Drawing up a road plan in difficult sections

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Abstract: The railway is the busiest transport and properly designed and used will further improve efficiency. For this reason, this article gives the most convenient transition model in the section of rail lifting from one plane to another. That is, in order for the movement of the train in the ascent section to be smooth, the trajectory in the turn section must be an arc of a circle. The plane in which the train stands should be an attempt at this circle. It is optimal that the upper plane is also in the wobbling position along the circular arc on the lifting part.
Keywords: railway plan, rail track, steepness, radius of contact, angle of rotation, profile of carriage movement.

1. Introduction

Drawing up a railway plan depends on the terrain conditions, consists of rectilinear parts and curved parts connecting rectilinear parts [1], [2]. A simple version of a curved part is a scheme where both straight parts belong on the same horizontal plane. We consider it difficult when the straight part is laid on horizontal planes at different levels. This variant also splits into two

a) angle between straight parts is equal to zero,

b) angle between straight parts

In this article, we will draw a curve equation describing the location of the railway and road plan path.

2. Content

The longitudinal profile of a railway line is the projection of its axis onto a vertical surface, which is then turned onto the plane [3], [4].

The ideal longitudinal profile is a straight line on a horizontal plane. But the geological and topographic features of the area through which the railway is traced cause the direction of the road to change or move to another level of the horizontal plane. These changes may occur simultaneously or will be repeated several times. In this case, the railway plan is considered complicated.

One simpler view of the difficult part of the road is to raise the level of the railway to some height δ, while the direction of the road does not change. This is indicated in Figure 1.

Here α and β are different horizontal planes, the distance between them is δ. The projection of the straight part b onto the horizontal plane α is denoted by $b'$and it belongs to α, the straight line b' is a continuation of the straight line a.

For lifting δ railway, there are strict conditions that provide the technical possibility of moving the train along this road [5-7]. The rise of road δ is associated with the overcoming by the railway of various kinds of high-altitude obstacles in the vertical plane. Depending on the direction, movement δ may indicate go or descent.

Usually on the railway, the rise or descent is called the steepness of the road [8], [9].

Sections of a profile of unambiguous slope are called a longitudinal profile element. In this diagram, segment AB is a longitudinal profile element.

Slope steepness AB is considered to be the main characteristics of the longitudinal profile.

Slope steepness is measured by the ratio of lifting (lowering) height δ in meters as a horizontal projection of its length $l -$ in kilometers [10].

The length of the profile element is usually measured not by the hypotenuse AB of the triangleABC, but by the leg AC, that is, by the projection AB on the horizontal plane α.

We are interested in the optimal mathematical model of the longitudinal profile. Therefore, parameters δ and $AC = l$ are considered to meet all technical and economic requirements.

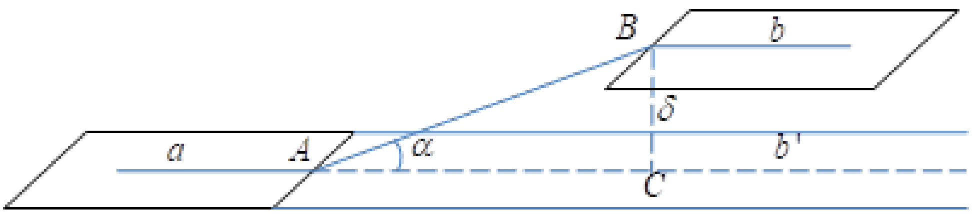

Fig. 1. Raising the level of the railway to height δ.

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We offer the most optimal version of the longitudinal profile, which ensures the most continuous movement of the composition without changing the speed of movement.

To do this, enter the Cartesian coordinate system, the abscissa coinciding with line a, select the origin O in the middle of segment AC, then eats $AO = OC$. The direction of the Oy axis perpendicular to the horizontal α plane. Then the considered points have the following coordinates $A\left(-\frac{l}{2},0\right), C\left(\frac{l}{2},0\right)$. The intersection of AB with the axis has coordinates $D\left(0,\frac{\delta}{2}\right)$. Equation of the line b: $y = \delta$.

Select the curve connecting points A and D (D and C) so that it is defined by one arc of the circle. Moreover, at point A, line a should be tangent to this circle. This means that its center must lie on line $x = -\frac{l}{2}$. We will put a similar requirement for arc DC. At points B, line b will be tangent to the circle connecting points D and B. At point D, these two circles must have a single tangent. Then we have at point D a smooth transition from arc AD to arc DC. Note that the center of the circle expressing arc DC belongs to line $x = \frac{l}{2}$ and is located symmetrically to the center of the circle of arc AD relative to point D.

Define the center of a circle E having an arc AD satisfying the above conditions. Segment AD is the chord of this circle. Therefore, the centre $E_1 -$ must lie on a straight line T_1 which is perpendicular to the length AD and which runs in its middle.

