Modern structures for slope stability in the design of artificial structures on railroad tracks

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Abstract. Rail transport is suitable for mass transportation, operating day and night regardless of the season and weather conditions. Railroads bring life to hard-to-reach areas and help to develop the riches of nature. It is necessary to provide for the safety of railroads from adverse impacts such as rockfalls, landslides, growing gullies, sand drifts and water scour. In this article, we will review modern approaches to the design and construction of man-made structures. It is essential that these approaches, namely design solutions, are durable and easy to use.

1 Introduction

The International Transport Summit was held in Moscow from August 24 to August 27, 2023. It was dedicated to the development of transportation in the world’s largest megacities. At the event, heads of cities, ministers, heads of transport companies from Europe, South and Central America, South-East Asia, Middle East and Africa presented the world's best practices in the transport sector. There was a discussion that it is necessary to build commodity turnovers and market relations with the countries. For this purpose we have to develop transport infrastructure. In this infrastructure, in construction there are complex issues with the design of artificial structures on the railroad tracks, because the roads pass through rocky terrain, plains [1]. In long stretches, railroad lines may cross different soils and climatic zones. Therefore, we have to consider this complex issue with the design of artificial structures so that the railroad tracks are high-speed and yet safe [2]. Also, raising the development strategy, let us cite the statistics of the leading countries with more than one billion tonne-kilometers per year (Table 1).

Various artificial structures are currently in operation on railroads in different countries of the world. They are structures erected where the railroad crosses rivers, streams, rain and melt water streams, other railroad lines, streetcar tracks and highways, mountain ranges, deep gorges and urban areas [3]. Also artificial structures provide:

- safe passage of people under or over railroad tracks;
- endurance of deforming and steep slopes;
- regulation of water flows in order to protect railroad tracks from scouring and oversaturation.

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Artificial structures include bridges, pipes, tunnels, overpasses, pedestrian bridges, retaining walls, regulation structures, galleries, reinforced earth structures, flumes, rapid streams, filter embankments, gabion structures. More than 90% of these structures are bridges and pipes [4].

Artificial structures require special attention in terms of repair and maintenance, so they are designed for a long service life. In order to provide for a long service life of structures, works are carried out to assess reliability and load capacity, repair and reconstruction. Reconstruction of pipes and bridges is mainly difficult, so the issues of reliability and serviceability of artificial structures are important in the organization of their radical use [5].

### 2 Slope stability due to reinforced soil structures

To strengthen and reinforce railroad track slopes, reinforced soil structures are used. In such structures, reinforced soil (reinforced soil) acts as the main material, which improves the strength characteristics of the soil due to the interaction forces between reinforcing elements and the filler soil. It also provides protection of the earth bed from dangerous geological processes such as scree, erosion, floods, landslides, avalanches.

#### 2.1 Armoground wall

The armoground structure for railroad tracks is an armoground wall. An armored earth wall is an array of drainage soil that is reinforced on the outside with a facing wall of reinforced concrete blocks and on the inside with reinforcement (metal meshes, geotextiles, geogrids) [6]. This wall can replace the counter-banket of drainage soil necessary for the stability of the embankment. The foundation is made of reinforced concrete blocks or monolith. To determine the depth of its embedment, it is necessary to find the frost depth of the embankment base. The facing wall consists of reinforced concrete blocks, which are stacked on top of each other and filled with sand-cement mortar. Metal reinforcing elements are arranged separately in height. In order for the wall to be stable internally and externally, non-woven synthetic material is laid in continuous width strips. Behind the cladding wall, drainage holes and wall drainage in the joints between the blocks are arranged in order to drain atmospheric water penetrating into the wall mass.

Armoground walls have a number of advantages:
- monolithic reinforced concrete structures are mostly free of disadvantages;
- good grip;
- no rot;
- chemical resistance;
- steepening of slopes;
- resistance to foundation settlement;
- compensation of temperature and shrinkage stresses;
- easy to build and economical;
- under prolonged and short-term stress the realization of shear resistance increase.

