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FAST BALLASTLESS SYSTEM

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Abstract

The ever-increasing demand for efficient and sustainable rail infrastructure and efficient land use has highlighted the necessity for innovative track systems. Traditional ballasted tracks, although widely used, present several challenges including additional high maintenance costs in the form of prolonged traffic disruptions and significant environmental impact. In contrast, ballastless track systems offer a promising alternative, enhanced durability, reduced maintenance, and a lower infrastructure and overall carbon footprint. Current technology offers many kinds of ballastless systems efficiently installable on new lines or during long traffic interruptions for existing lines. Unfortunately, there are no solutions for transitioning from ballasted to ballastless track on existing lines during temporary night interruptions with revenue service operations immediately after the works in the subsequent morning.

Thanks to this research it was possible to design a ballastless system that can be installed during short interruptions (non-revenue interruptions) already planned for ordinary maintenance activities in Italy. This achievement has paved the way for new installation opportunities for this reliable and easy-to-maintain track system. The proposed ballastless track system achieves ease of installation, rapidity, minimal invasiveness, modularity, durability, noise & vibration reduction. It provides capabilities and adaptability to different contextual needs for an additional ease in maintainability and reduced lifecycle costs thanks to its state-of-the-art grout mix and installation machinery leading to a stable and highly monitored workflow. The proposed system has successfully completed various strict quality assurance protocols for the verification and validation of its safe implementation and operational deployment in accordance with railway engineering standards and track infrastructure compliance requirements. The FAST system installation workflow for existing lines involves takeover of the track section requiring replacement and the subsequent handover of the interim replacement segment for its temporary transit period, followed by the conclusion of the track replacement on the second day.

Keywords: Noise/Vibration, Ballastless, existing lines, zero-line closure, tunnels.

1. Introduction

Many ballastless tracks currently available in the market provide different solutions based on specific manufacturer preferences. However, very little attention is paid to the hidden costs related to extended installation times and prolonged line closures for infrastructure interventions on running lines. Far too many cast-in-situ solutions currently available are relatively slow to build, have reduced quality and require elaborate preparation [1][2]. They allow little room for post-intervention track adjustment during the life of the system. However, many experts have been discussing ways to increase the rapidity of precast panel solutions, with consequently higher quality, better load bearing capacity and modularity in comparison to cast-in-situ solutions. A potentially longer shelf life would also contribute to reducing overall environmental impact. Precast ballastless solutions are deemed to be safer for air quality and the health of workers during construction phases particularly inside confined spaces such as narrow tunnels or underground environments.[2] Additionally, prestressed pre-cast ballastless solutions have a reduced climate impact, higher possibility of quality control while assuring a potential design life of 70-100 years[3].

The FAST SYSTEM, developed by OVERAIL Ltd., a subsidiary of the Salcef Group, is a patented system specifically designed to be installed with minimal disruption to existing rail traffic, especially during planned short non-revenue time track possession, allowing for rapid reopening of the lines by the next morning. Thanks to the system's modularity and its state-of-the-art elements and workflow automation, FAST can be adapted to most of the industry's rail network needs and even to the ever-evolving infrastructure requirements.

2. FAST System description

The main element of the system consists of a prestressed reinforced concrete prefabricated slab. Its dimensions are 187 x96x8 inches. The manufacture and installation methods have been designed to eliminate the use of maintenance adjustments provided by the Vossloh 300-1 fastening system during construction. The slab adjustments are carried out by temporary supports of the slab rather than by fastening system corrections. Moreover, the fastening system allows ample room for gauge regulation (+/- 3/8 inches) and vertical positioning (-3/16, +3 inches) after slab-track installation. In the fastening system, an additional under-rail EPDM plate 171,022 – 570,075 lbf/in is foreseen for additional noise & vibration mitigation. The slabs are equipped with two stopper holes that have the task of counteracting the actions occurring on the plane of the track, both longitudinal and transversal to it.

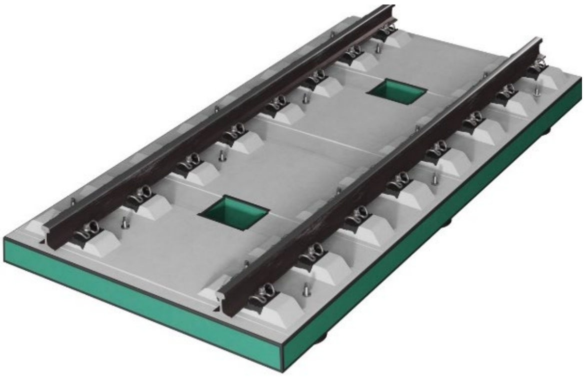


Figure 1: Fast slab

The stoppers consist of two retainers in reinforced grout, contained in two rectangular compartments aligned with the slab at the second and penultimate gauge, to be cast in place after the installation of the prefabricated element. The slabs are also equipped with mats for their separation to facilitate slab replacement in case of an accident during their design life.

