BALLASTLESS TRACK SYSTEMS 
EXPERIENCES GAINED IN AUSTRIA AND GERMANY 

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ABSTRACT 

The railway companies in Austria and Germany use ballastless track systems for many years. Due to their experiences it is obvious that such systems show a lot of advantages compared to ballasted tracks. 

Their experience demonstrates that such systems have substantial advantages when compared with ballasted tracks. Especially, on high-performance and high-speed routes, ballastless track systems like elastically supported slab track ÖBB-PORR are installed to ensure maximum track availability and minimum maintenance needs. 

INTRODUCTION 

Since the middle of the 20th century, several countries across the world have adopted and developed the use of ballastless slab-track systems.

The major reasons for these developments came as a result of increased levels of track traffic, which in turn restricted track maintenance time; this was coupled with the fact that train speeds increased up to 300 km/h. 

In the last 50 years many different types of ballastless track systems have been developed in different countries. The reason that each country developed its own system was due to different applications. Some countries focused on tracks in tunnels or on bridges, others focused on high-speed lines and earthwork. The main types of systems are: 

- Compact systems 
- Baseplate systems 
- Block systems 
- Embedded rail systems 
- Prefabricated slab systems 

Depending on the different aspects such as gained experience with the system and local circumstances the choice for one system is driven by determining the applicability and the life cycle costs of the system [1].

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DEVELOPMENT IN AUSTRIA

Within the national network of the Austrian Federal Railways (German: Österreichische Bundesbahnen, ÖBB) the use of slab track systems initially began in the 1980s.

As traffic loads, permissible travelling speeds and availability increased, it was proven that at least in tunnel routes the slab track has numerous advantages over ballasted track. Therefore in Austria, for new tunnel routes over lengths of 500 m, the installation of slab track is preferred.

Between 1982 and 1995 several types of ballastless track system were tested on the ÖBB network [2], which focused on the three main groups of systems:

- Monolithic systems (compact systems)
- Rubber booted sleeper systems (block systems)
- Prefabricated slab systems

After this first trial period, a concrete-based slab track system with elastically supported precast slabs called system ÖBB-PORR was identified as most suitable for applications for the ÖBB network.

This system consists of prefabricated reinforced concrete slabs which are placed with a 40 mm wide open joint between two adjacent slabs. The slabs are coated with an elastic layer to separate them from the under poor concrete. This design principle compensates for any deformations caused by creeping, shrinking and temperature changes. Furthermore the elastic coating leads to reduced noise and vibration levels. The system comprises two elastic layers: the highly elastic rail fasteners type 300-1 and the elastic coating.
Since 1995, nearly all ÖBB ballastless tracks have been equipped with the elastically supported slab track ÖBB-PORR system. Since the first installation of the system near Langenlebarn, 25 years of experience has been gathered. The main result of this experience is that ballastless track systems like ÖBB-PORR are nearly maintenance free permanent ways. The only regular maintenance work needed is rail grinding, similar to what is needed for ballasted tracks.
For reduction of ground-borne noise and in particular vibration emission, modifications of slab track in the form of mass-spring-systems (floating track slab systems) have been developed in the past years. With such systems the emissions can be reduced far below the level of ballasted track systems even with sub-ballast mats. For sensitive urban areas, the above-mentioned elastic-layered slab track system ÖBB-PORR alone is insufficient to mitigate against vibration. Therefore, a mass-spring-system constructed continuously from in-situ concrete without joints was developed. Since 1996, such mass-spring-systems are under operation in the railway network. At that time the new design principle of continuous concrete troughs carrying the ballastless track system ÖBB-Porr was installed in the Römerbergtunnel. Until now, many additional installations of that design have been realised, e.g. in the Wienerwaldtunnel and Lainzer Tunnel in Vienna.
BALLASTLESS TRACK SYSTEM ÖBB-PORR IN GERMANY

The Deutsche Bahn, the German railway company, installs slab track systems not only in tunnels and on bridges but also on earthwork sections. Since 2001 the ÖBB-PORR system is also used by Deutsche Bahn in the area of the main station in Berlin. There, the system is installed on a large number of bridges on the East-West corridor and also in the north-south line tunnels, partly on mass-spring-systems. For the design of these mass-spring-systems the experience in Austria was taken into account.

More than 150 km of double track ÖBB-PORR slab track system are currently under construction on the corridor VDE 8 – the high speed line between Berlin and Munich. Beside earthwork these sections contain a large number of bridges and tunnels.
The different types of bridges as e.g. short bridges (L < 25 m), long bridges and large viaducts for crossing valleys resulted in different solutions for the ballastless track on these bridges. Figure 5 shows for example the design principle for a double track long bridge.