This artificial structure can be easily landscaped and complements the existing style well when developing landscaping ideas.

Fig. 1. Reinforced concrete reinforcement wall for railroads.

A highly promising design in the creation of reinforced soil walls is recognized as a uniaxially oriented geogrid in the form of a roll material with rigid nodal points. Single-axis geogrid is a polymer product with oblong cells, which serves to reinforce earth structures and is capable of withstanding critical tensile loads in one direction only. Uniaxial meshes are manufactured from HDPE with the addition of special components to increase the service life [7].

Fig. 2. Single axis oriented geogrid.

Armoground structures are also used internationally. For example, the Austrian company "Chemie Linz AG" has developed a method of calculation and construction of retaining structures made of soil reinforced with geotextile of Polyfelt TS type - polymer fibers based on polypropylene. The most popular among such structures are retaining walls of slopes of embankments of railroads and highways. Reinforced soil retaining walls designed by this company are vertical or slightly inclined.

In Austria, there is experience in using Polyfelt TS geotextiles in soil retaining structures. For example, a railroad track running through rough terrain near Steyr is reinforced with retaining walls made of reinforced soil.
The main danger to the stability of the reinforced soil retaining wall with block lining is due to the large values of seismic earthquake waves. The tests confirmed the seismic resistance of the retaining wall. The determining value for seismicity of such structures under the impact of high-intensity earthquakes are the effects of consolidation of the system "reinforced compacted soil-geogrids-block lining" revealed in the experiments and, as a consequence, the absence of significant internal relative deformations under seismic vibrations. The statistics of seismic impact on reinforced soil walls is presented in Table 2.

Table 2. Tonne-kilometers of rail transport per year.

<table>
<thead>
<tr>
<th>Place of arrest, year</th>
<th>Magnitude, (ML)</th>
<th>Distance to the epicenter (km)</th>
<th>reinforcement material</th>
<th>Wall height, m</th>
<th>Damages</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA, 2001</td>
<td>6.8</td>
<td>23</td>
<td>block lining, geogrid</td>
<td>4</td>
<td>destruction</td>
</tr>
<tr>
<td>Taiwan, 1999</td>
<td>7.3</td>
<td>15-40</td>
<td>geogrid</td>
<td>30</td>
<td>cracks, 2 m, difference in settlement</td>
</tr>
<tr>
<td>Japan, 1995</td>
<td>6.9</td>
<td>16-40</td>
<td>geogrid</td>
<td>7</td>
<td>no</td>
</tr>
<tr>
<td>Italy, 1976</td>
<td>6.4</td>
<td>25-40</td>
<td>uniaxial geogrid RE</td>
<td>5</td>
<td>no</td>
</tr>
<tr>
<td>Belgium, 1983</td>
<td>5</td>
<td>0.8</td>
<td>uniaxial geogrid RE</td>
<td>4.5</td>
<td>no</td>
</tr>
</tbody>
</table>

3 Gabions for reinforcement of railroad track slopes

It is very important to provide for the safety of railway tracks against adverse impacts such as landslides, landslides, growing gullies, sand drifts and water erosion.

The high dynamic loads experienced by the railroad track over a long period of time require special attention from designers and builders. The loads are applied to the slopes, gradually destroying them, so their reinforcement has always been a difficult task. Entering the construction market gabion structures effectively solve this problem [8].

When it is necessary to reinforce a slope, the question of choosing a building material based on the design solutions arises. Depending on the location of the railroad tracks, different structures for slope reinforcement are used. In areas with difficult weather conditions and in areas adjacent to water bodies, the use of gabions is relevant. Armogrund wall is suitable for structures on weak soils. Let's consider comparative characteristics of structures for slope stabilization in Table 3.

Table 3. Advantages and disadvantages of gabions and reinforced soil wall.

