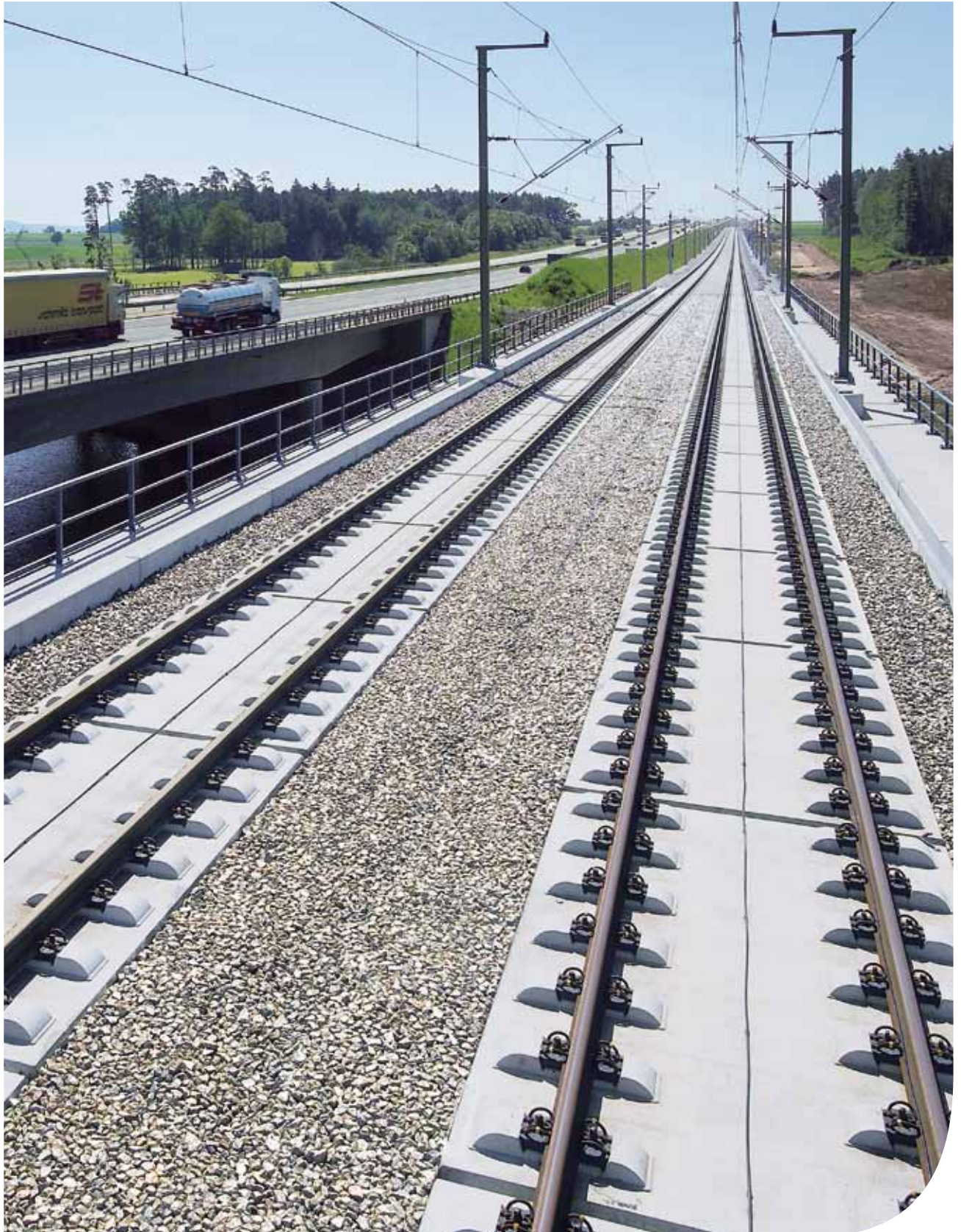


Ballastless track on high-speed lines

A guarantee for travel safety and comfort



SSF Ingenieure



Prologue

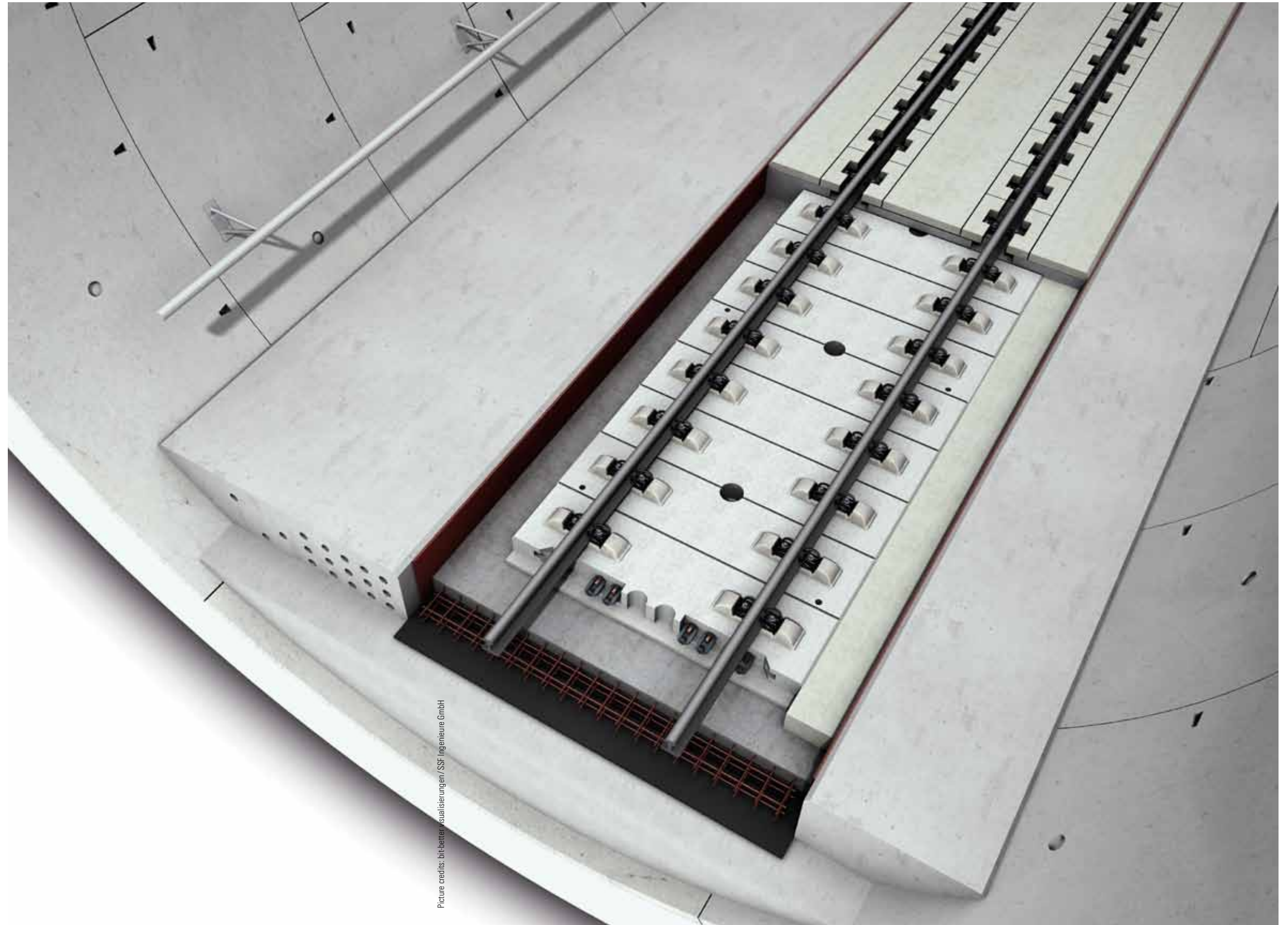
High-speed rail travel, as a fast connection between high-density population areas and as an alternative to frequently-overloaded air connections with an uncertain future, is gaining increasingly in significance all over the world. In the face of growing traffic density, critical views of life-cycle costs and significantly increased requirements of the availability of railway tracks, there is an increasing demand for track systems which have a long lifetime, low service and maintenance costs and which also guarantee travel safety and comfort.

Ballastless tracks (BLT) have numerous advantages over the traditional ballasted track, because of markedly reduced maintenance costs, longer duration of use, improved precision of the running track and the resultant quiet vehicle running.

