MECHANISM OF SPLASH FORMATION IN BALLAST PRISM SECTION

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ABSTRACT

The article considers a mechanism of conduct of railway track ballast section in the periods between cleaning or replacement of the ballast, investigates possibilities of preventing the formation of splashes, destroying the strength of basic elements and track geometry. Measures and ways are highlighted to prevent emerging threats and risks in terms of safety operation of railways.

Keywords: railway track, crushed stone ballast, smoothing, splash, operational safety, engineering solutions.

Background. *As it is known, ballast section, arranged from any materials from the viewpoint of its operation under the influence of the train load is divided into two layers – upper layer and underlying layer.*

The upper layer is active. It is the most heavily exposed to changes in thickness, grain size distribution of the material, pollution and displacement of particles in different directions. These processes are directly dependent on the size of dynamic effects of the rolling stock, load on a section, type of superstructure, climatic conditions, area of railway lines location and a number of other factors.

In crush-stoned materials active layer varies depending on the size of grains of crushed stone and is characterized by three different phenomena: movement of particles of the material, contamination of ballast section and mutual penetration of crushed stone and material of a separation layer. Movement of undestroyed particles of crush-stoned materials is insignificant and occurs at a very shallow depth under sleeper soles, and contamination with both destroyed particles of crushed stone and external pollutants spreads through cavities in crushed stone in the entire thickness of the layer of these materials to cushion or in part of its thickness. Pollutants in a predominant amount are concentrated near sleepers in the upper layer. In crushed stone with fraction 25-60 mm pollutants mostly retain in the upper layer, but significant amounts penetrate deeper, allowing crushed stone of this fraction to work en route for a longer period as compared with ballast comprising finer particles [2].

Under repeated loads of missed tonnage a track gradually deforms vertically and horizontally, causing deviations from a desired geometry. Since these deviations occur usually unevenly it is necessary to increase dynamic loads, which in turn causes even more irregularities. In most cases, in current maintenance of a railway track for correcting track geometry defects resulting from repeated dynamic loads ballast surfacing is used. The process of smoothing with surfacing includes up-grade and alignment of the track to obtain the desired geometry with simultaneous repackaging of the top of the ballast layer to fill cavities under sleepers, which allows keeping sleepers in their top position [1].

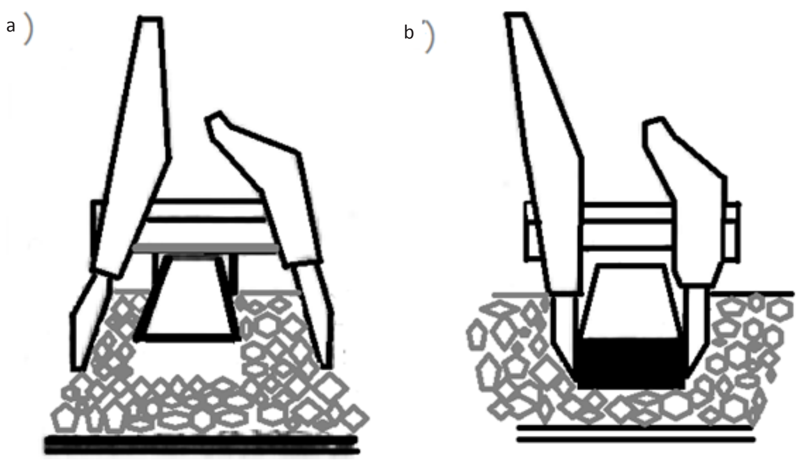
However, this is accompanied by some damage to the ballast due to tamping, loosening its foundation, and initial reduction of resistance to lateral displacement and track boil [2]. Subsequent smoothing leads to an increase in subsidence due to the deterioration of the ballast quality because of attrition of crushed stone grains and its obstruction in the process of track work under trains. In the end, it becomes necessary to perform smoothing again.

During the period of time between surfacing fine particles from different sources of pollution are accumulated in crushed stone, and this moment is known as accumulation process [2]. As a result such features of ballast deteriorate as drainage and the ability to maintain geometry after smoothing with surfacing, and the ballast itself requires replacement or cleaning. This process can be called interrepair maintenance cycle of or ballast lifecycle [1]. And it, in fact, determines timing between overhaul capital and mid-life repairs.

