Logistics Problems of Designing a Route for Public Rail Transport in the Psie Pole District in Wroclaw

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The text discusses current problems of the public rail transport in the Wroclaw agglomeration, as well as the opportunities for its extension and future plans of the Wroclaw Municipality in that respect.

Keywords: public rail transport, tramway route, trackage construction.

1. FORMULATING THE PROBLEM

A dynamic increase in the number of residential areas in Wroclaw has been observed in the recent years, especially close to administrative borders of the city. These areas, often of multi-family or single-family character (usually with terraced development) generate passenger traffic for those going from home to work, and later returning. Those result in congested roads in the area of Wroclaw.

It is a well known fact that costs of congestion are really high [6,7,8,9]: financial losses resulting from losing effective working time, increased fuel consumption, environment pollution.

The above mentioned phenomenon can be especially observed in the area of the Swojczycka and Strachocinska streets which are located within the county road No 455. They encompass the residential areas located in the central-southern part of the city: Swojczyce, Strachocin and Wojnów. These streets lead to exurban town which serve as the city's dormitory towns. The issue of traffic jams can be solved in a way that would not generate too high costs, as along the above mentioned streets, parallel to them, there is an unused railway track between Wrocław and Jelcz-Laskowice. Therefore, it is possible to launch public transport on that route, with the use of rail buses, making advantage of the unused stops Wrocław-Swojczyce and Wrocław-Wojnów.

The more dramatic situation can be observed while discussing accessing Psie Pole area from the city centre. Psie Pole is one of the biggest city districts, and it plays both industrial and living function [1]. Residents of that district have demanded a tram line connecting them to the centre for many years. There has been created a public action entitled 'A Tram to Psie Pole' and a petition to the mayor of the city has been formulated [1].

A suggestion for solving the problem has been presented, which included 4 variants of a tram route [1]. Next, as a result of a technical and economical analysis, the most beneficial variant has been marked.

2. PROJECT SOLUTIONS

2.1. GENERAL REMARKS

The location for the target reach of the tram route in Psie Pole has been suggested, in the area of Litewska and Żmudzka crossroads (Fig.1) [1]. Including the projected tram route into the already existing one is possible at the crossroads of three streets: M.Kromer Ave., T.Boy-Żelenski Ave. and Trounska street. A two-track tramline runs along Torunska street, on a separated trackage, with a construction similar to that of railway (rails 60E1, concrete beds with chipping ballast, and elastic attachments SB-3). However, the trackage of a tw-track tramline along M.Kromer Avenue is embedded in the road which runs to the city centre. The operation of including the designed route into the existing infrastructure will require some local reconstruction, in a range that will depend on the selected variant of investment, i.e. a one-track or a two-track tramline.

Four variants of the designed route construction have been suggested (length approx. 5.8 km), which differ as far as the number of tracks is considered (single-track line, or double-track line) and those with a terminus or without it. In a situation plan, the course of each variant is identical. Each of the variants has been divided into three sections in order to carry out a detailed analysis.

2.2. THE FIRST VARIANT OF REALIZING THE INVESTMENT

The characteristics of the route: a double-track on a trackage separated from the street, ending with a terminus where trams pass each other [1,7,8].

The section No 1 of the length os 1.3 km (Fig. 2) [1] includes Litewska street from the crossroads with Żmudzka street until the crossroads with Szewczenko and Gorlicka streets. Both trackages are situated on one side of the street. The terminus has been designed in the area where at present allotment gardens, unpaved road ad a local car-park are located, along Litweska street. Moreover, there will be the need to cut down some trees which collide with the terminus.