High speed and ballast

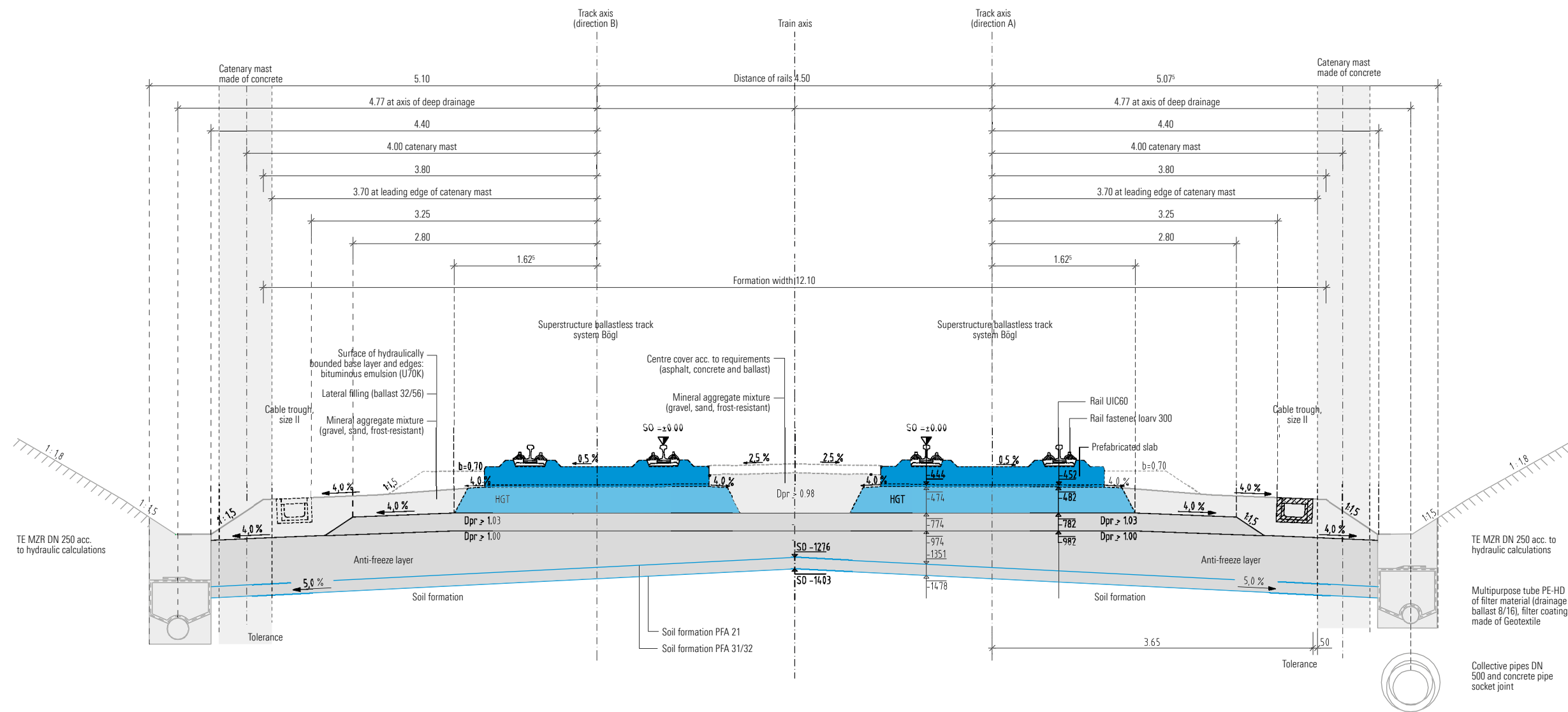
The nature of the route requirements is changing, as a result of an increase in travel speed or axle loads. The load transported creates inertial forces and the particular more-frequent faults arising from the rolling process are increasing dramatically. Altered deformation mechanisms with dynamic stimulation can result in major grain shifts during piling-up of ballast, which result in considerable impairment of the ballasted track and are responsible for uneven creeping and track displacement in the ballast bed. In addition, the track ballast stones are sucked up by vehicles at very high speeds (flying ballast) and may damage them. Despite the choice of harder types of stone for ballast in high-speed traffic, maintenance costs are considerably higher. Maintenance expenses usually double for a route covered at 250 to 300 km/h as opposed to one covered at 160 to 200 km/h. Replacing the ballast on such routes becomes necessary after 300 million load tonnes (load tonnes = total of axle loads), instead of after 1 billion load tonnes previously.

Visualization ballastless track as prefabricated part design (Type Bögl FFB) in the Tunnel Katzenberg



Picture credits: bit-better visualisierungen/ SSF Ingenieure GmbH

Ballastless track on earthworks in cutting area –
Type Bögl FFB on new railway line Nuremberg – Ingolstadt



The ballast bed is also sensitive to strong impurities which may occur in the bulk transport of mineral ore and of coal, in heavy rail transport. The lasting input of fine particles results in the ballast components "floating" and this phenomenon has to be countered by increased expenditure on ballast cleaning and tamping tasks.

As a continuous, largely rigid transport system with clearly-specified storage conditions and uniform rigidity conditions, the ballastless track design does not possess these kinds of disadvantage and is thus primarily ideally suited to use both in high-speed rail traffic and in heavy goods traffic under special conditions of use.

Comparison between ballasted and ballastless tracks

The salient feature of the ballasted track is its low production cost. The track can also largely be maintained automatically and during

night intervals. The track geometry can also be easily adjusted. It is a disadvantage that the track geometry is altered by the passage of the trains and has to be realigned periodically. This alignment process causes the track to be raised and the rails have to be installed at a lower height as in the case of a ballastless track. In this context, the term used is "lifting reserve". The mechanised steps with heavy track maintenance machines also cause considerable environmental stresses as a result of noise emissions and dust formation. Ballastless tracks, which replace the maintenance-intensive track ballast by a fixed design, guarantee a consistently good track geometry, and the maintenance of the highest standards in travel comfort at greatly-reduced maintenance expense. Compared to the ballasted design, this design makes it possible for greater lateral acceleration forces to be supported. The route study can be more closely focussed and curve speeds increased.

In addition, the standard types of construction for the ballastless track have a lower base height than the ballasted track. This is of particular advantage in minimising tunnel cross-sections or for structure clearances in the case of existing tunnel structures. It is a disadvantage that the updating of an ballastless track cannot be carried out during night intervals and that the type of construction is generally very sensitive to differential height alterations of the foundations, in view of the limited possibilities for adjustment of the rail support points. The initial investments are higher all-round than for the ballasted track.

Functionality

In practical terms, the ballastless track's functionality can be explained by comparing it to the ballasted track. In the case of ballasted track the dispersion of vertical and horizontal stresses, and,

as a result, track deformation at increasing speed, depend on the track geometry quality which is uneven along the track axis, because of the different bearing elasticities of ballast and subgrade.

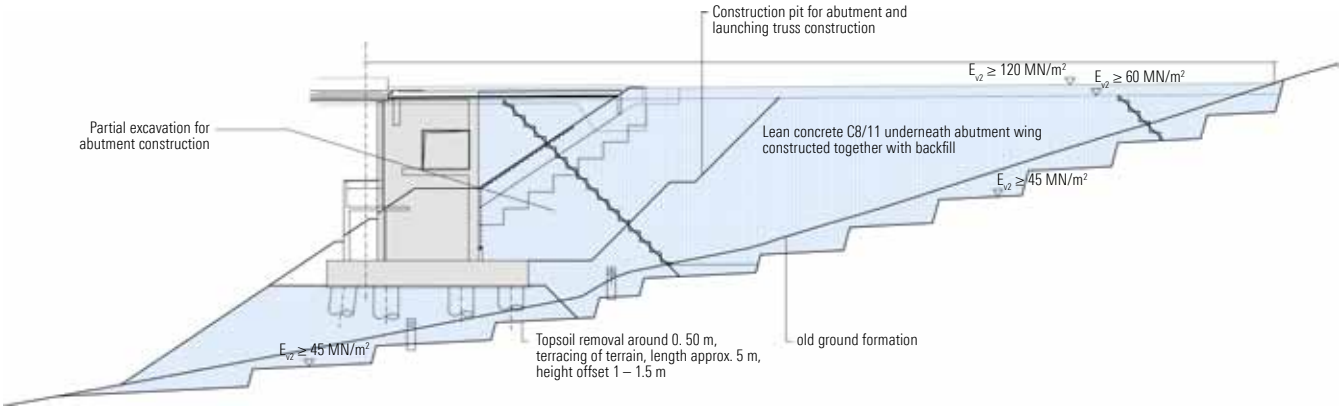
In the case of the ballastless track, a multi-layered, largely rigid supporting system is formed by differently-designed slabs and specified unbound base layers. The required track elasticity for the distribution of the traffic loads and damping of the dynamic effects is, in contrast to the ballasted track, achieved almost exclusively by means of intermediate elastic layers in the rail fastening system or by elastically-supported sleeper bearing systems. Thus a high level of homogeneity of vertical rigidity with precisely definable and only slightly dispersing values is achieved in the design of the ballastless track. This is of the greatest importance for the interaction of vehicle and track in high-speed traffic.

