EFFECT OF BALLAST POCKETS ON DECREASE IN BEARING CAPACITY AND STABILITY OF GEOTECHNICAL RAILWAY STRUCTURES

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Abstract

Frequent causes of decrease in bearing capacity and stability of geotechnical railway structures on the railways in the Republic of Croatia are in connection with the existence of ballast pockets. On examples of embankments on the railway Zagreb – Rijeka near Generalski stol, embankments on the railway Zagreb-Rijeka at Donje Dubrave and cutting on the railway Ogulin-Split at Plavča Draga, negative effect of these occurrences on the bearing and stability of geotechnical railroad structures will be shown. Presented will be applied methods of investigations, analyzed geostatic models and applied technical solutions for remedy. Paper will also present how by using available data on geometrical conditions of the railtracks and available geotechnical data from closer and wider locality, a quality estimate of the railway condition regarding the presence and degree of deformation and destabilization process can be made.

Keywords: ballast pockets, investigations, technical solutions for remedy

1 Introduction

In last 20 years, on Croatian railways there are more frequent occurrences of losses in bearing capacity and stability of geotechnical railway structures. These occurrences are registered on main railways: Zagreb – Rijeka (Donje Dubrave, Generalski stol, Galović selo), Ogulin – Split (Plavča draga), Zagreb – Slavonski Brod (at more localities where railroad is laid on lower embankments), Zaprešić – Varaždin (Novi Marof), as well as on other sections.
Common characteristics of these railways is that load-bearing set of rail body substructure (subballast and crushed stone-ballast) lays either on the base soil layer formed of clays or on embankments constructed of clayey materials. In all cases, accelerated movement (sinking) process occurred prior to the failure. Causes of these occurrences are in connection with weakening appearing in the bedding layer, known under the term of ballast pockets.

2 Genesis of ballast pockets

Occurrence of ballast pockets is connected to beddings and embankments formed of clayey-mouldy materials, and it develops due to characteristic dynamic loads from the railroad traffic, open type of the load-bearing set and mainly poor mixtures of subballast granulated material. Due to the influence of water, strength parameters of clays drop to their residual values, soil looses its bearing capacity and can not without consequences undertake dynamic loads from traffic. Extremely high differences in mechanical characteristics of gravel ballast and clayey material, cause impression of ballast material into the clayey bedding material. In the embankment already impressed ballast material, as extremely permeable, draws in water that is retained there and softens the bedding, while the ballast continues to impress deeper into the embankment core (Fig.1.). Depending on mechanical characteristics of clay in bedding, quickness of impressing crushed stone material from subballast and from ballast is different. In a clayey bedding, firstly smaller bodies are formed known as smaller pockets, which in time increase and turn into shapes called depressions, while in the last phase of genesis bigger bodies are formed, so called ballast pockets.

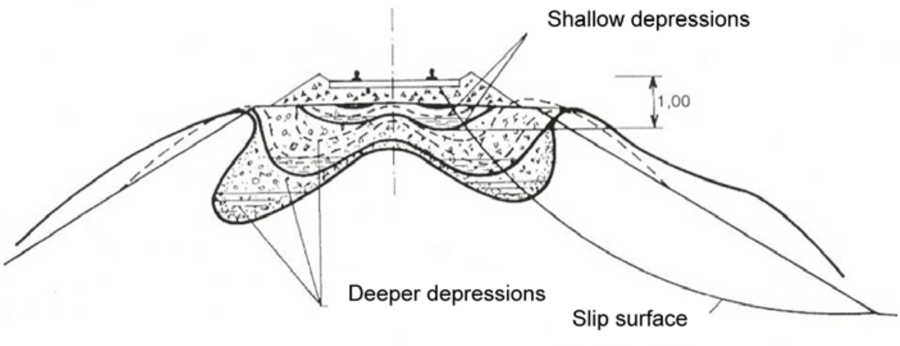

Figure 1 Ballast depressions and their genesis

On railway sections affected with deformations and destabilization process due to the described processes, vertical position of the railway alignment level was maintained by tamping railroad tracks. In the end, process of destabilization is stopped with technical solutions that eliminate causes of instability occurrence. In worst cases where this could not be executed on time, and the condition of advanced deforming and final failure of the structure occurred, railroad traffic had to be shut down, and serious remedy measures had to be undertaken (Plavča Draga, Galović selo).

3 Increase of ballast pocket depth – decrease of safety factor

By impressing, stone material is mixed with clay. Newly created material (Fig.2.) is of different grain size distribution, more permeable, saturated with water and with significantly lower mechanical characteristics compared to the bedding clays and subballast underneath. By the increase in the ballast pocket volume, surface that providing shear resistance to shear stresses consists of two parts:

- part having unchanged shear strength parameters (clay of which the embankment is constructed) and
- part having reduced shear strength parameters (ballast pocket).
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Result of described processes is a reduction of safety factor to failure alongside potential slip surface (surface of the least shear resistance).
Stability analyses conducted on a simple geo-statical model (Fig.3.).
Shear strength parameters used in this model are obtained from laboratory testing of embankment material from Donje Dubrave (shear strength parameters cl, fl of clayey material in ballast pocket are obtained by Krey Tiedemann method where strength parameters are tested on a sample at liquid limit). By the effect of water found in the ballast pocket and traffic load, shape and depth of the ballast pocket had changed and safety factors for each of assumed cases were obtained. Dependence of the safety factor reduction on ballast pocket depth is shown on Fig.4.

