

# Justification of the possibility of laying cable communication lines at the side of roads

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**Abstract.** One of the ways to improve road safety is to equip motor roads with automated traffic control systems. Such systems allow recording violations of traffic rules, responding to emergencies on the roads, providing automation of fare collection systems and driver information services, etc. To ensure the operation of automated traffic control systems, it is necessary to construct long cable communication lines. The best place for laying them can be the side of the road, however, at present in Russia there is not enough experience in construction that confirms the safety of such a solution. The authors present the results of research devoted to assessing the feasibility and safety of laying cable communication lines at the side of roads using micro-trenches.

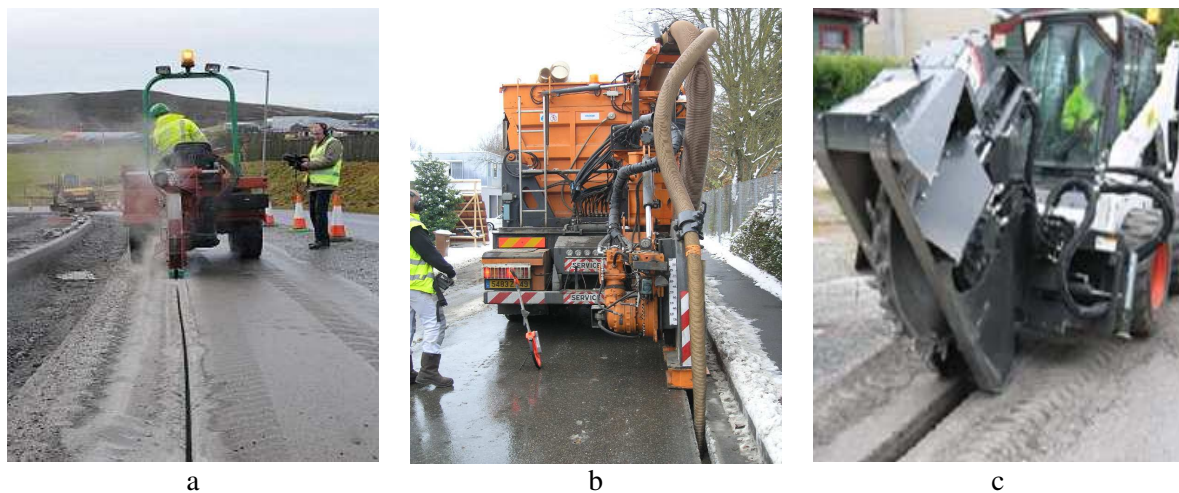
## 1. Introduction

Ensuring road safety is a vital social-economic and demographic task in many countries, including the Russian Federation. It is possible to improve road safety by equipping most motor roads with automated traffic control systems (ATCS). Such systems consist of various subsystems, which are controlled from a single traffic control center [1]. ATCS subsystems allow continuous video monitoring of the traffic situation, in order to record and promptly respond to traffic violations and other emergencies that occur on the roads; allow informing drivers about road conditions; solving commercial problems, such as automating the fare collection system and managing advertising information.

To ensure the operation of ATCS along motor roads, the construction of long cable communication lines is required. Current regulatory requirements specify that communication cables should be laid on the right-of-way. In this regard technical difficulties arise, as well as problems with the allotment and occupation of land property, even for temporary use, and problems in subsequent operation. The most effective solution is to lay cable communication lines (CCL) at the side of the road, as it has got the following advantages: reducing the time and cost of design, construction and operation; year-round and round-the-clock availability for operation and maintenance; minimum terms for carrying out repair and reconstruction work; facilitating the procedure for approval and land allocation; increasing the reliability of work due to the relative evenness of the right-of-way centerline; practically no intersections with other communications; reduction of damage arising from excavation work and the impact of rodents. At the same time there is not enough experience in the Russian Federation that confirms the safety of such a solution. In this regard the authors, basing on the analysis of world experience in laying CCL at motor roads and on applied numerical simulation, have evaluated the possibility and safety of laying cable communication lines at the side of the road.

