Design and layout of ballastless track systems using unbound base course layers

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Abstract

Up to now most of the ballastless track systems, which have been built on earthworks consist of a structure with a continuously reinforced concrete pavement (CRCP) or an asphalt pavement, both supported by a hydraulically or bituminous treated layer. For concrete road construction thick concrete pavements on unbound base layers had been established during the last years as an alternative technical and economic solution. General designs of ballastless track systems with asphalt or concrete pavements on unbound base course layers were investigated based on comparative calculations according to the required layer thicknesses as well as according to the layout. Ballastless track systems using discrete rail seats as well as systems with sleeper panels resting directly on an asphalt or concrete pavement or monolithically fixed, respectively, have been investigated according to their suitability for unbound base layers. Not only the loading of the ballastless track by traffic but the loading and the impact of construction work on the unbound base layer are decisive. Loading of the unbound base layer or of the earthwork by construction traffic can be significantly higher than the expected loads born by regular trains. The performance should be evaluated based on first test sections. Potential future ballastless track design can also be done based on the jointed plain concrete pavement technology, which is approved for road construction. But ballastless track systems using discrete rail seats would require a constructive reinforcement within the slabs.

1. Introduction

Conventional ballasted railway tracks require periodical tamping due to uneven settlements of the ballast during operation. The sleeper panel must be adjusted to guarantee a smooth run of the wheel sets. Based on the existing experiences this kind of maintenance work is significantly increased for high-speed lines. Ballastless track constructions offer therefore an alternative solution due to the enormous reduction of maintenance work and the long service life with constant serviceability conditions. Furthermore the application of higher cant and cant deficiency allow the reduction of the minimum values like radii for curves or the increase of speed for lines equipped with ballastless tracks. Unfortunately the initial investment costs for ballastless track superstructures are significantly higher compared with the conventional ballasted superstructures. For comparative calculations an improved ballasted track superstructure, which also meets the requirements for high speed traffic, must be used as basis. Based on the first test sections to investigate the construction and behaviour of ballastless tracks in Germany (Rheda 1972) numerous systems had been designed and optimized based on technical and economic aspects. Main characteristic of ballastless track superstructures is the multilayered design of the bearing structure, which is based on long term experiences born on road and airfield pavements. A good axle load distribution towards the slab is reached by resilient fastening systems. Those synergetic effects between road and railway construction also show potential new ideas for optimisation of ballastless track systems not only depending on special systems developed and provided by different companies. One possibility is the usage of unbound granular base layers instead of treated base layers, like cement treated base layers (CTB) or asphalt base layers.
2. Unbound granular base layers used for road construction

Till after WWII concrete pavements for highways had been built based on a design, which was characterized by concrete slabs in a length of up to 20m placed on an unbound base layer. Since 1970 the usage of short slabs without expansion joints has been enforced connected with the application of cement treated base layers (CTB). Due to economic and technical requirements thick concrete slabs on unbound base layers had been tested successfully and in 1981 this concrete pavement design had been implemented into the German specifications for road design. Practical experiences during construction show some advantages of this design compared with the usage of cement treated base layers (CTB):  
- Unbound base layers require no treatment after placing  
- Shortening of the construction time due to absence of hardening effects  
- Recycled material, which is sensitive to alkali-silica reactions, can also be used  
- Potential better adaptation between concrete slab and base layer due to changing gradients of temperature and moisture within the concrete slab  
- No reflective cracking

To achieve the requirements of this design following recommendations had been summarized:  
- Width of the unbound base layers at surface should be increased at least by 65cm towards both edges of the concrete slab in case slip form paving is planned for the concrete slab.  
- Immediately before construction of the concrete slab existing unevenness and loosened aggregates should be removed by a roller compactor.  
- Surface of the unbound base layer must be sprayed with water before concreting  
- Package cracking of the concrete slab must be taken into account, i.e. dependent on the actual season only every forth up to eights transversal dummy joint will crack. Width of joint opening will be partially wider and non-uniform.

