/2) = (0.5S)/(0.5L)$

This solution is illustrated by a practical example. For L=400m, S=50m, the angle α =15.8334^g the radius R, calculated using formula (5) is R = 813m. According to our standard, using formula (7) the radius R = 800m [8]. Obviously there is a difference between the two formulas for reverse curve calculation for straight sections.

(7) $R = \frac{L^2}{4S}$

2.2 Reverse curve in a non-straight section

For the given points - p.M, p.A, p.B и p.N, as well as the radius R_1 and radius R_2, the required elements are the end of the first curve (KK_1), the distance d and the beginning of the second curve (HK_2) (Fig.2) [9]. With a total station placed at point A the angle φ_1 is measured and from point B is measured the angle φ_2. A free coordinate system is introduced with X, У and $X_A = 0$ and $Y_A = 0$. The coordinates of p.O_1 are $X_{O_1} = 0$ and $Y_{O_1} = R_1$. From measured S_{AB}, and bearing angle $\alpha_{AB} = \varphi_1$, the coordinates of p.B are $X_B = S_{AB}\cos\varphi_1$, $Y_B = S_{AB}\sin\varphi_1$. Later the bearing angle is $\alpha_{BO_2} = \alpha_{BA} - \varphi_2 + 100^g$. The coordinates of point p.O_2 are:

(8) $X_{O_2} = X_B + R_2 \cos\alpha_{BO_2}$

(9) $Y_{O_2} = Y_B + R_2 \sin\alpha_{BO_2}$

From the coordinates p. O_1 and p.O_2 we find the angle $\alpha_{O_1O_2}$ and distance $S_{O_1O_2}$:

(10) $\alpha_{O_1O_2} = arctg\frac{|\Delta Y_{O_1O_2}|}{|\Delta X_{O_1O_2}|}$

(11) $S_{O_1O_2} = \sqrt{\Delta X^2_{O_1O_2} + \Delta Y^2_{O_1O_2}}$

The next formula is used to obtain the distance d:

(12) $d = \sqrt{S^2_{O_1O_2} - (R_1 + R_2)^2}$

The angles δ_1, and δ_2 are calculated using the relations:

(13) $\sin\delta_1 = \frac{d}{S_{O_1O_2}}$

(14) $\sin\delta_2 = \dfrac{R_1 + R_2}{S_{O_1O_2}}$

For the control $\delta_1 + \delta_2 = 100^g$. Working formulas for angles are:

(15) $\alpha_{O_1KK_1} = \alpha_{O_1O_2} - \delta_1$

(16) $\alpha_{O_2HK_2} = \alpha_{O_2O_1} - \delta_1$

(17) $\alpha_1 = \alpha_{O_1KK_1} - 300^g$

(18) $\alpha_2 = \alpha_{O2HK_2} - \alpha_{O_2B}$

Knowing α_1 и R_1, α_2, R_2 the tangents t_1 and t_2 are calculated.

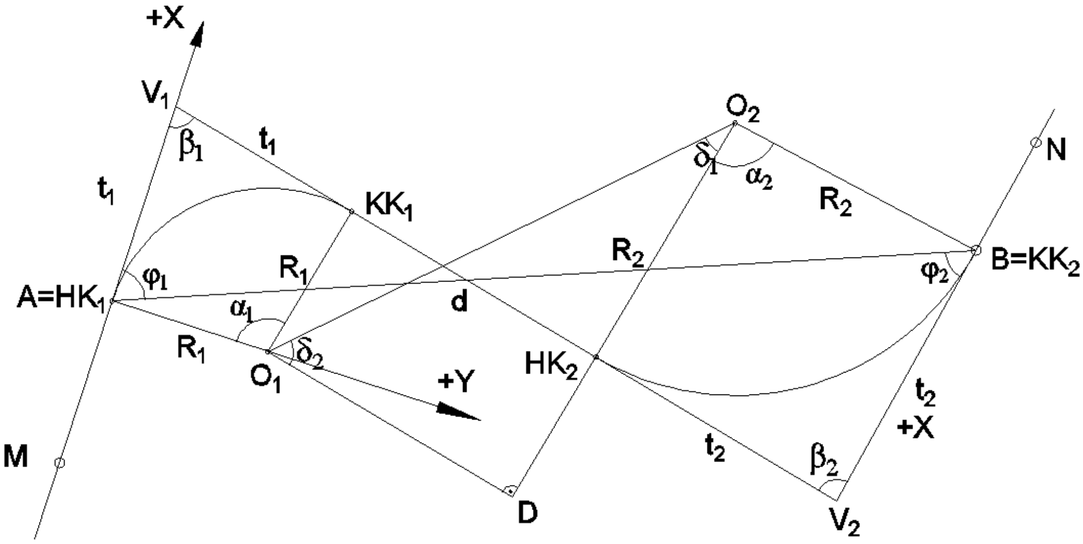

Fig. 2 Reverse curve

2.3 Setting out the reverse curve

From the beginning of the first curve (HK1) t_1 is measured and the intersection V_1 of tangents is obtained. The angle at V_1 is $\beta_1 = 200^g - \alpha_1$. An angle β_1 and the tangent t_1 is setting out. Thus we find a point KK1. Then the distance d is setting out. From a point B is measured t_2 and processed in the manner described above.

CONCLUSIONS

The presented solution and example prove that it is necessary to improve the normative documents in the field of transportation infrastructure. The application of these formulas to an example shows that there is a difference between two formulas applied for the calculation of the radius of the reverse curve.

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