Tension of ground pressure on the foundations of railway catenary supports

K. S. Lesov, M. M. Rasulmukhamedov, A. Kh. Mavlanov, and M. K. Kenjaliyev

Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. This paper presents the results of calculations of the values of soil pressure stresses on the base of the contact network supports by the developed program NDGFOKS in the programming language - C#. Design and construction of the foundations of the contact network supports is in accordance with the requirements of regulatory documents and technological charts. When selecting the methods of fastening the overhead contact network supports in the ground of the earth bed, experience in construction of overhead contact network supports in various engineering and geological conditions was taken into account. The methods of calculation of load-carrying capacity of the contact network bases on the ground were analyzed. Methods of fastening the overhead contact network pylons, including those on the weak ground bases, were given. The NDGFOKS program has been developed in the C# programming language in order to calculate the stresses of soil pressure on the foundation faces. The program has been developed taking into account the variety of soils, the characteristics of foundations and the methods of their driving. A block diagram and a diagram of the stresses of soil pressure on the foundations of the contact network supports at different foundations are given.

1 Introduction

An electrified railroad can be considered as a transport natural-technical system (TNTS), which consists of homogeneous elements - engineering structures. Each element of such a system performs certain functions, being in dynamic equilibrium interacting with other elements.

Maintaining the system, its subsystems and elements in a state of equilibrium is the main purpose of TNTS management in compliance with the normalized levels of environmental, economic and technical (functional) safety of the system as a whole [1].

Technical safety involves ensuring the structural reliability of the contact network supports [2].

The bases of contact network supports are designed and constructed according to the requirements of normative documents [3-6] and technological charts [7] on the types of construction and installation works.

The foundations of catenary supports ensure reliable operation of the catenary network during their service life. Three-beam steel foundations, as well as foundations of increased reliability and wedge-shaped anchors are mainly used to support the contact network of...
2 Objects and methods of research

2.1 Analysis of the methodology for calculating the load-carrying capacity of contact network pylons foundations on the ground

In order to ensure the required bearing capacity of the foundations of contact network supports in different soil conditions, standard or individual design solutions are used. If the load, the resultant force is located in one vertical plane of symmetry of the foundation, its stable attachment to the ground is considered to be secured if the values of design moment $M_d$ and design vertical force $N_d$ satisfy the conditions [3, 9, 10]:

$$ M_d \leq M_f; $$

$$ N_d \leq N_f. $$

where $M_f$ is the design load-carrying capacity of the foundation on the ground for the action of the moment or the horizontal force, applied at the height $H$; $N_f$ is the design load-carrying capacity of the foundation by the soil under the action of the vertical force.
The bearing capacity of the foundations of the contact network supports on the ground is determined in accordance with the method described in [3, 11], which is based on the experimental and theoretical studies conducted by E.P. Kryukov, K.S. Zavriev, and G.S. Shpiro [12]. The foundations of the contact network supports are calculated using the method of limiting states (Fig. 1).

**Fig. 1.**

(a) Scheme of the action of the load on the foundation,
(b) soil pressure diagram in the limiting state,
(c) the same in the elastic stage.

This calculation method is based on the envelope of soil pressure along the front and back faces of the foundation proposed by S.M. Kudrin (Fig. 1, b) [2]. This diagram reflects well the interaction of a foundation with the soil in the limiting condition corresponding to a full exhaustion of the soil resistance over the whole depth of the foundation when it is rotated [12]. To determine the internal forces in the cross-sections, the foundation's activity is considered in an elastic medium, and a parabolic envelope of soil resistance is used in the calculations (Fig. 1, c). Such an envelope is used, for example, in the German standards for the design of contact network support structures [13].

When vertical and horizontal forces act on the foundation without taking into account the ground friction on its lateral faces, tensions $\sigma_y$ of ground pressure on the front face of the foundation (at the section from $y = 0$ to $y = 0$) and on the back face of the foundation (at the section from $y = y_0$ to $y = d$) arise in the ground, the size of which in each point of these faces is directly proportional to the depth $y$ of location of this point from the design ground surface [3, 14-17]:

$$\sigma_y = \frac{R_g y}{b_f}$$

where $R_g$ is the proportionality factor that represents the design resistance of soil at the depth $y=1$ under the conditions of the spatial problem (at the foundation width equal to $b_f$); $b_f$ is the size of the foundation's cross-section in the direction perpendicular to the plane of the load.
\[ R_g = k_g R_u (b_f + C_f) \]

where \( R_u \) is the proportionality factor (kN/m\(^3\)) representing the ultimate (normative) resistance of soil at the depth \( y = 1 \) under the flat problem (with the foundation width equal to \( b_f \)); \( C_f \) is a ground characteristic, \( m \), that takes into account the spatial work of the foundation.