## 2. Materials and methods

The analysis of world experience of constructing CCL at motor roads [2-8] has proved that to lay them micro-trenches (width = 4 ÷ 8, depth = 20 ÷ 30 cm), mini-trenches (width = 8 ÷ 20, depth = 30 ÷ 60 cm) and macro-trenches (width = 20 ÷ 30 cm, depth = up to 100 cm) are used. Within the earth roadbed the communication lines are located at the traffic way or at the side of the road, inside asphalt-concrete coating (micro- and mini-trenches) and inside earth layers (mini- and macro-trenches) (see figure 1). As a rule backfilling (filling) of trenches for laying cable communication lines is performed using materials with properties similar to design data.



**Figure 1.** Types of trenches used when constructing cable communication lines at motor roads [5]: a. Micro-trenches; b. Mini-trenches; c. Macro-trenches.

To assess the impact of laying CCL using mini-trench technologies at the side of the motor road, verification calculations of sections of motor roads have been made along the traffic way adjacent to the side of the road where it is planned to lay cable communication lines (see figure 2). The calculations have been made by means of modeling the stress-strain state of the motor road's roadbed, the change of which may occur as a result of laying cable communication lines and may cause deterioration in the road's operational and traffic-operational characteristics.

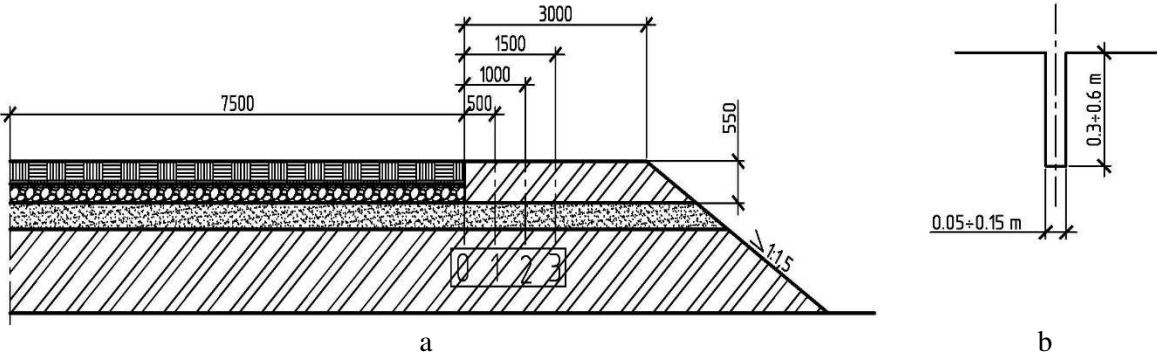
The stress-strain state has been modelled for three design cases.

Design case № 1: Existing operational conditions before laying CCL. The width of the traffic way, the structure of the road pavement and of the side of the road, as well as the physical and mechanical properties of their layers are accepted according to the engineering surveys for the public motor road of federal significance M-5 "Ural" km 1034 – the city of Togliatti. The temporary traffic load is taken according to "GOST 32960-2014. Motor Roads for Public Use. Design Loads, Design Load Distribution". In the calculations stability is 49.3 kN/m<sup>2</sup>, and in the calculations for deformations it is 12.4 kN/m<sup>2</sup>.

Design case № 2: Construction period, at the moment of building the trench up to design parameters. The difference between design cases № 2 and №1 is the presence of an open trench at the side of the road, and the decrease in temporary traffic load to the values typical for the construction period - 24 kN/m<sup>2</sup>. During calculations various parameters of the trench have been modeled: according to depth (from 0.3 m to 0.6 m, with a step of 0.15 m), according to width (from 0.05 m to 0.15 m, with a step of 0.05 m), as well as according to the planned position relative to asphalt-concrete coating edge (from zero to 1.5 m, with a step of 0.5 m).

