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ASPHALT PAVEMENTS OF TRAM TRACKS – CATALOGUE OF DEFECTS AND FAILURES

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Abstract

Pavement of tram track is an important part of its structure. Development of defects and failures significantly decreases the running comfort and safety of road traffic. Reparations of undesirable defects of pavements increase life cycle costs of tram track structures. Shortening of lifetime adversely influences the economic efficiency.
Defects and failures of pavements of tram tracks have been monitored by the Department of Railway Structures and Constructions and the Department of Road Structures in cooperation with Brno City Municipality for more than ten years. Many of the tram track sections with asphalt pavements in different technical stage have been monitored. Nevertheless one section has been continuously monitored more than seven years including the construction works.
The main result of these investigations is a catalogue of defects and failures of asphalt pavements. These defects and failures are typical for tram track. The catalogue supplements the catalogue for general defects of asphalt layers. The catalogue summarizes most of defects and failures which are figured out in the photograph annex. The catalogue also provides information about the main reasons and mechanisms of defects development. The recommendations for maintenance and reparation works are included to the catalogue too.
These days the main solved task is designing of a modern structure for tram tracks of Brno City. This design takes into consideration all experience from the monitoring of asphalt pavements. The design is aimed especially to noise and vibration reduction and in regard to reduce life cycle costs.
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Keywords: tram track, noise, vibrations, environmental protection

1 Introduction

The surface of tram track is an important part of its structure. A development of defects and failures on the pavement surface decrease the ride comfort and influence unfavourably the traffic safety. Dynamic load components are increasing. The higher dynamic load conduces to faster development of defects which induce even structures failures and unfavourably influence track geometry parameters.
Reparation of undesirable defects of pavement increases the total cost of a tram structure. A reduction of the lifetime contributes proportionally to a reduction of the economic efficiency. The selection of the optimal structures of a tram track surface and recommendations to their

next improvement of the quality are carried out with the help of monitoring and diagnostic of defects and failures of a tram track surface.
The subject of this paper is a proposal of a catalogue of asphalt surfaces defects and failures. Recommendations for modern structure of tram track with anti-noise and anti-vibration structure components are introduced at the end of the paper.

2 Long-term monitoring of asphalt pavement defects of tram track

Asphalt surfaces of the tram tracks in Brno have been built up as a common structure since 1993. A lot of defects of the surfaces have appeared since the time. The catalogue of asphalt pavement defects is focused on a categorization of these defects. The catalogue also solves their feasible reasons and mechanisms of a defect development and suggests ways of their maintenance and reparations works.
A section for monitoring of a development of tram track defects and failures was chosen which was introduced into service during summer 2003. It is monitored regularly in the spring and autumn season since that time. The individual types of the incident defects and failures were summarized and categorized. The aim of the next monitoring is a description of supposed defect development due to traffic loads and climatic conditions in winter season.
The development of significant failures of asphalt surfaces can be prevented by effective precautions. It is necessary to describe the reasons of the failures and mechanisms of their development for decision about the use of preventive maintenance works. The long-term monitoring of asphalt surface defects development of the monitored tram track provides valuable information which is used for draft of the Catalogue of Asphalt Pavement Defects of Tram Tracks. A systematic monitoring of failures and a proposal of appropriate maintenance and reparation works provide an instrument for a decrease of the total life cycle cost of structure.

3 Proposal of catalogue of defects and failures

3.1 Generally

A failure classification, a failure inspection is the aim of the catalogue for a proposal of maintenance and reparations of asphalt pavements which are in the connection with a grooved rail which are loaded by rail vehicles, road traffic and climatic conditions. The catalogue follows the Czech standard ČSN 73 6114 and the specifications TP 170 Pavement design and TP 82 Catalogue of the degradation of asphalt pavement [1].
Every occurred failure has its relevancy in the term of ability to operation and pavement bearing capacity. The relevancy has an influence on operation safety on a road, on speed, fluency, economy and comfortable of traffic operation and on a deterioration of a pavement structure.
A performance of operation ability and pavement bearing capacity is possible to describe by a qualitative and quantitative report and a failure evaluation. A failure register is added to measured characteristics of a neighbourhood of a connection between rails and pavement surface. A qualitative failure classification takes into account a stricken thickness of pavement courses. A removal of failures in surface courses of a pavement in a neighbourhood of rail is the cheapest and brings the largest removal of losses in urban road traffic.
An increase of failure quantity is representative for a development of common occurrence of failures. Therefore it is important to take care of failure quantification (i. e. the number of failures per the stricken area of the monitored pavement) during a failure classification. A failure development is regularly spread along the rail as we monitored failures which originate at the grooved rails-asphalt surface courses interface. The length of failure is in this case an important quantitative parameter.
Furthermore the catalogue is coupled with "Standard technology of maintenance and reparations" which solves the questions of detailed investigations of tram track structures with as-

