Procedia Engineering
Volume 143, 2016, Pages 1051–1058
Advances in Transportation Geotechnics 3 . The 3rd International Conference on Transportation Geotechnics (ICTG 2016)

Problems with Railway Track Drainage in Finland

Juha Latvala, Antti Nurmikolu and Heikki Luomala
Tampere University of Technology, Finland.

juha.latvala@tut.fi, antti.nurmikolu@tut.fi, heikki.luomala@tut.fi

Abstract

Several studies have shown that water plays a significant role in phenomena that weaken track geometry. For instance, water may cause frost heave, thaw softening, attrition of ballast, and weakening of the load bearing capacity of a track. Functioning drainage can prevent water damage, but no researched data on the magnitude of the impacts exist.

Most of the Finnish rail network has been built in times when earthworks were kept to a minimum. Drainage generally functions well along new and renovated rail sections, but the situation is quite different with old tracks. If unevenness problems can be dealt with adequately by improving drainage, it is considerably more advantageous compared to massive renovation. The aim is to find out whether systematic improvement of drainage can produce significant savings in rail network maintenance.

The study examines the unevenness problems discovered along the Finnish rail network where the functioning of drainage is thought to be a major factor, while seeking solutions to the problems. This article presents the technical and administrative problems related to drainage in the Finnish rail network. Based on observations made so far, even basic drainage solutions are beset with problems since e.g. ditches are not cleaned with sufficient regularity.

The on-going study aimed to determine the impact of drainage on track unevenness at monitored sites. However, the method did not work as expected since no suitable sites, where other significant measures had not been carried out in connection with drainage renovation, could be found along the rail network. Moreover, it was difficult to get information about earlier renovation measures.

It can be said already at this phase of the study that drainage maintenance should be improved. There are also problems with drainage assessment methods which consist mainly of visual inspection instead of more sophisticated methods. Subjective assessment methods and maintenance contracts that call for maintenance 'as required' easily lead to postponement of maintenance measures.

Keywords: drainage, drainage monitoring, track maintenance, frost heave, track geometry

Selection and peer-review under responsibility of the Scientific Programme Committee of ICTG 2016

doi:10.1016/j.proeng.2016.06.098

1 Introduction

In recent years Finnish rail networks have suffered from unevenness problems that have significantly disturbed rail traffic. Frost heave and thaw softening – which lowers the load bearing capacity of the track during thaw periods – are among the phenomena that cause track deformations. For instance, recent studies at TUT have shown that the moisture condition of a railway embankment has a significant impact on track frost heave (Isohaka, 2014: Impact of water availability on frost heave) and can lower load bearing capacity especially during thaw periods due to softening (Metsovuori 2013: Thaw settlement as the cause of track unevenness). Many international studies also verify the role of water in the behaviour of soil materials (e.g. McGaw 1972; Guthrie & Zhan 2002; Guthrie & Hermansson 2003; Selig & Waters 1994; Hermansson & Guthrie 2005; Otter 2011; Mamou 2013). In connection with the *Frost damaged tracks renovation project (ROPE)* of the Finnish Transport Agency, inadequate drainage was almost always found to contribute to frost heave to some extent.

The assessment/quantification of the benefits of more effective drainage has, however, proved challenging. For instance, it is difficult to devise assessment and classification methods for the functioning of drainage, and to determine the magnitude of the change in the moisture condition attainable by more effective drainage and the advantageousness of different renovation alternatives. The overall aim of the on-going ‘Technical and economic efficiency of improved drainage of existing rail lines’ study at Tampere University of Technology is to provide a reasoned assessment of the impacts improved drainage can have, and the conditions under which it is technically and economically justifiable to repair track unevennesses by improving drainage. The study began in autumn 2014 by an examination of the present state of drainage, and it will continue until the summer of 2016. The study was commissioned by the Finnish Transport Agency which also finances it. The results and methods presented in this paper are an interim report on the state of the research project.