A crucial aspect of the FAST system is the use of the 14 under-slab provisional support spindles during installation consisting of mechanical devices that allow the transit of trains after the reopening of revenue services along with the adjustment of the horizontal and vertical positions before grout pouring. The number of spindles depends on the specific work condition (either total or temporary outage). The spindles and the slab structural verification was carried out in the TUM laboratories in Munich using **FEM analysis** with reference to the **56,202 lbf /axle LM71 train** load model. This method ensures that the track remains aligned with design geometry throughout the installation process and allows revenue reactivation of the railway vehicles by morning both in absence of grout and with fresh grout. Once the grout has been poured and cured, the track is stable and the screws of these provisional supports are removed, leaving a fully functional and durable track system for the intended design life. The automated workflow of the FAST SYSTEM as discussed in **§2.2** along with its installation machinery described in **§2.3,** is a significant advancement in railway construction technology. Further details are discussed in later sections of this paper.

2.1 FAST® Workflow

The key component of the FAST ballastless track system is its capability to complete the installation from track

possession to track hand-over within a 5-hour net time window and guarantee a fully functional revenue service track segment. A monitored workflow ensures the functional reliability of the system during the temporary line reactivation phase. Thanks to the in-house developed automation of rolling stock discussed further in this document, the FAST workflow streamlines the construction phases and significantly reduces manual workforce input, thereby further reducing any margin of error.
The workflow is distributed over two consecutive days of track replacement on the same segment allowing an intermediate revenue day-time track functionality. The FAST workflow involves initiation of work activity immediately following the scheduled nighttime interruption and track possession. It is represented as follows:

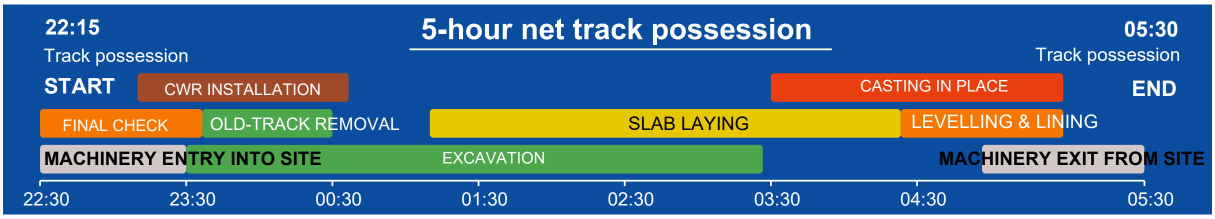


Figure 2: FAST system intervention 5 hr chrono-program.

Day 1: Removal of old track + installation of slab track on provisional supports + monitoring start.	**Day 2: Casting of under-slab grout and removal of provisional supports + monitoring system toggle.**
• Track possession + site equipment entry • Pre-intervention survey • Thermal cutting/removal of existing track panels with sleepers and ballast/sub-grade, cleanup of the planned replacement segment • Compaction of support surface for the slab followed by base stiffness tests • Placement of FAST slabs + pre-adjustment • Short rail joints + temporary under-rail support joint + topographic survey • Installation of slab stability monitoring devices which collect data in real time and start of workflow monitoring	• Simultaneously, Day 1 activities are carried out on the adjacent/subsequent track segment. On the previously laid slab track: • Removal of monitoring sensors • Casting of under-slab grout • Post intervention adjustment • As built survey • Site machinery exit • Site handover • Line reactivation

2.2 FAST automation equipment.

The SRT Ltd company, a subsidiary of the Salcef Group, develops and realizes specialized machinery trains that streamline the installation process, ensuring efficiency, reliability and precision.

2.3 Machinery

The main specialized machinery for the FAST workflow is described below:

1. Ballast and old track removal train: This train carries away the old track segment with sleepers and removes the existing ballast. The train is equipped with wagons to stack the removed track segments or new slabs and has a built-in conveyer system to ensure that the removed ballast is transported away from the intervention segment, thus minimizing the time and personnel required for this phase. This mechanized train reduces manual labour and speeds up the overall process, allowing for faster track renewal. The vehicle is specifically designed with reduced loading gauge profile and minimal pollutant emissions for compatibility in metropolitan areas and the environment.

2. Concrete Batching/Mixing Train: This train is equipped with dry-inert hoppers and silos with built-in high precision dosing equipment to produce precise quality and quantity of grout. This guarantees high quality of the mix and ensures that the slabs are supported by a case-specific design mix of grout while minimizing wastage. The train system is programmed and automated to allow full control on the grout output directly from the single operator preventing any further manual physical manoeuvre.