phalt surface which are appropriate to maintenance and reparation including a determination of a reason of incurred failures and a proposal of technologies for their removal. Appropriate technologies of maintenance and reparation are assigned to the defined cause of failure by means of the technology standard.

The following failure mechanisms were found out during the long-term monitoring of failure occurrences at rail–asphalt mixtures interface:

a The degradation of a contact rail with asphalt wearing course belong to the most common defects. The problematic contact between an asphalt wearing course and grooved rail creates an open leaking structural joint. Rain water and impurities, which induce longitudinal uplifts of an asphalt wearing course above the rail level, infiltrate between an asphalt course and a rail. Furthermore rain water infiltrate along the rail web and it is a source of below described failures.

b The degradation of the function of rail expansion joints occurs almost in all these mechanisms unfortunately. The expansion joint is unfavourable in regard to track axial forces in continuous welded rail. The use of an expansion joint in an asphalt pavement is very unsuitable according to visual inspection results and a state estimation of expansion joints within 5 years. It is necessary to clean the joint between rail ends when an expansion joint is installed. If the joint is fouled a lateral rail imperfection happens which has negative results for monitored asphalt pavements.

c The deep corrosion and the loss of mass from a wearing course result from a damage connections between aggregates in an asphalt course by effects of static and dynamic load, water action, asphalt degradation and aggregate crushing. First of all asphalt binder (mixture from asphalt and aggregates up to 2 mm) dislodge from asphalt wearing course especially if it contents little binder and therefore it is friable

These failure mechanisms lead to these main types of asphalt surface failures: mosaic cracking, pot-hole in wearing course, transverse cracking and longitudinal cracking (thin, wide, branched), spalling, local fall, see Table 1.

The basic measures which the lifetime of asphalt surface of tram track extends are:

- optimal (maximal) compaction of the asphalt mixtures;
- flexible asphalt sealing between the rail and pavement surfacing;
- remove of expansion joints in continuous welded rail track.

Table 1 The summary of the designed catalogue sheets.

Name of catalogue sheet	Name of catalogue sheet	Name of catalogue sheet
Abrasion of construction joint	Transverse branched cracking	Pot-hole in the wearing course
Deep corrosion	Longitudinal thin cracking	Transverse rutting, slide
Degradation of contact rail with asphalt wearing course	Longitudinal wide cracking	Rutting
Stripping of binder by construction joint	Longitudinal branched cracking	Local fall
Stripping of aggregates by construction joint	Mosaic cracking	Spalling of the wearing course
Transverse thin cracking	Alligator cracking	Patching
Transverse wide cracking	Degradation of function the rail dilatation mechanism	Filling of the construction joint

A compaction of asphalt mixtures up to rail head without additional arrangements is an origin of future difficulties and failures. An asphalt mixture (a mixture of aggregates and asphalt binder) is an inhomogeneous material. A connection between this material and steel rail is therefore problematic also in the case of an implementation of a side surface coating which improves a rail adhesion. A cutting off a stripe of compacted asphalt mixture along the rail

in the distance of c. 20–30mm, a remove of the mixture and a filling of the space by asphalt compound is a significantly better resolution.
Ever catalogue sheet contents a basic failure description and a description of its appearance. Analogous failures, a failure cause, its development and a brief proposal of reparation are presented. A photo of a basic example is in a catalogue sheet. One page of additional photos completes most of the sheets.

