**Strengthening of Railroad Track Bed Slopes During   
High-Speed Train Traffic**

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**Abstract.** With high-speed train traffic and seismicity of the railway location, strengthening the slopes of the roadbed provides its static and dynamic rigidity by reducing the relative humidity of the soil. The choice of the most rational and justified design-technological and organizational solutions does not mean the real achievement of the efficiency that is potentially embedded in these solutions. The proposed design for strengthening the slopes of the roadbed of railways ensures its stability and sustainability.

**Key words:** ballast prism, subgrade, high-speed train traffic, subgrade reinforcement, piles and reinforced concrete retaining walls, seismic forces

**INTRODUCTION**

High-speed railways are a complex technical complex, including both technical elements, such as infrastructure, rolling stock and control systems, and technological methods, in particular, the organization of operation, maintenance of systems and devices, as well as components that allow solving financial, commercial, environmental, social and management problems, taking into account the human factor. High-speed rail transport is a system of various elements, each of which is the highest achievement in its field of engineering and technology. [1, 2, 3, 4, 5, 6, 7].

High-speed rail transportation offers important benefits to consumers and society: safety, high carrying capacity, and environmental friendliness . It is a tool for political integration, provides connections between regions, stimulates the modernization of other types of transport, and significantly increases people's mobility.

Global experience in organizing high-speed rail service demonstrates an improvement in the quality and comfort of life of the population, contributes to an increase in the general and labor mobility of passengers, and also ensures high territorial connectivity of regions and their subsequent development in areas of high-speed highways, which has a beneficial effect on the socio-economic state of the country as a whole - a multiplier effect [8].

**RESULTS AND EXAMINATION**

Currently, the general task of JSC Uzbekistan Railways is to ensure safe passage trains at established speeds. At the same time, the movement trains is planned to be extended to the city of Urgench. For this purpose, a new railway line Bukhoro-Misken was built and put into operation. To ensure achieve the set goal, that ensure the safety of high-speed train traffic, an analysis of the joint operation of the existing roadbed and the superstructure, as well as the track, is carried out; if necessary, this is achieved by strengthening the railway structures.

The design, construction and operation of railway lines in desert areas consisting of sand dunes is a very complex task, and the absence of coarse and medium-grained sands in the specified territory, as well as quality material in the form of rocky soils for the railway construction and ballast layer, further complicates the implementation of this task, and the transportation of these materials from other places leads to a significant improvement in the estimated construction price. To solve these similar problems in the design and construction of railway lines erected in desert conditions, it is necessary to determine the factors security of the ballast layer, eliminate them, and develop design and technological solutions that ensure stable and reliable operation of the railway track.

The practice of operating high-speed rolling stock has put forward a number of unresolved problems for operators and has sharply complicated their work. Due to the fact that the railway workers of Uzbekistan are planning to increase the network of roads with high-speed traffic and exceed the speeds already achieved in the practice of operation, this will be possible only with a targeted, comprehensive scientific approach to solving this problem [7].

To ensure seismic resistance of the roadbed of railways, it is necessary to choose the route of the road correctly, i.e. seismically advantageous, since the estimated seismicity of the route sections depends on the conditions of its laying. Estimated seismicity within one seismicity zone, as is known, depends on the geological, hydrological and relief conditions of the area. Therefore, it is very important to have at least approximate data on the parameters that affect the initial seismicity of the area where the road passes [1, 7] .

Analyzing foreign documents regarding the design of the roadbed of the high-speed railway, it can be stated that they all provide for the possibility of the occurrence of residual deformations of the roadbed during operation and contain standards limiting their values.

The maximum settlement is 15 mm. The settlement of the roadbed with a ballast track at speeds of 300–350 km/h is no more than 50 mm, the settlement rate is no more than 20 mm/year.

In particular, when using ballastless track superstructure structures, the maximum value of residual deformation of the main platform is assigned based on two conditions: the possibility of adjusting the fastenings (or using another technical method); the possibility of creating a vertical curve, the parameters of which are determined by the speed of the train. Thus, residual deformations are also allowed in these standards.