Figure 2 Ballast pocket material

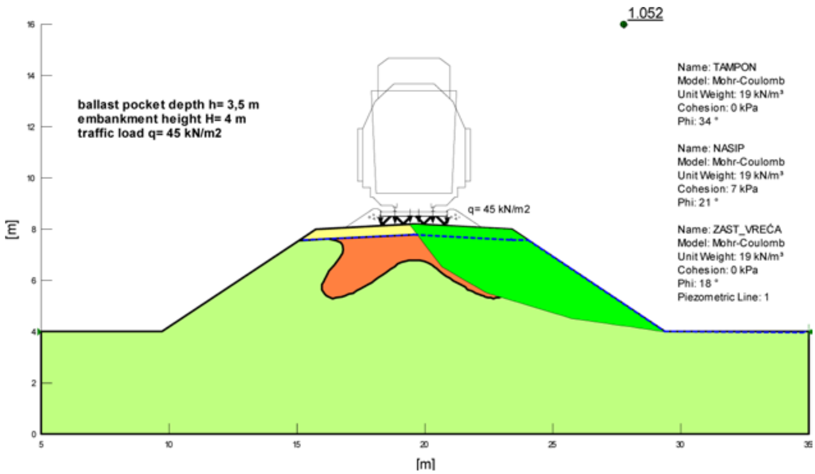

Figure 3 Geo-statical model

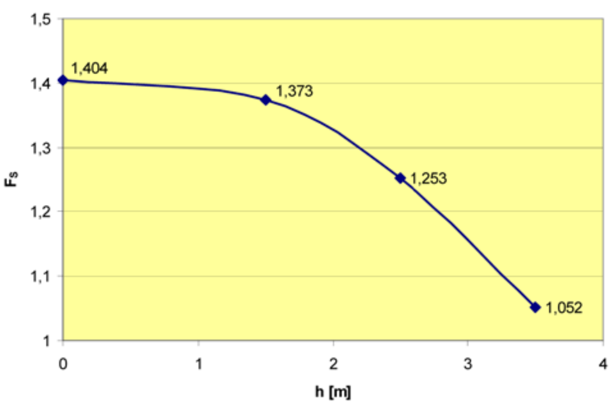

Figure 4 Decrease of safety factor in respect to ballast pocket depth increase

Results obtained from conducted analyses imply following conclusions:

- Increase in ballast pocket size reduces safety factor to occurrence of sliding – failure,
- Reduction of safety factor is not linear. Increment of reduction enlarges when ballast pocket depth reaches approximately 2 m,
- Transition to the unstable equilibrium (Fs‹1,20) happens when ballast pocket reaches depth of approximately 2,5 m.

Correlating these results with exploitation period and destabilization incidences on our railways, it can be assumed that safety factors to possibility of failure occurring, are on some sections significantly lower than the ones those railways had after their original construction (end of 19th and the beginning of 20th century), i.e. that they are in the state of unstable equilibrium. Indicating to this are also findings obtained from geotechnical investigation works for the purpose of repairing certain railway sections (Vc Corridor, Vinkovci–Tovarnik, Botovo–Križevci, Greda–Velika Gorica,...).

4 Investigating positions and sizes of ballast pockets

Combination of destructive and non-destructive methods of investigations is applied for purposes of detecting position and size of ballast pockets. By georadar (GPR) measurements (method applied on our railways since 2002.) continuous longitudinal profile of the recorded track line is obtained, while on positions with potential instabilities further investigations are carried out (excavation of investigation pits, dynamic probing, drilling investigation boreholes). Figure 5. shows an example of investigation results of GPR method and DPH probing of embankment fill. Longitudinal GPR profile indicates existence of ballast pocket of more than 4m in depth, while DPH profile indicates significant resistance reduction in the very zone of ballast pocket existence.