Ballastless track substructure

The ballastless track design requires a foundation which is almost free of deformation and settlement. The ballastless track must normally be prepared to a depth of at least 2.5m beneath the slab by using suitable customised, quality-assured earthwork materials. In cases of low load-bearing, soft or pulpy soil conditions, special foundation improvement measures are generally necessary to guarantee stability and usability or for settlement stability. With ballastless tracks on earthworks, an adequately-sized foundation in the form of a layered package is now provided for even and long-term low-deformation support for the track structure, consisting of a hydraulically-bound load-bearing layer or, alterna-

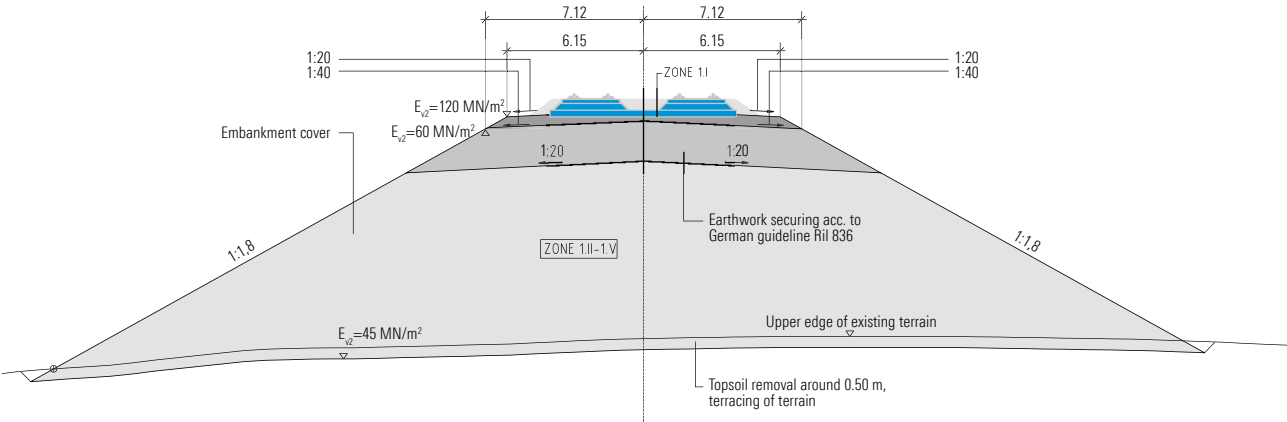
tively, an asphalt load-bearing layer, a frost-protection layer underneath it and the bottom load-bearing layer (earth subgrade) with overall proven properties. The hydraulically-bound load-bearing layer or the asphalt one protects the multi-layered system with the upper frost-protection layer, by distributing the forces over a large area before dynamic stresses have their effect. The unbound load-bearing layer underneath the frost-protection layer consists of scarping, in the case of specially documented embankments and as a foundation in cuttings, with equally documented properties, with soil replacement, if necessary.

Abutment of a viaduct with transition to earthworks



Earthwork requirements backfill and embankment						
Zone		Permissible grain size	Soil classification acc. to DIN 18196	Compaction	Bearing capacity	Special requirements
1.I	superstructure: frost protection layer	KG 2 acc. to DBS 918 062 (Germany railway standards)	GW	Dpr ≥ 1.0	$E_{v2} \geq 120 \text{ MN/m}^2$ on upper edge earth formation	$k_f \geq 1 \times 10^{-5} \text{ m/s}$
1.II	substructure base layer + abutment filling	max. thickness ≤ 20 mm after treatment of initial material	GU, GT, SU, ST	Dpr ≥ 1.0	$E_{v2} \geq 60 \text{ MN/m}^2$ on upper edge earth formation	Soil binder mixture: Binding agents ≥ 5 wt.% *) frost-resistant upper layer thickness ≥ 0.3 m, $q_{u,M} \geq 0.8 \text{ MN/m}^2$ $q_{u,M} \geq 1.0 \text{ MN/m}^2$
1.III	substructure: backfill	max. thickness ≤ 20 mm after treatment of initial material	GU*, GT*, ST*, SU*, UL, UM, TL (TM, TA) use acc. to UIG	Dpr ≥ 1.0 and $n_A \leq 0.12$	$E_{v2} \geq 60 \text{ MN/m}^2$ on upper edge earth formation	Soil binder mixture: Binding agents ≥ 5 wt.% *) frost-resistant upper layer thickness ≥ 0.3 m, $q_{u,M} \geq 0.8 \text{ MN/m}^2$ $q_{u,M} \geq 1.0 \text{ MN/m}^2$
1.IV	substructure: backfill	max. thickness ≤ 20 mm after treatment of initial material	GU*, GT*, ST*, SU*, UL, UM, TL (TM, TA) use acc. to UIG	Dpr ≥ 1.0 and $n_A \leq 0.12$	$E_{v2} \geq 60 \text{ MN/m}^2$ on upper edge earth formation	Soil binder mixture: Binding agents ≥ 6 wt.% *) frost-resistant upper layer thickness ≥ 0.3 m, $q_{u,M} \geq 1.6 \text{ MN/m}^2$ $q_{u,M} \geq 2.0 \text{ MN/m}^2$
1.V	backfill underneath abutment	max. thickness ≤ 20 mm after treatment of initial material	GU*, GT*, ST*, SU*, UL, UM, TL (TM, TA) use acc. to UIG	Dpr ≥ 1.0 and $n_A \leq 0.12$	$E_{v2} \geq 60 \text{ MN/m}^2$ on upper edge earth formation	Soil binder mixture: Binding agents ≥ 5 wt. % *) frost-resistant upper layer thickness ≥ 0.3 m, $q_{u,M} \geq 0.3 \text{ MN/m}^2$ $q_{u,M} \geq 1.0 \text{ MN/m}^2$

Ballastless track on earthworks, in embankment area



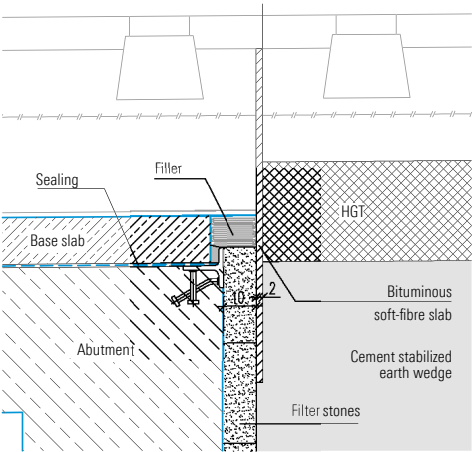
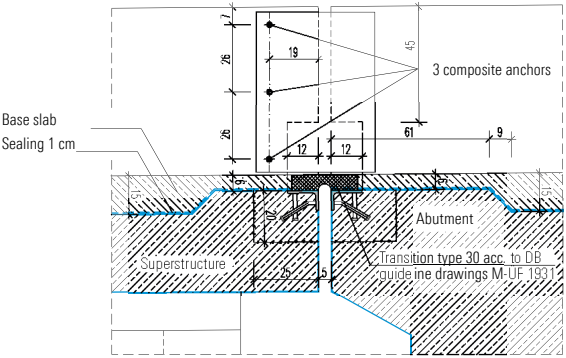
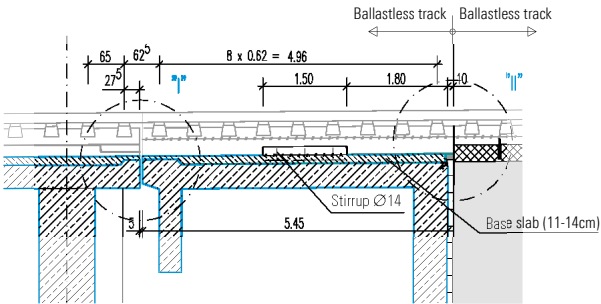
New railway line Nuremberg - Ingolstadt – Allersberg regional / overtaking station
Main lines: Bögl System ballastless track; station / overtaking station: ballasted track



