ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)
https://doi.org/10.31803/tg-20250410145252

Professional paper
Received: 2025-04-10, Accepted: 2025-04-25

Bicycle Transport – An Original Solution for Building Cycle Paths on Unused Railway Tracks

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Abstract: The issue of functional cycle paths is a long-term pressing problem in Slovakia. Cycling combines many benefits that are related to a healthy lifestyle, an environmental approach to transport and, last but not least, the development of the given region. Construction of modular cycle paths on unused railway tracks is one of the possible and modern approaches. The total length of long-term unused railway tracks in Slovakia is approximately 180-220 kilometers. This approach offers several benefits, such as the meaningful use of unused tracks, addressing legal aspects of land use, recycling of unusable waste, or the possibility of quick restoration of the original railroad track. The aim of this article is to present an innovative project for building cycle paths on unused railway lines with the meaningful use of plastic and rubber waste.

Keywords: bicycle transport; modular; original patent solution; prefabricated panels; railway tracks; removable system

1 INTRODUCTION

Current statistical data of the Ministry of Transport and Construction of the Slovak Republic for the year 2020 indicate that the total length of railway tracks in Slovakia is approximately 3,650 km, of which more than 180 kilometers have not been used for a long time [1]. The main reasons are the long-term lack of interest in the use of rail transport by shippers, no declaration of a possible interest in the resumption of rail transport in the future, a decrease in passenger numbers due to the loss of job opportunities in the region of interest, unsatisfactory technical condition of the track or the lack of strategic development near the tracks. The solution proposed by the presented project is to enable the temporary or long-term use of non-operational railway tracks as routes for alternative modes of transport, such as cycle paths or pedestrian paths. Under Act no. 513/2009, [2] as amended, on railways the owner may lease or sell the unused railway tracks to a municipality, an association of municipalities or to a self-governing region to be used for transport purposes [3]. The use of the railway for operating bicycle/ transport, for temporary construction of local traffic paths – including a bicycle route or a footpath – is possible with the approval of the Ministry of Transport and Construction for the period of 3 years minimum, a maximum of 10 years with the possibility of another 10 - year maximum extension [2].

In addition, as early as 2013, the Slovak government approved the draft of the National strategy for the development of bicycle transport and bicycle tourism in the Slovak Republic [3]. One of its basic goals was to make bicycle transport equal to other types of transport, to improve the visibility of cyclists in the transport space, to facilitate cycling tourism, to support tourism and improve mobility, and to improve the population's awareness of economic, ecological and health benefits of bicycle transport.

2 A PROGRESSIVE SOLUTION

The number of abandoned, non-functional and unprofitable railway tracks in Slovakia presents a problem that may be addressed in a meaningful way.

There are a number of original solutions for overlapping rails, [6-10]. The advantage of the solution we propose is based on a simple principle (only two components), easy assembly (without screw connections), and the possibility of creating customizable surface and 3D solutions. The goal of the proposed solution is to cover such tracks with a modular prefabricated panel system [4]. The proposed modular system is based on two assembly elements – a prefabricated panel and a connector as illustrated in Fig. 1.

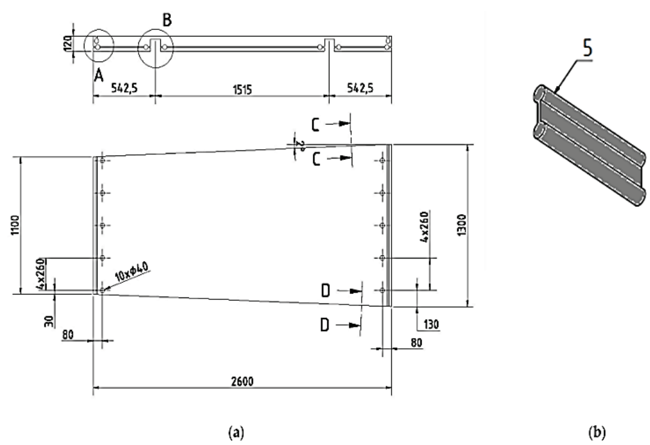


Figure 1 Prefabricated panel system, a) prefabricated panel; b) connector

The prefabricated panel is made up of a flat body with a square geometric shape made of composite concrete containing secondary raw materials of plastic or rubber. The body of the panel has a continuous groove (3) on the sides around the perimeter, Fig. 2. Each corner of the body has two mutually perpendicular holes (4) in the grooves (3) set off from the corner edge on the lateral sides to enable overlapping joints; the diameters of the holes (4) are larger than the width of the groove (3). The body has two continuous anchoring profile grooves (6) spaced from each other on the bottom side between the opposite sides of the body and two holes (4) in the groove (3) spaced on the sides of the profile groove (6) for creating a clamping connection between the body and external carrier, whilst the diameters of the holes (4) are larger than the width of the groove (3).

