Construction and Current Maintenance of the Reinforced Ballast Layer of the Railway Track

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Abstract. The article presents the ideas for the construction and the current maintenance of the reinforced plastic geogrid top ballast composed of crushed solid rock. Meanwhile, the reinforced ballast material acquires new properties, which lead to the formation of a composite material with new properties. In the reinforced material, only micro-deformations occur under the dynamic load, which is intrinsic to solid rock. In this case, laboratory simulation of reinforced ballast with a cyclic load showed that multilayer stabilization with three geogrids reduces settlement by 67% and does not require cleaning during the entire service life of the reinforced top ballast.

The construction and the current maintenance of the composite structure make a real difference from the ballastless structure of the railway track as the work techniques with geosynthetics in the ballast subgrade are properly developed, and they are widely used during the repairs of railway track, because the development of the technology for the creation of reinforced geocomposite will not cause any problem.

1. Introduction

The overhaul repair of one kilometer of railway track on new materials or the repair of one layer (according to the Rules of Technical Operation of the Russian Railways*) costs on average from 30 to 50 million rubles or 400-675 thousand dollars. The repair of the ballast costs up to 25% of this amount. The average service life is a period during which the top ballast composed of new or reconstructed crushed solid rock ballast performs its main functions at the low level of the current maintenance costs, is about 350 million tons of the passed tonnage for the track of Class 1*. The service life of the remaining elements of the railway track is much more times higher than this figure. The main reason is the contamination of the ballast section with the products of crushing and abrasion of the ballast granules during the stabilization of the top ballast composed of crushed rock [1 - 3].

Attempts to expand the service life of the ballast section by installing flat plastic geogrids under the ballast layer or directly into the ballast section have been made in the world for quite a long time [4-7]. The reduction of contamination is achieved due to the fact that the reinforcement prevents the lateral displacement of the ballast granules under the impact of vertical load, which reduces the track settlement and abrasion of the ballast granules because of the rotation and vertical movement [3]. This effect is achieved by the penetration of some ballast granules through the geogrid cells, followed by their elastic blocking there (Figure 1). Such reinforcement of the ballast section reduces its contamination by 1.9 times [4]. Moreover, the reinforced ballast shows better failure resistance even at...
40% contamination [5]. The optimum ratio between the size of the ballast particles and the size of the geogrid cells is 1.1-1.4 to 1, respectively [6]. This was confirmed by the laboratory experiment carried out in MIIT in 2017 [8]. As a result of this experiment, it was also confirmed that the area of the complete stabilization of ballast particles for a rectangular geogrid is 100 mm, and for a three-axle geogrid is 150 mm [6,8].

Figure 1. Blocking of ballast granules in the cell of a flat geogrid.

Figure 1 shows that the ballast granule is optimally blocked in the cell in such a way that when the vertical load is applied, the retaining forces of the geogrid cell wall resistance to stretching become active. In their turn, the granules in the next row are blocked, falling between the granules have been already stuck with the geogrid [6]. To manifest this effect to the greatest extent, the granule size range should vary from 110% of the cell size in light to 140% [6]. According to these facts [6], the thicker the stiff edge of a geogrid is, the better, in comparison with the horizontal edge shape, the vertical edges are.

If all the conditions are met, it is stated that micro-deformations, which are intrinsic to granular material, are replaced by micro-deformations under load in the reinforced material, like in the case of solid rock [4]. It should be stated that when the graded ballast is reinforced with the flat geogrid, the material with new properties, which are different from the loose ballast, is generated. This material we call a geocomposite.

A geocomposite due to its properties, perhaps, is closer to the ballastless structure of the railway track than to the standard ballast one. Meanwhile, it is quite soft, in comparison with a reinforced concrete ballastless structure, much more technologically advanced in construction and much cheaper. Moreover, such a structure is not supposed to be very sensitive to temperature oscillations, which is especially important for the climate of 3/4 of the territory of the Russian Federation. It should keep in mind that the proposed technological operations for the construction of such a geocomposite structure were utilized long ago during the repair and the current maintenance of the ballasted railway track.