3. Slab track laying train: The slab laying train is specifically designed to transport, handle, lay down and accurately adjust the prefabricated concrete slabs. This single train is equipped with stacker/transport wagon, -high-precision handling equipment and a sturdy crane that allows for the slabs to be placed with minimal manual intervention. The use of transitable prefabricated slabs not only speeds up the installation process but also ensures uniformity and quality across the track.

All the construction/installation rolling stock machinery is designed to minimum clearance envelopes to allow installation in the smallest possible working spaces.

The prefabricated slab designed by **Overail** is in compliance with the **UNI EN 16432 parts 1,2,3** and RFI (the Italian National Railways) guidelines. The installation machinery designed by **SRT** is in compliance with the specifications and directives of **EN 14033 parts 1, 2, 3:2017** and **EC Machinery Directive 2006/42/EC.** This machinery is also authorized by ANSFISA (the Italian Railroad Safety Authority) for its access into the **AISM** market to circulate in "running mode" train composition with a max speed of 62 mph as towed vehicles, whereas it is authorized by RFI to circulate under the "track interruption regime" as towed vehicles at a maximum speed of 37 mph.

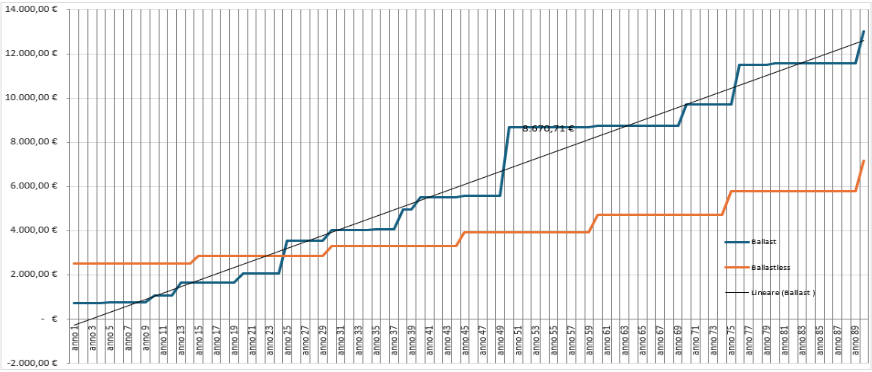
3. FAST system in stats

Fast Productivity and output: The Fast system typical output is 12 slabs each night for the transformation of a ballasted tracks into ballastless tracks during a 5 net-hours nightly non-revenue time possession, that is, 190 feet. In the case of new constructions, the system guarantees the output of 60 slabs for each 8-hour shift, that is, 945 feet. Installations executed by the mechanized slab-laying and batching convoy (SRT equipment) for new line constructions demonstrate a productivity in out-of-service regimes reaches **576 m/day (1889 ft/day)** (two shifts × 288 m (945 ft)).

In terms of application and rollout, Starting in 2022 the FAST ballastless system has been deployed on revenue lines across Italy and has replaced over 18.30 km (≈ 11.36 miles) of ballasted track for multiple use-cases, 90% of which is on regional train lines on single/double track with speeds ranging from 60-150 km/hr (≈ 37.2 - 93.2 mph) (e.g., RFI's Lamezia Terme–Catanzaro Lido, Avezzano-Roccasecca, Roma Sulmona and various others) whereas the rest is on urban metro lines on multiple segments in Rome metro at 40 km/hr (≈ 24.85 mph - Line A)—demonstrating the systems adaptability to tunnels, at-grade alignments and station platforms while maintaining service during circulation hours and intervening by night time closures.

Fast Life Cycle : Acc. to LCA[12], Quantified life-cycle results on the Italian network show a **>90-year** service-life design (carbonation-based verification per FIB approach), **–42%** greenhouse-gas emissions over 90 years (**–1,840 tCO_2 eq/km ≈ 0.62 miles**), and **–35%** life-cycle energy consumption versus ballasted track with PSC sleepers; the total-cost breakeven occurs at ~**year 25**, with **–44.91%** cumulative cost to year 90 (**€5,842 ≈ US$ 6836 per track-meter** saved at 2025 tariffs). Assuming a **social cost** of **$185 per metric ton of CO_2 equivalent**, the economic savings per track-kilometer from CO_2 reduction can be calculated as:**1,840 metric tons × $185/ton = $340,400 per km**. Consequently, for every **10 km (≈ 6.2 miles)** of track installed with the FAST System, the avoided social costs exceed € **3.13 million** (**≈ US$ 3.66 million)** [12]