3.2 Failure inspection

The quality failure classification is the first presumption of a right proposal for maintenance or reparation works. The next presumption is a reliable assessment of a failure extent, a surface failure appearance, a length of failures and a failure frequency. A number of factors have an influence on the quality of a failure inspection, e. g. climatic conditions, the traffic load composition, the frequency of rail traffic, the quantity of crossings etc. The failure inspection is not possible to carry out during unfavourable conditions, especially when the road is snowy or fouled (mud, fill), during heavy rain and thick fog. Only trained workers with experience can carry out the failure inspection.
A proposal of a form for a failure registration during a walk through inspection is a part of the catalogue. A method of a stationing measurement and a method of a register of failure parameters are described in the proposal of failure inspection.

3.3 Utilization of failure catalogue for determination of maintenance and reparation of tram track asphalt pavements

The technology of the current and continuous maintenance and local pavement reparations is proposed according to the type, the frequency and the range of failures. Technologies are presented in each catalogue sheet of a failure. The failure catalogue can be used without additional tests and investigations at a proposal of maintenance and local reparation. The review the failures by additional tests which are to be carried out by a special laboratory or workplace is recommended when a proposal of maintenance and local reparations are more complicated and more extensive. Instructions for the selection of maintenance and reparation technology are contained in the catalogue.
Economic contributions of maintenance and reparations during a selection of an appropriate technology are taken into account. A continuous maintenance technology is chosen which has the value of the quotient “the cost of continuous maintenance” / “the maintenance lifetime” the lowest. The main factors are local climatic conditions, traffic load and work quality. The next aspects which are necessary to take into consideration are especially a road category, aesthetic, ecology and other contributions, technological, local and other restrictions.

4 Modern design of tram track structure

These days the main solved task is designing of a modern structure for tram tracks of Brno City. This design takes into consideration all experience from the monitoring of asphalt pavements. The design is aimed especially to the noise and vibration reduction and in regard to reduce the life cycle costs.
The reduction of noise and vibration levels caused by rail transport on tram tracks is possible due to rail damper, absorbing mats, mats on a tram track surface, resilient rail fastening or by constructions of anti-noise walls.
Absorbing rail damper can be of different shapes. They can cover whole rail profile (exception of the running table or the running edge of a rail) or only a part of the rail profile, especially a rail web or a foot rail. This solution is effective especially in regard to reduction of noise emission into track vicinity. Ballast mats are installed in tram track structures regularly both

on the horizontal surface of construction bearing layer and on vertical surfaces of sides of tram track structure. This solution is effective especially in regard to reduction of vibration transmission into track vicinity.
Absorbing mats on a surface of tram track (e.g. grass or rubber mats) are effective in regard to noise emission but inefficient in regard to a vibration transmission. Absorbing mats are usually not aesthetic but they could effective in regard to an optical differentiation of surface parts of roads which are not appointed for passage by cars or trucks.
A resilient rail fastening has positive influence not only to noise or vibration emission but especially to lifetime of the tram track structure. Because of constant clip forces act on a rail the resilient rail fastening reduces significantly rail shifting. So the risk of an occurrence of critical parts of track from point of view of stability is negligible. A special very soft rail fastening can help to deuce a development of long-pitch corrugation as well as common rail corrugation which decrease evolution of noise.
The new design of tram track structure for Brno city includes most common and available anti-noise and anti-vibration components. The design was proposed in regard to the experience obtained from the monitoring of asphalt pavements of tram tracks. The design of modern tram track structure takes into account principles that components and their sets should be commonly available in the market in the Czech Republic. A construction of tram track should be as possible quick and easy. The maintenance cost should be small and life cycle costs should be reduced especially thanks to extended lifetime. The introduction of anti-noise and anti-vibration components increases investment budgets. But the most important factor for life cycle costs is lifetime of tram track structure.
The structures were designed for different design situations. The basic type is tram track with asphalt pavement of course. Track with grass pavement should be used at such situation in which the aesthetic factor is essential. A track pavement which is travelled by cars only exceptionally could be constructed from concrete slab panels. All structures were designed in two alternatives: with an absorbing mat or without an absorbing mat.
The examples of tram track design are on Fig. 1 and Fig. 2. A prefabricated concrete slab or a monolithic concrete slab is designed as track base. The construction of track by method “up to down” is proposed in the case of the monolithic concrete slab.

