Investigation of fastening failure in tram track structure on a bridge over the Vistula River

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Summary

The paper presents an investigation undertaken when partial disintegration of rail supporting material occurred on a bridge with a total length of over 500 m. The new embedded tramway track structure was built in 2009. Modified polyurethane resin was used as rail fastening material. Soon after completion, problems with the fastening material integrity appeared, including delamination, deformation and cracking in the polyurethane resins. The fastening material was found to have lost its adhesion and integrity due to design faults and errors in the execution of the works.

Keywords: urban bridge; assessment; track structure; railway systems; track failure.

1. Introduction

Modern tramway track technology allows tram lanes to be shared by buses and other passenger services [2, 4, 5]. Plastics with good adhesive properties are used to fasten the grooved rails into the road surfaces without the need for anchors. However, the properties of such plastics are highly vulnerable to site and weather conditions during construction.

The paper presents an investigation undertaken when partial disintegration of rail supporting material occurred on a bridge with a total length of 527 m. Soon after completion, problems with the fastening material integrity appeared, including cracking, delamination and deformation in the polyurethane resins. Samples of fastening material were taken from the track structure on the bridge. The track structure design and the construction photo database were studied. Laboratory tests allowed the existing parameters of the material after three years in service to be checked.

2. The bridge and tramway track structures

Fig. 1: General view of the bridge

The bridge was constructed in 1864 as the first permanent steel bridge over the Vistula river in Warsaw. The bridge received a new steel structure in 1949. A general view of the bridge is shown in Figure 1. In 2009, a refurbishment project for the W-Z route was conducted, which included replacement of the tramway track structure on the bridge. A slab track structure with embedded groove rails was introduced, and asphalt pavement laid on the tram lanes. The contract was a “design & build” project. The design for rebuilding the tram track structure on the bridge adapted a typical solution for railway track structures [1, 2]. A continuously embedded rail system (ERS)

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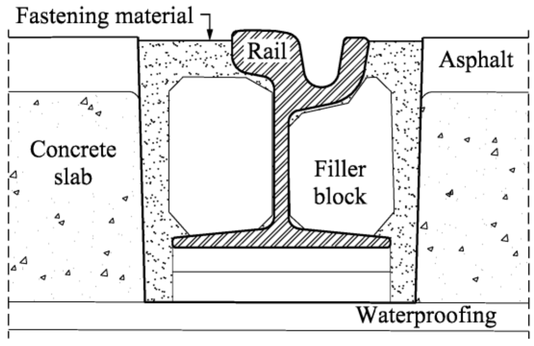

Fig. 2: Cross section of the rail system

with rails poured in-situ was developed (Fig. 2). Polyurethane resin was used as a structural adhesive that forms chemical bonds between the adherent surfaces. Shortly after completion of the work the first damage to the fastening material appeared, as the poured upper part of the fastening material detached from the surfaces of the adherents. The bond durability appeared to be very low and resulted in the splitting and loosening of the upper fastening parts. After losing its bond, the fastening material deformed, twisted and settled down. The damage quickly increased to cover the total length of the track structure on the bridge.

3. Investigation process and tests

The first initial visit was on a rainy day, so the insufficient subsurfacing drainage system could be seen immediately. Samples of loose embedding material were taken from the track structure to assess the composition and mechanical properties of the fastening material. The material was tested in tension, compression and tear. Hardness was also measured. Additionally, the composition of the fastening material was verified by Dynamic-Mechanical-Thermal Analysis (DMA) at temperature range from -120°C to +100°C. The average values of the tensile properties are: tensile strength 0,92 MPa, tensile modulus 5,34 MPa and elongation at break 57,9% (Fig. 3).

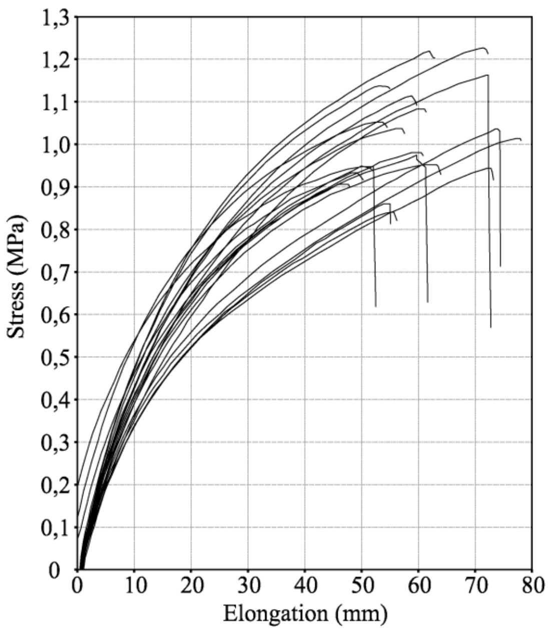

Fig. 3: Stains – stress curves

The composite fastening material consisting of a polyurethane resin and granulated rubber was developed in the tram track structure on the bridge over the Vistula River. Under test conditions, its material properties are quite good but partial damage has occurred in the upper parts of the track structure. The elastomeric polyurethanes bind well to both the cleaned rail surfaces and the concrete trough surfaces. They are expensive materials and also difficult for in-track construction; their handling and application should therefore be undertaken with care by qualified workers. Design and construction errors led to the premature failure of the fastening material.

4. Conclusions

The composite fastening material consisting of a polyurethane resin and granulated rubber was developed in the tram track structure. A source of damage to the fastening material was a loss of bonding to the surrounding materials and elements. The mechanical properties and composition of the fastening material were assessed, along with the design and the construction technology. This investigation highlighted faults both with the design and the execution of the track works that prevented the track system from functioning on the bridge. The failure of the fastening material was most likely caused by the combined effects of poor design detailing, poor workmanship and neglecting the requirements for plastic composite materials poured in-situ.

References

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