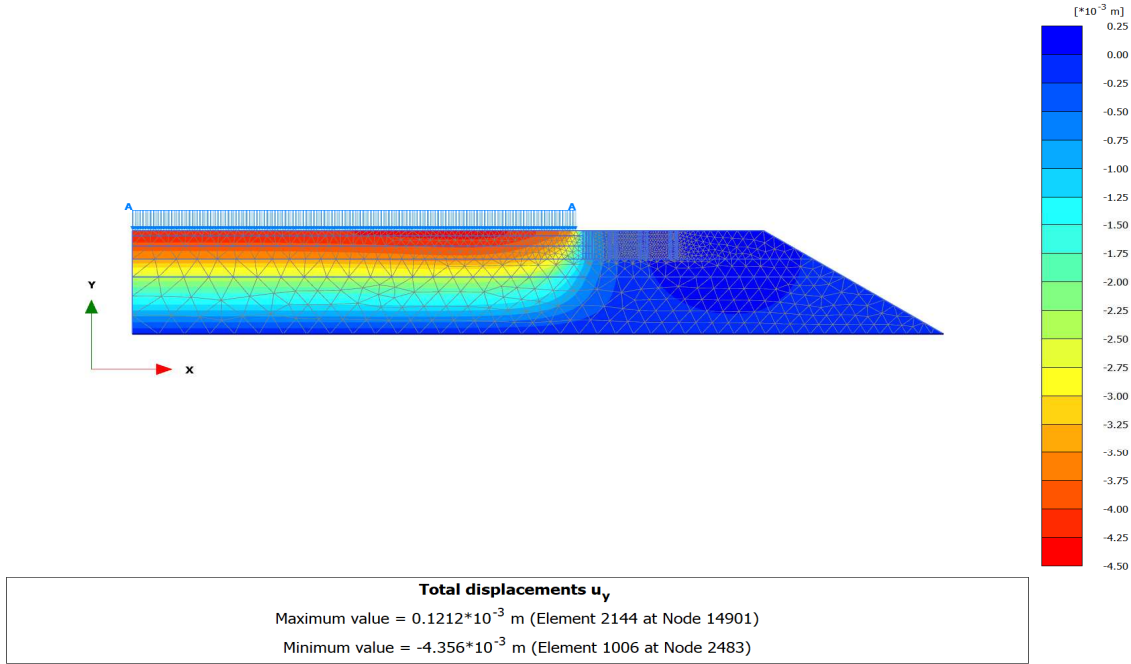
Design case № 3: Operational period. At this stage the stress-strain state of the road is assessed, taking into account the building and subsequent backfilling of the trench located at its side, as well as the presence of a package of micro-pipes at the bottom of the trench. The assessment has been carried

out for the parameters of the trench described in design case № 2, taking into account its filling with excavated soil, and the temporary traffic load is taken as similar to design case № 1. The parameters of the micro-pipe package are as follows: width = 160 mm, height = 17.7 mm, shell thickness = 0.85 mm, weight = 975 kg / km, tension load when laying it = over 9200 N.