The magnitude of residual deformations in the foundation or in the earth structure depends mainly on the stress state of the soil. The stress in dense rocky soils is many times greater than the stress in loose soils at the same earthquake intensity, which occurs due to the high strength of rocky soils.

Residual deformations are not the same in loose and cohesive soils, since according to the principles of soil mechanics, the ultimate equilibrium is expressed for cohesive and sandy soils, respectively, by the formula:

(2)

where - – tangential and normal components of the total stress of the soil mass; – the reduced values of normal stresses, or:

(2)

Here:

(3)

C – clutch.

It follows that the stability of an earth structure and the deformability of the foundation depend significantly on the angle of internal friction of the soil. The appearance of large residual deformations in waterlogged soils is also explained by the formula of relative deformations:

Subsidence soils, in particular loess, have a structure due to which capillary phenomena, deformations and filtrations develop equally, which leads to a change in the terrain due to subsidence of large areas.

Currently, most of the scientific works related to the roadbed are aimed at strengthening the main platform of the roadbed or at leveling and reducing stresses on the general platform of the roadbed by laying geomaterials on the main platform or in the ballast prism, respectively [1, 2].

All anti-deformation structures must be inspected, repaired, restored or replaced in accordance with the project. If they are no longer needed, they are mothballed according to special projects. In conditions of increased freight traffic and rolling stock loads on the rails and increased train speeds, the intensity of track breakdowns increases, which has an adverse effect on the carrying capacity of railways.

The following design for strengthening the roadbed on a hillside section of the road route is proposed (Fig. 1). The roadbed is additionally compacted with reinforced concrete piles onto the foundation, where triangular grooves up to 30 cm deep are arranged, which provide a connection between the embankment and the foundation. Soil piles are formed around the driven piles, which also increase the stability of the roadbed from sliding along the plane of the slope.

The distances between piles that have spherical lateral planes, which gives an increase in the pile reinforcement zone by 30 % due to the increasing pile influence zone and the increase in the pile adhesion surfaces to the soil, are equal to:

|  |  |
| --- | --- |
|  |  |

**FIGURE 1.** Scheme of pile reinforcement of the embankment of the roadbed:   
a) stress diagrams in the section of the roadbed and the location of the pile; b) the location of the reinforced concrete piles in the plan. σ z – stress from high-speed movement of rolling stock; 1 – ballast prism; 2 – roadbed; 3 – roadbed base; 4 – zone of greatest stress in the roadbed; 5 – reinforced concrete piles for strengthening the roadbed; 6 – reinforced concrete sleepers

; (4)

where b is the width of the roadbed, m; – a coefficient taking into account the speed of trains; – for speed 40 km/h; – for speed 60 km/h; –for speed 80 km/h; – for speed 120 km/h; – for speed 160 km/h; H – height of lifting, m; – a dynamic coefficient that takes into account the properties of soils. – for dune sands = 40; – for clay soils = 20; – for gravelly soils = 10. h – pile length, m; – seismic coefficient [3].

**TABLE 1.** Distances between piles depending on the height of the embankment and the speed of trains

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Subgrade width | Coefficient taking into account the speed of trains | B height of embankment | Dynamic coefficient taking into account soil properties | Length of piles | Seismic coefficient | Distances between piles |
| 1 | 7.6 | 0.7 | 2 | 20 | 5 | 1 | 25.82 |
| 2 | 7.6 | 0.8 | 2 | 20 | 5 | 1 | 29.32 |
| 3 | 7.6 | 0.9 | 2 | 20 | 5 | 1 | 32.8 |
| 4 | 7.6 | 1.0 | 2 | 20 | 5 | 1 | 36.2 |
| 5 | 7.6 | 0.7 | 5 | 20 | 5 | 1 | 11.5 |
| 6 | 7.6 | 0.8 | 5 | 20 | 5 | 1 | 12.8 |
| 7 | 7.6 | 0.9 | 5 | 20 | 5 | 1 | 14.2 |
| 8 | 7.6 | 1.0 | 5 | 20 | 5 | 1 | 15.5 |
| 9 | 7.6 | 0.7 | 10 | 20 | 5 | 1 | 6.6 |
| 10 | 7.6 | 0.8 | 10 | 20 | 5 | 1 | 7.3 |
| 11 | 7.6 | 0.9 | 10 | 20 | 5 | 1 | 8.0 |
| 12 | 7.6 | 1.0 | 10 | 20 | 5 | 1 | 8.7 |

