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Modern solutions in the construction of tram junctions

Abstract: In this article, a brief overview of solutions in the construction of tram junctions is presented. The authors discuss both currently used methods and new construction approaches. As a solution combining innovations in the construction process and in the construction of junctions, a description of the Contrack technology is provided, which involves using prefabricated turnout plates in the process of building a tram junction. The article provides a brief overview of solutions for the construction of tram junctions. The authors present currently used solutions and new construction solutions. As a solution combining both innovations in the construction process and in the construction of nodes, a description of the Contrack technology was presented, consisting of the use of prefabricated turnout plates in the process of building a tram junction.

Keywords: Tram turnout; Prefabricated turnout plates; Tram track

Introduction

Tram turnouts play a key role in the construction, modernization, and maintenance of tram tracks, forming complex junction systems at intersections and roundabouts. The turnout structures directly influence safety, comfort, and the very possibility of ensuring smooth tram traffic. They also generate significant costs in the event of repairs, overhauls, or replacement—financial and organizational (in the form of substitute transport), as well as social (manifested in difficulties connecting a given part of the city).

This issue is especially important for turnout junctions integrated with the roadway, as it impacts not only tram traffic but also bus, car, bicycle, and pedestrian flows. Hence, on one hand, it is crucial to ensure high initial quality, durability, and reliability of turnout junctions, and on the other hand, to minimize the time needed for their assembly or replacement. Consequently, there is a search for technologies that address these challenges and reduce both municipal expenses—calculated over the entire life cycle of a given section of the tram network—and the inconvenience stemming from track maintenance, overhauls, or replacement.

Overview of Currently Used Solutions

Currently, several technologies are available for constructing tram track surfaces at turnout junctions integrated with roadways, bicycle paths, or pedestrian crossings—i.e., places where multiple modes of traffic are accommodated alongside trams.

A commonly used solution in urban infrastructure involves concrete structures that integrate tram and road surfaces. Prefabricated concrete slab systems [1,2] are ballastless track surfaces intended for tram routes shared with road traffic (so-called tram-road surfaces) as well as for segregated tram tracks. This technology was developed not only to accelerate and streamline track construction or modernization but also to allow easy disassembly and reassembly of rails, necessary in the event of rail breakage or operational wear. These systems are the only technological solution that withstands frequent, heavy, and intensive tram and bus traffic; however, they can only be used on straight or possibly curved sections of track (main lines).

Due to the complex geometries often found in urban tram networks—shapes that may be unique to a specific road layout—as well as the need to integrate point machine drives, power supply and control systems, drainage systems, and turnout heating, domestic producers of track slabs do not offer prefabricated solutions for individual tram turnouts or entire turnout junctions. Where turnout junctions occur, the most commonly employed method involves anchoring and grouting the turnouts with special mixes onto on-site, monolithically cast concrete slabs. This approach requires staging the work (dividing the turnout junction) and pouring concrete in two layers: a lower concrete slab and an upper (surface) concrete slab. After the lower concrete slab is laid, the turnout is installed on it and aligned both horizontally and vertically by welding and anchoring the entire track structure. Only once this is complete is the system integrated with the road surface by finishing and leveling—typically using asphalt, paving stones, or additional concrete.

A complete description of this construction process, along with an analysis of the advantages and disadvantages of both prefabricated tram slab systems and continuous grouting systems, can be found in the article "Torowiska tramwajowe – roboty budowlane" ("Tram Tracks – Construction Works") by Eng. Grzegorz Dąbrowski (2017) [3].