The prefabricated panel system consists of a set of prefabricated panels (1) in at least a 2D arrangement, which are connected to each other by overlapping joints (2) between adjacent corners of the overlapped panels (1). The overlapping joint (2) fits into the hole (4) of one adjacent panel (1) and a complementary connecting member (5) fits into the hole (4) of the second adjacent panel (1), and into the adjacent grooves (3) of both adjacent panels (1). The prefabricated panels (1) have clamping joints (8) between the external carriers, where the external carriers fit into continuous anchoring profile grooves (6), whilst complementary connectors (5), whose free ends are in clamping contact with external carriers, are inserted into the holes (4) and grooves (3) at the clamping joint (8).

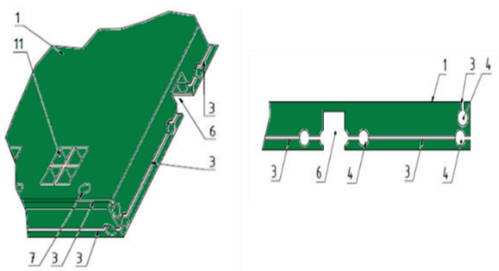
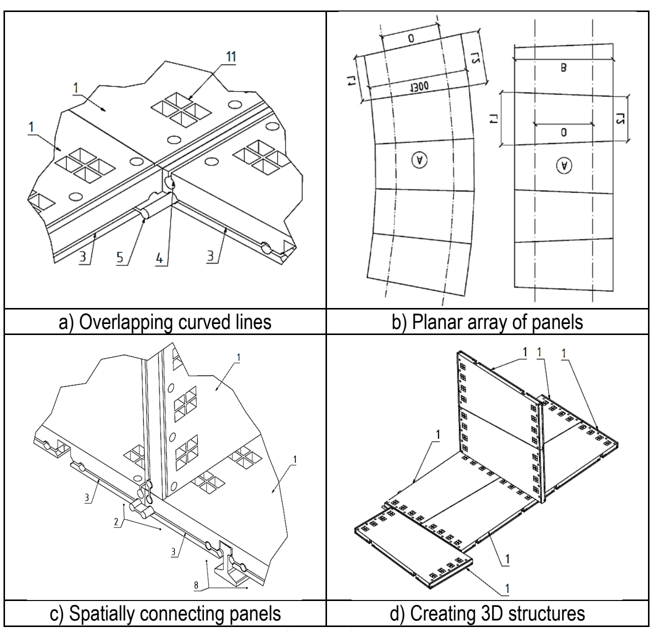


Figure 2 Design of the prefabricated panel

The design of the prefabricated panel system allows the connection of panels in a plane behind each other or next to each other. This makes it possible to cover one track but also, for example, two tracks next to each other or even to cover entire platforms with several tracks. However, the design also enables the creation of a spatial arrangement of panels, Fig. 3.



a) Overlapping curved lines | b) Planar array of panels | c) Spatially connecting panels | d) Creating 3D structures

Figure 3 Variability of the prefabricated panel system

The benefits of the prefabricated panel and the prefabricated panel system are the universality, the use of only two mounting elements, and a simple and clean design solution. The assembly is very simple and consists only of inserting the connectors into the appropriate openings of the panels depending on the required joint. These connectors are not accessible from the outside. As a result, it is not possible to disassemble the panel system at any place without mechanical damage. The real possibilities of the prefabricated variable panel system are apparent from Fig. 4. The spatial arrangement of the panels also allows for the construction of small structures, such as shelters for cyclists, tunnels, or barriers against landslides on a slope. However, the panels do not have to be installed on railway tracks but can be used to cover any appropriately prepared surfaces, such as pavements, or various platforms or parking areas.