The interaction between bridge and track superstructure leads to special ballastless track design on the bridge and causes transition elements for the expansion joints at the ends of the bridge decks. At the ends of the bridge superstructure, the track system has to resist the movements and rotations between bridge and abutment. These movements and rotations lead to an increase of rail stresses and forces on the rail fasteners adjacent to the bridge joint. Movements occur in longitudinal and lateral track direction, rotations lead to vertical pressure and tension forces on the rail fastening system. Figure 5 shows the impacts on the track system at bridge joints.

Figure 5: Transition bridge superstructure – abutment [3]
Figure 6: Cross-section of bridges with ballastless track system
Figure 7: Cross-section of tunnel with ballastless track system

Figure 8: Cross-section of earthwork with ballastless track system
Due to the very high train operation speed, additional investigations were made to ensure a well-tempered dynamic system behaviour avoiding resonance effects. These investigations proof that the dynamic adjustment of the elastically supported slabs is very well suited for train speeds up to 330 km/h.

**MAINTENANCE, REPAIR AND LIFE CYCLE COSTS**

Experience shows that following parts of ballastless track systems may need maintenance works during lifetime of the system:

- Rails: grinding or milling, repair of welds, exchange of rails
- Rail fasteners: adjustment works, exchange of angled guide plates, exchange of elastic pads, exchange of clips, exchange of screws
- Drainage system: cleaning of pipes, trenches

Long-term studies from ÖBB and extrapolations of these results show that the concrete elements of ballastless tracks will have a lifetime of about 80 years without maintenance needs caused by environmental conditions and regular train operation.

ÖBB-experiences concerning maintenance costs per km track are published in [5]. In comparison to ballasted tracks, figure 8 shows the break-even point for the total track costs after 24 years of operation based on a daily track loading of about 70,000 gross-tons. Thereafter, the payback of the higher initial investment costs of ballastless track is achieved.

![Comparison of costs for ballasted and ballastless track per km](image)

**Figure 9: Comparison of costs for ballasted and ballastless track per km**

Beside these results for regular train operation, it has to be considered that extraordinary situations can occur. E.g. derailment of train may lead to severe damage on the track system. Therefore, the ease of reparability of a track is of major importance. It is obvious that ballastless track systems are more difficult to repair than ballasted tracks. The development of
the elastically supported slab track ÖBB-Porr was particularly driven by the repair ability aspect. The system allows the following repair measures:

- Repair of rails, rail-welds, a.s.o. and exchange of rails (see above mentioned maintenance needs)
- Repair/exchange of Rail fasteners (see above mentioned maintenance needs)
- Repair of concrete slabs, e.g. of seats/shoulders for rail fasteners (e.g. after derailment of boogies/trains)
- Repositioning/replacement of concrete slabs (e.g. in case of large settlements of sub-construction)

For every single repair measure, detailed consultations have taken place and the required time-span for each measure has been investigated. Therefore, in case of repair, minimum investment in time is required to conduct the works. This ensures maximum availability of the track.
CONCLUSIONS

The ballastless track system ÖBB-PORR is used for many years on earthwork as well as on bridges and in tunnels. The system is proven for usage on high-performance lines as well as on high-speed lines and shows many advantages in comparison with other types of ballastless and ballasted track systems.

REFERENCES

1) UIC Project Ballastless Track “Report about the application and the experience with ballastless track” version 2005-11-03, not published.
2) Schilder, R., 2005: “Experiences in Ballastless Track gained on ÖBB”, European Slab Track Symposium, Bruxelles.
4) Adam, C., 2011: “Expertise concerning the dynamic performance of the ballastless track system ÖBB-PORR” (German), not published.

FIGURE CAPTIONS

Figure 1: Elastically supported slab track system ÖBB-PORR
Figure 2: System ÖBB-PORR in Langenlebarn (first installation in 1989)
Figure 3: Mass-Spring-Systems with ballastless track system ÖBB-PORR
Figure 4: System ÖBB-PORR in Tunnels of North-South Corridor in Berlin
Figure 5: Transition bridge superstructure – abutment [3]
Figure 6: Cross-section of bridges with ballastless track system
Figure 7: Cross-section of earthwork with ballastless track system
Figure 8: Cross-section of earthwork with ballastless track system
Figure 9: Comparison of costs for ballasted and ballastless track per km
Figure 10: Exchange of slabs
Ballast-less track systems
Experience Gained in Austria and Germany

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General

**Ballastless Track**

- Heavy concrete sleeper track (uniform European track)
- Ballast substructure 40%
- Rail fastening Rail pads 60%

**Ballasted track**

- Elasticity without subsoil

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**The Main Construction Principles for Ballastless Track**