Installing turnouts in locations where road and pedestrian traffic also occurs is much more complex than on ballastless track sections used solely by trams. The currently used installation method entails the following key drawbacks:

1. Time required to replace turnout junctions – full functionality is achieved only 28 days after pouring each concrete layer (time needed for concrete curing and setting).
2. Varying weather and temperature conditions during turnout junction installation significantly affect the stress state of the steel turnout structure and the concrete base and casing.
3. Degradation of the road surface within the turnout area after only a few years of use, due to weaknesses of the traditional technology when exposed to heavy bus traffic.
4. Impossibility or major difficulty in hardfacing steel components if the turnout degrades (wear).
5. Replacing the turnout structure requires removing the top layer of concrete (and often the lower slab as well) and redoing time-consuming anchoring and grouting from scratch. This is critical because rails in turnouts typically wear faster than the concrete surface does (the service life of properly assembled and maintained turnout rails is 10–15 years, while concrete surfaces can last 25–30 years). Consequently, even if the concrete layer remains in good condition, it may have to be removed prematurely during rail replacement.

Innovative Solutions for Tram Junctions

The search for quick, efficient, and high-quality methods of assembling turnout junctions has driven the development of innovative technologies based on prefabricated turnout slabs. Applying prefabricated track slabs on main lines naturally prompts extending the approach to the turnout junction itself, to achieve a durable track system built to uniform standards.

One of the earliest applications of prefabricated slabs for tram turnouts took place in 2008 in Frankfurt, where a technology was used that combined prefabricated concrete slabs with a turnout structure ultimately fixed using continuous rail support. The top layer—integrating the rail with the road surface—was asphalt [4].

1. Installation and assembly of a turnout in a prefabricated slab – Frankfurt 2008 [4]

Also, within the work carried out by a team consisting, among others, of manufacturers of steel turnout components, a turnout in a prefabricated slab was installed on Rue Baeck in Brussels [5].

2. Installation and assembly of a turnout in a prefabricated slab – Brussels [5]

These solutions have not found widespread application. The reason for this situation lies in the fact that, unlike railway solutions, tram turnouts are characterized by high variability in geometry—each one is a custom product. Another barrier was that the solutions stemmed from cooperation between a prefabricated concrete slab manufacturer and a turnout manufacturer, meaning there was a lack of an effective "technology integrator" who could reconcile often incompatible requirements for producing the concrete and steel parts. It is evident that, for this type of turnout to be produced under prefabrication conditions, a specific technological mix must be developed, combining prefabrication of the concrete slab, production of the steel turnout components, integration of the point machine and its control system, and the method for installing them at the manufacturer's plant (resin casting). Additionally, due to the dimensions (the turnout is divided into at least three blocks, each concrete slab measuring 2.2–3.4 × 3/4/6 m and weighing no more than 25 tons—see attached diagram), it is crucial to develop suitable technologies for transporting and installing such a turnout.

A Solution Focused on Innovation in Both Construction and Construction Processes

Traditional methods of building tram junctions result in prolonged traffic disruptions. The most time-consuming element of this process is the curing of concrete layers, which in favorable conditions can take up to 28 days. Added to that are so-called weather windows. During this entire period, traffic in the construction area must be halted, and network operators are forced to organize substitute transportation, which generates high costs—including social costs. Detours, street narrowings, single-lane alternating traffic, and other inconveniences—as well as the time irretrievably lost—affect all users of urban infrastructure: residents, visitors, and businesses alike.

The main categories of social impacts from transport infrastructure investments (with particular emphasis on tram tracks) are described in detail in the Blue Book for the Public Transport Sector in cities, conurbations, and regions [6]. As indicated by CUPT [7], the Blue Books (JASPERS) [8] are the primary source of methodologies for detailed cost-benefit analyses in the transport sector. Time savings resulting from a technology that focuses not only on product innovation but also on logistics, installation, and maintenance, occur not just during comprehensive overhauls of tram junctions but also during every turnout repair.

Using the appropriate technology at the stage of rebuilding or renovating should also translate into savings over the entire technical service life of the rail infrastructure investment. A track surface rebuilt or renovated using innovative technologies should meet the fundamental needs of tram network managers. Compared to "old" technologies, it should be less prone to wear, more reliable, and require fewer maintenance and repair operations, more economical in terms of LCC (Life Cycle Cost) and all indirect costs, and, ultimately, more durable.