Fig. 1. A fragment of the city plan of Wroclaw, with a course of a designed tramway line (marked blue) and the existing tramway line along Torunska street (market orange) [1].
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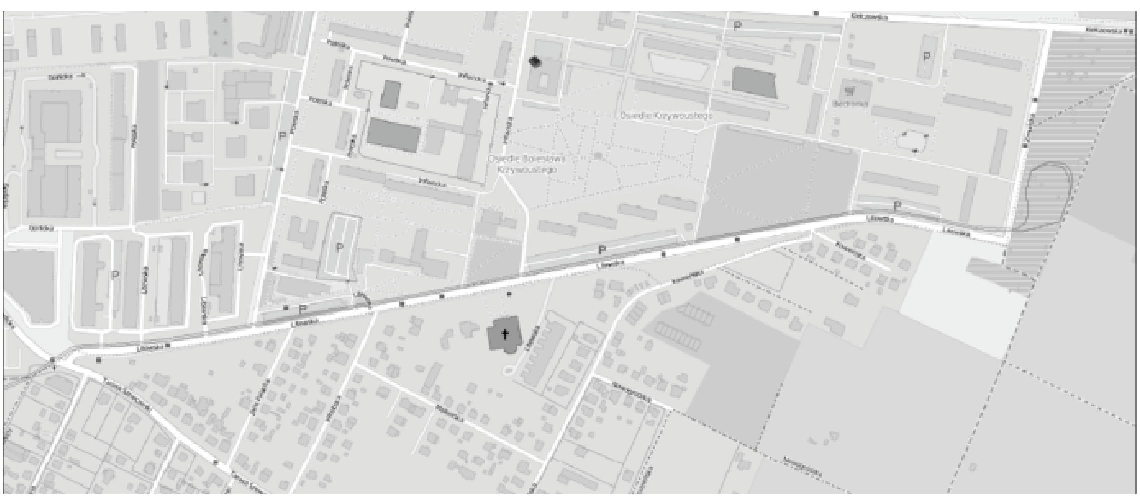

Fig. 2. The situation plan of the first section of the designed tramway line, according to variant I (marked blue) [1].
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The beginning of the second section (of the length of 1.6 km), presented in Figure 3, is the crossroads with Szewczenko and Gorlicka streets [1]. The section ends with the entrance to Jan III Sobieski Ave., and Krzywousty street. The route partly runs across undeveloped grounds, which are a wasteland. It will be necessary to cut down some trees.

suggested outside the street, within the existing green area, close to the sidewalk. It is necessary to redevelop:

- The crossroads of B.Krzywousty street and A.Bruckner Ave., in order to move the trackage into the lane that divides the two streets (it will be necessary to cut down some trees on that lane),

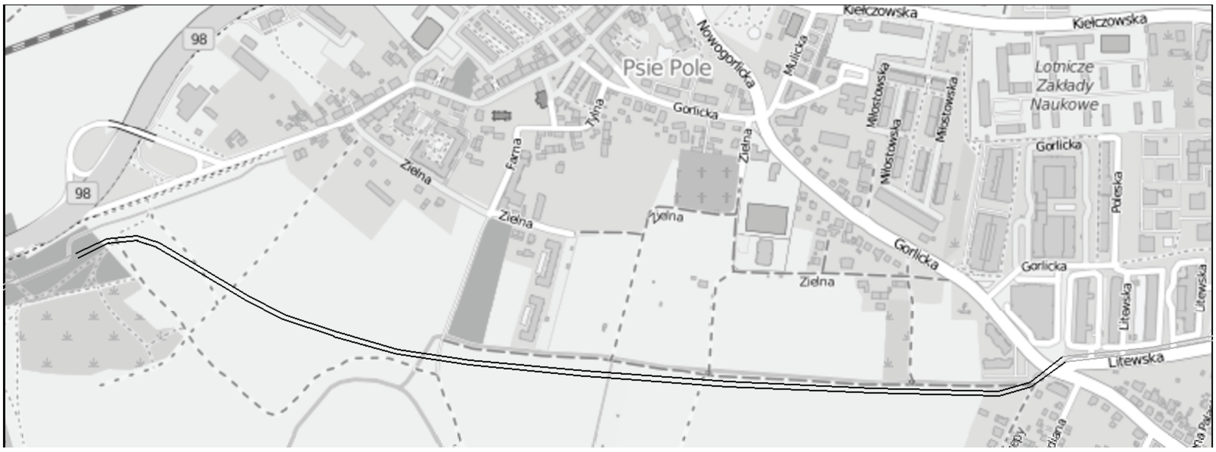

Fig. 3. The location of the second section of the tramway line according to variant I (marked blue) [1].
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The third section of the length of 2.9 km ands at Kromer Ave., close to the crossroads of T.Boy-Zelenski and Torunska streets, and connects to the existing tramway track leading to the city centre (Fig. 4) [1].