Compliance and acceptance are anchored to recognized frameworks: FAST is designed to the **EN 16432** ballastless-track series (CEN/BSI) and is stated as approved by **EN** for general application; Italy-wide deployments and RFI communications further evidence network acceptance. The LCA cited above was conducted by **Nexia Audirevi – ESG & Sustainability** (member of the Nexia International network), providing third-party assessment of environmental impacts. Operational and logistical outcomes material to O&M include stable long-term track geometry (reducing planned tamping/lining), 60 mm (≈ **2.36 inches)** insulated rail-slab offset with sloped slab surfaces and high-insulation fastenings to limit stray-current corrosion (notably in humid tunnels), and a fully accessible longitudinal drainage at slab level to faciliate inspectability without extended possessions. Beyond computable metrics, the FAST system's elimination of ballast mitigates supply-chain risk from aggregate scarcity—in some cases—while enabling parallel work fronts and limiting passenger disruption through night-only interventions. These advantages, though project-specific and hard to monetize, materially enhance program delivery and demonstrate FAST's adaptability to both local and global operational contexts.[12]



Realtime comparative Vibrational and disturbance performance evaluation (Case: Rome Metro). Further independent accelerometric and structural-vibration measurements carried out at executed stations Battistini, Cornelia and Baldo degli Ubaldi stations by **A.C.N.D. S.r.l.** to assess pre-/post-renewal intervention outcomes in terms of local impact show post-FAST reductions in human-perception-weighted acceleration per **UNI 9614/UNI ISO 2631**—**Cornelia a_n,w,95: 7.86→5.42 mm/s² (−31%)**; **Battistini a_n,w,95: 3.78→2.56 mm/s² (−32%)**—with all post-renewal values compliant (e.g., **V_sor,max = 5.4 mm/s²** at Cornelia below the relevant UNI 9614 limits). Structural peak velocities remained well below damage thresholds per **UNI 9916/DIN 4150-3**, indicating effective mitigation of ground-borne vibration and associated disturbance after conversion to FAST slab track.[13]

The **system's approval** tests were carried out at the Technical University of Munich laboratories to verify the characteristics of the components of the track system (Precast slab transit reliability) in all installation conditions and assure compliance to the **RFI** technical specifications and guidelines for ballastless track systems. The system has qualified additional qualification tests for various Italian, US and international railway approval bodies specializing in system reliability and quality, listed below:

- 5-million cycles test for train transit simulation and performance under sustained train transit conditions.
- Electromagnetic compatibility standards for the installation of signalling transponder components on the FAST slabs.
- Compressive strength of hardened concrete as per UNI EN 12390-3.
- Resistance deterioration due to freeze-thaw cycles measured in accordance with UNI.
- Water penetration resistance as per UNI 12390-8:2017.
- Electrical resistance tests in accordance with UNI EN 13146-5.
- Pull-out resistance as per UNI EN 13146-10.
- Strength in relation to repeated loads 13146- 4.

4. What is new about the research?

With reference to technological advancements, the research focused on the practical aspect of the installation period reduction. An innovative aspect of the FAST SYSTEM is its intermediate reactivation mode that allows the possibility of work execution during night shifts without additional traffic interruption thanks to the FAST slab equipped with provisional supports, capable of sustaining stable train transit even before casting of the final foundation grout underneath the slabs. Furthermore, the FAST mechanized slab installation process, thanks to specialized machinery, allows the intervention with the lowest amount of personnel involved, thus accelerating the overall process, minimizing the possibility of human error and reducing the necessity of complex workforce safety protocols, particularly in confined spaces such as old single-track tunnels.

5. Future developments

As of the date of this writing, further 17.5 km (**≈ 10.877 miles**) of FAST installations are planned to start replacing existing ballasted lines by October ’25 across various lines in the Italian Railway network. Further Research & Development is in progress for the FAST mass-spring systems mainly focusing on case-specific noise & vibration reduction to adapt the system case-wise to the specific technical and environmental requisites of the project. Development and approval of the system to different rail-track gauges, for case specific necessities and experimental studies are envisioned.

6. Conclusion

Desired outcome and impact of research for key beneficiaries & international partnerships: The ease of installation of the system minimizes the use of personnel, waste of time and interferences involved in the construction/renovation of a railway line, thus reducing complexity in the workflow. Citizens, commuters and passengers will benefit from reduced noise & vibration, as well as reduced line interruptions. The infrastructure stakeholders will benefit from the improved performance, reduced maintenance, and longevity of the overall transport infrastructure Thus paving for a truly vast potential for international partnerships. By the involvement of infrastructure managers, the system can become part of a new way of transitioning to ballastless tracks without interrupting rail traffic by collaborating with companies that are aiming to plan and install our system, as well as those aiming to start producing such a cutting-edge system under our supervision.

References & Norms

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