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

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Abstract. This paper presents the calculations and the results of an experiment to create, with the aim of improving straightening work within the framework of the current content of the railway track, a new design of the basement of the ballast prism, including a plastic mesh with a mesh size of 5 mm and small granite crushed stone mixed with rubber crumb recycled car tires. This design is created by injecting a mixture of fine gravel and crumb rubber into the space between the bottom of the sleepers using compressed air railway track and riding ballast. The experiment showed that to prevent the migration of small particles of crushed stone and crumb rubber into the ballast, it is necessary either to lay a plastic grating in the form of a separation layer or to select the size of small crushed stone in such a way as to exclude the migration of its particles into the ballast.

1. Introduction

The Research Institute of Railway Transport (JSC VNIIZhT) and the Department of Path and Track Management RUT (MIIT) conducted tests to investigate the possibility of using a new design of the basement, which can be created using stone straightening technology at the VNIIZhT Experimental Ring training ground, Shcherbinka. Stoneblowing is a pneumatic injection of granite crushed stone with a size (fraction) of 5-10 mm under a sleeper.

Initially, it was not intended to use any separation layer between small particles (stoneblowing) introduced by means of injection by compressed air and a ballast prism; therefore, the experimental design of the sleeper base was as follows (Fig. 1)

![Figure 1. Initial design of the experimental basement without a plastic grill.](image)
However, in order to create an experimental design of the basement, it was necessary to preliminarily evaluate the possibility of migration of small gravel to ballast prism due to the fact that when injected and ballast gravel work together, there is a danger of the migration of small particles of gravel to ballast voids and blocking of these voids in the ballast prism. As a result, there is a decrease in the porosity of the ballast and an increase, as a result, of the stiffness of the ballast prism, which, in turn, leads to an increase in the rate of abrasion and fracture of the ballast granules. This can lead to the rapid loss of part of the ballast layer of drainage properties and provoke the appearance of a dry and then a wet splash.

The issues of migration of small particles of incoherent granular material into the voids of a larger incoherent granular material in our country were dealt with when designing multilayer reverse filters of soil dams.

The selection of the size of adjacent layers of material was decided on the basis of the absence of migration of particles of protected soil through the pores of the adjacent layer.

There are several ways to select layers of a multilayer inverse filter, differing in the methodology for assessing the obstruction of small particles of material through large pores.

The assessment of the possibility of migration of small gravel to the ballast prism was carried out according to three design methods for multilayer reverse filters of soil dams adopted in Russia - the method of V.S. Istomina [1], According to the VNIIG methodology [2] And the contact discharge of disjoint materials was calculated according to the VODGEO method [3] using all three methods, crushed stone with a size of fraction 5-10 was allowed to be placed on top of crushed stone of a ballast prism of fraction 25-60. However, according to the geometric estimation method proposed by Sodergren, [4] minimum particle size of stoneblowing material should be 7.7 mm. Such a discrepancy in the methods for assessing the migration of small gravel into the ballast prism led to the need to change the design of the experimental model (Fig. 2).

![Model of the basement accepted for testing](Image)

**Figure 2.** Model of the basement accepted for testing.

In areas with high contamination of the ballast prism, which often occurs when the tonnage missed in the site is close to or exceeds the standard overhaul tonnage, there is an increased abrasion of ballast gravel particles due to its intensive work in the basement. This phenomenon is characteristic, first of all, of the track on reinforced concrete sleepers, since in a long-running ballast prism the ballast material is maximally compacted due to fracture and abrasion of the ballast granules, large pores are closed by smaller particles, and ballast stiffness increases [7]. The result of this process is often the formation of the so-called "dry" splash. A comparative study conducted by VNIKTI JSC in 2018 showed that on a “dry” splash, the rigidity of the sleeper base is 2.2 times higher, which causes an
increase in the average values of the vertical forces of interaction between wheels and rails by 1.37 times. [8]

Thus, a thin layer of soufflage gravel falls between a kind of “hammer” in the form of reinforced concrete sleepers and an anvil (a re-compacted ballast layer). The danger of abrasion of soufflage gravel is that in this case particles of the finest clay fraction are formed, which does not pass water through itself [7]. Considering that the large and medium pores of the ballast of the basement are already covered by the products of fracture and abrasion of the ballast layer, the likelihood of complete blocking of the pores of the ballast prism and, consequently, the complete loss of the basement of the basement of drainage properties increases many times.