Along B.Krzywousty street a tramway tracks is

- The square where the following streets connect M.Kromer Ave. and T.Boy-Zelenski and Torunska streets, in order to introduce a projected tramway line into the existing terminus, where the route of trams coming from the city centre ends.

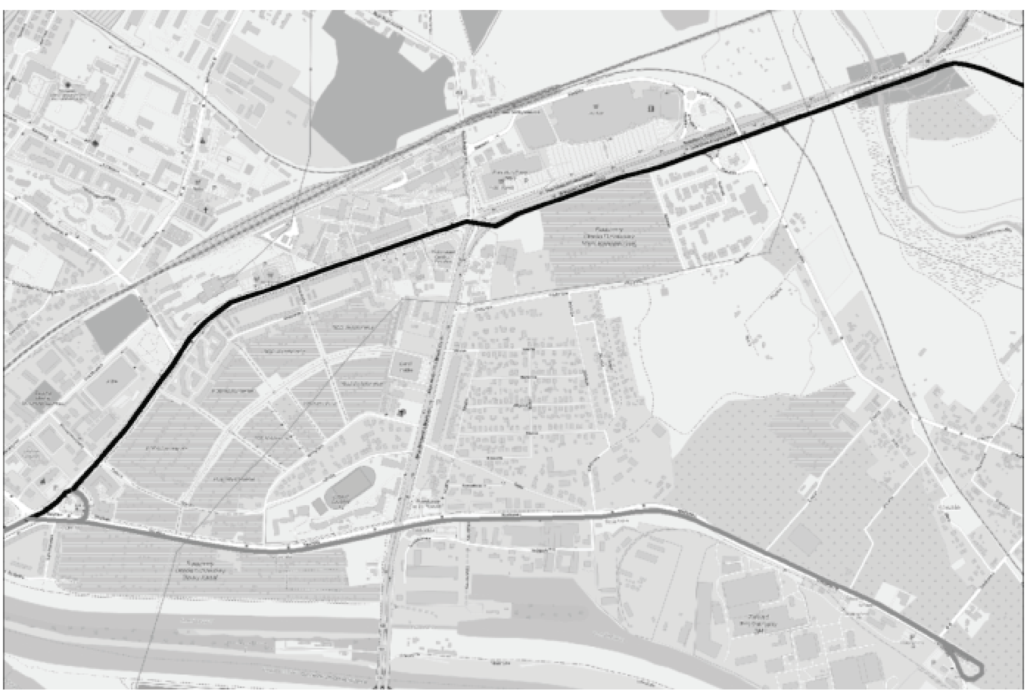

Fig. 4. The plan of the third section of a tramway route according to variant I (marked blue).
The orange colour was used to mark the existing tramway route along Torunska street [1].
(source for the map: © authors of OpenStreetMap under the license of Open Database License CC-BY-SA).

2.3. THE SECOND VARIANT

The route in the project runs as in the variant I. The characteristics of this solution: a single-track line ending with a terminus, including a track where trams pass each other (Fig.5) [1], the trackage separated. In a few cases the trackage cuts through the existing roads. The advantages of this solution include lower cost and taking up less space than in case of a double-track line.

2.4. THE THIRD VARIANT

This solution is different from the previous ones, as it lack the terminus because the alternating traffic was suggested, with the use of two cabins of tram drivers, active at the ends of a tram (Fig. 6) [1]. The inspiration for this solution was introduction of a so called Tram Plus in Wrocław in recent years, which operates in alternating traffic mode and that eliminates the necessity to build a traditional terminus.