Monitored sites are used to examine the impact of different drainage solutions and the most common drainage-related problems along the rail network. The functioning of track maintenance is examined from the administrative and technical viewpoints. The situation in track maintenance has been examined e.g. by interviewing railway track managers/maintainers. The data produced by the *Frost damaged tracks renovation project (ROPE)* of the Finnish Transport Agency were also utilised. Calculational modelling was also used in an effort to model a track structure drainage system. Its aim was to reveal the impact of different drainage solutions on the moisture condition of the railway embankment.

2 Impact of Water on Behaviour of Track Structures

Natural materials always contain water. The amount of water influences significantly the behaviour of materials and thereby the functioning and durability of an entire earth structure. The impacts of water can be divided into deformations due to frost heave and phenomena related to deformation of unfrozen soil.

Guthrie & Hermansson (2003) examined the impact of water on frost heave by laboratory tests. Their results indicated that the water required for frost heave to occur originated mainly from an eternal source. However, in some instances the water contained in a material may become redistributed as it freezes so that actual frost heave may occur within the material without extra external water. The water content of the sample also plays a role. Guthrie & Hermansson continued their study in 2005 as they looked more closely at the impact of the distance to the water surface on frost heave. It involved testing frost heave in a silty sample using different water levels from 300 mm to 150 mm measured from the bottom of the sample. Lowering of the water slevel by 150 mm decreased frost heave by 24.1% which is a significant result. Naturally, without extra water the difference was even greater. Based on the results, they also concluded that improved drainage can reduce frost heave considerably in embankment structures. Corresponding results have also been received earlier e.g. by McGaw (1972) who tested the impact of the distance to water surface on frost heave in several materials.

The matter has been examined in Finland e.g. by Isohaka (2014) in his study *Impact of availability of water on frost heave*. He used frost heave tests and field data to provide a comprehensive explanation of the impact of extra water on frost heave. The frost heave test results showed the significance of the distance between the frost limit and the water level for frost heave in a material. On the other hand, in the case of materials highly susceptible to frost heave, their moisture content could also cause detrimental frost heave. Thus, the results were very similar to those of Guthrie & Hermansson.

The thawing of a frozen structure in spring also increases the risk of unevenness problems. As thawing begins, the deeper structural layers are still frozen which prevents water from flowing down from the upper layers which may result in oversaturated soil (Guthrie & Zhan, 2002). That naturally lowers the bearing capacity of the structure. Metsovuori (2013) has investigated the matter as it relates to the Finnish rail network. His study also indicated that reduced stiffness due to extra moisture causes permanent deformations.

Water content does not have an impact only on things related to the freezing of soil. Surplus water in a structure may cause ”mud pumping” which weakens it and leads to attrition of ballast (Selig & Waters, 1994; Nurmikolu, 2005). Clay pumping in subsoil is not a common problem in Finland because of thick structure layers. Water also affects the behaviour of the materials of a structure – which is a quite extensive and complex subject area. In any case, it can be said that moisture content affects e.g. the suction pressures occurring in the unsaturated zone (Otter 2011, Mamou 2013) and friction between soil particles. It is also clear that through these various impact methods water content also affects the shear strength of soil. Based on the literature review by Brecciaroli & Kolisoja (2006), an increase in water content also weakens the durability of a structure against repeated loading.

3 Present State of Drainage

The drainage arrangements of new and renovated rail sections are generally in good condition unlike those of old sections. A significant portion of Finnish tracks were built at a time when keeping earthworks to a minimum was important, which is why tracks were often laid on flat ground on top of thin structural layers. The properties of old tracks were sufficient for the speeds and axle loads of their day. Then delays did not block completely the flow of traffic and prevention of permanent deformations was not considered as important as today. The great structural differences are the reason for the various types of drainage-related problems.

