DESIGN OF HIGH-SPEED COMBINED MOTOR ROADS AND RAILWAYS

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ABSTRACT

The article considers the problems of construction of high-speed combined motor roads and railways in Russia. The design of these objects requires special attention, since the object itself is a complex transport system, each element of which requires increased operational reliability. Therefore when designing combined roads a full accounting of natural and man-made impacts on engineering structures is required. On the basis of the studies, recommendations are given on the methodology of design works and geological surveys, the question is raised about the need to update the accompanying legal framework.

Keywords: high-speed combined roads, engineering and geological surveys, design, construction, highway, railway, transport system.

Background. *Speed and high-speed railways and motor roads are among the progressive trends in the field of transport construction. The speed of movement of rolling stock on high-speed railways should be 200–400 km/h, on motor roads – more than 150 km/h.*

In recent years, the experience has been obtained in construction of combined motor roads and railways. In order to improve the infrastructure in some cases, economically and technically, the combination of those types of roads is more appropriate than their separate existence. For example, the speed combined motor road and railway Adler–«Alpika-Service» (Krasnaya Polyana settlement) was the main transport artery of the 2014 Olympics. The designers took into account the peculiarities of the natural landscape and laid the railway and motor road in parallel. The carrying capacity of the rail line is 6 pairs of trains per hour with a speed of 160 km/h. The carrying capacity of the motor road is 11 000 buses/day with a speed of up to 100 km/h.

It is planned to combine the high-speed railway Moscow–Kazan with the toll highway M7. The federal M7 road is Moscow–Vladimir–Nizhny Novgorod–Kazan–Ufa highway. Its length is 1351 km. The management of JSC High-Speed Railways considers it expedient to combine these roads.

Objective. *The objective of the authors is to consider and generalize under certain aspects approaches to design of high-speed combined motor roads and railways.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, scientific description.*

Results.

The combined motor road and railway (speed or high-speed) is a complex transport system. Failure to take into account the conditions of one of its components in the design of a structure can lead to a disruption in operability of the entire system. Therefore, it is important to study the degree of influence of natural and technogenic impact on the behavior of structures [3, 4, 7]. To this end, it is necessary, as a minimum, to do the following:

– to assess the zone of dangerous geological processes for a motor road and a railway;

– to identify the vulnerabilities of man-made impact;

– to identify areas of typical and individual design of a motor road;

– to identify areas of group solutions and individual design of the railway;

– to identify the locations of the monitoring system for the dynamics of development of both natural and man-made processes.

The composition and volume of engineering surveys should be assigned taking into account the existing regulatory documents for motor roads and railways. However, scientific research in this direction and practical experience in the construction of combined roads (speed and high-speed) can make appropriate adjustments.

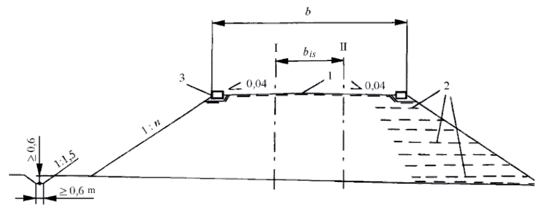
The research carried out by JSC VNIIZhT makes it possible to give certain recommendations. When performing engineering and geological survey of railways under uncomplicated conditions and medium complexity, the depth of excavations (wells) should be assigned not less than 4 m below the estimated freezing depth of the roadbed. Ground base under the embankment must be traversed by excavations to a depth of at least 6 m. On each diameter the wells should be assigned to the axis of the tracks and in the middle part of the slopes.

To increase the accuracy and informative nature of the surveys, it is necessary to use georadar sounding (for example, «Loza» geoporadar) and electrocontact dynamic sounding

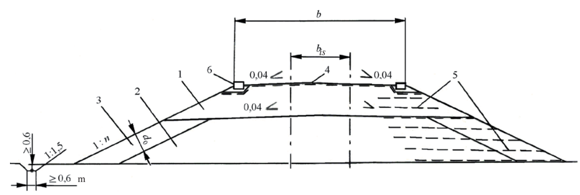
The type and construction of the roadbed of high-speed railways and motor roads is designated in the feasibility study of their routes on the basis of the analysis of the state of objects under similar conditions, the study of geomorphological and climatic conditions, landscape characteristics of the terrain, natural processes and phenomena and other parameters. These indicators are specified in the design process after the engineering survey. When designing, it is necessary to ensure the load-bearing capacity of soils and the stability of the roadbed of railways, taking into account the vibrodynamic effect of trains, and roads – taking into account the dynamic impact from motor transport [5].

