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# Road and Rail Infrastructure V

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## ISSUES IN DESIGNING PAVEMENT SURFACES FOR PUBLIC TRANSPORT LANES

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### Abstract

Traffic volumes have been simultaneously increasing in both individual and public transportation, which cause troublesome traffic jams in our cities. Separated track is provided for track-based transportation systems, so they don't have conflict with road traffic, but the buses and trolley-buses depend on the traffic circumstances. Covert tramway tracks provide protected routes between the stops for buses, moreover, it is an important point of view for sustainable land uses. The public transportation lanes, where the same surface is used by trams, buses and trolley-buses, mean the spread of a new view in transportation and urban design. In a short time period after installation the new tramway tracks, pavement structure problems appeared possibly due to bus and trolley-bus use. Since the appearance of the pavement structural problems, warranty works are often on these tracks. These works cannot be fulfilled on week and school days, so every summer they have to work on. From the operator's point of view, these warranty works are not convenient because every work needs traffic distraction and temporary traffic changes, which causes high costs on both operator and user sides. The aim of this research is to collect the tramway superstructures where these pavement problems appeared and to systematize them all by the observable failures in asphalt and concrete upper layers. After reviewing the tramway track design regulations and looking for new technologies, I would like to suggest new guidelines to design the future superstructures in this kind of traffic situations.

*Keywords: public transportation, common-used lanes, pavements, tramway tracks*

### 1 Introduction

One of the most important criteria when people select transport means is the time duration the travelling will take, which can be reduced in public transport by providing priority, shortening transfer time and improving its quality. Public transport lanes started to appear in Hungary several years ago, yielding an immediate benefit in the transport system, however, from infrastructure point of view they pose a constant source of issues for the operators especially when it comes to pavement surfaces.

The volume of traffic in our cities has been steadily increasing in terms of both individual and public transport which often results in unpleasant traffic jams for travellers. Rail-guided transport uses segregated tracks thus are less sensitive to traffic jams meanwhile buses and trolleybuses are much more prone to suffering from traffic jams due to common traffic surface they use shared with personal vehicles [1]. Rail-guided public road sections provide buses and trolleybuses with good opportunity to use these protected tracks between stops and the-

se are also beneficial from area usage point of view too, which are really important to manage in cities. Public transport lanes bring a new approach to traffic management when the same pavement surface can be used either by trams, buses or trolleybuses (Figure 1).



Figure 1 Trams, trolleybus and bus conjunction in Szeged, Dugonics square

## 2 Problem identification

### 2.1 Failure appearance in short time period

Several months, which is pretty short time, after re-building of road railways as part of the Szeged big project, pavement defects otherwise common on other public road surfaces, started appearing due probably to the load caused by buses that are travelling on these public road lanes regularly on time table basis [2]. There are several track sections in Budapest, too, on which certain extent of public transport also takes place in addition to road railways traffic, causing similar issues to appear just like in Szeged (Table 1).

Table 1 Visited and inspected public transport lane sections

Visited and inspected public transport lane sections	
Szeged	Budapest
Kossuth Lajos avenue	Krisztina boulevard
Tisza Lajos boulevard	Bartók Béla street
Anna-kút junction	Múzeum boulevard
Dugonics Square	Böszörményi street
	Ady Endre street

For basalt concrete pavement structure, the pavement defects appeared as cracks and in spite the road operator tried to manage these cracks with crack-eliminating technologies, the cracks developed further in each case. For pavement constructions built with asphalt wearing course, the most common defect is disjoining of asphalt from the bitumen filling and from the rail allowing water to enter which subsequently causes additional cracks and pot-holes. When observing the way the buses and trolleybuses pull off to stop in bus-stops I found that tires of the vehicle place burden typically on a narrow pavement band just 20-30 cm apart from the

rail outer surface due to the given vehicle wheelbase distance (tires included) and it is also observed that vibration induced by public road vehicles causes the highest load also within this 20-30 cm wide band to certain pavement structures built here (Figure 2).



Figure 2 General position taken up by bus tire on rail guided public road

Hungarian regulatory requirements have been fully observed during design phase: designers were able to choose superstructure systems by catalogue, for which the BKV's (Budapest Transportation Operator Ltd.) Yellow Book provided a guide for pavement surface selection (Szegeged Transportation Ltd. does not have own engineering specification system in place) [3]. In Hungary, superstructure systems can be built only if they have valid compliance test documented. These tests include both laboratory evaluations and calculation-based evidences that are used to determine characteristics and installation criteria for each system. Concrete base plates, which are fundamental structural elements of all pavement solutions, are sized in accordance with the Hungarian Standards and the Eurocode.