Picture credits: Photographie Wolfgang Seitz

Picture credits: SSF Ingenieure GmbH

Details of transition between bridge and open track – Füllbach Viaduct



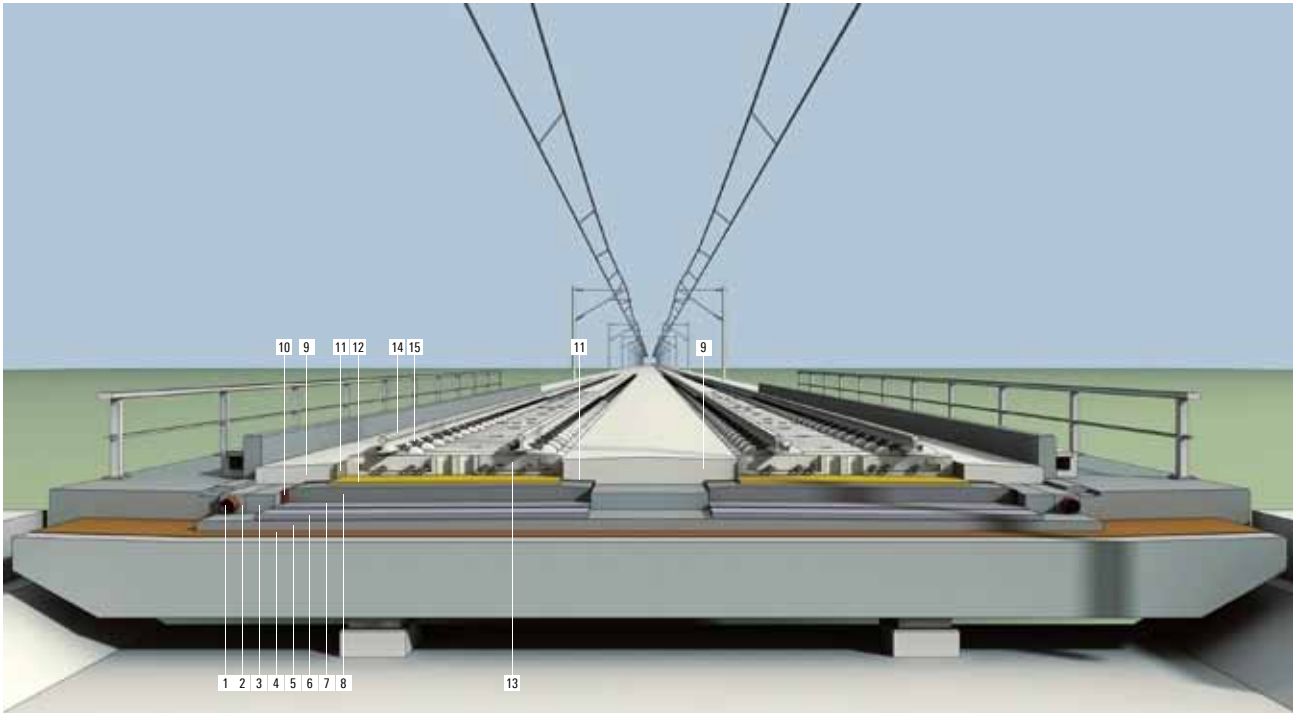
BLT on bridges

For structural and maintenance reasons, it is advisable to implement the design of the open track’s BLT across the bridge without changing it. In addition to the discharge of longitudinal forces, the transition between bridge and open track, and also between separate spans of the bridge, is decisive for the use of BLT on bridges.

The length of the bridges is the decisive factor in the application of the ballastless track on bridges. That is why we make the distinction between ballastless track on short bridges and ballastless track on long bridges. Short bridges apply up to an expansion length of 25m. This limitation of the expansion length causes the horizontal forces resulting from braking or starting to be transferred from the continuous welded track in a lengthwise direction (x direction) without exceeding the permitted stress relief of 92 N/mm². The continuous welded track must continue for up to 40m beyond the end of the bridge.

The BLT is basically movably supported in a lengthwise direction on short bridges by a gliding surface. Guide bearings for the discharge of horizontal lateral forces (y direction) are provided (lateral guiding with elastomer bearings).

Long bridges apply from an expansion length of 25m. The track slabs must be fixed to the superstructure in order for them to be able to transfer the larger proportion of the longitudinal forces from braking or starting to the superstructure and from there to the bridge bearings. This guarantees that the proportion of longitudinal forces remaining in the track does not exceed the permitted stress reliefs (coupled bridge-to-track system). Basically, the track slab is securely connected to the superstructure, i.e., immovably elastically supported, longitudinally and laterally. A frictional connection guarantees the longitudinal force transfer between track slab and bridge via a diamond slab, in which the track slab engages with cams (“stoppers”). Simple elastomer cushions in the vertical areas of the diamond design ensure the transfer of the x- and y-aligned loads. Along with the thin elastomer tracks on the horizontal dividing areas, this guarantees that insignificant rough spots and small twists and tilts can be absorbed. To guarantee optimal maintenance of the ballastless track on bridges, the track slabs are subdivided into short slabs, approx. 4.50m to 5.50m in length.



Visualization ballastless track design on short bridge (span < 25m) - Type Bögl FFB

- | | |
|--|---|
| 1 Drainage pipes PE-HD DN 250/mineral aggregate, antifreeze (gravel/sand), KG1 material, Dpr. \geq 0.98 | 9 Protective concrete layer C20/25, un-reinforced |
| 2 Single grain concrete 8/16 or mineral aggregate 11/16 | 10 Elastomeric bearing 0.20 m x 0.10 m x 0.01 m made of stainless steel sheeting thickness 0.005 m |
| 3 Lateral guiding of ballastless track | 11 Separating layer Styrodur thickness = 0.01 m vertical and horizontal |
| 4 Sealing – superstructure, thickness 0.01 m | 12 Grouting mortar, thickness = 0.03 m for bond between prefabricated slab and hydraulically bound base layer |
| 5 Protective concrete/base slab, C20/25, thickness 0.11 m | 13 Track slab of ballastless track prefabricated slabs system Bögl, C45/55, width 2.55 m |
| 6 Rigid foam slab 0.05 m, Styrodur 5000 glued | 14 Rail UIC 60 |
| 7 Formation of sliding surface, 2 bearings bituminous paper (150 g/m ²)/2 layers PE-sheets (each 0.245 mm) | 15 Rail fastening system Vossloh Ioarv 300-1 |
| 8 Compensating concrete/base slab, C25/35, reinforced, thickness = 0.17 m | |



Visualization ballastless track design on long bridge (span > 25m) - Type Bögl FFB

- | | |
|--|---|
| 1 Ballast, upper part (thickness = 0.10 m) glued with Kryorit | 6 Elastomeric bearing thickness 0.0015 m, all around the hump and stopping surfaces, absorption of loads in x and y direction |
| 2 Sealing – superstructure, thickness = 0.01 m | 7 Grouting mortar thickness 0.03 m between hump slab and separating mat |
| 3 Protective concrete/base layer thickness 0.11 m, C25/35, reinforced with stirrups for connection with hump plate | 8 Track slab ballastless track, prefabricated slabs system Bögel with stoppers (buffers), C45/55, width 2.55 m, slab length 5.50 to 6.50 m, transversal joint at hump and stopper areas, joint width 0.10 m |
| 4 Hump plate C25/35, reinforced | 9 Rail UIC 60 |
| 5 Elastic separating mat, thickness 0.0012 m glued to all horizontal surfaces of the track slab | 10 Rail fastening system Vossloh Ioarv 300-1 |

Designs

In the design of the ballastless track, it is basically possible to specify three basic shapes.

- monolithic designs: sleepers or support blocks (e.g., Rheda or Züblin system), concreted into a cast-in-place track slab, supported on a hydraulically-bound load-bearing layer
- monolithic designs: flexibly–encased sleepers or support blocks (e.g., LVT system), concreted into a cast-in-place track slab
- designs with prefabricated slabs: prefabricated concrete parts/ concrete slabs (e.g., Bögl and Porr systems) with grouting mortar, supported on a hydraulically-bound load-bearing layer.