2. Suggestions on the results of the experiments
The construction of the reinforced ballast section may be carried out with the mechanical method in several stages:

When a new railway track is being constructed, after laying the first layer of the geogrid and the assembled rails and sleepers (ARS) on the solid subgrade, the first layer of the graded ballast is unloaded from the hopper dispensing wagons. After that, the electric ballast machine (the electric ballaster) pulls the geogrid onto the surface of the graded ballast, then it moves in the opposite direction and lifts the ARS to lay the second layer of the geogrid. After the geogrid has been laid, the dynamic rail track stabilizer should pass along the section for better blocking. Similarly, the next layer of the reinforced ballast section is constructed. When a three-axle grid is used, 2 layers of the geogrid are sufficient in the ballast section body, while when a geogrid with a rectangular cell is used, there should be three layers to achieve a thickness of the ballast layer under the sleeper of 400 mm. Each filled layer should be dynamically stabilized by the dynamic rail track stabilizer in 2 passes.
Figure 2. The scheme of surfacing and rolling out a flat geogrid under the assembled rails and sleepers: 1) Rolling out of a geogrid; 2) Unloading of crushed stone out of the hopper dispensing wagons; 3) Lifting of ARS on the ballast; 4) Dynamic stabilization of the track.

After filling the ballast under the sleeper with the required thickness, the final layer of the ballast with a fraction of 10-20 mm is created as an intermediate layer between the graded granules and finely crushed stone for pneumatic measured packing (a fraction of 5-10 mm) in order to further maintain the current composition of the reinforced ballast section, and the spaces between sleepers are filled with it, using the ballast leveling machine (BLM). If such a structure is constructed on the operating track, then first a complete cutting off of the old ballast is performed with laying of the geogrid on the solid subgrade. Then, the construction of the reinforced ballast section is carried out in the same way as during the construction of a new track. The current maintenance of the reinforced ballast section should differ from the current maintenance of the standard ballast section. Due to the fact that in the ballast mass there are reinforcing elements in the form of flat plastic geogrids, it is impossible to use such operations of the current maintenance as the alignment of the ARS in the profile by tamping the ballast under the sleepers, both in mechanical and mechanized forms. It is planned to replace the alignment with tamping with laying of sleeper pads and pneumatic measured packing. Laying of sleeper pads is recommended according to the results of an experimental assessment of the rolling stock dynamic impact on the track with laying of sleeper pads, which confirms the decrease in the rate of ballast failure under the sleeper. This decrease is achieved by an "enveloping" like of the ballast granules with the elastic material. All of these reduce the specific pressure from the permanent way to the ballast and leads to the increase in the service life of the ballast (Figure 3).
Pneumatic measured packing is the alignment of ARS in the profile by filling fine (the size from 5 to 20 mm) ballast under the sleepers. Filling is carried out with the help of the compressed air flow, which picks up fine particles of the ballast and redistributes them under the rail supports in an even layer (Figure 4).

3. Conclusions
1. When the graded crushed stone of solid rocks of a certain size and a three-axle flat plastic geogrid are utilized, the construction of reinforced substructure does not present any technological problems with the use of standard special-service trains, involved in the current maintenance and overhaul repairs of the railway track.
2. For the current maintenance of such a structure, it is necessary to use non-tamping methods of alignment the track in the cross section, such as laying of sleeper pads and pneumatic measured packing, meanwhile, a combination of sleeper pads and pneumatic measured packing is possible.
3. The created and operated structure like this one is able to provide high survivability and duration of the maintenance-free operation. The costs for the current maintenance of such structures are assumed to be low.

4. References

[1] Selig E T, Waters J M 1994 Track Geotechnology and Substructure Management (London: Thomas Telford)

[2] Abrashitov A, Semak A 2017 Experimental study of stoneblowing track surfacing technique Procedia engineering 189 75 - 79

[3] Assessment of sources of pollution of the ballast layer from crushed granite and modeling of destruction and abrasion of crushed stone particles under dynamic loading, Collection of materials of the international scientific and technical conference "Modern problems of designing the construction and operation of the railway track" 2016 II 184

[4] Kwan C C J 2006 Geogrid reinforcement of railway ballast PhD thesis University of Nottingham

[5] Indraratnaa B, Ngoa N T, Rujikiatkamjorna C 2017 Improved Performance of Ballasted Rail Tracks using Plastics and Rubber Inclusions Procedia engineering 189 207 - 214

[6] Abrashitov A A 2020 Creation of a two-layer ballast prism of a railroad track from granite rubble using plastic flat geogrids and rubber crumb of recycled automobile tires IOP Conference Series: Materials Science and Engineering International Science and Technology Conference "FarEastCon 2019" C 032016

[7] Rakowski Z 2017 An attempt of the synthesis of recent knowledge about mechanisms involved in stabilization function of geogrids in infrastructure constructions Procedia engineering 189 166 – 173

[8] Tutumluer E 2016 Geogrid-aggregate interlock mechanism investigated Special sessions on Geosynthetics in Road Construction EuroGeo 6 (Ljubljana, Slovenija)