Embedded Rail Slab Track

A NEW high performance affordable embedded rail slab track system for high speed and heavy freight traffic, also suitable for light-rail applications, delivering:

- Integral broken rail containment
- Integral derailment prevention
- Buckle-proof rail containment at all temperatures
- Lowest system height for improved clearances (370mm)
- Configurable to reduce airborne noise and ground borne vibration
- Environmental drainage control and easier cleaning
- Unique rail head stability

Compared to traditional track forms:

- Up to 90% reduction in the number of components required
- An installed cost approaching that of ballasted track
- Up to 50% increase in rail life
- A 70% reduction in the use of quarried aggregates
- An 80% reduction in inspection and maintenance costs
- A 50% reduction in risk of track related fatalities
- Increased operational availability and capacity

Balfour Beatty Rail has developed, for supply to railway clients, main contractors and track installers, an embedded rail system, invented by Charles Penny, that provides greater safety, performance and availability, with lower maintenance and reduced whole life costs. The rail is continuously supported in an elastomeric pad and a fibre reinforced plastic shell. The system enables an efficient, low profile reinforced concrete track slab. Initial installation using either slipform or pre-cast concrete is both fast and economical.

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Balfour Beatty Rail Technologies Ltd
Midland House Nelson Street Derby DE12SA Tel: +44 (0) 1332 262 424 Fax: +44 (0) 1332 262 027 www.bbrail.com Patent W099/63160

Commissioned section of the BBEST system on the West Coast Main Line at Crewe in September 2003

Network Rail
Acceptance
PA05/00535/PU
ACCEPTED FOR SITE SPECIFIC APPLICATION

QUALITY IN CONSTRUCTION AWARD
Balfour Beatty Rail has considerable experience of designing and installing many different slab track systems worldwide. Recent projects include the Lantau Airport Railway in Hong Kong, the Oresund Tunnel between Sweden and Denmark and Line 4 of the Santiago Metro in Chile.

This experience has led to recognition of the need for slab track systems that meet the increasing demands of railway clients. Their key drivers for change, which the new system accommodates, include:

- Very high availability
- Heavier axle loads and increasing speeds
- Higher annual gross tonnages
- Mixed freight and passenger traffic
- Move to 24 hour services
- Reduced noise and vibration
- Minimizing inspection and maintenance costs
- Improvement in track geometry quality
- Lower whole life costs
- Increased safety for passengers and staff
- Improved clearances especially in tunnels giving structural savings or increased capacity

A Balfour Beatty Rail development group concluded that a continuously embedded rail system would provide the step change in technology required to meet these new challenges.

Development work, including dynamic testing at Munich Technical University, confirmed the unique performance of the system. Trial installation tests were then carried out at Beeston in the UK, followed by installation in a high speed test track at Medina del Campo in Spain.

The first scheduled traffic installation took place at Crewe in the UK in August 2003 where a section of the system is now carrying passenger and freight traffic for Network Rail. The system received Network Rail Acceptance in February 2006.

The system can be designed to meet each Client’s specific needs including rail and pad characteristics.
Embeddaded Rail System

Mk II System

Normally high speed track has to be concreted with the rails in position. The very high manufactured tolerances of the system and the new temporary clipped lid ensure the correct track alignment is set without needing the rails in place.

Benefits of the system:

- Separation of the critical concreting, alignment and railing activities:
  - Less risk of programme overrun
  - Quick installation, shorter programme
  - High quality finished product
- Only two replaceable components:
  - Less inspections, fully automated
  - Less risk of component failure
  - Less maintenance
- Opportunity for low cost high output mechanised installation with inexpensive light equipment
- Pad shear characteristic aid rail renewal and maintenance
- Benefits of the ‘top down’ installation maintained and:
  - No need to handle heavy rails while setting the alignment
  - No need to maintain rail alignment while vibrating concrete
  - No concrete shrinkage issues
  - Rail head profile to meet EU standard
- An ability to design performance characteristics to client’s specific requirements. (i.e. vertical stiffness, longitudinal restraint, lateral support, gauge etc.) Varying as appropriate along the track

A new shell lid has been designed that accurately holds the shell into the required alignment before grouting takes place.

For the new single piece seal and pad simulation has been carried out through a sophisticated software and validation testing procedure.

High performance, simple and cost effective

Only three sub-system components
1 Integrated seal and pad
2 Robust rail
3 Shell anchored into grout
System Description

Performance
Tests on the system undertaken at the Technical University of Munich and on test tracks in Spain and the UK, show exceptional static and dynamic spring characteristics and bi-axial load fatigue performance. It gives superior gauge retention with no pad deterioration or performance loss after 4.7 million cycles of fatigue loading. The resilience meets the current Deutsche Bahn AG requirements for slab track.

The system is ideal for high speed passenger, heavy haul freight and mixed traffic railways, metros and light rail, and for tunnels, viaducts and open route. The pad resilience can be tuned to meet each client's requirements for ride quality, noise and vibration.

Lower Maintenance Costs
With only three components and no fastenings or fittings to come loose or corrode little inspection is required. This lowers the costs of inspection, maintenance and spares stocks. The pad and shell resist grease and acid.

The system may also allow increased rail side wear. In the event of excessive wear or contamination the rail and pad can be removed and replaced with new components without disturbing the shell or track slab.

Construction
The track slab uses a suitably prepared formation. The concrete slab is cast in-situ, slip formed or pre-cast with slots for the sub-system. Rail is supplied in long or short lengths for aluminothermic or flash butt welding. The rail, pad and shell are held by special alignment frames and grouted into position. Storm water is directed away from the slab and formation by a drainage system. Electrical details can be provided to suit third and fourth rail traction power and signalling equipment requirements.