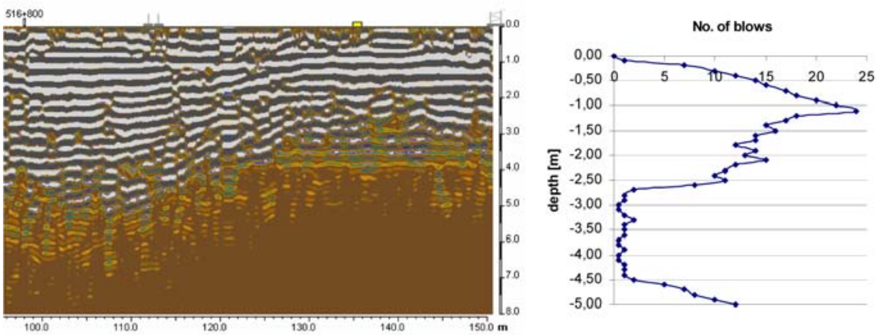

Figure 5 GPR and DPH profile

5 Examples of improvement measures

Localities on which investigations have been conducted indicate that sporadically in the clayey bedding, ballast pockets of more than 2m of depth are found. Bringing this information in connection with the previously given diagram, it is right to assume that some railway sections are in the condition of insufficient degree of stability to failure occurrence. In practice, reduction of safety factor in an interval from Fs= 1,1 to Fs= 1,0 is followed with fast increase of deformations ending with failure.

According to the experience based on rough observations of these occurrences by workers of HŽ Department for rail tracks, time of this final phase of safety factor dropping and failure

occurring, lasts from 15 to 30 days. In this period, vertical railway alignment level is maintained with frequent tamping of railway tracks.
Shown is the importance of interventions before last phase and failure occurrence or, if the process is started, as soon as it is detected. Usual improvement mode of railway sections affected with destabilization comes down to execution of excavations perpendicular to railway axes, in conditions of traffic shut down. In these excavations, replacing existing with drainage gravel-stone material is carried out, captured water is drained and extracted from the embankment (Fig.6.). While conducting these works, special wagons for material transport and trench excavators are used.

Figure 6 Execution of transversal drainage ribs

On the embankment at Donje Dubrave, due to its height, drainage load bearing rib wasn't applicable, so the improvement solution was to be found in making a ballast pocket material composite (grouting, "mixed in place",…) and draining the material of the ballast pocket, respectively, construction of the new embankment since the existing one was in the curve. Besides constructing new embankment in controlled conditions, this would improve elements of the track alignment (larger curve radius).

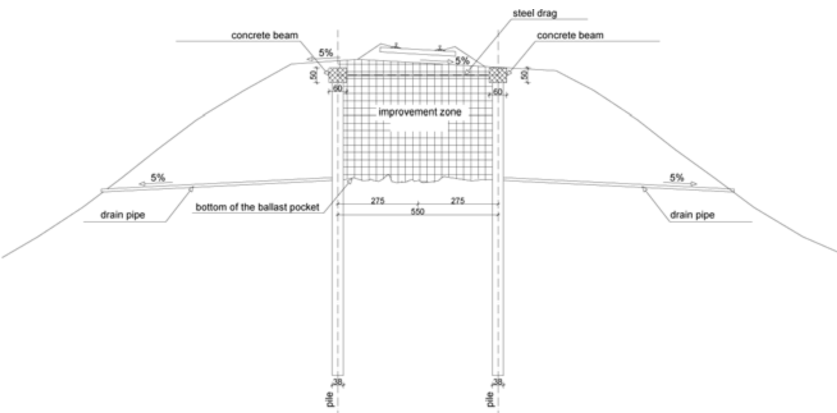

Figure 7 Cross section of the ballast pocket improvement measures on the embankment Donje Dubrave

In cases when this process is not identified on time, unwanted consequences can occur as it was the case on the locality of Plavča Draga. Frequent tamping of railway tracks maintained railway's vertical alignment line. After unfavorable hydrological conditions (sudden snow melting) deformations accelerated leading to failure. Traffic was shut down for 4 days. In this period preliminary geotechnical works have been carried out and temporary construction was set up (steel provisory) (Fig.8.), founded on piles of small diameter. After restoration of traffic, investigation works and selection of the permanent improvement solution was continued with. As optimal permanent improvement solution, reinforced soil structure was selected.

Figure 8 Temporary improvement measure

6 Conclusion

Presence of ballast pockets in embankments of the existing railways represents a very serious problem, and for the purpose of avoiding unwanted consequences of processes that can be initiated by existence and expansion of ballast pockets, it is necessary to conduct following:

- visual monitoring and archiving conditions of geotechnical railway structures by the competent Department in charge,
- regular observation of track geometrical elements by measuring with measurement vehicle ,
- conduct interdisciplinary geotechnical investigations (geophysics, geomechanics, geology) for the purposes of obtaining quality input parameters for preparation of project documentation for the railways repair works,
- while conducting repair works, it is necessary to build in separating layer of geotextile on the contact of subballast and clayey bedding material, and in some zones to build in polymer geowebs,
- right on time deliver project design solutions that on critical sections must definitely include execution of drainage systems that will enable water discharge from the ballast pockets, improvement of material mechanical characteristics of the pocket body by grouting, jet grouting or other improvement methods.

Processes of destabilization and larger deformations of soil and geotechnical railway structures most commonly are not incidents occurring all at once. By right on time identification of instability processes and preventive strength increase, construction quality is ensured while unwanted conditions connected with traffic shut down are avoided. Far more comprehensive and more expensive construction works are also avoided.

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