- supported designs: asphalt load-bearing layer (e.g., Getrac system) or, less frequently, concrete load-bearing layer with directly-supported track span and installation of individual sleepers

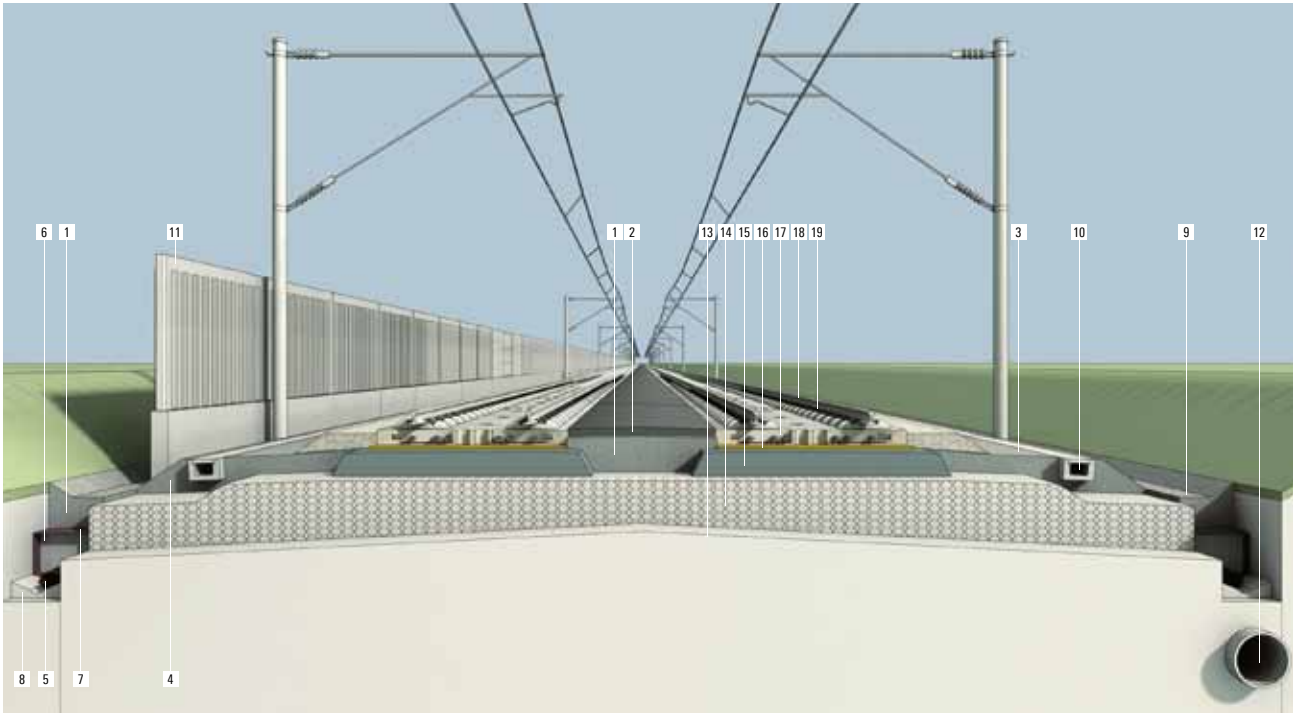
The specific requirements of the earthworks and the use of prefabricated rail fastening–points are common to all the designs, whether with single- or twin-block concrete sleepers or with individual supporting blocks/prefabricated slabs.

The monolithic BLT systems or the designs with prefabricated slabs are installed according to the top-down principle. The pre-

cise horizontal and vertical positions of the rails (usually slab rails) on the track span or on the prefabricated slabs are set, before they are fixed permanently by cast-in-place cement or grouting mortar. The supported designs stand out mainly in the mechanical safeguarding of the track length against lateral movement and take-off, when a vehicle axle is in forward or reverse drive. With monolithic designs and the designs with prefabricated concrete parts, the track span is primarily safeguarded against the external effects of train traffic and temperature, because of the track footing and the friction contact with the hydraulically–connected

load-bearing layer. On the other hand, with the “Direct track-span support on load-bearing asphalt layer” design, the sleepers are laid directly on top of the asphalt covering layer and permanently flexibly fixed, with “anchor blocks” of very high-strength grouting concrete, which transfers the longitudinal and lateral track forces to the asphalt.

The above-mentioned basic shapes, each being set down on a hydraulically-bound load-bearing layer, require no differentiation of any kind regarding earthwork requirements of the substructure/foundation.



Visualization ballastless track display on earthworks in embankment area without cant. BLT - Type Bögl FFB (prefabricated slab with grouting mortar on hydraulically-bound load-bearing layer).

- | | |
|---|---|
| <ul style="list-style-type: none"> 1 Mineral aggregate, frost-resistant (gravel/sand); KG1-material, Dpr. ≥ 0.98 frost resistant material 2 Water-tight centre covering (asphalt or concrete)/asphaltic base aggregate mix 0/16, thickness 10 cm 3 Sidewalk 4 Lateral backfill with ballast; grain size 32/56, canopy width 0.40 to 0.70 m 5 Deep drainage – drainage pipes PE-HD DN 250 6 Deep drainage – ballast, grain size 8/16 7 Deep drainage – geotextile fleece coating 8 Lean concrete 9 Ditch next to railway with filter-stable rock material 10 Prefabricated cable duct, width 0.40 m 11 Noise barrier highly-absorbent, founded on bored piles | <ul style="list-style-type: none"> 12 Main pipe with concrete tubes DN 400 13 Earth formation (= lower unbound layer); $E_{v2} \geq 60 \text{ MN/m}^2$ 14 Frost protection layer (= upper unbound layer); KG2 material, $E_{v2} \geq 120 \text{ MN/m}^2$; min. thickness = 0.50 m 15 Hydraulically bound base layer, thickness = 0.30 m, canopy width 2.95 m, contact surface 3.25 m, lateral incline 2:1 16 Grouting mortar, thickness = 0.30 m for bond between prefabricated slabs and hydraulically bound base layer 17 Track slab for ballastless track prefabricated slabs system Bögl C45/55, width 2.55 m 18 Rail profile CHN 60 19 Rail fastening system Vossloh Ioarv 300-1 |
|---|---|

The higher flexibility of the load-bearing asphalt layer with less dynamic stresses to the foundation can be opposed to the greater rigidity of the concrete slab with consequently lower, even stresses when a train passes over it. Both are, however, considerably more suitable than ballasted track.

Vibration and structure-borne noise protection

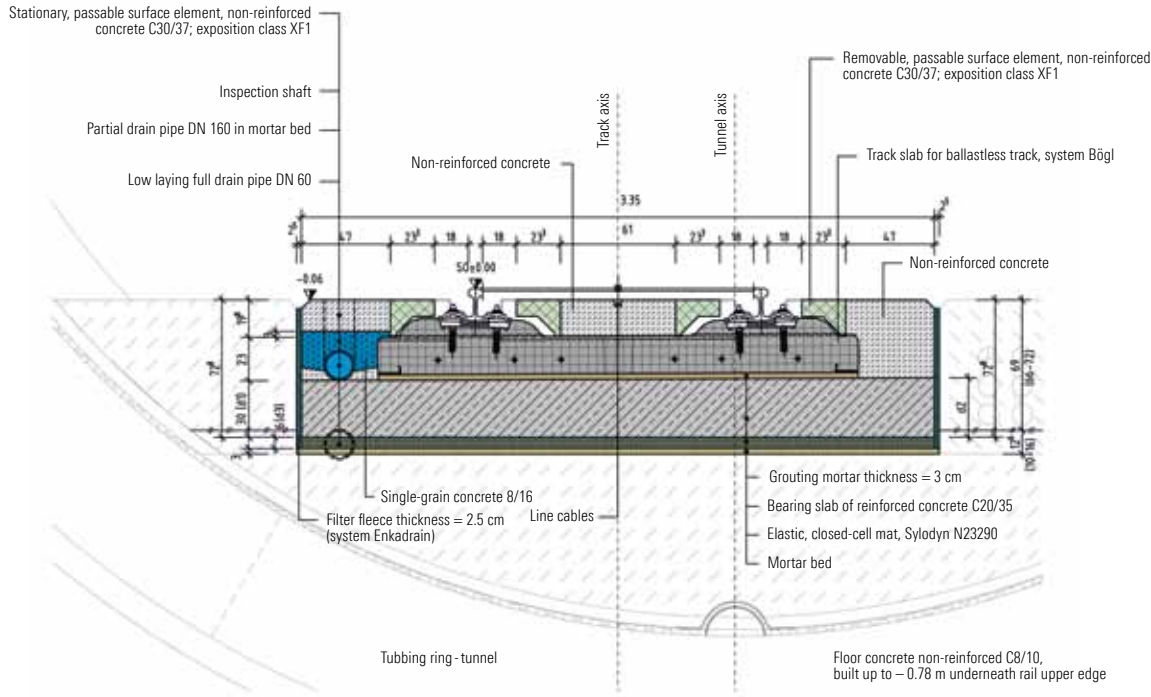
In the case of tunnel routes in the area of heavily-populated sites, vibrations or secondary airborne noise, which are occurring or are likely, must be reduced in rail traffic in such a way that the fixed legislated limits are observed and the quality of life of the lineside

residents or the manufacturing processes of industrial enterprises are not impaired.