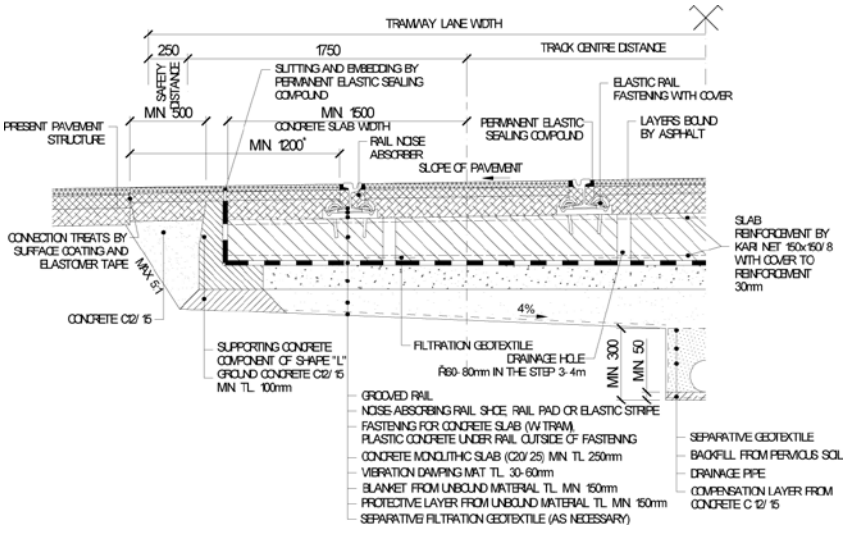

Figure 1 The design of tram track with monolithic concrete slab with absorbing mat

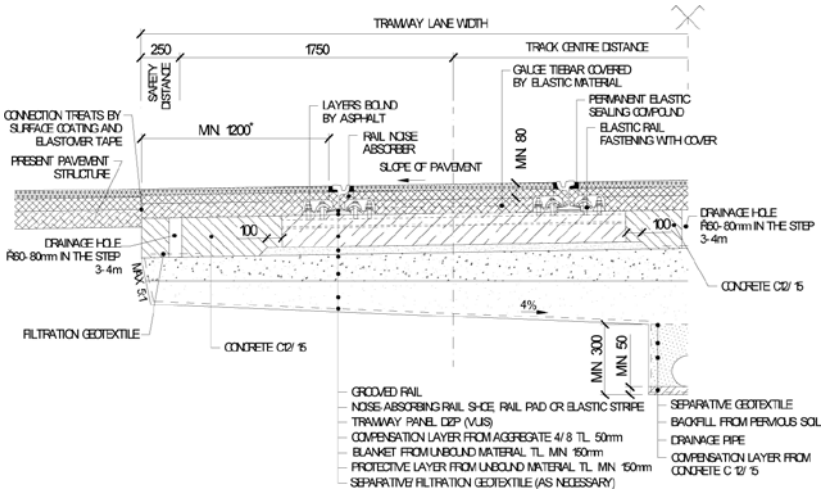

Figure 2 The design of tram track with prefabricated concrete slab without absorbing mat

5 Conclusion

The defects free performance of tram track can't be ensured during whole lifetime of course. But such precautions and technical solution are desirable in order to maintain the structures without defects or failures. It is evident that it is not effective to let asphalt pavement in service after the end of its lifetime. The published catalogue of defects and failures should help to qualify the defect or failure and briefly recommend a proper remedial procedure.

The design of tram tracks respects currently used tram track structure in the Brno city as well as structures in other cities in the Czech Republic. All designed structures consist of common, in the Czech Republic available, components. The technical solutions for all design situations correspond to state of art.

The use of rail dampers and absorbing foot profiles were proposed for all designed structures. The basic component of the modern tram track structure is resilient rail fastening. This rail fastening is typical by the set of standard elements. All structures were designed in two alternatives: with an absorbing mat or without an absorbing mat. We recommend the use of absorbing mats in regard to significantly higher investment cost in such situations in which the effective protection of track vicinity against vibration is necessary.

The economic analysis evaluated the increase of investment costs due to the introduction of anti-noise and anti-vibration components. In regard to the expectable extended lifetime the increase of life cycle costs is not as considerable as the increase of the investment costs. The cost for current structure with prefabricated concrete slab could be comparable with newly designed structure with monolithic concrete slab from the point of view of life cycle costs.

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