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Improvement of fixed railway tracks using fatigue-resistant cementitious fibre reinforced composite material

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Abstract

This paper presents a successfully executed project for the renewal an existing fixed railway track in a heavily frequented underground train station Zurich Airport by the application of ultra-high performance cementitious fibre reinforced composite material (UHPFRC). UHPFRC has so far been used mainly for the rehabilitation of road, roadways and railway bridges. The use of UHPFRC and novel technologies allowed to improve the existing fixed railway track, increase the service duration and reducing the construction cost by 30% compared to the traditional renewal methods. In frame of this project, the existing fixed railway track has been modernized in such way that the previous wearing components became part of the bearing structure. The minimum service duration of more than 100 years is expected for the improved fixed railway track.

Furthermore, the use of UHPFRC to cast the new rail pedestals allowed to obtain uncracked structural elements for the anchoring of the rail fasteners, which is not possible to obtain in the case of blocs in traditional reinforced concrete.

Keywords: fixed railway track, UHPFRC, uncracked structural elements, rail fastener.

1 Introduction

This contribution presents a successfully executed project for the renewal an existing fixed railway track in a heavily frequented underground train station by the application of ultra-high performance cementitious fibre reinforced composite material (UHPFRC). UHPFRC has so far been used mainly for the rehabilitation of road and railway bridges and roadways. The use of UHPFRC and novel technologies allowed to improve the existing fixed railway track and increase the service duration. The existing fixed railway track has been modernized in such way that the previous wearing components became part of the bearing structure. The minimum service duration of more than 100 years is expected for the improved fixed railway track.

The existing fixed railway track of the railway station Zurich Airport was constructed in 1980. It consists of four 640 m long tracks constructed as slab tracks of traditional concrete. According to the state-of-technology at that time, the fixed railway track was executed as reinforced concrete slab and prefabricated monoblocs of the LVT L77-B type which are fixed by means unreinforced concrete on the top of reinforced concrete slab.
Already after a few years of operation, the first cracks were detected in the area of the connection the L-shaped rods and the original monoblocs. After 30 years of operation, damages in terms of cracking and fracture of blocks were detected directly under the rail foot.

As a consequence, it was decided to renew the fixed railway track. In addition, the height of the platforms were adjusted in order to meet the requirements for people with disabilities. This project was carried out in 2019-2020 during short rail traffic closures. Thanks to the application of UHPFRC, the four fixed railway tracks of the station Zurich Airport could be taken into operation already a few hours after casting. Moreover, the use of UHPFRC allowed reducing the construction cost by 30% compared to the traditional renewal methods and the use of ordinary concrete. A significant part of the construction cost reduction was achieved by the reduction of height of the blocks of the fixed railway track, thus lowering the position of the rails such that no intervention was necessary to modify the existing platforms.

In addition, the use of UHPFRC to cast the new rail pedestals allowed to obtain uncracked structural elements for the anchoring of the rail fasteners, which is not possible to obtain in the case of blocs in traditional concrete.

2 Methods

In this project, the method of partial replacement of the existing slab track was applied. The damaged monoblocs of the original system were carefully removed with lifting devices and replaced by the new rigidly supported rail pedestals with the reduced thickness that were casted on the construction side.

The original fixed railway track of the Sonneville [1] system was designed in such a way that the monoblocs are belonging to the wear elements that can be replaced one-to-one in case of damaging. This construction advantage was used in the development of the renewal concept.

The applied method is based on investigations of damage causes, development of new building materials and infrastructure requirements.

The construction of the fixed railway track was modified such that the required rail track elasticity is achieved only by means of the rail pads. The use of an elastic layer under the pedestal was avoided in order to reduce tensile stress in the bottom of the pedestal.

The applied method also prevents fatigue damage in form of cracking that occurs in traditional concrete blocks immediately under the rails, due to the cyclic loading of passing train axles leading to low tension – compression stress reversals. Opposite to traditional concrete, the new UHPFRC pedestals are tension-compression fatigue resistant and are thus expected to remain uncracked during the entire service duration.

In addition, the applied method allowed to reduce the content of steel reinforcement bars. The knowledge gained from this project reveals that there is no need to add any steel reinforcement bars in the UHPFRC pedestal.
Furthermore, UHPFRC is also suggested for the rehabilitation and improvement of existing fixed railway track systems exposed to aggressive environments, since UHPFRC is a very dense and waterproof material leading to high durability.