Figure 4 Mockup of provided options of the variable prefabricated panel system. Legend: 1 - covering of straight tracks, 2 - covering of curved tracks, 3 - covering of platforms, 4 - shelters, 5 - tunnels and underpasses, 6 - protection against landslides, 7 - easy bridging

Figure 5 Robotic panel laying

In the proposed solution for building cycle paths, lighting was also considered. Red lights along the track were connected to photovoltaic cells installed on a black pole. Electronic contacts built into the panels served to check the unbreakability of the track. Holes in the panels were designed for drainage of rainwater and enabled the easy installation of the railing over bridges and other elevated structures. Any utility networks can be installed in the available openings in the panels.

When designing the structure of the panels, efficient and quick assembly or disassembly was considered. The panels were equipped with holes for their attachment during transport and assembly itself. The resulting system thus assumes automated assembly of individual panels, and – in an alternative solution – also the transportation of panels directly by railway and the assembly of panels, e.g., by using a suitable crane system.

Subsequently, the first demonstration models of the panels in real dimensions were produced as illustrated in Fig. 6.

Figure 6 The figure shows the assembly of the demonstration panels

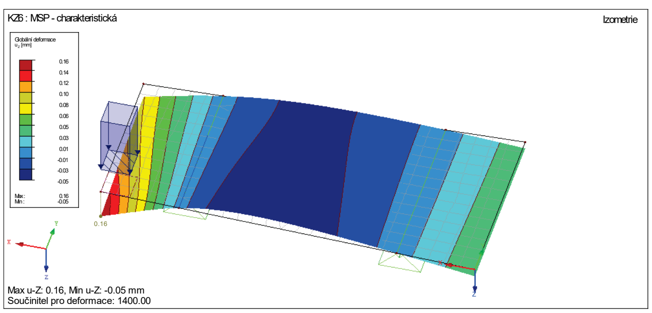


Figure 7 Strength analysis, deflection of the panel - load on the cantilever

An example of the strength analysis of a prefabricated panel is shown in Fig. 7 and Fig. 8. The slab calculation model was created in the Dlubal RFEM program, [5]. The model was linearly supported at the location of the rails. The load was considered in the form of self-weight and a point load of 10 kN from one wheel on the console (Fig. 7) and in the mid- span (Fig. 8). The dimensioning was carried out according to the European standards EN1992-1-1 for the effects of bending moments and shear forces. It is clear that the extreme stress is achieved in the cross section above the rail. To transfer these moments, concrete reinforcement was subsequently designed on the upper and lower surfaces of the panel. The production of our own panels took place in a prefab factory in a standard form, into which reinforcement was inserted and concreting was carried out, as shown in Fig. 9 and 10. Four transport anchors, located on the shorter sides, were intended for lifting the panel.

As a result of the analysis, a proposal was made for the required strength of the panel and its minimum thickness directly above the rails. Subsequently, the final construction of the panel with the required reinforcement was determined. To verify the load-bearing capacity of a typical prefabricated panel, load tests with two load sets were performed – ZS1 – load of the exposed end of the panel and ZS2 – load of the middle of the panel. The designed concrete class was C30/37. A demonstration of the load placed on the edge of the panel is presented below. The loading was performed through distribution plates with dimensions of 0.1 × 0.1 m. The detailed loading scheme is shown in Fig. 11. During the test, the force – FV4 and FV6 (FV5) and the deflections V1 – V6 were monitored.