The roadbed should preserve the stability of the railway upper structure and the efficiency of the road pavement of the motor road in order to realize the specified volume of traffic with the estimated speed of traffic with minimum discounted amounts of construction and operating costs, maximum preservation of valuable land and least damage to the natural environment. At the same time, it is necessary to take into account the difficult conditions of operation of the railway and the individual characteristics of the motor road users.

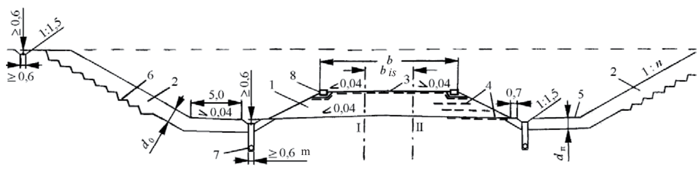
The main technical characteristics of the highway when combining the roads should be taken approximately as follow: the number of lanes – not less than 4; the lane width – 3,75 m; separating strip – 6 m; intersections at different levels; design speed – not less than 150 km/h; the load on the most loaded axle –11,5 tf; the traffic intensity – more than 7000 cars/day.



Pic. 1. Transverse section of the embankment from draining soils on a solid base: 1 – non-woven material and geogrid from basalt fiber on the main site; 2 – geogrid from basalt fiber in the embankment; 3 – cable tray.



Pic. 2. Transverse section of the embankment from clay soils on a solid base: 1 – protective layer; 2 – clay soils; 3 – draining soil in the slope; 4 – non-woven material and geogrid from basalt fiber on the main site; 5 – geogrid from basalt fiber in the embankment; 6 – cable tray.



Pic. 3. Transverse section of the excavation, which is more than 4 m deep, in clay soils on a solid base: 1 – protective layer; 2 – draining soils; 3 – non-woven material and geogrid from basalt fiber on the main site; 4 – geogrid from basalt fiber in the protective layer; 5 – back slope; 6 – ledges in the clayey soil of the slope; 7 – back slope drainage; 8 – cable tray.

Requirements for the composition and condition of soils are the same as those given in SP 34.13330.2012 «Motor roads» [7]. Coefficient of soil compaction in the working layer of the roadbed should be taken as 1–0,98. The same requirements as in SP 34.13330.2012, remain for drainage facilities. It may be advisable to provide common culverts for groundwater abstraction for motor roads and railways using a specially developed method.

Cases of model and individual design of motor roads should be taken from SP 34.13330.2012. The design methods can be used, in addition, from GOST 33149–2014 «Motor roads of general use. Rules for designing motor roads in difficult conditions» [1]. In addition to them, it is worth taking into account the latest scientific developments on the evaluation of the active compression zone, the introduction of evaluation criteria for the beginning of soil compression at the base and filtration of pore water.

The cases of using group solutions in the design of railways under difficult conditions and the design methodology can be taken from SP 119.13330.2012 «Railways of 1520 mm gauge» [8]. In addition to them, the conclusions of VNIIZhT specialists should be taken into account for the purpose of the construction of the roadbed, the requirements for soil and materials, the construction of a protective layer, the effectiveness of which has been confirmed by domestic and foreign experience. The main ones are as follows.

When designing a roadbed of high-speed rail lines, the calculation should take the load from the rolling stock equal to 294 kN (30 tf) per axle of a four-axle freight car.

At a height of embankments of more than 9 m and embankments in bogs with a depth of more than 7 m, a bridge overpass should be provided in place of a embankment, and in place of excavations with a depth of more than 9 m – the construction of tunnels.

Embankment filling in bogs up to 7 m deep, as well as on a moist and wet basis, established by the degree of moistening, should be designed from draining soils with the substitution of soils in the base for these soils.

The draining soils, according to the work conditions of the roadbed, should include unconnected soils having a filtration coefficient of at least 3,0 m / day and a content in the granulometric composition of not more than 10 % of particles smaller than 0,1 mm at a maximum density according to standard compaction.