2.5. THE FOURTH VARIANT

Figure 7 [1] illustrates the course of the first section of the projected route in a situational plan.

2.6. REMARKS TO THE TECHNICAL-ECONOMICAL ANALYSIS OF THE PROJECTED ROUTE VARIANTS

Table 1 [1] presents the comparison of the suggested variants of the tramway route. For every solution it is necessary to redevelop the crossroads of B.Krzywousty street and A.Bruckner Ave., in order to run the trackage towards Psie Pole to the destination in M.Kromer square on a separated lane existing between the roads of the last section of B. Krzywousty street. The first variant proved to be the most expensive one due to the widest scope of the planned infrastructure. In this case the significant costs are also generated by a complicated technical redevelopment of M.Kromer Ave. in the place where Torunska and Boy-

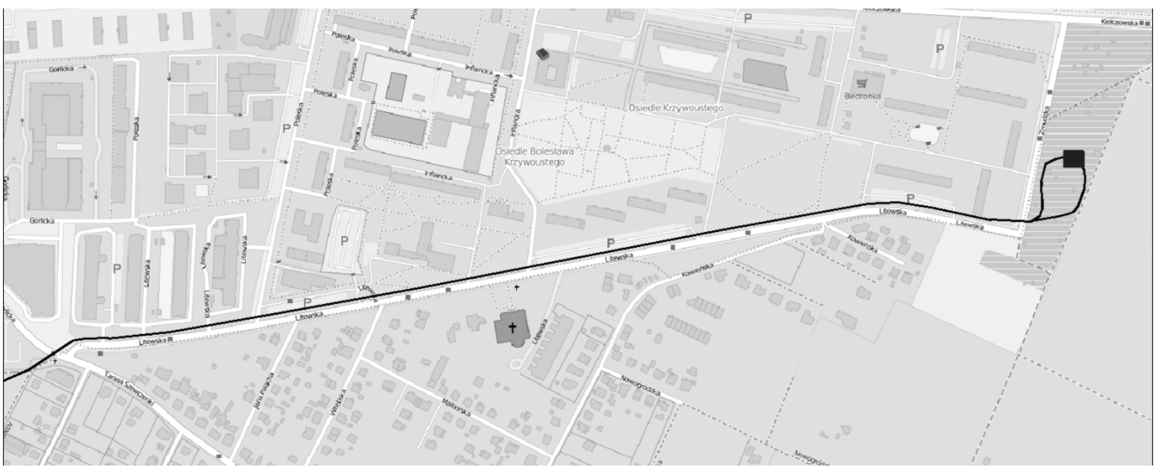

Fig. 5. The course of the first section of a tramway route in variant II (marked blue) [1].
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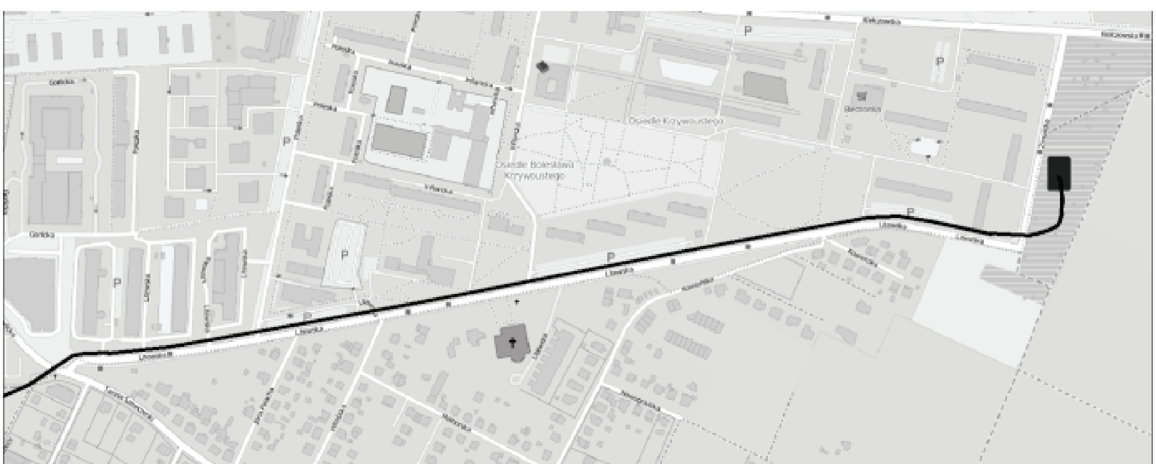