Let's calculate the equation of the line AD as a line passing through points $A\left(-\frac{R}{2},0\right)$ and $D\left(0,\frac{\delta}{2}\right)$.

$$AD:\ y = \frac{\delta}{l}x + \frac{\delta}{2}, \quad R = \frac{\delta}{l}.$$

The middle of chord AD has coordinates $\left(-\frac{l}{4},\frac{\delta}{4}\right)$. The equation of line T_1 perpendicular to the line is defined as a line passing through point $\left(-\frac{l}{4},\frac{\delta}{4}\right)$ and perpendicular to line AD. From the condition of perpendicularity, the angular coefficient of the line T_1 is determined from equality $R = -\frac{1}{R_1} = -\frac{l}{\delta}$.

Then equation T_1 has the form

$$y = \frac{\delta}{l}x + \delta.$$

Define the coordinates of the center E_1 as the intersection of the lines

$$\begin{cases} x = -\frac{l}{2}, \\ y = \frac{\delta}{l}x + \delta. \end{cases}$$

Then E_1 has coordinates $\left(-\frac{l}{2},\frac{3l^2+\delta^2}{4\delta}\right)$

The radius of circle $R_1 -$ is equal to the distance between point E_1 and axis Ox, therefore

$$R_1 = \frac{l^2+\delta^2}{4\delta}.$$

The equation of the circle to the center at point E and radius R is

$$\left(y - \frac{l^2+\delta^2}{4\delta}\right)^2 + \left(x + \frac{l}{2}\right)^2 = \left(\frac{l^2+\delta^2}{4\delta}\right)^2.$$

From this one can obtain the equation of arc AD

$$y = \sqrt{\left(\frac{l^2+\delta^2}{4\delta}\right)^2 - \left(x + \frac{l}{2}\right)^2} \qquad (1)$$

This equation makes it possible to determine the coordinate of arc AD with sufficient accuracy, given the values of parameters l and δ.

In a similar way, you can define a circle equation in which DB is an arc.

The equation of arc DB is

$$y = \sqrt{\left(\frac{l^2+\delta^2}{4\delta}\right)^2 - \left(x + \frac{l}{2}\right)^2}. \qquad (2)$$

It is easy to prove that the arcs defined by equation (1) and (2) intersect at point $D\left(0,\frac{\delta}{2}\right)$ and at this point both curves have a single tangent.

The arcs defined by equations (1) and (2) may be referred to as the transition portions of the longitudinal profile of the railway line. Then point D is an inflection point. Besides, arc AD will be concave, and arc $DB -$ will be convex part of transition part. In this case, the transition part of the longitudinal profile is considered half of the entire rise.

When the lift $AB -$ is protracted, i.e. the length $l -$ is sufficiently large and the steepness determined by the value δ is relatively large, the inflection point D – can be replaced by segments $D_1D_2 -$ so that the straight line D_1D_2 is tangent to both parts of the transition part defined by equation (1) and (2).

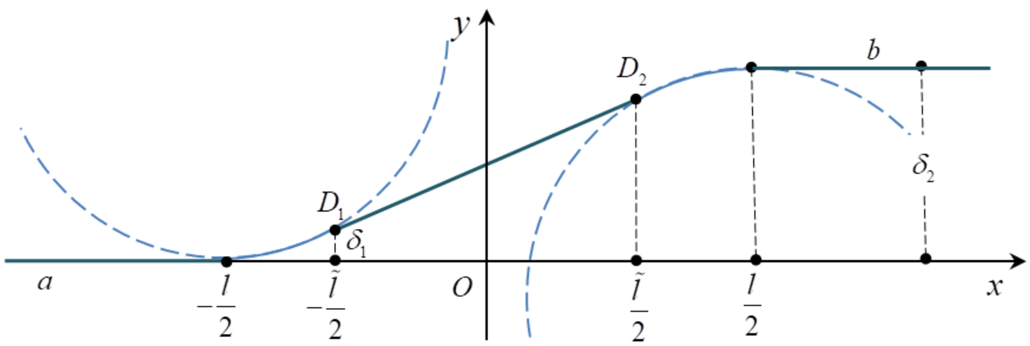

Fig. 2. Connection type with sufficiently large gap between lifts

In this case, δ_1 and δ_2 are determined by the choice of interval $\left(-\frac{l}{2},\frac{l}{2}\right)$ and the condition of parallelism to chord AD.

3. Conclusion

When the ends of the rectilinear part of the railway track plan belong to different horizontal planes, the distance between which is δ, the steepness of the road appears [11-13]. To ensure a smooth transition from a horizontal straight line to a straight line with a given steepness, the arcs of the circles defined by equation (1) and (2) can be taken as the transition part of the longitudinal profile of the railway line. When the lifting part of the road is protracted, that is, l is large enough, the inflection point can be replaced with a straight segment determined with the specifications.

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