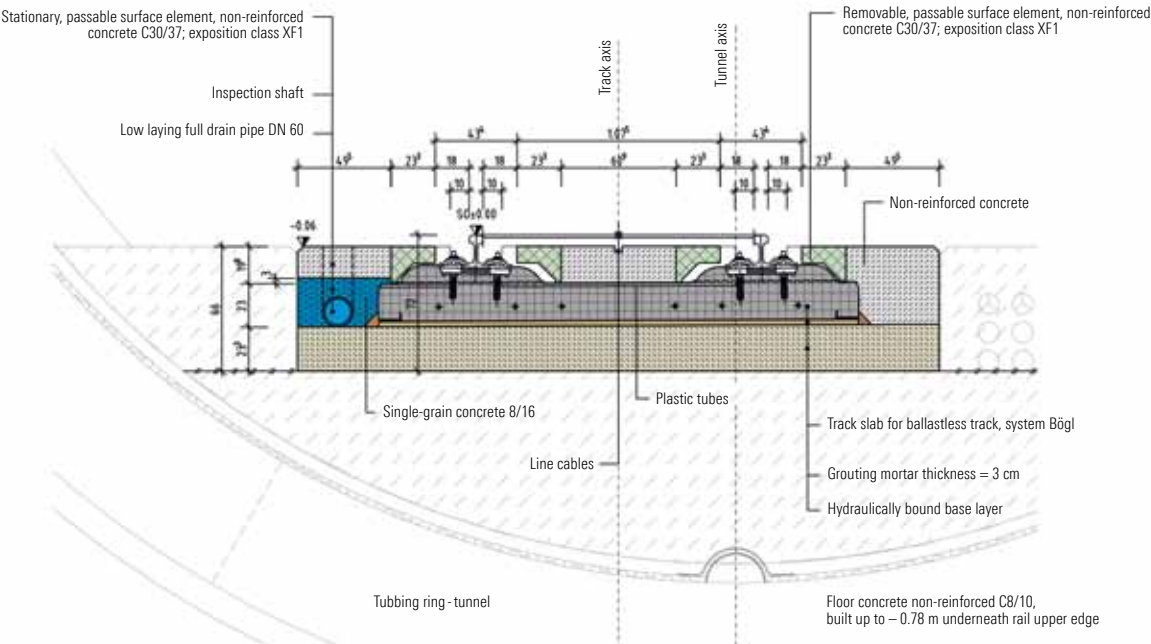
This can be most effectively achieved by using spring mass systems. In this system, the ballastless track system is set on top of a heavy elastically-supported slab. The slab's elastic support causes track and foundation to be uncoupled and thus results in a highly considerable reduction in the speeds applied to the foundation as a result of the railway operation.

At the forefront is the particular reduction of high-frequency power. The spring mass system's basic principle rests on the theory of the linearly-damped single mass oscillator. In principle, every

Ballastless track design cross-section as prefabricated part design (Type Bögl FFB) in the tunnel with light spring mass system as vibration protection



Ballastless track design cross-section as prefabricated part design (Type Bögl FFB) without light spring mass system



spring mass system consists of two components, that is, of a rigid oscillatory mass m and a soft flexible spring with spring stiffness c . Fundamentally, it is essential to seek to achieve the finest adjustment of the spring mass system (natural frequency f_0 as low as possible).

Advantageous spring mass systems are based on a jointless spring mass slab, on the above-mentioned ballastless track design and on a modular structure with the following components:

- substructure (= tunnel floor or floor concrete above the tunnel floor)
- elastic mat (= damping cushion)
- continuous spring mass slab (= trough or slab)
- track system (= BLT track slab, including any grout layers)
- rails + equipment.

For the dynamic design of spring mass systems, a knowledge of the transfer behaviour between tunnel floor and buildings to be protected is indispensable. The transfer behaviour can be determined only by testing (e.g., with VibroScan vibration test controller).

By determining the transfer feature, the necessary adjustment of the spring mass system can be calculated by the prognosis procedure. A condition of this is the time difference between end of skeleton construction and start of ballastless track production. Since this is almost never possible in practice, planning must usually be for a range of different adaptations or limiting behaviour must be considered.

In the draught for spring mass systems, the requirements of noise and vibration protection must be taken into consideration, in addition to the requirements from the aspect of vehicle movement dynamics and load transfer. From this come the demands for continuous gradation of the stiffnesses in the extension of a line and a restriction of the elastic deflexion curve regarding tangential inclination and ratio of overall batter to elastic deflexion curve length and overall batter. In the case of spring mass systems for switching zones, vibration peaks must be heeded as a result of disruption of smooth vehicle running in the area of the point frogs

and the tongue rails and any additional buckling which occurs must be limited. The supported floating mass must be fixed in the position by flexible horizontal retainers, especially in the case of bends in the route.

Precautionary deformation monitoring on the BLT track, settlements and tolerance compensation

Considering the limited possibilities of adjusting the track geometry after completion of the ballastless track, the deformation behaviour of the substructure is of decisive importance in the case of earth and engineering structures. Particularly at the transitions, particular demands must be made of the restriction in the deformation differentials. To guarantee functional capability during the period of use, a full deformation inspection must be carried out, to check all matters connected with of ensuring usability.

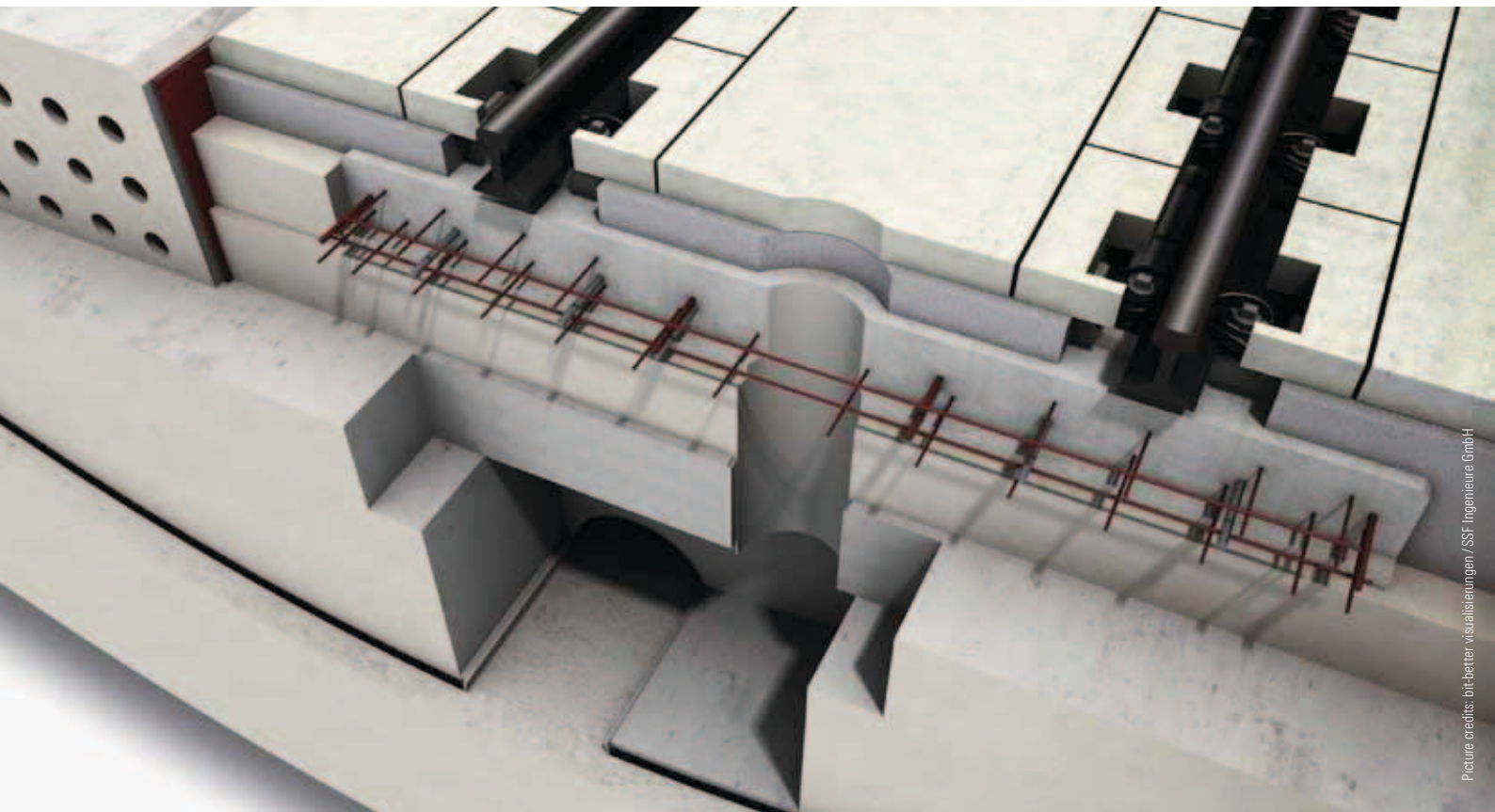
After the ballastless track has been installed, the corner radii of the target gradients alter locally, if necessary, as a result of re-

sidual settlements and the settlement cavities which appear as a result. The corner radii, which are determined by the capping of target radii and the residual settlements, which are expected or forecast through calculations, must be seen as a substantial evaluation criterion, forming the connection between route study limit values which must be observed and the track geometry to be expected.