Fig. 6. The course of the first section of a tramway route in variant III (marked blue) [1].
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Fig. 7. The course of the first section of the tramway route in variant IV (marked blue) [1].

Zelenski streets meet, which is indispensable in order to connect the last section of a double-track route into the existing tramway structure. The main advantage of the solution in question is the possibility for public transport running in both directions simultaneously, which in turn reduces the waiting time for a tram as compared with a single-track line.

Table 1. Basic tasks to be implemented in the production system.

Variant	Section	Type of Route	Terminus
Variant I	Section I	Double-track, separated	yes
	Section II	Double-track, separated	
	Section III	Double-track, separated	
Variant II	Section I	single-track, separated	yes
	Section II	single-track, separated	
	Section III	single-track, separated	
Variant III	Section I	single-track, separated (plus)	no
	Section II	single-track, separated (plus)	
	Section III	single-track, separated (plus)	
Variant IV	Section I	Double-track, built-in in the road	yes
	Section II	Double-track, built-in in the road	
	Section III	Double-track, separated	

3. DESIGNING THE TRACK'S SUBSTRATE

The information provided by the Geological Office in Wrocław says that the area where the route will run has clayey soils (of expansive character), which are characterized by a deformation module approx. 25 MPa. In road catalogues these soils qualify for G3 category [3,4]. According to the exploitation guidelines for railway tracks, it is required to increase carrying capacity of the substrate so it reaches the value of 80 MPa by means of strengthening layer. Taking decision on a tramway track construction identical to that of a railway track, the layer was designed by means of equivalent module, used in rails [2,5,9,10,11]. The thickness of the protective layer is agreed, which is made of aggregate with such a deformation module E_0, that after applying the layer on the existing substrate – characterized by E_g module – the equivalent substrate module E_e estimated on the upper level of the protective layer, was defined by the condition:

$$E_e \geq E_{designed}$$

where:

$E_{designed}$ is a designed deformation module of the reinforced substrate.

The guidelines [2] see two variants of the strengthening system: a single layer, or a system of several layers.

When the thickness (h_0) of a single strengthening layer is estimated, the following rules apply:

E_g = 25 MPa,
E_0 = 120 MPa (coarse sand),
The required equivalent module $E_{e,w}$ = 80 MPa.
If we assume:

$$E_e = E_{e,w} = 80 \text{ MPa},$$

Quotients are marked:

$$E_g / E_0 = 25 / 120 = 0.21$$
$$\text{i } E_e / E_0 = 80 / 120 = 0.67.$$

For both quotients it was read from DORNII nomograph [2,5]:

$$h_0 / D = 1.48,$$

where $D = 0.33$ *m* is a diameter of a standard plate of a VSS device, used to carry research on deformation module in a pavement and substrate of railways and roads.

Due to the above, the thickness of the protective layer is:

$$h_0 = 0.30 \cdot 1.48 = 0.44 \text{ m}.$$

assuming h_0 = 0.45 m, it is necessary to apply in two stages: the lower element with the thickness 0.25m, and the upper one 0.20m.

Figure 8 presents a vertical cross-section through a designed aggregate construction under a substrate [9].