The actual German specification for the standardisation of the superstructures for road pavements RStO 01 [5] requires for all types of gravel or crushed rock base layers a minimum thickness of 20cm (gravel) or 15cm (crushed aggregates) respectively and a surface deformation modulus of at least $E_{v2} = 150$ N/mm² (plate bearing test - second loading). The tables of the specification show that the effect on the bearing capacity in case of using unbound base layers is equalized by a respective increase of the asphalt or concrete layer resting on the
unbound base layer. The increase of asphalt or concrete pavement thickness for roads is +4 cm compared with the superstructures using cement treated base layers if full bond between layers is assumed, which is a requirement for actual ballastless track systems in Germany. The increase of thickness for gravel base layers compared with crushed stone base layers has been done to address the lower deformation resistance of those materials. The deformation resistance of the unbound base layer has an decisive effect not only on the long term behaviour of the asphalt or concrete pavement, but on the behaviour during construction time. Contact pressures of heavy construction vehicles (truck: \( p \approx 0.7 \) to 0.9 N/mm²) at surface of the unbound base layer is about 10-times higher compared with the vertical stress level between concrete slab and base layer assuming load scheme 71 and including all additional load-factors for ballastless track design. Therefore traffic load on unbound layers during construction should be limited!

Only crushed stone base layers are accepted as support for concrete pavements, which have to fulfill special requirements to meet sufficient deformation resistance and water permeability:
- Aggregate size 0/32 and minimum thickness 30 cm according to [6],
- Limitations of fines < 0.063 mm maximum 3 % for delivered material and maximum 5 % after compaction of the layer,
- California Bearing Ratio \( \geq 80\% \) determined on material 0/22 (after removal of aggregates > 22mm) [6], which is used as an indirect parameter for water permeability.

Practical experiences showed, that the top layer of the unbound base layer (minimum thickness 12cm) should be laid using a paver to meet the requirements.

### 3. Material properties of unbound base layers

Investigations in laboratory enable comparative testing of different mixtures under cyclic loading. The impacts of load or contact stress and the load cycles on unbound base layers according to plastic and elastic deformations are decisive. Important for ballastless track design is the dynamic modulus of elasticity during service time. Increase of the dynamic modulus can be assumed if load and stress-level within the unbound base layer cause mainly elastic deformations (elastic shakedown behaviour) [8]. Steady increase of load and therefore shift towards plastic deformation behaviour will cause a significant increase of plastic deformation. Test series performed on aggregate mixtures show a high influence on vertical strain and deformations by small changes of the water content. Therefore sufficient drainage during the whole lifetime of the superstructure is required for roads and ballastless track systems [8].

To increase the deformation resistance of gravel base layers some crushed aggregates like crushed sand or chippings had been added for laboratory test series [12] performed in a trough, which was equipped with a Ethylene-Vinyl-Acetate-(EVA) foam mat to simulate the elastic behaviour of substructures like earthworks. During repeated load tests with an upper load of 35kN (maximum load of plate bearing test) 6000 load cycles and additional 4000 load cycles with an upper load of 50kN (assumed maximum wheel load of construction traffic) had been applied by a load plate with a diameter of 300mm. For all types of unbound base layers a digressive increase of deformation had been observed for upper load 35kN, so stresses were within the range of elastic shakedown behaviour. The behaviour under the upper load of 50kN clearly shows, that elastic shakedown behaviour has been exceeded and progressive increase of deformation had been observed. Plastic deformations can be explained by movements of the aggregates. Therefore at least 15% of crushed aggregates should be added to gravel base layers to reach an effective reduction of plastic deformation. Only little improvements are reached in case more than 30% of crushed aggregates are added [12].