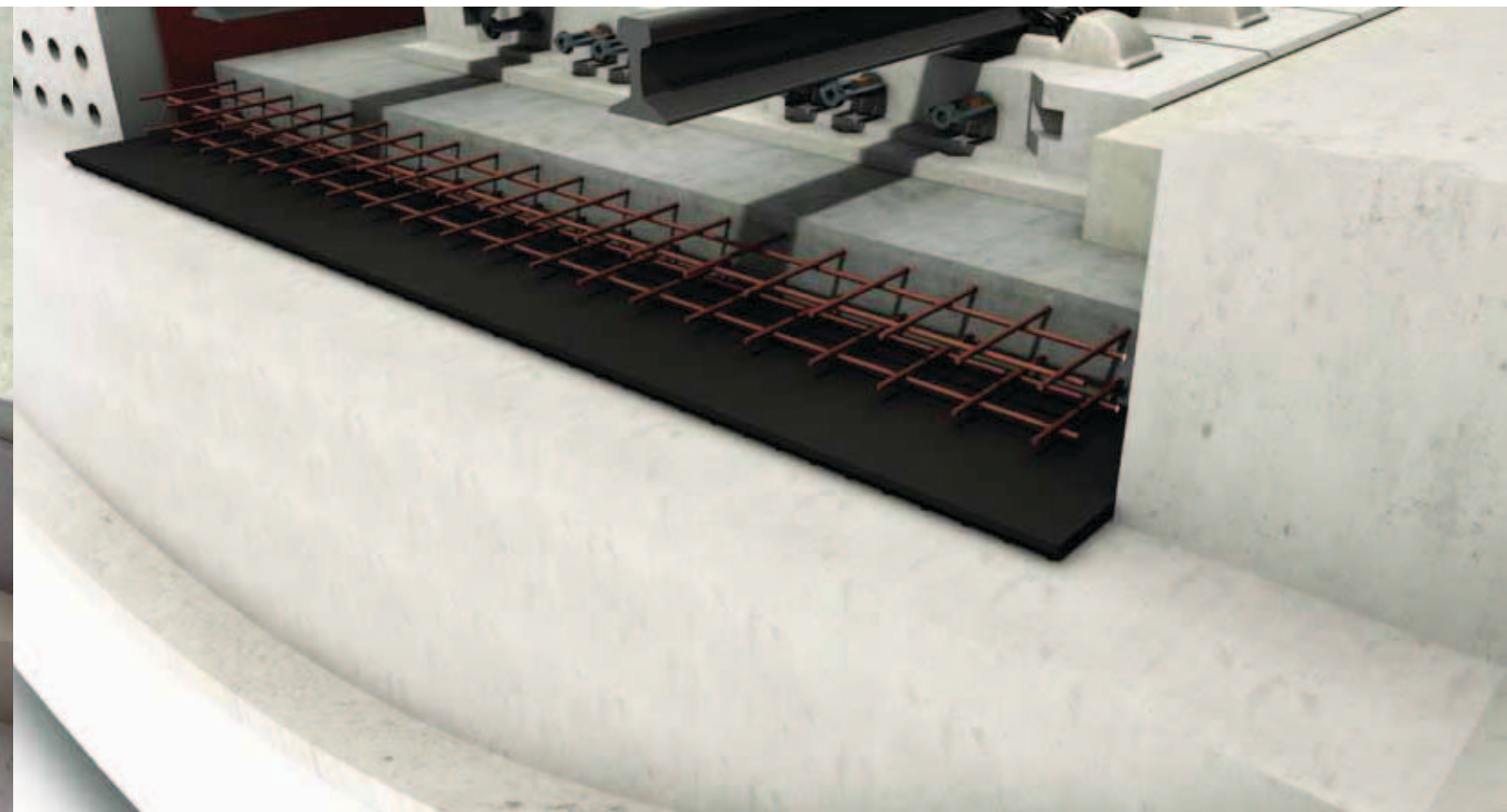
A realistic appraisal of the residual settlements to be expected after installation of the ballastless track assumes particular significance.

The real basis for creating reliable settlement and residual settlement forecasts is a cautious projection and all-round observation of the settlement behaviour before the ballastless track is installed. For engineering structures and special cutting or embankment areas, which harbour increased potential for settlements, the production/control survey data of the production conditions of the structures/earth are appropriately incorporated in the one suitable database, in order to be able to determine an underly-

Visualization ballastless track as prefabricated part design (Type Bögl FFB) in the Tunnel Katzenberg



Picture credits: bit-better visualisierungen / SST Ingenieure GmbH



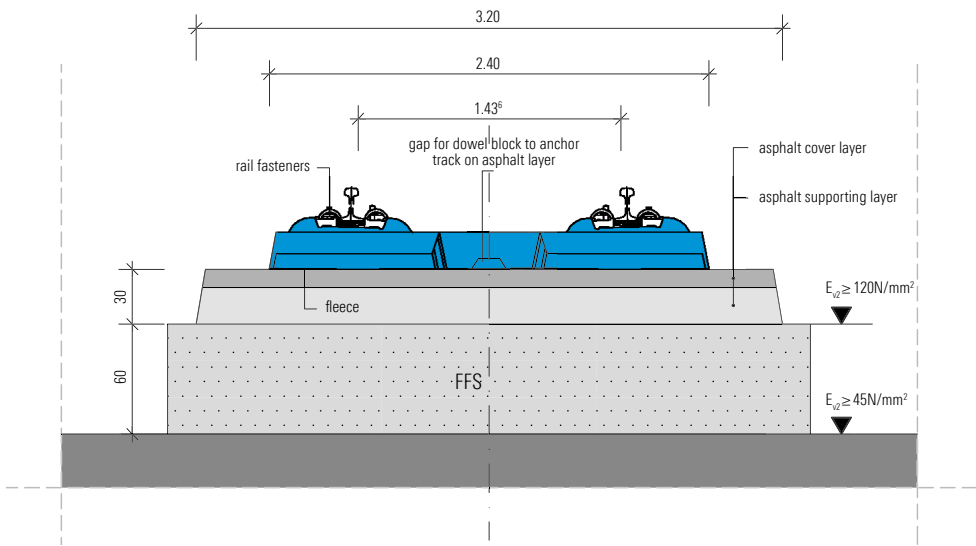
ing tendency regarding settlements, before the particular parts are provided. The forecast values are adjusted to the possibilities for expansion in the area of rail support points and applied route studies (control and limit values) which are still permitted (and theoretical) and still available, to all intents and purposes. For the residual settlement value, resulting from the total settlement differential (after commissioning) and possible readjustment, a lasting settlement cavity is created. This must be evaluated in the capping with target gradient corners, regarding the specified definition of limit values.