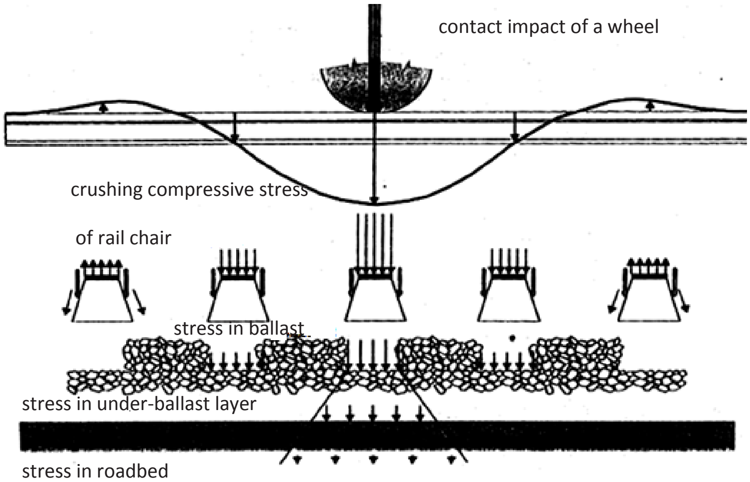
Objective. *The objective of the author is to study a mechanism of splash formation in ballast section.*

Methods. *The author uses general scientific methods, evaluation approach, simulation.*

Results. *The functions of smoothing-surfacing-alignment machines (hereinafter referred to*



Pic. 1. The mechanism of ballast consolidation under a sleeper: a) insertion of strikers; b) compression.



Pic. 2. The distribution of stresses in elements of a high-speed track from the passage of a single wheel set.

as SSA)on track smoothing in the plan are that surfacing working bodies (strikers) are immersed in the ballast between sleepers and then are compressed towards each other under the sleeper (Pic. 1) with vibration. This causes abrasion of sharp edges of ballast particles and its disintegration (i.e. particles of smaller fraction than the lower boundary (size) of the fractional composition of ballast or pollutant is created). Surfacing can produce a significant amount of contaminants, primarily due to the impact of ballast repacking under the sleepers and its further stabilization [1]. Factors affecting the amount of ballast pollutants are related to the type of ballast, compression force of strikers, their vibration characteristics and the number of dives of an instrument attributable to a certain machine.

One consequence of the total plastic deformation of ballast including subsidence is that between bottom support surface of sleepers and the ballast a clearance may form. The clearance may also appear due to up-grade in the front of a wheel (Pic. 2). Then there is a rapid closure of the clearance via applied load of a wheel set. If the clearance is filled with water in conjunction with ballast particles of small size, strong erosion process can increase the speed of subsidence under the sleeper. This phenomenon leads to an increase in the value of the rate of subsidence and an increase in the rate of decline in the quality of ballast [2].

Analysis of changes in track geometry and their causes shows that in most cases the ballast is becoming a major element that undergoes subsidence between operations on track smoothing in the longitudinal profile. And quite often subsidence is accompanied by the formation of splashes [2].

A particularly serious problem of ballast pollution is marked in the zone of rail joints exposed to high dynamic effects of wheels of rolling stock. In this zone ballast particles undergo separation and form fine powder. This powder in combination with water forms a pulp, which destroys the ballast forming cavities under sleepers. In such cases, called splashes, it was found that material of pollution contains particles of 10 mm to a size of clay, and size of fine sand particles becomes dominant. The destruction of the sleeper bed due to fragmentation of particles of ballast is connected with high hydraulic gradient of the liquid slurry under the sleeper, especially where cavities are developed (Pic. 3). The rate of application of the load in combination with the value of the axle load is a determining factor in the destruction of the ballast, accompanied by its erosion [1].

Under the influence of the train load a sleeper moves downward, leading to high pressure of fluid in the form of pulp under the sleeper. This excess in pressure of the liquid is dissipated in the form of spray. Spray flew toward the sides and up from under a sleeper. The higher is the speed of motion, the higher is the speed of load application and the higher is induced pressure of water. However, in areas with a set speed of 40 km / h, this type of failure is rare.

The problem of hydraulic erosion can also be triggered by other sources of pollution (ore, coal dust, cement, softening of ground of a subgrade), causing tightness of ballast around the sleeper, which is fraught with accumulation of a mud-water pulp [2].

Scouring action of the pulp is sufficient to displace ballast particles around the sleeper, as shown in Pic. 3. This reduces the lateral resistance of sleepers to shear.

The resulting from destructive action of pulp a material with highly abrasive properties is capable even to destroy concrete sleepers, and in the worst case, to expose on them armature of prestress [1]. The product of this erosion is an extra reason to further reduce the permeability of the ballast around the sleeper and adding abrasiveness to sloped fluids.

Splash of a formed mud can due to the mixture of fine particles and the water lead to contamination of ballast of surrounding (adjacent) sleepers (Pic. 3), thereby developing defect and increasing the hydraulic erosion. Such a mechanism can exacerbate failure to solid splash, spreading from nearby sleepers (where usually begins the problem) to the adjacent areas.