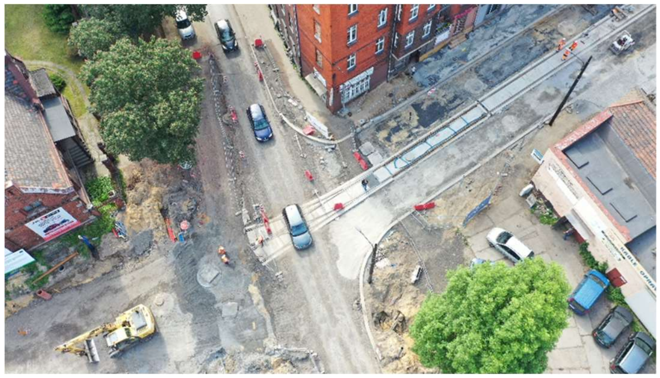
In response to these requirements, a research and development team at the KZN Bieżanów Group (comprising experts in concrete and steel materials, specialists in the production of concrete slabs and turnout structures, logistics experts, and experienced rail construction engineers) took on the challenge of developing a technology encompassing the design, logistics, and installation process for a prefabricated tram turnout, as well as its safe replacement. It became essential to find a solution that would accelerate the construction of tram junctions while significantly reducing the number of construction operations and on-site labor, and mitigating the influence of external factors (e.g., weather conditions affecting the concrete curing process) on final quality.

The resulting technology for prefabricated tram turnouts (trademark name CONTRACK) enables:

- Shortening the time needed to replace turnout junctions integrated with the roadway (no need to wait for the concrete base and surface to reach the required strength parameters, no need for anchoring and multiple mobilizations related to creating the polyurethane area around the rails),
- No need to dismantle the overhead catenary (only de-energizing is required),
- Extending the scope of prefabrication in tram tracks to include turnout junctions – currently, the increasingly popular use of prefabricated slabs is limited to main lines, while continuous grouting and poured concrete (a time-consuming method) are still used for turnout junctions,
- Significantly increasing the service life of the road surface within turnout junctions,
- Facilitating quick replacement of turnout components when their wear makes further hardfacing of steel elements impossible, without affecting the slabs themselves (removing the turnout components along with the filler compound and installing new ones in their place). This replacement process is very short and can be carried out over a weekend,
- Maintaining consistent use of prefabricated technologies on adjacent straight track sections – using prefabricated slabs along the entire length of a section, including turnouts, provides uniform parameters in terms of rigidity and surface durability.

Developed by this team, the Contrack technology makes it possible to integrate the steel turnout structure with dedicated prefabricated concrete slabs using a polyurethane material for continuous, elastic rail fastening, under strictly controlled workshop conditions. The prefabricated elements also include point machines, cable ducts for supplying and controlling them, drainage boxes integrated with channels for rainwater runoff, and space for installing and connecting electric control and turnout heating systems. The design further allows for inspection of the prefabricated slab and all the above-mentioned components (as well as their repair or replacement) throughout their service life without compromising the reinforced concrete structure.

A crucial aspect is also the rapid and efficient introduction of innovation into the tram network. The prototype solution was installed in May 2023 in Bytom at the intersection of Powstańców Śląskich and Piekarska Streets (on a network managed by Tramwaje Śląskie), allowing the team to gain the necessary experience and make adjustments to accompanying processes: logistics, installation, and subsequent maintenance.



3. Prototype installation of a turnout in prefabricated slabs in Bytom

Summary

An important aspect in both designing new tram lines and modernizing existing ones is the use of innovative solutions that achieve an advantage through their comprehensiveness. Overlooking organizational and social costs or failing to account for the entire life-cycle cost of a given piece of infrastructure during the investment planning process can lead to the selection of solutions that generate complications and are costly, while very good products remain unavailable to urban infrastructure users. Efficient implementation of modern solutions for turnout junction construction based on full prefabrication represents an opportunity for tangible savings in the development of tram infrastructure in Polish cities.

Source materials

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