Engineered Value
Simple • Increased route capacity • Safe
Cost effective • High performance • Quick installation

Increased Availability and Clearance
Lower maintenance increases track availability and reduces the un-planned delay risk and speed restrictions. The track slab has a typical system depth of only 370mm (top of rail to bottom of slab) saving 300-400mm over a ballasted system. This gives extra clearance for larger vehicles or smaller tunnels, for new overhead electrification or for reducing weight on viaducts and bridges. The system is shallower than all equivalent systems. The stability and durability of the system reduces the kinematic envelope allowing:

- Avoidance of structure gauge clashes
- Larger vehicles
- Higher loads
- Tilt technology
- Higher speeds

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The system is designed to deliver the best possible safety performance. The Balfour Beatty system dramatically reduces or eliminates:

- Gauge spreading
- Track twist faults
- Cyclic top faults
- Broken rails
- Track buckles
- Vandal intrusion

The Safety Case process has shown that the risk to passengers due to the track form could reduce by 50%. Risk of worker death or injury during inspection or maintenance will be dramatically reduced as a consequence of lower maintenance requirements.

A comprehensive hazard identification exercise and a detailed risk assessment of hazards has been carried out on the system. This work has been independently assessed by AEA Technology Rail. These documents are available to all clients wishing to approve the system for use on their railways.

Due to the rail support conditions, the maximum total stress in the rail is significantly less than a flat bottomed rail in all ultimate loading conditions.

**Best Value**

*The system delivers the most benefit for the least cost to client, installer and operator.*

**Key Safety Benefits**

- Rail held safely and securely
- Long-term good quality track geometry
- Optional integral derailment prevention
- Broken rail containment
- Reduced exposure for maintenance workers
Environmental Noise

Embedded Rail System

Noise generated from the railway has significant and negative effects on both the surrounding environment and the travelling public.

The primary source of noise from the railway system is rolling noise which is generated and emitted by the wheel/rail contact and by structures. Factors affecting this are the surface roughness, the physical shapes and the dynamics of the key components.

Rail head corrugation are the most extreme form of rail head roughness and the most common cause of high train noise problems.

The reduction in corrugations achieved by continuous support of the rail in the Balfour Beatty system is crucial for the reduction of rolling noise.

The high quality track level and alignment provided also ensures significantly reduced likelihood of train ride instability – a known trigger of damaging rail head wear and fatigue conditions.

Quiet Rail Shape

The rail shape used by the system has been shown to be fundamentally quieter! This is because its shape has a smaller surface area even without being embedded, than flat-bottomed rails such as BS113A and UIC 60. The embedment also offers a benefit as it forms an integral shielding of the bulk of the rail.

The dynamics of the rail depend on its resilient support pad, which can be configured according to customer requirements, including noise.

Measurements in Spain

Measurements taken on the system in Spain found that it was less noisy than an equivalent section of adjacent ballasted track. With less noise generated at the rail the extent of any barriers for residual noise is reduced.

Key Environmental Noise Benefits

- The BB14072 rail is a quieter rail shape
- Continuous support minimises rail corrugation risk
- The system can be less noisy than ballasted track
- Reflected noise is minimised due to narrow slab width
- Additional tuned noise absorption can be provided

Bridge Noise

The simplicity of the design allows it to be integrated into a railway bridge deck to give maximum structural efficiency and enable the structure to be optimised for noise control.

Reflected Noise

A common concern with concrete track beds is the potential for additional reflection of noise from the concrete surface.

The system minimises this effect as a narrow slab width of 2.2m can be designed, and the system reduces the angle of reflected noise from under the train, making noise barriers more effective. Grass track, or other noise absorbing overlays, can also be used to further enhance the benefits if required.

Additional Noise Absorbing Potential

Another exciting option is the inclusion of a tuned absorber within the embedded rail support structure. This can be tuned to the particular frequencies of the rail in its support pad to dramatically reduce rail emitted noise from the system.
Environmental Vibration

Embedded Rail System

Vibration is emitted into the environment as moving trains interact with the track structure. This can seriously disturb people living and working in the vicinity of the railway. It manifests itself as:

- Directly perceptible vibration (low frequencies)
- Rumble noise inside buildings caused by walls and floors vibrating at low frequencies (~40-80Hz)
- Low frequency noise radiating from the railway structures such as bridges

Environmental Vibration is traditionally controlled by isolation using soft rail support systems or with ‘floating slab track’. Slab track can also reduce vibration generation by providing a smoother track profile and by reducing the deformation of the ground at low frequencies under dynamic train loading.

The continuous support to the rail provided by the Balfour Beatty embedded rail system and the integrity and accuracy with which it can be installed provides the optimum conditions for a permanent smooth track profile at all wavelengths. In particular it minimizes the risk of rail head corrugation, the most extreme form of rail head roughness and a known cause of rumble noise.

The system isolates vibration by:
- careful configuration of the stiffness characteristics of the continuous rail pad.
- embedding the rail, while allowing very low stiffness, retains controlled rail stability without the need for complex dual resilient systems and fixings.

Minimum Depth Floating Slab

In the most extreme cases, vibration isolation may require a floating slab track form. In such instances, the system enables the most efficient design of track slab and support arrangement to be created, by the:

- Embedment of the rail, allowing maximum mass to be used in the least depth of track slab, or the smallest feasible diameter of new tunnel; and
- The simplicity of the support system - maximum use can be made of the structural section with less concern over slab flexing, which is a greater constraint if discrete rail supports are used.

Key Environmental Vibration Benefits

- BBEST isolates vibration using tailored low stiffness rail pads, without compromising rail stability.
- BBEST reduces low frequency vibration generation and propagation by strength and smoothness of line.
- Continuous rail support minimises rail corrugation.
- Allows least height mass spring system design.