The question arises of the fundamental possibility of straightening pneumatic soufflage paths on reinforced concrete sleepers with a re-compacted basement, because it is impossible to change the stiffness of reinforced concrete sleepers, and it is possible to change the rigidity of the basement only with deep cleaning of the ballast layer.

The problem can be solved by adding a certain amount of crumb rubber to the souffle gravel corresponding to the size of the souffle material. Distributed between the solid particles of the soufflage rubble, rubber particles envelop the souffle granules, thereby preventing their destruction. Studies at the University of Granada (Spain) [9] Showed that with the combination of ballast and rubber granules obtained from the disposal of automobile tires in the ratio of one part of rubber granules and three parts of ballast granules, the effect of changing the stiffness of the railway track is achieved, similar to that achieved when placing concrete sleepers on hard under sleeper pads.

To test the design of the basement in the section 2 of the ring path of the experimental railway ring of the VNIIZhT two experimental joints were selected:

the joint between rails No. 291 and No. 292 and the joint between rails No. 292 and No. 293.

The joints are located at 6 km 2 of the track, at a distance of 12.5 meters from each other and have the following structure of the track’s upper structure (Table 1):

| Joint   | Kilometer stone | Rail type | Track structure | Fastening, sleeper type | Ballast   | Position in the plan | Material for Stoneblowing |
|---------|-----------------|-----------|-----------------|-------------------------|-----------|---------------------|--------------------------|
| 291-292 | 6 KS 3          | R-65      | Jointed         | KB, RFC                 | Hard stone| Straight            | Fine crushed stone        |
| 293-294 | 6 KS 3          | R-65      | Jointed         | KB, RFC                 | Hard stone| Straight            | Fine crushed stone with rubber |

Traffic that was missed in the section at the time of testing amounted to 2 billion 200 million tons of gross (standard overhaul tonnage exceeded 1.5 times, standard tonnage between ballast cleanings exceeded more than 3 times).

The track was hung with hydraulic jacks mounted on both rail threads one against the other. The lifting height of the rail-sleeper lattice was determined using the track pattern and amounted to exactly 35 mm when laying the experimental sections.

After two sleepers that were closest to the joint, at both joints, after hanging on the jacks, a plastic grid with a mesh of 5 mm in the light (the so-called "masonry" mesh) was placed, and the alignment at the joint 293-294 was made with a mixture of crushed stone and rubber crumb size 5-8 mm in a ratio of 3 to 1, respectively.

After the two rail threads were signaled using the STIL BR 200 blower equipped with a special nozzle, we straightened them with a pneumatic souffle using a specially painted granite crushed stone of a fraction of 5-10 mm and a mixture of granite crushed stone and crumb rubber (Fig. 3).
Based on the results of profile measurements, in combination of leveling data and rail deflection values, power profiles of the rail head under the rolling stock were obtained. The most characteristic force profile was obtained on the left thread of the junction 293-294 (Fig. 4).

As a result of visual inspection and inspection after removing the ballast from the sleepers of the sleepers straightened by stoneblowing, it was found:

1. At the junction, there are signs of intensive work of air-crushed stone under straightened sleepers (Fig. 5 a);
2. The stoneblowing rubble did not penetrate into the underlying layers of the ballast prism only where a plastic net was laid under it, even after passing 25 million tons of traffic (Fig. 5 b);
3. Where no plastic mesh was laid under the crushed stone for stoneblowing, the crushed stone penetrated into the road crushed stone after 6 million tons of traffic had passed, which is consistent with laboratory studies conducted earlier in the RTH (MIIT) [10] (Fig. 5 c).

Figure 3. Stoneblowing dressing using specially painted granite crushed stone of fraction 5-10 mm.

Figure 4. Force profile of the left rail of the joint 293-294.

Figure 5. a) Signs of the intensive action of stoneblown crushed stone under the aligned sleepers; b) Stoneblown crushed stone under the sleeper after the passage of 25 million tons of traffic; c) The migration of the crushed stone after the passage of 6 million tons of traffic when there is no plastic grid under the crushed stone.
Visually, after passing 25 million tons of traffic, it was found that in the joint 291-292, the destruction of stoneblowing gravel occurs more intensively than in the joint 293-294 (Fig. 6).

Figure 6. The state of the souffle layer after passing 25 million tons of traffic: a) stoneblowing crushed stone with the addition of crumb rubber; b) stoneblowing crushed stone without adding crumb rubber.

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