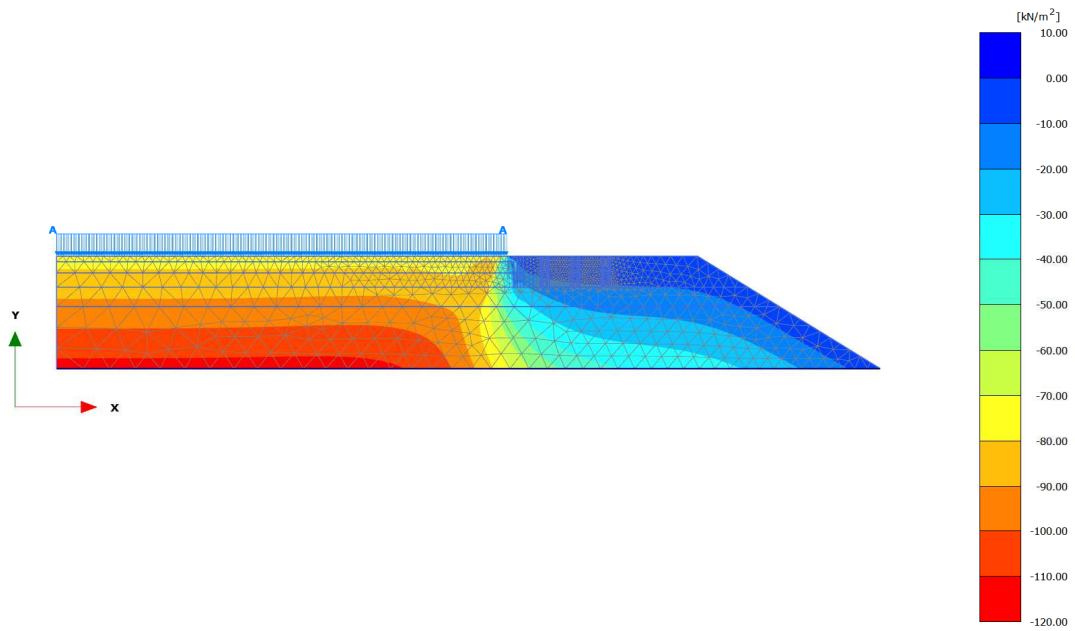


**Figure 2.** Geometric diagram of the design structure: a - geometric diagram of the earth roadbed; 0-3 accepted options for the location of the trench, b - geometric diagram of the accepted trench options.

The calculations have been made using Plaxis 2016 2D software package, which allows performing an advanced calculation of the stress-strain state and the stability of geotechnical objects used for various purposes, applying finite element method in a 2D problem. Design models are made of 2D elements. The calculation has been made by setting the stages of the CCL life cycle, in order to obtain the most accurate result. Each stage is a separate nonlinear analysis with iterative method for solving the stiffness matrix. The first stage is necessary to obtain the initial stress values in the original earth body and in the road pavement, which have developed over years. At this stage there is no movement of the model joints. At the following stages the values of deformations in the joints and of stress in the elements are recalculated. So, within the framework of the calculations 37 design models have been considered, examples of the graphical presentation of the calculation results are shown in Figures 3-5.

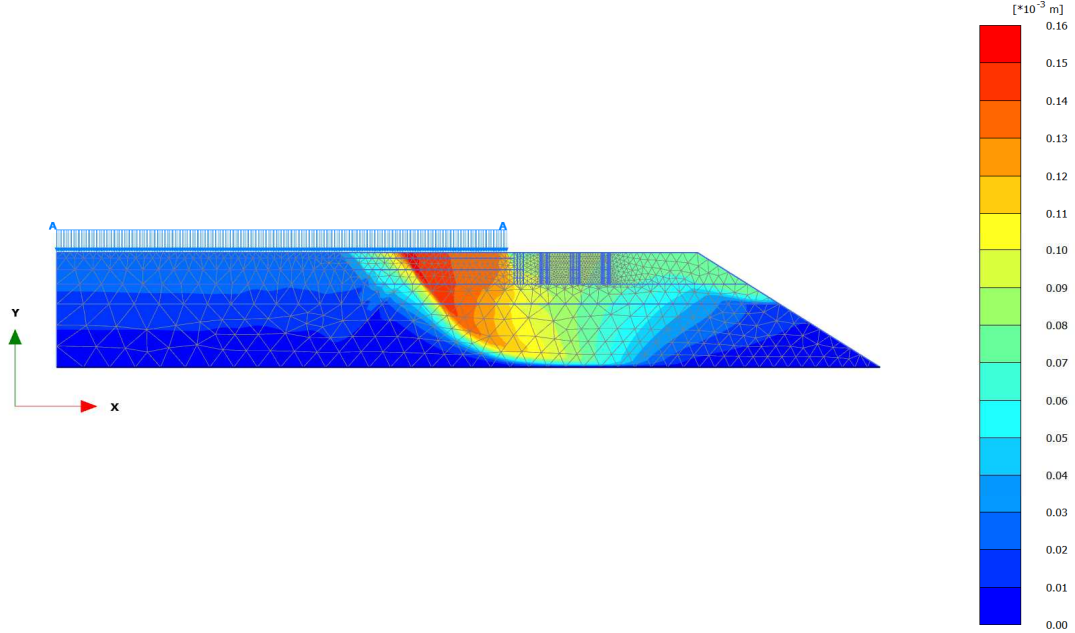


**Figure 3.** Defining placement.



**Cartesian total stress  $\sigma_{yy}$**   
 Maximum value = 1.909 kN/m<sup>2</sup> (Element 976 at Node 4282)  
 Minimum value = -113.9 kN/m<sup>2</sup> (Element 57 at Node 2256)