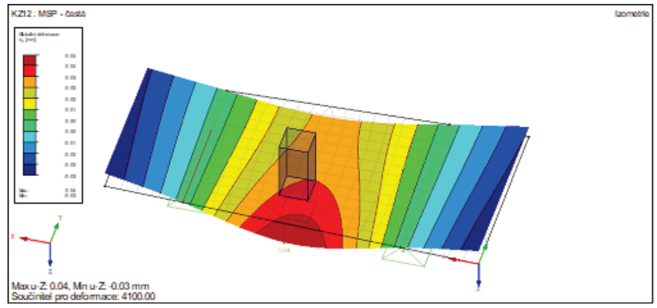


Figure 8 Strength analysis, panel deflection - mid-span load

Figure 9 Form of prefabricated panel with reinforcement

Figure 10 Manufactured prefabricated panel

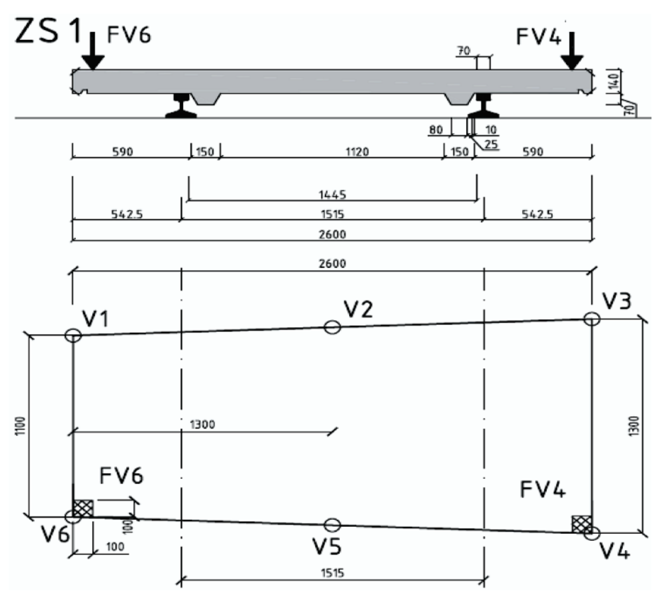


Figure 11 Load scheme

Both ends of the panel were simultaneously loaded with the same static force, Fig. 12.

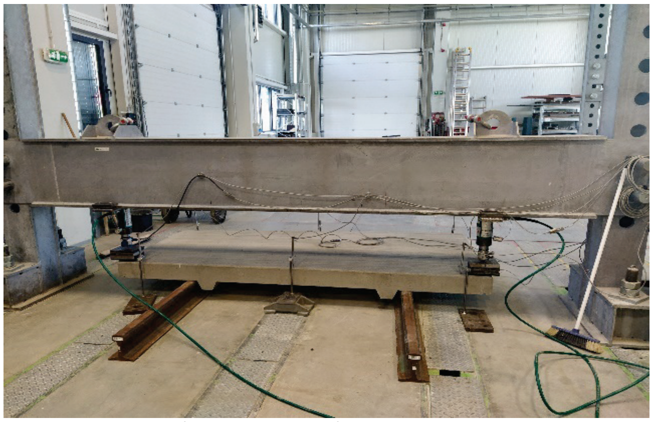


Figure 12 View of the arrangement of the load pins during measurement

The first hairline cracks appeared at approximately 15 kN above the rail. With increasing force, bending cracks gradually began to form in the panel at the upper surface and shear cracks started to form at the console. At a load of approximately 40 kN, more significant cracks with a width of 0.2 mm were formed (at a deformation of the console v6 approximately 5 mm).

From this load level, the panel behaved significantly nonlinearly, deformations increased and cracks developed, the force increased less as shown in Fig. 13. The maximum limit value of the load FV4 was equal to 65 kN and deflection was reached.

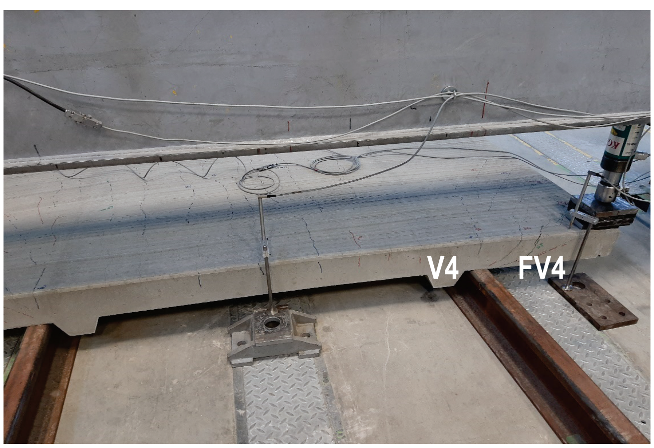


Figure 13 Overall failure of the panel by flexural cracks at the upper surface and shear cracks at the point of solitary force (right)

At the given minimum thickness, it can be subsequently defined how much secondary raw materials can be added to pure concrete, so that the required strength of the concrete composite is maintained.