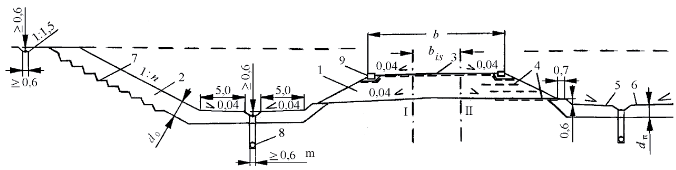
Embankments up to 9 m in height and excavations up to 9 m in depth should be designed according to group solutions.

The width of the subgrade at the top (the main site) should be equal to b = 15,5 m, the width of the intertrack space – b_{is} = 5,5 m. The surface of the main site should be given a bi-directional inclination of 0,04 from the middle of the intertrack space towards the pads of the roadbed.

The steepness of the embankment slopes should be taken from 1:1,5 to 1:2, depending on the type and condition of the soils.

In the upper part of the roadbed of all types of clayey soils, as well as in zero places and in excavations composed of small and silty sands, easily eroded and eroded rocky grounds, it is necessary to provide for the arrangement of a protective layer. This layer is arranged 0,5 m below the maximum predicted depth of freezing-thawing with a thickness of at least 2,5 m.

In the protective layer draining soils should be used. When using sands in the upper part of the protective layer (on the main site) and on its slopes, with the exception of their lower part, a height of 0,8 m, the strengthening of these sands is assigned. The steepness of the slopes is taken equal to 1:2. It should be noted that clay soils under the protective layer in the excavations, at zero places and embankments are also subject to strengthening. For this purpose, the composition of the mixture was developed and experimentally tested [2]. The reinforced layers should contain a mixture of 70 % medium sand and 30 % clay



Pic. 4. Transverse section of the excavation, which is up to 4 m deep, in clay soils when it is being developed under the embankment: 1 – protective layer; 2 – draining soils; 3 – non-woven material and geogrid from basalt fiber on the main site; 4 – geogrid from basalt fiber in the protective layer; 5 – pre-drain slope; 6 – back slope; 7 – ledges in the clayey soil of the slope; 8 – sub-drainage; 9 – cable tray.

loam, characterized by moisture at the yield point w_L = *0,28. This mixture in a 0,4 m thick layer is strengthened with liquid and powder additives of polyfilizators, respectively, in an amount of 1,4 l/m*^{3} *and 60 kg/m*^{3}*. The surface of the reinforced soil under each track should be given an inclination of 0,04 to the field side.*

On the main site, a covering of non-woven material with a mass of not less than 500 g/m^2 *should be laid on top of a geogrid of basaltic fiber with a mass of not less than 1000 g/m*^{2}*.*

In the protective layer of the embankment, along the entire length geogrid is laid from the basalt fiber with the indicated mass after 1 m of their height (Pic. 1, 2).

Excavations of more than 4 m in depth in clayey soils, loess, coarse clastic soils with clay aggregate, fine and silty sands are recommended to be designed with back slopes 6 m wide (Pic. 3).

Zero sites and excavations with a depth of up to 4 m in clay soils should be developed under the embankment (Pic. 4).

In the sloping parts of the embankment from clay soils, it is necessary to envisage the arrangement of a layer of draining soils (Pic. 4). The thickness of the layer of these soils should be $d_o = 0{,}6\,Z^{rd}_{fr-th}$*, where* Z^{rd}_{fr-th} *is the calculated depth of freezing-thawing of the roadbed folded by draining soil (along the track axis).*

In the sloping sections of excavations composed of clayey soils and sands, a layer of draining soils of thickness $d_o = 0{,}6\,Z^{rd}_{fr-th}$ *is envisaged (see Pic. 3, 4). To ensure the performance of the roadbed, it is necessary to consolidate the soils layer by layer until the compaction factor is 1,03.*

Conclusion. *All the above proposals concerning the design features of combined motor roads and railways (speed and high-speed ones) should undoubtedly be taken into account when creating the relevant regulatory documents. Numerous reports by scientists, specialists, leading designers, heads of federal territorial roads mention the lack of such documents.*

In creating a regulatory framework for the design and construction of high-speed roads, Russia has lagged behind many countries. That's why we need a qualitative leap in this direction. It is required to find the best way to incorporate the proposed recommendations into the technical conditions and codes of rules, which are currently being developed by JSC High-Speed Railways and National Association of Designers. At the same time, it is necessary, without delay, to organize a professional discussion of the issues raised, including with involvement of independent experts.

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