The *Frost damaged tracks renovation project (ROPE)* carried out in the last few years by the Finnish Transport Agency has systematically mapped sites where track unevenness problems occur repeatedly (Silvast et al. 2013). The situation at the sites has been examined by modern methods (ground penetrating radar, digital video, laser scanning and track inspection data) and traditional field inspections. In the ROPE project problems at the sites were classified and more attention was paid to the functioning of drainage than earlier. Bold experimentation with lighter renovation alternatives was also experimented with in planning renovations, such as improved drainage, in case drainage at the site was clearly inadequate. This study assesses the site-specific results and related problems revealed by ROPE analyses conducted in two different years. Currently, site-specific reports give the most accurate picture of the problems besetting the Finnish rail network.

It is important to understand that problem sites often suffer from many problems, drainage being one of them. Often it also difficult to estimate how the situation changes if an attempt is made to remedy a defect. Many of the sites of the ROPE analyses also often suffered from several different problems.

Many problems are related to soil and rock cuts where structural layers are thin and drainage depth is shallow (Fig. 1). Old materials also cause problems since they may include water-retaining layers. At places drainage is missing completely or does not function as planned. The drainage systems of stations also have major shortcomings. Many sites were also located on soft ground where the track sank creating an unevenness problem in the transition zone. Moreover, points of discontinuity, such as culverts and transition wedges of bridges, often caused unevenness problems.

Fig. 1. Track in a cut. Drainage of the area is inadequate and recurrent problems of unevenness have been observed at the site.

A questionnaire study concerning drainage directed at maintainers in early 2015 revealed various problem sites. The problems varied by rail section, which was to be expected, since the level of maintenance varied and conditions differed by geographical location. The study found numerous problem sites along the network in need of renovations which had been ignored. The existence of ditches beyond the track area is problematic for drainage since cleaning and maintaining of just the ditches within the track area is then not sufficient. It requires assessing, planning and making functional the present overall drainage system of the entire area. There are also sites along the rail network where ditches cleaned a few years ago look like they had not been cleaned in ages. That would seem to indicate that cleaning should be considerably more regular, and it should be studied whether it is possible to improve the sites' drainage so that the problems do not recur in a few years. The functioning of covered drains and ensuring their condition is also problematic. The study also indicated that more attention needs to be given to sprouting by the track and beyond. In favourable conditions sprouting occurs very quickly and the current clearing rate is not necessarily sufficient. The study did not determine whether the sprouting problem was due to contractual reasons or prioritisation by the maintainer. However, there were indications that sprouting was not being dealt with as required by the general maintenance guidelines. Thus, many of the problems are related to tasks that should already be performed based on existing maintenance contracts.

4 Assessment of Drainage Solutions Based on Monitored Sites

In connection with the study, sites were sought along the track which would allow examining the impact of improved drainage on unevenness. The aim was to find sites where drainage had been improved 2–10 years earlier with no other major measures having been performed at the sites. Another aim was to compare the difference between the impacts of light drainage improvement (e.g. cleaning of ditches) and large-scale drainage improvement.

The intention was to use non-desctructive methods like field inspections, the track image service, and the Rail Doctor program developed by Roadscanners. Depending on the site, the program can use laser scanning data, ground penetrating radar data, a geological map, digital videos shot from several different angles, and EMMA measurement data. Of the data produced by the EMMA track inspection vehicle, mainly the elevation deviation data were used, but in some instances also the deviation in alignment data.

The finding of monitoring sites proved more challenging than expected. It became apparent that drainage had often been systematically improved, generally in connection with renovations, when other heavy maintenance measures on the track structure had also been carried out, such as sieving of the ballast layer. It is clear that in the case of sites like that, it is difficult to point out the impacts of a change in drainage on the performance of a structure. It was also surprisingly difficult to find the actual data on the sites. That is probably mainly due to the fact that the various actors responsible for maintenance are replaced by others as a result of competitive tendering. Railway track managers have also changed whereby memory-based history data on suitable sites are lost. The situation can also probably be partially explained by the content of maintenance contracts since drainage structures are renovated primarily only e.g. when flow has weakened essentially. Then the extent of renovation is generally quite small. There were also clear indications that the priority given drainage maintenance had at some sites been quite low. Yet, some sites were investigated, but based on the results, their problems were mainly due to factors other than drainage.