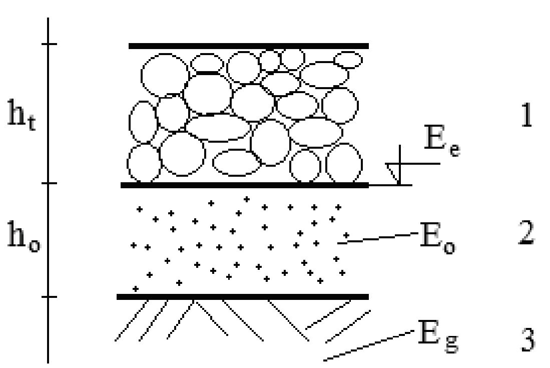


Fig. 8. The construction of a track substrate (vertical cross-section) [9]: 1 – metalling bedding of a layer thickness of h_t; 2 – a single protective layer of a thickness of h_0, 3 – local soil of subgrade.

Designing a two-layer system, the thickness of a lower layer is initially assumed, but the thickness of the upper layer is calculated as presented above. The data for calculations are as follows:

E_g = 25 MPa, E_{01} = 150 MPa (medium sand was assumed as a lower strengthening layer), lower strengthening layer of the thickness of h_{01} = 0.20 m, designed equivalent module $E_{designed} = E_e$ = 80 MPa.

Considering the above data, for the quotient of:

$$E_g / E_{01} = 25 / 150 = 0.17,$$

and for h_{01} = 0.20 m, the dependency E_{e1} / E_{01} = 0,38 is read from the DORNII nomograph. Next, the value of the equivalent module for a reinforced substrate strengthened by a lower layer is specified: $E_{e1} = 0{,}38 \cdot 150 = 57$ MPa.

As far as the upper protective layer is concerned (basaltic chippings were assumed with a module E = 180 MPa), the calculations look as follows:

$$E_g = E_{e1} = 57 \text{ MPa},$$
$$E_{e1} / E_{02} = 57 / 180 = 0.32;$$
$$E_{designed} / E_{02} = 80 / 180 = 0.44.$$

On the basis of the calculated quotients, the dependency is taken from DORNII nomograph:

$$h_{02} / D = 0.40.$$

next, the thickness of the upper protective layer was estimated:

$$h_{02} / 0{,}30 = 0.40.$$

Therefore

$$h_{02} = 0.40 \cdot 0.30 = 0.12 \text{ m}.$$

The total thickness amounts to:

$$h_0 = h_{01} + h_{02} = 0.20 + 0.12 = 0.32 \text{ m}.$$

it must be noticed, however, that the Catalogue [3] assumes alternative solutions for the above one, which in that specific case (bedding of G3 category, of expansive character) means:

- providing a geo-synthetic mat directly onto a bedding surface, which as a separator,
- providing (on a geo-synthetic mat) a strengthening layer of thickness h_0 = 0.15 m, made of ground base stabilized by binding materials (concrete, lime, active volatile ashes). The required resistance to compression is R_m = 2.5 MPa.

4. THE SUGGESTED CONSTRUCTION OF PAVEMENT

In the presented variants of the route, the trackage is assumed to run outside the street, but in the zones of crossing with the existing roads – a trackage built-in in the street.

In the first case a popular solution of the city of Wrocław was suggested (e.g. Torunska, Kwidzynska, Slezna, Mickiewicz streets) and of the city of Krakow i.e. a construction of a railway track.

Figure 9 presents the pavement of a tramway track in Torunska street in Wrocław. The photo shows a dilatant device used for compensating for rail strains. The pavement is a modern construction composed of rails type 60E1, pre-stressed concrete beds, elastic attachments type SB3 (connecting rails by beds) and ballast chipping.