Ballastless Track Design Planning

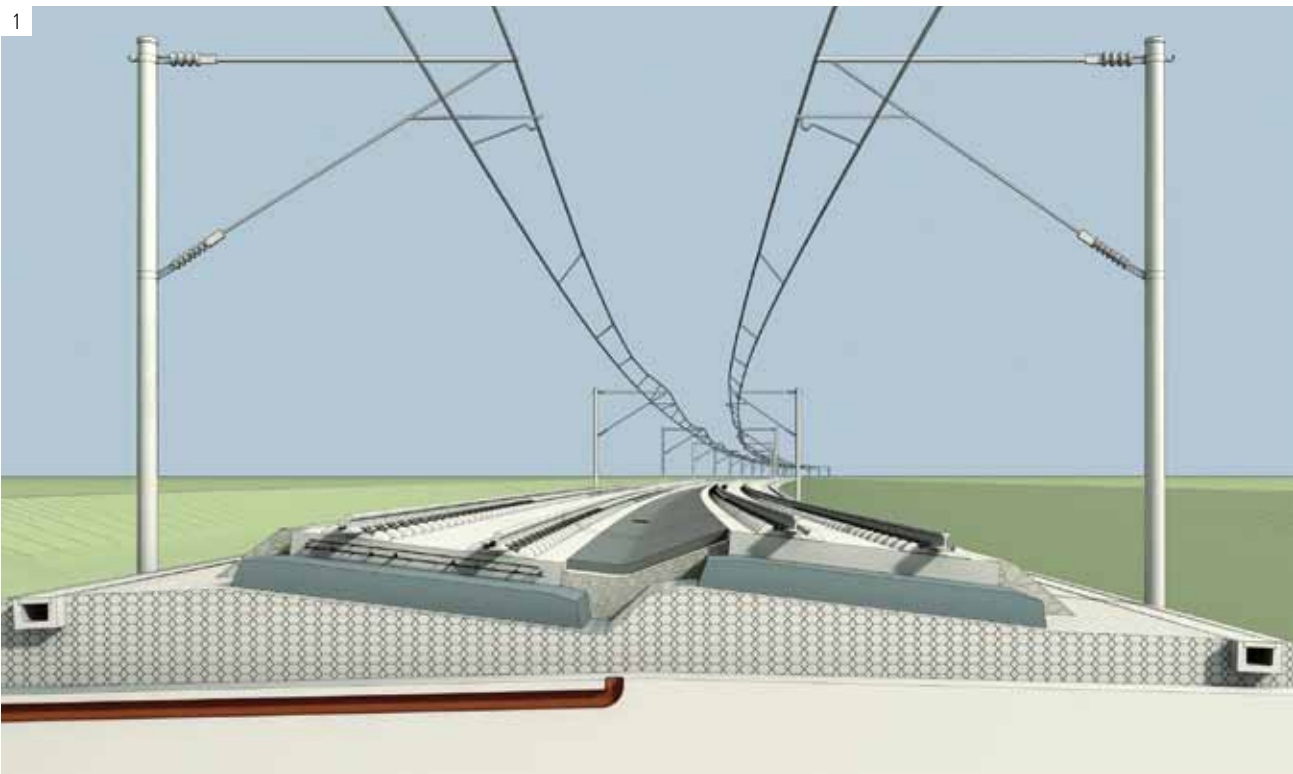
Because of the advantageous supporting system and the layer structure, the ballastless track design is ideally suited to use both in high-speed rail traffic and with heavy goods trains. The system is distinguished by long life capacity, low life-cycle costs and high running track precision. Consistent, smooth geotechnical appraisal, assessment and monitoring is one of the essential conditions for an almost settlement-free track and the above-mentioned advantages of this design. A close, direct combination of building and geoscientific approaches results in optimised processes and

technical solutions in this case. Particular attention must be paid to the careful planning of the transitions between route and engineering structures (bridges and tunnels) in terms of preventing discontinuities. Also, in the rail-bridge interaction, all external influences and component reactions must be precisely recorded and adapted to become compatible with the requirements of the ballastless track design. In the building process, it is essential to heed the quality demands, which are well above the norm in terms of foundation preparation, installation and use of materials and not least in terms of production of a precise, homogeneous track geometry.

SSF Ingenieure have many years of experience in and deep specialised knowledge of providing comprehensive consulting and engineering services in the planning and structural implementation of high-speed routes in the ballastless track design. Experienced SSF Ingenieure building engineers, geotechnicians, concrete technologists and specialists in construction work assist in implementing to the highest standards the high quality and precision requirements in the construction of ballastless tracks.



Schematic diagram of supported ballastless track design, GETRAC A3 system in asphalt design



- 1 Visualization ballastless track on earthworks, in embankment area cant u=170 mm, Rheda 2000 BLT system
- 2 Automatic laying of the track slab
- 3 Fixing of the rail profile
- 4 Placing of concrete of the ballastless track

SSF Ingenieure – Projects

Germany	
Upgraded/new line Karlsruhe – Basel, Katzenberg Tunnel	
Type of traffic:	Mixed traffic (goods and passenger trains)
Max. speed:	v _E = 280 km/h
Length in km:	10 km, including 9.4 km in Katzenberg Tunnel (separate tubes)
Track design:	Bögl System ballastless track
Services to be provided:	Implementation planning for ballastless track design, trafficable route cover slabs, First Aid posts and light spring mass system (vibration protection)
New line Nuremberg – Ingolstadt, North lot	
Type of traffic:	Mixed traffic (goods and passenger trains)
Max. speed:	passenger traffic: v _E = 300 km/h; goods traffic: 160 km/h
Length in km:	35.02 km (2 main lines)
Track design:	Bögl System ballastless track
Services to be provided:	General plan for all structural and equipment
Newly built railway line Nuremberg – Ebersfels – Erfurt – Leipzig/Halle Section Ebersfeld – Erfurt, line 5919, chainage km 153.1+19 to km 185.4+61	
Type of traffic:	Mixed traffic (goods and passenger trains)
Max. speed:	main track, continuously v _E max = 300 km/h overtaking track in the stations v _E = 100 km/h interchange of track connections v _E = 130 km/h
Length in km:	32.34 km
Track design:	Bögl System ballastless track
Services to be provided:	Final design
New line Erfurt – Leipzig/Halle, VDE 8.2, line 5919, including Planena branch-off	
Type of traffic:	Mixed traffic (goods and passenger trains)
Max. speed:	Route 5919: v _E = 300 km/h; Route 6394: v _E = 160 km/h/ passing tracks-overtaking stations v _E = 100 km/h; connections: v _E = 160 km/h
Length in km:	90.241 km (2 main lines)
Track design:	Main lines including 8 connections: ballastless track open-system; stations: ballasted track
Services to be provided:	Creating invitation-to-tender documents for the various trades
Renewal of the old tunnels in the City of Mainz	
Type of traffic:	Passenger line
Max. speed:	v _E = 160 km/h
Length in km:	0.662 km
Track design:	Ballastless track, Rheda 2000 system
Services to be provided:	Final design

India	
Railway project Udhampur – Srinagar – Baramulla	
Type of traffic:	Passenger line
Max. speed:	v _E = 160 km/h
Length in km:	10 km, total length 160 km
Track design:	Ballastless track, Rheda 2000 system
Services to be provided:	Concept and design for execution of the railway line in the tunnels
Mexico	
Underground Railway in Monterrey, Nuevo Lean, Mexico	
Type of traffic:	Passenger line
Max. speed:	v _E = 100 km/h
Length in km:	7.66 km
Track design:	Ballastless track, Mexican system
Services to be provided:	Technical consulting on the implementation planning



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China	
Sui-Yu-Line Test Track: Suining – Chongquing	
Type of traffic:	Passenger line
Max. speed:	v _E = 160 km/h
Length in km:	26 km
Track design:	Ballastless track; Systems: Japanese system, Rheda/Rheda 2000 system, Frame system
Services to be provided:	Ballastless track consulting, points and transitions consulting for implementation planning, inspection of the static and dynamic calculations for various ballastless track systems and for points
Rapid transit connection Beijing – Tianjin, Lot 1 Intercity Railway	
Type of traffic:	Passenger line
Max. speed:	v _E = 350 km/h
Length in km:	66 km
Track design:	Bögl China ballastless track system
Services to be provided:	Ballastless track superstructure supervision/consulting
Zhengzhou – Xian rapid transit connection	
Type of traffic:	Passenger line
Max. speed:	v _E = 350 km/h
Length in km:	10 km test track
Track design:	Ballastless track, Züblin system
Services to be provided:	Implementation planning for ballastless track on track and bridges
High-speed railway line from Wuhan to Guangzhou - Passenger Dedicated Line	
Type of traffic:	Passenger line
Max. speed:	v _E = 350 km/h
Length in km:	116 km
Track design:	Ballastless track, CRT II system
Services to be provided:	Ballastless track superstructure supervision/consulting
Rapid transit connection, Beijing – Wuhan Passenger Dedicated Line	
Type of traffic:	Passenger line
Max. speed:	v _E = 380 km/h
Length in km:	1,208 km
Track design:	Ballastless track, CRT II system
Services to be provided:	Foreign Quality Management (FQR) as joint venture with the Second Survey and Design Institute in Chengdu, China

Changsa – Hangzhou rapid transit connection	
Type of traffic:	Passenger line
Max. speed:	v _E = 350 km/h
Length in km:	840 km
Track design:	Ballastless track, CRT II system
Services to be provided:	Ballastless track superstructure (route, bridges and tunnels) supervision/consulting
Heifei – Fuzhou rapid transit connection	
Type of traffic:	Passenger line
Max. speed:	v _E = 350 km/h
Length in km:	810 km
Track design:	Ballastless track, CRT II system
Services to be provided:	Ballastless track superstructure (route, bridges and tunnels) supervision/consulting



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