Part of the sites of the ROPE surveys are well suited for use as monitored sites since data on well performed measures and preceding problems exist. Yet, the challenge of ROPE sites from the viewpoint of this study is that there is not yet enough data on the change in the situation after the performance of a measure. However, these sites should be used in follow-up studies to verify the true effects of changes in drainage.

5 Development of Drainage Methods

Traditionally, drainage surveys have been based primarily on visual inspection. Measurements have been made mainly in connection with planning. This type of assessment makes comparison of sites and monitoring of the development of the situation problematic. Modern technology provides more opportunities for assessing the functioning of drainage so that it is not based merely on the competence and view of the assessor. Laser scanning is the new method that appears most useful for drainage assessment as it allows creating a clear digital terrain model of the site. It also allows collecting numerical data on e.g. the depths of ditches and changes in them over time.

The Finnish Transport Agency's *Rato 13 Track inspection guidelines (2004)* define the compulsory inspections for the rail network. The number of inspections varies by maintenance level, but all rail sections are generally subject to a walking inspection at least 1–2 times per year. Inspections are also made from rolling stock. As far as drainage is concerned, inspections are to focus e.g. on the functioning of side ditches and culverts, vegetation and the condition of embankments. Thus, the functioning of drainage is, at least in principle, assessed several times a year. A questionnaire study was also directed at railway track managers and maintainers to further clarify the matter. The responses indicated that assessment of drainage was based on the visual inspection methods set in the guidelines. No more advanced inspection methods were used.

The attitudes of track managers and maintainers toward current inspection methods and their development revealed by the questionnaire study divided roughly in two categories. Some considered the existing drainage inspection methods adequate with no need for more regular and thorough assessment. Others wanted to improve drainage monitoring. These differences of opinion are probably, at least partly, the result of regional differences since the situation with the high volume and high maintenance level tracks in the Capital Region is completely different from that of the low volume tracks up north.

The responses of regional managers and maintainers reflect the typical problem related to visual inspection: perceptions of the functioning and quality of drainage vary according to the assessor. It is also difficult to issue guidelines since it is hard to determine when the flow in the ditch has weakened substantially or there is too much vegetation in the ditch. Definitions are also partly site-specific as the consequences of drainage problems differ by site. Yet, the study indicates that drainage problems need to be studied further. Other methods, independent of the view of an assessor, are also necessary to allow objective assessment of changes in the drainage system based on measurements.

6 Administrative Problems in Drainage Maintenance

The Finnish rail network is divided into 12 maintenance areas. The level of track maintenance varies by rail sections: high volume main lines are maintained better than low volume sections. Maintence companies are selected by rail sections on the basis of competitive tendering which means that companies assume responsibility for maintenance for the term of their contract. Maintenance is done under supervision of track managers. The Finnish Transport Agency has prepared instructions for maintenance, which together with a maintenance contract, set out the tasks to be performed as part of maintenance. Consequently, there has been considerable variation in the maintenance of drainage structures.

The study analysed seven maintenance contracts from the viewpoint of drainage. Five of them call for maintenance only ‘as necessary’. The Transport Agency’s general guidelines define the criteria for when maintenance is required which include substantial weakening of flow or sprouting. In two more recent contracts the issue has been clarified as to contractual practice by setting distinct minimum requirements for ditch cleaning. Only one contract calls for the cleaning of all ditches during the contract period. In the best contract other factors promoting drainage have also been improved, such as removal of trees too close to the track. The contracts awarded for maintenance areas that were not examined in connection with the study are similar to the five analysed ones where maintenance is performed only ‘as necessary’. Accurate recording of the tasks to be performed is in the interest of both the client and the maintainer, as it leaves no ambiguity about the actual number of required tasks, which makes tender calculation and work supervision more straightforward. The new maintenance contracts should be used as models also in other maintenance areas while mere need-based definition should be abandoned.