Rail-guided public road sections being investigated has been requiring repair work under warranty and otherwise continuously since defects started to appear, however these repair work cannot be done during school hours or working days due to the volume of traffic and this results in repair work to do every summer in Szegeged ever since from project take-over. This is not a convenient situation neither to the system operator or the city itself because it always implies diversions and temporary changes in traffic schedule, and raises additional costs for the operator and traffic users too.

## 2.2 Undamaged track slabs

Superstructure systems in Szegeged have been built according to national standards and conformity test requirements i.e. the first layer is made of 8-10 cm thick non-reinforced upper basalt concrete as wearing layer for rubber jacketed pavement surface. Under this layer, a reinforced concrete slab is installed with average thickness 27-30 cm. During construction, the trackage is suspended in place, aligned in proper direction and seating, then armoring is installed and finally the concrete track slab and wearing course layer are applied. There is no physical connection between the rubber jacket and concrete layers.

Pavement surface structure on Tisza Lajos boulevard in Szegeged and on Museum boulevard in Budapest utilizes a 2×4 cm thick asphalt wearing course and binding layer, meanwhile

bitumen or moulded rubber is poured in to fill the space between the chamber rubber elements extending to the railhead bottom plane and the asphalt layer. Base concrete and/or reinforced concrete track slab of 30 cm thickness has been installed in two layers beneath the asphalt layers. Normally, a separating layer (such as geotextile) is installed between the base concrete and reinforced concrete track slab.

In general, it can be said that each reinforced concrete track slab that were exposed during warranty work under the upper wearing course and binding layer is found undamaged, which is in line with common sense and was actually expected since their conformity is statically justified (most often upon the request of the operator or customer) which calculations include excess loads caused by road vehicles.

### 2.3 Road pavement defects on tramway tracks

As mentioned earlier, only pavement defects are affected, since, generally speaking, only the wearing course and binding layer and/or wearing asphalt and basalt concrete cover may suffer damages. These surfaces are in contact continuously with vehicles consequently these can be considered public road surface and in turn the defects emerging on those surfaces is considered typical public road surface defects (Table 2).

**Table 2** Summary of used pavements by pavement surface types

Used superstructure type	Location	Used road surface type	Road surface defects found
Wooden sleeper rail set in concrete	Szeged, Dugonics Square	10 cm rolled asphalt	Cracks, pot-holes
Filled-section rail, large panels	Budapest, Böszörményi street	18cm reinforced concrete slab	Cracks, chipping-out
Installed on base plate anchored using limited clamping force devices	Szeged, Tisza Lajos boulevard Budapest, Múzeum boulevard	2×4 cm rolled asphalt; 2×4 cm cast asphalt	Cracks, pot-holes
Constructed without using connecting elements and rail braces, rubber jacketed design, continuous rail bedding	Szeged, Kossuth Lajos avenue	8-10 cm basalt concrete (non-reinforced)	Cracks

In Szeged, the most common defect mechanism is the crack development with potential future aggravation that the operator attempt to avoid by carrying out crack-treatment work continuously. Starting point of cracks are generally seen at the corners where chips come off allowing further cross- and longitudinal cracks to develop which in turn create an extensive mesh-like cracking pattern over the entire surface (Figure 3). Reinforcement was not installed in the basalt wearing course layer during construction phase, and now, during warranty work phase, reinforcement and/or track slab anchoring has been taken place on selected concrete slabs upon customer request, which made the structure visibly more resistant to the heavy load caused by public road transport, however, it is noticed also that wavy wear marks appeared at several places on the top of railheads in this region.

The most common defect found on rolled asphalt pavements is the gap developing between the edge of pavement and the bitumen/rubber filler material along the rail, which is prone to turn into wide cracks or pot-holes in extreme cases (Figure 4). In addition, rail braces caused problems on the Tisza Lajos boulevard by allowing hard-spots development at these locations and preventing the structure from post-compacting, when at the same time it facilitated more cracks to develop on the pavement in the close vicinity.

Cast asphalt wearing layer has been used in Szeged, which tends to create troughed tracks (Figure 5) and similarly to rolled asphalt wearing layer, there can be seen here, too, disintegration or openings along the rail.