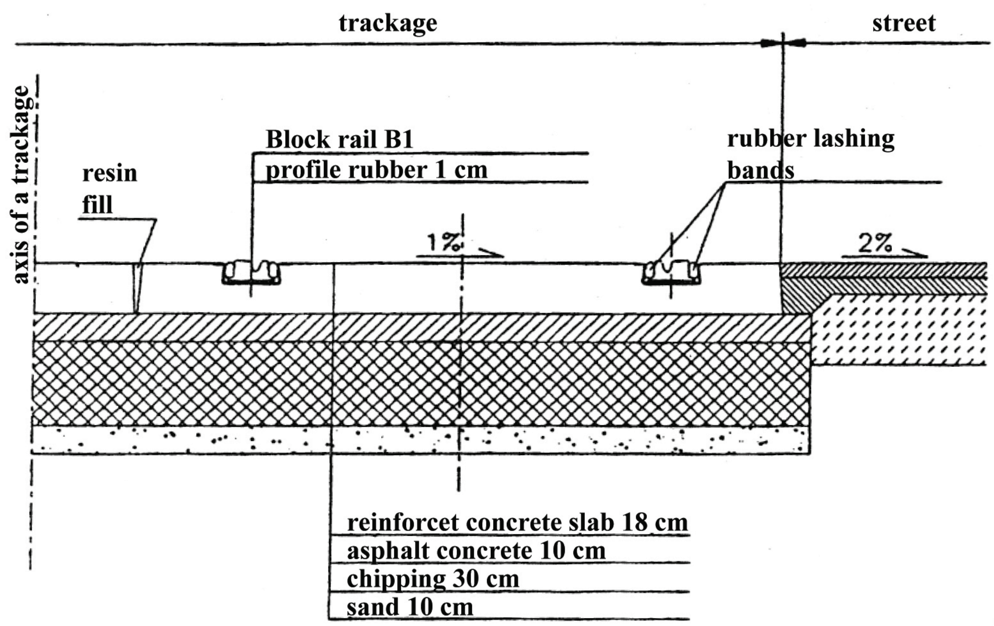
Fig. 9 General overview of a tramway track in Torunska street in Wrocław.

In case of a trackage built-in in the street, it is purposeful to use a modern construction of Hungarian type, which has been successfully used, with some modifications, in Wrocław for the last 20 years. Below are some of the Wrocław applications:

- Lokietek and Poniatowski streets (1994),
- Traugutt street (1996),
- Wroblewski street, from Mickiewicz until Wystawowa street (1997): chipping beds were replaced by concrete beds,
- Sw. Jadwiga street (1997): the existing concrete bed was used, and due to historic character of the area, plates of cobblestone texture were used,
- Sienkiewicz street (2008).

Figure 10 illustrates a vertical cross-section across the trackage in Lokietek and Poniatowski streets (1994) [10]. The Hungarian technology shows some significant advantages:

- Low construction height of pavement,
- Low labour-consumption due to pre-fabrication and mechanization of works,
- High reliability due to elimination of screw connections,
- Being eco-friendly (low level of vibrations and noise).



[photo A. Surowiecki]

Fig. 10. A trackage in Lokietek and Poniatowski streets, prepared in the Hungarian technology (1994) [10].

5. FINAL REMARKS

The suggested tramway route could complement the public bus transport, especially during peak times, and in critical situations would serve as an alternative.

The key element of the discussed project is a trackage, whose type and surface type affect the environment to a greater or lesser extent (among others the noise issue).

In a variant recommended by the authors, a tram would move along a double-track, separated from the street, trackage (parallel to a one-road street, or centrally between two streets). In such case the authors recommend (in analogy to a tramway in Torunska street, existing for a few years) to use a typical railway pavement consisting of rails type 60E1, pre-stressed concrete beds PS94, SB3 attachments, and basaltic chipping aggregate of thickness min. 0.25 m.

In the areas where tramways would cross with the existing roads, and within the existing crossroads (Litweska-Szewczenko-Gorlicka, Krzywousty-Bruckner-Poprzeczna) and in the zone of connecting a section that closes the route into an existing trackage at the crossroads Krzywousty-Boy-Zelenski-Torunska, a Hungarian type of pavement was suggested, with the use of reinforced concrete plates, commonly used in Wrocław.

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