The calculated weight loss with different composition of the composite is evident from Fig. 14.

When manufacturing the panels, the assumption is that up to 30% of the concrete filler would be made from rubber or plastic waste. The diagram below show the total weight of one panel with the different ratios of the materials used.

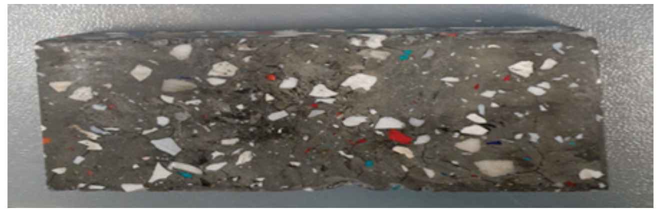


Figure 14 Test sample created in the composition 85 concrete/15 plastic

The final proportions of added waste will depend on the continuous supply of a sufficient amount of waste, as well as on the results of strength analysis and experiments with real panels. The change in panel weight by adding plastic waste can be seen from Fig. 15.

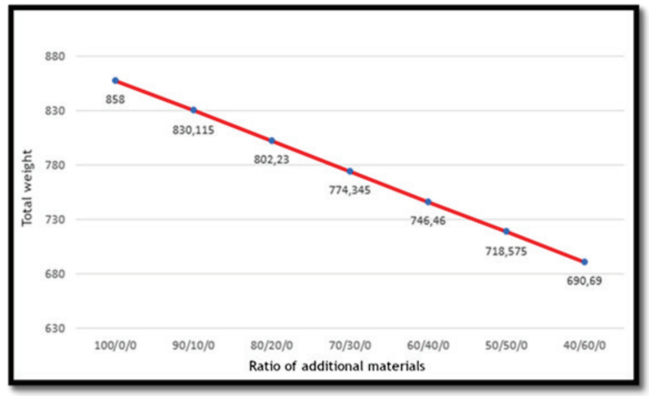


Figure 15 Changing the weight of the panel by adding plastic waste

Based on the results of calculations, experimental tests and the design of the technological production process, the first test section was implemented with real panels, Fig. 16. The objective of this test section was to verify the technological method of production, transport, handling of the manufactured panels and possible problems during laying. All test results were plausible. This created all conditions for the implementation of a pilot project for creating cycle paths on unused railway lines.

Figure 16 The first test section created from real panels

3 CONCLUSION

Slovakia has a total of more than 300 km of minimally used railway tracks. Of these, more than 100 kilometers have not been used for a long time. In general, it can be concluded that Slovak Railways has a problem of maintaining the currently operable tracks. Many foreign countries have turned abandoned railway tracks into Greenways – multifunctional paths- or for other tourist and commercial purposes. Usually, such repurposing was done by dismantling the tracks and then pouring a concrete-asphalt mixture, often also directly in nature.

The aim of this article is to present a new and innovative technology for the use of abandoned railway tracks as a basis for building new cycle paths. The Trailpanel project proposes to transform unused railway tracks into cycle paths without removing the existing rails, just by simply changing their purpose. The idea is based on the installation of prefabricated panels on existing tracks. The present innovative project offers a comprehensive analysis of the possibility of transforming unused railway tracks into functional, modern cycle paths.

The aim of further research of the presented project is to design a suitable optimal composition of the composite material for the production of panels, design a large-volume mold, the final technological process for the production of panels and design a technological line for the serial production of panels. In the production of composite concrete, it is planned to use otherwise unusable waste, mainly from plastics and rubber. During 2025, we plan to implement the first pilot project of a cycle track with a length of approximately 10 kilometers.

The load tests were successfully completed. This is also a prerequisite for the successful use of panels in-situ.

Acknowledgement

This publication was created with the support of the Agency for the Promotion of Science and Research for the project "APVV-23-0619 Research of progressive technology of decomposition of glued layered materials". We would also like to thank the Grant Agency of the Czech Republic GAČR for its support in the project CL02000084 "Development of a complete prefabricated system for the construction of cycle paths on disused railway lines with the possibility of restoring railway transport".

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