Figure 3 Basalt concrete layer with crack treatment applied (Szeged, Kossuth Lajos boulevard)



Figure 4 Pavement defects starting from rail pavement connection (Budapest, Múzeum boulevard)



Figure 5 Troughed track and disintegration along the rail (Szeged, Anna-kút junction)

## 2.4 Heavy bus vehicle loads on tramway track surfaces

Based on the Szeged local public transport timetable two sections were selected to observe transport, these are the section built with basalt concrete wearing layer between stops on Kossuth Lajos Avenue, Vásárhelyi Pál street and at Rókusi church, and the section built with rolled asphalt wearing layer between Tisza Lajos boulevard, Dugonics square and Centrum Hypermarket. Public transport lanes on the Kossuth Lajos boulevard is used by buses and rail-guided public road vehicles, meanwhile priority lanes on the Tisza Lajos boulevard are used by buses, trolleybuses and rail-guided public road vehicles. On the Kossuth Lajos Avenue, 10 buses and 2 rail-guided public road vehicles circulate in peak hours (between 7am and 8pm), it means 16 buses and 13 electric vehicles in one direction every hour. This number is higher on the Tisza Lajos boulevard: in peak time (between 7am and 8pm) it means 16 buses and 24 trolleybuses in one direction (latter ones are of articulated, most of the time) and an additional 9 tram-lines pass through this area too [4].

Let's take this 40 buses as starting data to calculate designed traffic (TF) value according to Road Technical Specification "Sizing and Strengthening of Asphalt Pavement Surfaces" (Útügyi Műszaki Előírás (ÚME), "Aszfaltburkolatú pályaszerkezetek méretezése és megerősítése") which provides (TF) value of 21 352 500  $F_{100}$  unit-axle-passes. Based on the calculated value, this road section falls in class "K", especially heavy traffic load.

Let's consider the reinforced slab layers installed under the rail of the pavement surface is equal to the weak concrete quality typically used in road constructions, in which case the ÚME prescribes asphalt layer of 19 cm in total thickness, comparing against the wearing- and binding layers thickness of 4-4 cm used on the Tisza Lajos boulevard.

## 3 Possible solutions for the dedicated problems

Based on the experiences collected, possible solutions might be sought for by segregating the problems into three groups (Figure 6). The three main groups would consist of one set where most of the problems occur in relation with connection between rail and pavement, one set where the structure and quality of wear and binding layers cause problems, and one set where the regulatory tools need focus.

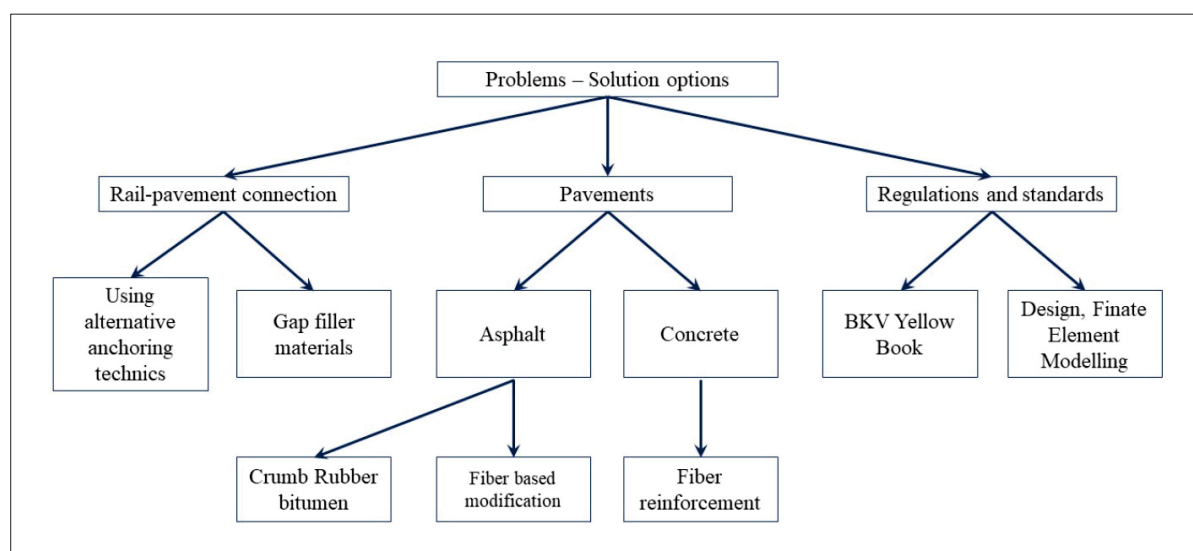


Figure 6 Diagram for summarizing the main problems and their solution options

Pavements to be used on public roads are described in detail in the Road Technical Specification allowing sizing of a given pavement structure section to complete in an easy way. Applicability of road rail superstructures is verified by conformity tests, but suitability of track