Thanks to the good workability and self-compacting properties of fresh UHPFRC [2], new structural elements are also cast on the construction site that helped to achieve the required high precision of the railway gauge geometry.
Since the compressive strength of UHPFRC is relatively high, the required value of compressive strength of 12 MPa was already reached after a few hours of curing, allowing to take into operation the fixed railway track a few hours after casting.

The proposed intervention method is also well adapted to the often given compact construction site conditions allowing to conduct the construction works next to adjacent track under railway operation.

3 Results

The realised project demonstrated that the developed method using UHPFRC is cost-effective for the renewal of existing fixed railway tracks made of traditional concrete. The use of the UHPFRC allowed to optimize the construction of the original fixed railway track in order to avoid the costly reconstruction of the existing platforms.
Furthermore, the existing concrete slab track was not just repaired, but the technical performance also was improved that allows to expect a significant increase in service duration and thus reduction of future infrastructure maintenance intervention and cost.

Primarily, the application of UHPFRC was required due to construction reasons. It had been determined that the rail pedestals should only be 11.9 centimetres high at the lowest zone to avoid costly reconstruction of the platforms (Figure 1). But, the 11.9-centimetre-thin pedestals could not be realized in traditional reinforced concrete, because of improper rebar deployment (rounding radius of rebars) and the maximum aggregate size of concrete.
Moreover, the required lap and anchorage lengths of rebars in UHPFRC are about 3 times shorter than in concrete. The cover of rebars in UHPFRC is 1 centimetre instead of 3-5 centimetres depending on the exposure class of concrete. Therefore, and because of the high compression, tension and fatigue strengths, the building material UHPFRC provided an effective solution in this project.

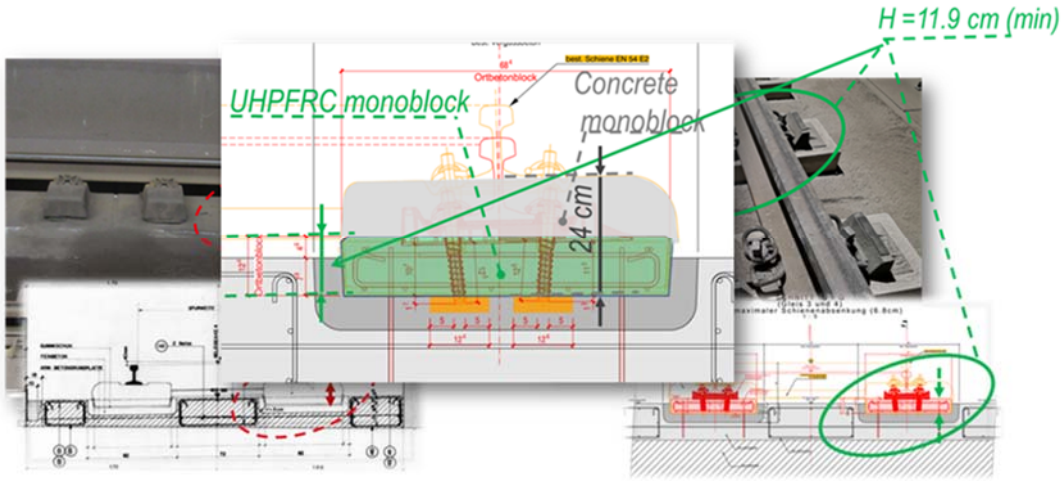

Figure 1: Application of UHPFRC instead of traditional concrete.

The consideration of the mechanical properties of UHPFRC, which was initially ordered purely for construction reason, allowed to improve the existing fixed railway track significantly.
The design and verification according to Swiss Standards and the detailed analysis of fatigue behaviour showed that the degree of material utilization is just 50%. Therefore, the UHPFRC pedestals can be optimized and performed even without rebars.
In addition to the development of the presented UHPFRC renewal concept, the damage causes of other existing fixed railway track in Switzerland were investigated. It was found out that same damage mechanisms occur making the UHPFRC renewal concept appealing for next renewal interventions of fixed railway tracks [3].

4 Conclusions and Contributions

The experience gained in the presented project revealed the use of UHPFRC for the renewal of an existing railway slab track of traditional concrete according to the concept of direct rail fastening on pedestals to achieve a more effective solution in terms of technical performance and economy. The main results are:

- Costly modification of the existing platforms was avoided by means of railway track lowering up to 12cm by reduction of the thickness of the UHPFRC pedestal

- Reduction of reinforcement content in the UHPFRC pedestal
- Increasing of the expected service duration to more than 100 years and thus reduction of maintenance work and cost.

The probably first application for the rehabilitation of the fixed railway track using UHPFRC has confirmed the suitability of UHPFRC for components subject to relatively high concentrated loads and fatigue.

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