Factors contributing to the occurrence of this type of failure are:

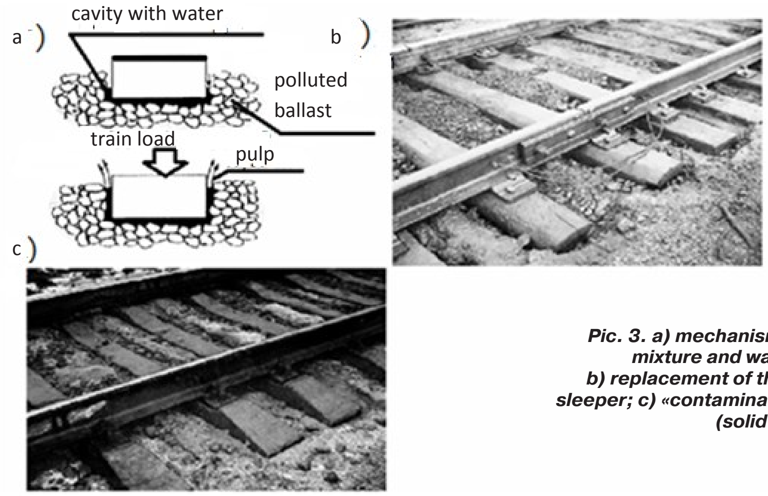
1) Inadequate drainage.

2) High contact stresses transmitted from concrete sleepers to ballast particles.

3) Low wear-resistance of ballast material.

4) Influence of hydraulic effects on railway sleepers [2].

Examples of such situations have been identified in upper layers of the contaminated ballast located above the clean ballast. It seems that this type of destruction accelerates the development of erosion due to increased concentration of the resulting pulp, its hydraulic speed and force of impact. Depletion of ballast in sleeper bed, caused by ballast pulp, may be



Pic. 3. a) mechanism of action of abrasive mixture and water to the ballast; b) replacement of the ballast from under a sleeper; c) «contamination» of adjacent sleepers (solid splash).

prevented by ballast material which is highly resistant to natural degradation.

The ballast under the sleeper can be made healthier through its cleaning or the new ballast, which has a high resistance to abrasion, and provides good drainage properties [3].

Ballast pollution leads to the fact that it prevents the performance of its functions by the ballast section. The presence in the ballast of contamination particles having a size corresponding to the particle size of fine sand and crushed particles of crushed stone of a low of fractional composition increases shear strength and stiffness of the ballast. These particles increase stability and resistance to plastic deformation as long as larger particles support a common skeleton of ballast section, thereby increasing the resistance to freezing. However, at the same time it reduces the amount of free space and reduces elasticity of the ballast section. Operations on smoothing and alignment become more difficult because ballast cavities are filled. Drainage gradually reduces its effectiveness, but it may be satisfactory as long as the majority of cavities are filled with small particles [2].

Loss of functionality of the ballast section occurs mostly when materials of pollution contain particles with the size of clay or silt. The number of these particles, which lead to serious problems, depends on the number and size of the components of larger crushed particles of because they reduce the pore space, making it smaller and combine with particles of the abrasive slurry. Clay particles do not form abrasive slurry, but the form of silt particles. Both types of particles hinder drainage and therefore there will be a significant deterioration of ballast properties as water –the inevitable source of risks in the current maintenance of ballast. The most damaging effect on the ballast is produced by:

– Hydraulic erosion, abrasion;

– Deformation of the roadbed;

– Loss of stability due to grease of ballast particles with mixture of water and fine particles.

Ultimately, at a sufficiently high level of contamination (30% or more) it becomes impossible to operate the ballast section and to maintain satisfactory track geometry. With increasing pollution from the destruction of ballast particles smoothing with surfacing become ineffective for the following reasons:

1) When pollutant is dry crushed ballast, for strikers of SSA it is difficult to penetrate into it and moreover to repack grains which remain unchanged;

2) when the ballast moistens particles on the contact are covered with grease mixed with crushed ballast, the latter has a weakened structure after smoothing [4].

The complexity of services will grow because the state of the ballast will be unsatisfactory, especially in layers with the presence of silt and clay particles, and it will require a deep cleaning and filling it (at mid-life and overhaul repairs).

Conclusions. *The outlined data leads to the conclusion that, in accordance with the ideology of maintenance of tracks on the principles of preventive maintenance it is necessary to fight with splashes timely, using the results of a comprehensive diagnosis of the track, revealing their presence at the early stage of erosion process.*

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