This table allows us to conclude that if the height of the embankment increases, then the distance between the piles decreases and if the height of the embankment decreases, then the distance between the piles increases.

The technology of constructing an earthwork in desert areas consists of preparing the embankment base by cutting triangular-section ditches 20÷30 cm deep, then a gravel or crushed stone cushion of 10÷15 cm layers is poured onto the base. It is advisable to drive the main piles at an angle, which is more effective and allows increasing the distance between them. Then the earthwork is poured to the design mark.

The compacted soil zone along the road reaches up to 1.5 m in length. If the calculation formula shows that the distance between piles is less than 2 m, then retaining walls should be designed and an economic comparison of options should be made.

The steepness of the slopes of the cuttings for high-speed highways, taking into account seismicity, is recommended to be calculated using the formula obtained experimentally:

(5)

where: L is the length of the active soil zone; h is the excavation depth; Kc is the calculated seismicity coefficient; K1 is the calculated coefficient taking into account the permissible damage to railways (K1 =0.25) – [7]; m0 is the coefficient for laying the slope of the excavation of the roadbed without taking into account the seismicity of the area and high-speed train traffic (for clayey and gravelly soils m0 =1.5, for sandy soils m0 =1.75).

For the embankment of the roadbed, with the possible impact of seismic forces and high-speed train traffic, the empirical formula for determining the slope is recommended - mca.

(6)

where: B0 – width of the main platform of the roadbed; Kc, m0, – designations from formula (4).

Previously developed roadbed strengthening in desert areas does not have a central reinforcing pile, which ensures reliable stability of the roadbed when exposed to earthquakes, which also saves on pile consumption, increasing the calculated distance between them, which increases sharply. In addition, the recommended design includes piles with spherical lateral planes, which significantly increases the area of compacted soil along the road route, which acts as buttresses of retaining walls, and the support screen is the soil itself. In addition, such pile designs are more elastic, which allows bending deformations without destruction. The base of the embankment is a gravel pad, instead of cut shelves, easily arranged grooves are provided that are not associated with large volumes of earthworks.

Another engineering solution to ensure the stability of the embankments of the roadbed with weak soil foundations may be the appointment of more gentle slopes or the replacement of slopes with retaining walls. Firstly, this is expensive, secondly, on weak foundations, it is even more difficult and economically unacceptable to ensure reliable operation of retaining walls. In addition, with high-speed train traffic, the active pressure of the soil on the retaining walls, like seismic ones, increases sharply and if it is destroyed, it will be almost impossible to avoid a catastrophe with the rolling stock. Unlike retaining walls, pile fortifications are not only cheaper, but are also more flexible, i.e., they allow some deformations without destruction, which ultimately keeps the entire structure suitable for further operation of train traffic, after a technical examination.

**CONCLUSIONS**

1. Strengthening high liftings of the roadbed with reinforced concrete piles increases the required rigidity during high-speed movement and increases rigidity of the roadbed by 15–20%, which is sufficient to ensure seismic resistance of the railway up to 9 points of estimated seismicity.
2. Piles driven at an angle contribute to a more uniform distribution of stresses in the subgrade soil and the transfer of part of the vertical components of the forces to the foundation soil, which ensures the overall stability of the subgrade from the impact of circling stock during high-speed movement. Measurements of amplitude-frequency characteristics subgrade and the track superstructure show an increase in the dynamic rigidity of the structure, which confirms the feasibility of using piles, especially in seismically active areas.

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