- Compact Systems (Monolithic systems e.g. System Rheda, System Rheda 2000)
- Baseplate Systems (e.g. Vossloh, DFF21, Pandrol VIPA)
- Block Systems (Booted sleeper systems e.g. System Stedef, System LVT)
- Embedded Rail Systems (e.g. Edilon-Sedra EBS, CDM-Track)
- Prefabricated Slab Systems (e.g. System Bögl, System ÖBB–PORR)

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**Practical Examples in Austria**

**Development in Austria**

<table>
<thead>
<tr>
<th>Year</th>
<th>System</th>
<th>Feature</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>Rheda</td>
<td>Tunnel rehabilitation</td>
<td>480 m</td>
</tr>
<tr>
<td>1985</td>
<td>JOARB</td>
<td>Tunnel rehabilitation</td>
<td>638 m</td>
</tr>
<tr>
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<td>ÖBB-PORR</td>
<td>Embankment</td>
<td>264 m</td>
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<tr>
<td>1989</td>
<td>Strassengarten</td>
<td>Tunnel rehabilitation, embankment</td>
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<tr>
<td>1991</td>
<td>Rheda</td>
<td>New tunnel, light MSS, 4 turnouts</td>
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<tr>
<td>1993</td>
<td>Strassengarten</td>
<td>Bridge</td>
<td>52 m</td>
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</table>

**Total length**

22,631 m

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**Decision-making of ÖBB**

**Slab Track System in Austria**

1. Construction (space requirements,...)
2. Method (sensitivity of laying,...)
3. Quality (track set, acoustics,...)
4. Economy

⇒ System ÖBB-PORR is the STANDARD SYSTEM in Austria
Decision-making of ÖBB - Construction
System ÖBB-PORR

- High degree of prefabrication
- Low construction height

Cross-section beside pouring aperture

Decision-making of ÖBB - Method
Structural Implementation

Criteria: Quality
System Comparison

Comparison of evaluated vibration emission KB between the ballast track and different slab track systems in ÖBB.

Criteria: Quality
System Comparison

Comparison of structural-borne noise - Slab Track vs. Ballast Track
**Decision-making of ÖBB - Quality**

*Acceptance Certificate*

- Frequency distribution of deviations
- Example 638 measurement points, specifications in %

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<th>Gauge</th>
<th>Moving chord position</th>
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<td>8.8</td>
<td>3.4</td>
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<tr>
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<td>8.8</td>
<td>3.4</td>
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<td>2.5</td>
<td>8.8</td>
<td>3.4</td>
<td>18.8</td>
<td></td>
</tr>
</tbody>
</table>

**Decision-making of ÖBB - Quality**

*Precision of Track Base Plate*

- +/ - 0,3 mm tolerance for precast

**Decision-making of ÖBB - Economy**

*Life-Cycle-Costs (LCC)*

- Graph showing costs over years

- Ballasted track - discounted present value
- Ballasted track - discounted present value

**Decision-making of ÖBB - Summary**

*System Comparison*

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<thead>
<tr>
<th>System</th>
<th>Space</th>
<th>Track Quality</th>
<th>Safety</th>
<th>Repair Concept</th>
<th>Settlement Adjustment</th>
<th>Vibration</th>
<th>Installation</th>
<th>Investment</th>
<th>Maintenance</th>
<th>Proven</th>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>--</td>
<td>--</td>
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<td>+</td>
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<td>++</td>
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<tr>
<td>Bögl</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
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<td>--</td>
<td>++</td>
<td>+</td>
<td>--</td>
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</tr>
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<td>ÖBB – Porr</td>
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<td>++</td>
<td>++</td>
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</table>

**Decision-making of ÖBB**
Special Solutions for Ballastless Track

**Mass-Spring-Systems**
Modification of superstructure for ground born noise and vibration attenuation

=> Mass-Spring-Systems (floating track slab systems)

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**Example Römerberg tunnel**

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**Transitions**

Ballastless Track vs. Ballasted Track

Austria RZ 17220

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**Transitions**

Ballastless Track vs. Ballasted Track - Germany, Berlin

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Practical Examples in Austria