slabs built in the substructure must be verified by performing static calculations (for which it is needed to take into account the load effect by road traffic). There are two well-detailed but separate road and rail specifications. However, interoperability between the two specifications is not ensured in principles, so neither the Road Technical Specification nor the Road Construction Conformity Testing and Standards offer solution for pavement structures that would be suitable to use for public traffic lanes, particularly not for filling layers applied in rail tracks. It is important to note that pavement cannot be considered geometrically homogeneous at all if we approach the issue from road pavements point of view, neither horizontally nor vertically due to the rails and their environment, consequently it cannot be guaranteed that the catalogue system which is appropriate for pavement layers is suitable also for the intertrack area. It is therefore necessary to examine what other methods can be utilized in the future based on the principles of analytic track construction sizing technology to allow us to take into account geometrical constraints, inhomogeneity of the pavement structure and increased stresses.

For technology devices, many successful or less successful methods are known to operators, as they have tried several options during warranty work. As an example, Densiphalt, which was successfully applied first for industrial floors, was used to repair pavement on the bus stop area of Dugonics Square in Szeged, though it started to crumble in 2-3 months time. Later, reinforced concrete layer was spread as a wear layer, which demonstrated a good result in the subsequent 3 years, but its construction costs are higher than the solutions applied so far. Later on, this technology was used also to renovate Bartók Béla road, which yields further positive results in this regard. Using similar approach, modifiers can be used in asphalt, which may help to increase load bearing capacity of the asphalt mix even if facing geometrical constraints and increased stresses. Moreover, the efficiency of the working-in process can be increased too. Vegetable fiber based modified upper pavement layer incorporated in rail-guided public road in Sweden, but also in Graz were used to build track sections with modified mixtures. SMA asphalt mixtures (crushed mastix asphalt) are often used to motorways due to effects induced by heavy load vehicles, it is worth evaluating their adaptability and usability in the future. Combined effect may be reached by creating as thick built-in layer as possible in case of asphalt and by breaking the connection between vertical plane rubber jacket or chamber element and the pavement. A good example for this is the RCS Phoenix system: 15-20 cm thick asphalt have been used in Germany for building pavement structures. The advantage of the system is that the rubber jacket geometry follows the rails allowing joining plane to the asphalt to be not vertical. In Szeged, in order to fill the gap between the asphalt pavement and the railhead they successfully used such grouting compounds that created physical bonds and these were found more durable than bituminous joints or rubber interstices.

## 4 Conclusion

In the future it is necessary to investigate possible methods for completing sizing tasks where extraordinary geometrical and load conditions exist and will allow us to take into account static and dynamic effects induced by road vehicle load. Technologies that have been successfully utilised already by professionals on high-load road sections have to be applied. Relationship between the pavement and the rail must be investigated and conclusions obtained should be incorporated into the national conformity tests. Irregular geometric shapes can often occur in the vicinity of passing places, which needs particular attention to making surfaces as large as possible and to performing joint closure precisely.

When looking at regulatory status of the subject it is seen that significant deficiency exists regarding public road lanes regulations: the Yellow Book is not a harmonised Hungarian public and railway road regulatory document, therefore rather dissimilar engineering solutions have been applied in the recent years in different Hungarian cities where rail-guided public roads had been operated and even the Road Technical Specification provides very few guidance on

these transport operating systems. Consequently, it becomes necessary to create some sort of document to include defined regulatory requirements and include also recommendations for pavement structure solutions and probably should be a good source to answer sizing related questions too.

More attention must be paid to selecting material quality and work execution details in public railway constructions with special focus on public transport lanes and keeping in mind that good solutions applied meticulously will ensure trouble-free traffic surfaces for long term. The use of concrete asphalt composite can be realistic in the long run but only if conditions required for this are met.

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