<table>
<thead>
<tr>
<th>Type of work</th>
<th>Gabion</th>
<th>Armor plaster wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mounting</td>
<td>Can be produced all year round. Low manual erection speed. Can be installed in hard-to-reach places.</td>
<td>Concrete should be poured in one go for monolithic construction.</td>
</tr>
</tbody>
</table>
Aesthetics | Eco-friendly. Fits perfectly into the landscape. | Additional decorative finishes are required to add to the look.
--- | --- | ---
Service life, durability | About 50 years, depends on the composition of the mesh metal and PVC mesh coating | May collapse in 10 years due to floods and storm flows
Drainage | Have drainage properties. In most cases do not require a drainage system. | Drainage devices are required.

Based on the data in Table 3, we conclude that gabion structures have more positive characteristics. They are more durable and reliable, they require less costs, and they can be installed all year round.

Gabions are prefabricated wire structures. This is done to simplify transportation. At the installation site they are assembled and carefully filled with filler, the choice of which depends on climate, external influences and individual aesthetic requirements.

Fig. 3. Gabion structures.

Long service life makes gabions more durable. The process is that they accumulate soil where, over time, plants can sprout, the roots of which do not destroy the gabion, but on the contrary - only bind it together. Thus, the service life can be considered unlimited. This explains the active reconstruction of our railroads, especially its dangerous sections. They help to strengthen slopes and slopes well, protecting them from erosion.

They are also used to make retaining walls and reduce the load on railroad tracks. Box gabions, including those with a reinforcing panel, are most often used to strengthen the slopes of railroad tracks, because this type of gabion structures allows you to effectively solve the task.

Mattress-tuff gabions are used much less frequently. The main parameters, properties and functions of gabions for railroads put them on a par with other solutions to the problems of soil instability near the close passage of tracks, but bring them to the forefront in terms of cost. These products allow to save money, which is especially important.

The height of walls made of mesh gabions for design seismicity up to 8 points inclusive - 8m, more than 8 points - 6m.
Easy and affordable installation without the use of heavy machinery, quick erection compared to gabions made of double torsion mesh. Durability, ergonomics. High drainage properties. Possibility of combining and combining with usual types of reinforcements used for aesthetic purposes. In contrast to gabions made of double-torsion mesh, higher frame rigidity of structures due to the welded method of bonding and the thickness of the material.

For filling of welded gabions it is recommended to use granite rubble, rubble stone, cobblestone, pebbles or lump colored glass with stone fraction: 40÷60 mm (fine), 70÷150 mm (medium) or 100÷250 mm (coarse) depending on the size of the gabion card cell.

They are made of low-carbon wire heat-treated hot-dip galvanized according to GOST 3282-74 in accordance with TU 5262-001-97495310-2011. The structure is assembled at the place of installation from welded cards with mesh 50x50, 50x100, 50x200 and 100x100 mm with diameter of bars 4,0-6,0 mm after their cutting to the required dimensions. It is possible to produce reinforced cards with twin horizontal bars (triplet) [9].

The cards are fastened with 10x500 or 10x1000 mm spirals made of galvanized wire Ø3.0 mm, or with galvanized SIMPLEX clamps.

Welded gabions differ from conventional gabions in that their cells are spot-welded together rather than simply intertwined. The use of welding makes it possible to produce structures of almost any size. The wire mesh is covered with a dense zinc layer, which is applied with deep adhesion. The minimum mass of zinc per unit surface area is at least 50 g/m², taking into account the diameter of the wire [10].

4 Conclusion

Having analyzed and compared the options, we assume a methodology for designing artificial structures on railway tracks using modern designs. This allows us to make these solutions typical and implement them in the projects. The conducted analysis of design solutions, depending on the physical and mechanical properties of the soil, has shown that modern approaches are more effective, and they can be used to design artificial structures on railroad tracks.

References

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9. *Methodical recommendations on application of gabion structures in road and bridge construction* (FGUP "Soyuzdorproekt", Moscow, 2001)