7 Conclusions and Next Phases of the Study

It is clear already at this phase of the study that several sites along the Finnish rail network suffer from drainage problems. The exact impact of these problems is still difficult to assess since the study of the monitored sites proved difficult. However, the situation will improve in a few years as data on the renovated ROPE sites becomes available. The next phase of the study will deal largely with modelling aimed at determining the extent to which functioning drainage can affect the moisture condition of the embankment. Computational modelling will be used to determine e.g. the impact of ditch depth or one-sided drainage on the embankment, as well as the influence of different materials on the moisture condition. The results will be used to assess the true role of drainage problems in the occurrence of unevenness problems.

It is also clear that drainage management is inadequate at many sites. That is partly due to the conditions of maintenance contracts as well as the ambiguity of guidelines. Yet, it can be stated that the measures to be performed ‘as necessary’ have not been performed even when the set criteria are met. In future, new assessment methods should be introduced, such as laser scanning, in order to be able to produce numerical data on the state of drainage. Thereby a change in the state of drainage can be reliably established which makes it easier to target measures. Another alternative is to draw up maintenance contracts that clearly define the minimum number of ditches to be cleaned annually. The current ‘as necessary’ contracts should be abandoned unless they are tied e.g. to data and limit values produced by laser scanning.

References

Brecciaroli, F. & Kolisoja, P. 2006. Deformation behaviour of railway embankment materials under repeated loading: Literature review. Publications of Finnish Rail Ad-ministration A 5/2006. Helsinki, Finnish Rail Administration. 201 p.

Finnish Transport Agency. 2004. Ratatekniset ohjeet (RATO) osa 13 Radan tarkastus (in Finnish). 51 s. + 23 liites.

Guthrie, W.S. & Hermansson, Å. 2003. Frost heave and water uptake relations in variably saturated aggregate base materials. Transportation Research Record: Journal of the Transportation Research Board 1821, 13– 19. 22 p.

Guthrie, W., & Zhan, H. 2002. Solute effects on long-duration frost heave behavior of limestone aggregate. Transportation Research Record: Journal of the Transportation Research Board (1786). pp. 112-119.

Hermansson, Å. & Guthrie, W.S. 2005. Frost heave and water uptake rates in silty soil subject to variable water table height during freezing. Cold Regions Science and Technology ,Volume 43, Issue 3, pp. 128–139.

Isohaka, M. 2014. Influence of water availability on frost action in railway track structures. Master of science thesis (in Finnish). Tampere University of Technology, Dept. of Civil Engineering. 132 p. + 7 p. app.

Mamou, A. 2013. Effects of principal stress rotation and drainage on the resilient stiffness of railway foundations. Doctoral dissertation. University of Southampton.

McGaw, R. 1972. Frost Heaving Versus Depth to Water Table. In Highway Research Record 393. Washington DC, Highway Research Board, National Research Council. pp. 45-55.

Metsovuori, L. 2013. Thaw settlement as cause of railway track unevenness. Master of science thesis (in Finnish). Tampere University of Technology, Dept. of Civil Engineering. 93 p.

Nurmikolu, A. 2005. Degradation and frost susceptibility of crushed rock aggregates used in structural layers of railway track. Doctoral dissertation, Tampere University of Technology.

Otter, L. 2011. The influence of suction changes on the stiffness of railway formation. Doctoral dissertation. University of Southampton.

Selig, E.T. & Waters, J.M. 1994. Track geotechnology and structure management. London, Thomas Telford Publications. 446 p.

Silvast, M., Nurmikolu, A., Wiljanen, B. & Mäkelä, E. 2013. Efficient track rehabilitation planning by integrating track geometry and GPR data. Proceedings of the 10th International Heavy Haul Conference, New Delhi, India, February 4-6, 2013.