Development in Austria

1982 - 1995: FIRST PERIOD OF TESTING DIFFERENT SYSTEMS

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
<th>System</th>
<th>Feature</th>
<th>Length</th>
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<tbody>
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<td>Großer Türkenschanztunnel</td>
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<td>Rheda</td>
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<td>Hausrucktunnel</td>
<td>1985</td>
<td>JOARB</td>
<td>Tunnel rehabilitation</td>
<td>638 m</td>
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<td>FJB Wien - Glogau, Bereich Langenlebarn</td>
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<td>Sub track ÖBB-PORR</td>
<td>Embankment</td>
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<td>Dürrbergtunnel</td>
<td>1991</td>
<td>Züblin</td>
<td>Tunnel rehabilitation, embankment</td>
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<tr>
<td>Arlbergtunnel</td>
<td>1992</td>
<td>Slab track</td>
<td>Tunnel rehabilitation</td>
<td>3 491 m</td>
</tr>
<tr>
<td>Teichtunnel</td>
<td>1992</td>
<td>Slab track</td>
<td>Tunnel rehabilitation</td>
<td>3 491 m</td>
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<tr>
<td>Schießbergtunnel</td>
<td>1992</td>
<td>Rheda</td>
<td>New tunnel, light MSS, 4 turnouts</td>
<td>9 010 m</td>
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<td>Helwegstraße</td>
<td>1993</td>
<td>Bridge</td>
<td>Bridge</td>
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<tr>
<td>Höllingwegbahn</td>
<td>1994</td>
<td>Züblin</td>
<td>New tunnel, embankment, bridge</td>
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<td>Total length:</td>
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<td>22 631 m</td>
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Langenlebarn - First Installation in 1989

1996 – ONGOING: PERIOD OF SLAB TRACK ÖBB-PORR (EXTRACT)

<table>
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<th>Project</th>
<th>Year</th>
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<td>Slab track</td>
<td>New tunnel, light MSS, embankment, bridge, 4 turnouts</td>
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<td>Rinnerbergtunnel</td>
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<td>Slab track</td>
<td>Light and heavy MSS</td>
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<tr>
<td>Zimmerntunnel</td>
<td>1996/1999</td>
<td>Slab track</td>
<td>New tunnel, Light and heavy MSS</td>
<td>4 477 m</td>
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<td>Widlingulbental - Ellental</td>
<td>1999/2000</td>
<td>Slab track, passable with cars</td>
<td>New tunnel, medium-weight MSS, 4 turnouts</td>
<td>3 732 m</td>
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<td>Stegbettunnel</td>
<td>2000/2001</td>
<td>Slab track</td>
<td>New tunnel</td>
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<td>Arlbergkessel</td>
<td>2004</td>
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<td>Arlbergkessel</td>
<td>2005/2007</td>
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<td>Tunnel rehabilitation, 8 turnouts</td>
<td>3 912 m</td>
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<td>Lainzer Tunnel</td>
<td>2010</td>
<td>Slab track</td>
<td>New tunnel, Light, medium-weight and heavy MSS</td>
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<td>Kunstlehr/ Badkirchen</td>
<td>2010</td>
<td>Slab track</td>
<td>High-speed line, new tunnel, light, medium-weight and heavy MSS</td>
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<td>Wischerwaldtunnel</td>
<td>2010/2014</td>
<td>Slab track</td>
<td>High-speed line, new tunnel, bridge and embankment, light, medium-weight and heavy MSS</td>
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<td>Total</td>
<td></td>
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<td>580 031 m</td>
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Ballastless Track on Floating Track Slab

Light Mass-Spring-System (MSS)

<table>
<thead>
<tr>
<th>Wienerwaldtunnel</th>
<th>Light MSS</th>
<th>4.4 t/m, 18 Hz</th>
</tr>
</thead>
</table>

Heavy MSS with strip layers

| Wienerwaldtunnel         | Heavy MSS    | 9 t/m, 8 Hz    |
Practical Examples in Austria

**Wienerwaldtunnel**

- **Heavy MSS with single layers**

9 t/m, 7.5 Hz

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Practical Examples in Germany

**Development in Germany**

<table>
<thead>
<tr>
<th>Project</th>
<th>Year System Feature</th>
<th>Feature</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lehrter Bahnhof</td>
<td>2001/2002 Slab-track</td>
<td>14 extension joints, line length 86 bridge</td>
<td>4,216 m</td>
</tr>
<tr>
<td>Lehrter Bahnhof</td>
<td>2002/2004 Slab-track</td>
<td>approx. 10,000 m gpm, medium weight and heavy MSS</td>
<td>14,068 m</td>
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<td>2012/2013 Slab-track</td>
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<td>329,468 m</td>
</tr>
</tbody>
</table>

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Practical Examples in Germany

**North-South Corridor in Berlin**

- **Cross-section Tunnel**

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Practical Examples in Germany
North-South Corridor in Berlin

High-speed Line VDE 8

- Structural Implementation
- VDE 8.1.2
- VDE 8.1.3
- VDE 8.2

Σ > 300 km track with ÖBB-PORR System

Cross-section on Embankment

Cross-section Bridge Sector

Cross-section Tunnel
Ballast-less track systems
Experience Gained in Austria and Germany

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