### 4. Experiences on unbound base layers for ballastless tracks

Ballastless tracks in Germany require a frost blanket layer with a high water permeability \( (E_{\alpha} = 120 \text{ N/mm}^2) \). Concrete slabs for ballastless tracks had been usually built with a cement treated base layer (CTB) in a thickness of 30 cm (see fig. 1). But following ballastless track systems using asphalt pavements on unbound base layers had been installed:
Within a 15km long section (double track) of the railway line between Bitterfeld and Halle a ballastless track system with Y-shaped steel sleepers resting on an asphalt pavement has been installed in 1995 (System SATO-FFYS). 30cm of asphalt on a CTB or 40cm of asphalt on a frost blanket layer in a thickness of 60cm were planned and constructed [13]. An additional section in a length of 4.7 km (double track) has been built using prestressed concrete sleepers resting on a 40cm asphalt pavement supported by a frost blanket layer (System Walter). This design was initiated by practical reasons as an alternative solution compared with the original design of a 32cm thick asphalt pavement on a 25cm thick CTB (see fig. 2). Deflection measurements performed in 2002, 7 years after installation, showed no changes or discontinuities of the bearing behaviour [10]. Using well graded aggregate mixtures for frost blanket layers and gravel or crashed stone layers a deformation modulus of $E_{v2} = 150 \text{ N/mm}^2$ can be reached to reduce the required thickness of the asphalt pavement to 35 cm. This has been done within a 3.8km long section between Berlin Ruhleben and Westkreuz for the GETRAC system [11].

![Diagram of ballastless track system with sleeper panel on asphalt pavement](image)

**Figure 2:** Design of ballastless track system with sleeper panel on asphalt pavement

5. Design of ballastless tracks

Bearing behaviour of ballastless tracks is characterised by a defined elastic support of the rails and a slab system with a sufficient bearing capacity. Up to now continuously reinforced concrete pavements (CRCP) with free or controlled transversal cracking in combination with a cement or bituminous treated base layer or asphalt pavements had been chosen for the multi-layered ballastless track design. CRCP are determined by longitudinal reinforcement (diameter 20mm) placed at the neutral axis of the slab in an amount of 0.8 to 0.9% of the total cross section. This reinforcement takes care about a sufficient vertical load transfer at the crack or dummy joint and a limitation of crack widening as well. The design of slab thickness is based on the tensile bending stress capacity of the concrete, which is based on the experiences of road and airfield pavement design.
Figure 3: Ballastless track with discrete rail seats on a continuously reinforced concrete pavement (CRCP) with dummy joints (controlled transversal cracking). Test section near Waghäusel.

Figure 4: Distribution of bending tensile stresses within longitudinal direction of a 36 cm thick concrete pavement (controlled cracking in a distance of $a = 2,60m$) with discrete rail seats. Loading by load scheme 71.

For ballastless track systems using sleeper panels, which are resting on the slab or which are embedded within the concrete slab, a sufficient load distribution along transversal direction of the slab (width 3,0 to 3,2m) can be taken into account. Therefore the design work can be done based on the beam model with continuous elastic support (Zimmermann procedure [3]). For discrete rail seats a two-axial loading must be assumed and therefore a slab model with elastic support must be used (equitation of Westergaard [3]). Those models have been used first of all to verify the 2D and 3D FE-Models (e.g. see fig. 4) designed for the following investigations. For all calculations and models following parameters had been used:

- Rail 60E1 with resilient rail fastening systems, whereas for the design a dynamic spring coefficient of $c_{dyn} = 40$ kN/mm with regard to the situations at low temperatures and high frequencies of loading has been used.
- Prestressed mono-block sleepers in a length of 2,40 or 2,60m for supported or monolithic (Rehda) systems,
- Concrete slab with $E = 34000$ N/mm$^2$, bending tensile strength $\beta_{BZ} \geq 5,5$ N/mm$^2$, bending tensile fatigue strength within longitudinal direction for systems with free cracking $\beta_{BZ,D} = 0,85$ N/mm$^2$ (taking into account a maximum stress level during winter time of 3,0 N/mm$^2$) and bending tensile fatigue strength within longitudinal direction for systems with controlled cracking $\beta_{BZ,D} = 1,80$ N/mm$^2$ or 2,0 N/mm$^2$ for crack spacing 2,6 m or 1,95 m, respectively.