**Figure 4.** Determining stress values



**Incremental displacements  $|\Delta u|$**   
 Maximum value = 0.1531\*10<sup>-3</sup> m (Element 1004 at Node 2516)

**Figure 5.** Determining stability factor (further –  $F_{stab}$ ).

### 3. Results

The results of verification calculations have been assessed for compliance with "GOST R 50597-2017. Motor Roads and Streets. The Requirements to the Level of Maintenance Satisfied the Traffic Safety. Methods of Testing.", namely: the traffic ways next to the side of the road should not have any defects in the form of an S-wave more than 3.0 cm deep, and in the form of a track - more than 2.0 cm deep; the side of the road in which the CL is laid should not have any defects in the form of the height of the side of the road reduced by more than 4.0 cm; loss of stability of the motor road is evaluated by determining the stability factor, thus, the slope or its morphological element is considered stable if its stability factor is more than one ( $F_{stab} > 1$ ).

Basing on the verification calculations results, the following conclusions have been made:

- the deformation values of the soils in the body of the motor road and in the layers of the road pavement for the initial design case (Design case № 1) are 4.36 mm, during the period of maintenance (Design case № 2) they are between 1.3 and 1.4 mm (except for the case of trench location at the edge of the traffic way, when the walls of the trench collapse), and during the operation of CCL (Design case № 3) they are between 4.3 and 4.4 mm, which is similar to the indicators for the initial design case (Design case № 1).

- the stress values of the soils in the body of the motor road and in the layers of the road pavement for the initial design case (Design case № 1) are 113.9 kN/m<sup>2</sup>, during the period of maintenance (Design case № 2) they are 62.0 ÷ 78.0 kN/m<sup>2</sup> (except for the case of the trench location at the edge of the traffic way, when the walls of the trench collapse), and during the operation of CCL (Design case № 3) they are between 113.0 ÷ 114.0 kN/m<sup>2</sup>, which is similar to the indicators for the initial design case (Design case № 1);

- when the trench is located at the edge of asphalt concrete coating (the location of the trench is "0") at the depth of 300 mm or more, the stability of the soils in the body of the motor road and in the layers of the road pavement cannot be ensured ( $F_{stab} < 1$ );

- the stability factor values of the soils in the body of the motor road and in the layers of the road pavement for the initial design case (Design case № 1) are  $F_{stab} = 1.805$ , during the period of maintenance (Design case № 2) they are between  $F_{stab} = 1.1 ÷ 3.2$  (except for the case of traffic load application at the edge of the trench, when its walls collapse), and during the operation of communication cables (Design case № 3) they are between  $F_{stab} = 1.5 ÷ 1.9$ , which is similar to the indicators of the initial design case (Design case № 1). The difference of the calculation results for Design case № 2 from the other cases is largely due to the fact that during maintenance period the traffic load from vehicles on the traffic way adjacent to the side of the road was accepted as lower than during operation period.

### 4. Conclusions

The performed analysis of the international experience of constructing CCL at motor roads and the verification calculations of motor roads' sections along the traffic way adjacent to the side of the road, as well as of the side of the road where it is planned to lay the communication cables, have shown that it's possible to build up a safe trench, if the trench is reconstructed with materials identical in characteristics, but not worse in quality than those used when constructing the motor road. In general it can be concluded that laying the cables at the side of the road does not affect the stress-strain state of the road, however it is recommended to apply traffic load at a certain distance from the edge of the mini-trench, which is justified by a calculation in each specific case, based on the design features of the motor road. Also proceeding from the condition that the drainage of the pavement should be maintained, the micro-pipes should be laid above the drainage layers (not deeper than 0.4 - 0.5 m), and in case there is a separating layer of geotextile the depth of location should be over it.

## References

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