When designing, in order to determine the value of the carrying capacity of a given foundation, the conditional foundation is calculated, and then the obtained value is multiplied by the working conditions factors that take into account the actual factors that affect the carrying capacity of the given foundation in the soil [18–21].

A prismatic foundation of rectangular cross-section (Fig. 2), installed on a horizontal site in the absence of a railroad track in the immediate vicinity, is considered as a conditional foundation.

Fig. 2. Calculation diagram of a notional prismatic foundation.

2.2 Methods for securing the catenary supports

The supports can be fixed in the earth bed on sections of stable earth bed made of strong bulk soils and located on a solid base mainly with the use of shallow foundations. In this case, foundations can have a different design and be made of concrete, reinforced concrete, metal. The design of foundations is determined on the basis of technical and economic calculations and available experience in the construction of contact network supports [22, 23].

The depth of the foundations or the foundation part of the undivided supports shall be determined by calculation. In this case, the calculation must ensure that [24, 25]:

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3 Results and their discussion

3.1 Calculation of soil pressure stress on the foundation face
The results of calculating the soil pressure stress on the foundation faces using the NDGFOKS program are shown in Table 1. The stress diagram of the soil pressure on the foundations of the catenary supports for various foundations is shown in Figure 4.

Table 1. Tension of ground pressure on the foundations of the overhead system pylons

<table>
<thead>
<tr>
<th>Form of foundation cross-section, depth of embedding, m</th>
<th>Soils, varieties</th>
<th>Tension of the soil pressure on the foundation, kN/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-beam, d = 4.5</td>
<td>Coarse and medium sands</td>
<td>671.37</td>
</tr>
<tr>
<td></td>
<td>Fine sands</td>
<td>478.85</td>
</tr>
<tr>
<td></td>
<td>Dusty sands</td>
<td>346.03</td>
</tr>
<tr>
<td></td>
<td>Sandy</td>
<td>204.51</td>
</tr>
<tr>
<td>Three-beam, d = 4.0</td>
<td>Coarse and medium sands</td>
<td>596.78</td>
</tr>
<tr>
<td></td>
<td>Fine sands</td>
<td>425.64</td>
</tr>
<tr>
<td></td>
<td>Dusty sands</td>
<td>307.58</td>
</tr>
<tr>
<td></td>
<td>Sandy</td>
<td>181.79</td>
</tr>
<tr>
<td>Three-beam, d = 3.5</td>
<td>Coarse and medium sands</td>
<td>522.18</td>
</tr>
<tr>
<td></td>
<td>Fine sands</td>
<td>372.44</td>
</tr>
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<td></td>
<td>Dusty sands</td>
<td>269.13</td>
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<td></td>
<td>Sandy</td>
<td>159.07</td>
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<tr>
<td>Rectangular, d = 7.5</td>
<td>Coarse and medium sands</td>
<td>1118.96</td>
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<tr>
<td></td>
<td>Fine sands</td>
<td>798.08</td>
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<tr>
<td></td>
<td>Dusty sands</td>
<td>576.72</td>
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<td></td>
<td>Sandy</td>
<td>340.86</td>
</tr>
</tbody>
</table>
4 Conclusions

For normal operation of the contact network, the ground pressure stresses on the foundation faces must guarantee its stable anchoring in the ground and ensure the bearing capacity of the foundations of the contact network supports of railroads.

The methodology for calculating the load-carrying capacity of the foundations of the contact network supports on the ground is based on the ground pressure diagram at the front and rear faces of the foundation. When vertical and horizontal forces act on the foundations without taking into account the friction of soil on their side faces, the soil stresses $\sigma_u$ of soil pressure on the front face of the foundation and on the back face of the foundation occur in the soil.

When designing to determine the bearing capacity of a given foundation, a conditional foundation installed on a horizontal site in the absence of a railroad track in the immediate vicinity is calculated. In order to ensure the bearing capacity of the supports depending on the existing loads, the method of fixing the contact network supports through the use of pile foundations of 6 to 10 m in length has been considered.

NDGFOKS program has been developed in C# programming language and a block diagram for calculating the soil pressure on the foundation faces of the contact network supports.
References


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