In case of controlled cracking the joint must be sealed using elastic joint filler materials or joint profiles. To guarantee a sufficient length of slab contraction the continuously reinforcement needs de-bonding to the concrete within a certain length.
Bending tensile fatigue strength within transversal direction $\beta_{BZ,D} = 2.10 \, \text{N/mm}^2$ taking into account the warping stresses activated by non-linear heating during summertime.

- Asphalt (mean values): $E = 5000 \, \text{N/mm}^2$ and bending tensile fatigue strength $\beta_{BZ,D} = 0.80 \, \text{N/mm}^2$.
- Crushed stone base layer: Modulus of deformation for all designs $E_{v2} = 150 \, \text{N/mm}^2$.
- Frost blanket layer: $E_{v2} = 180 \, \text{N/mm}^2$ is only used for potential optimisation of certain systems.
- Subbase: Decisive for the design $E_{v2} = 45 \, \text{N/mm}^2$, but for construction $E_{v2} = 60 \, \text{N/mm}^2$ is required according to [2].

Decisive load scheme for the design of ballastless tracks is the theoretical model 71, which is determined by four 250 kN wheel set loads in a spacing of 1.6 m. This load model has been used as a basis for all ballastless track designs. Additional investigations had been done using real axle load schemes of high speed trains. It must be taken into account that if only high speed trains are planned for track loading a reduction of the load model 71 to 80% can be done.

Wheel load transfer to the field side within curves is considered by factor 1.2 at field side rail and 0.8 at in-side rail. A factor of 1.5 according to a maximum statistical safety of 99.7% has been added to the maximum bending stresses to include dynamic changes of wheel loads, which are born by imperfections of wheel-rail interaction. A dynamic factor of 1.17 is sufficient for the determination of the maximum vertical stresses according to a maximum statistical safety of 68.7%. It must be taken into account, that only rail seat loads within the positive section of the influence line of the bending moment along the slab have been used. Those rail seat loads, which would cause a reduction of the maximum bending moment of the slab were not included.

5.1 Sleeper panels supported by asphalt pavements on unbound base layers

Due to the large contact areas between sleepers and asphalt pavement the contact pressures $p$ acting on the pavement surface during passage of regular trains $p < 0.3 \, \text{N/mm}^2$ are significantly lower than the vertical contact stresses born by heavy trucks $p \approx 0.7$ to 0.9 N/mm² during construction time. Based on the decisive asphalt modulus $E = 5000 \, \text{N/mm}^2$ and a tensile strength of 0.8 N/mm² all the systems shown above equipped with an asphalt pavement in a width of 3,20 m and a thickness of 35 cm on an unbound base layer ($E_{v2} = 150 \, \text{N/mm}^2$) are sufficiently designed according to [3] in case sleepers with a minimum contact area per rail seat of 1,0 m x 0,3 m (sleeper length 2,60 m) are used. This was confirmed by FEM calculations, which had been performed for detailed investigations concerning the influence of sleeper length or contact area and width of asphalt pavement. In case larger contact areas are used significant reductions of required pavement thickness are possible. For e.g. the usage of wide base sleepers ($l = 2,60 \, \text{m}$) with a contact area of 1,0m x 0,6m per rail seat (maximum contact pressure $p = 0.17 \, \text{N/mm}^2$), allows the reduction of the asphalt pavement thickness up to 26cm. But an additional reduction of length of the wide base sleeper (e.g. contact area per rail seat 0,9m x 0,6m) will cause an increase of tensile stresses within transversal direction of the asphalt pavement, which will be the decisive parameter in this case. In general the interaction between sleeper length and slab width (pavement width) must be taken into account.
5.2 Sleeper panel on a continuously reinforced concrete pavement (CRCP) with controlled transversal cracking on an unbound base layer

<table>
<thead>
<tr>
<th>System</th>
<th>1</th>
<th>2</th>
<th>optimisation</th>
</tr>
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<tbody>
<tr>
<td>Concrete slab</td>
<td>$h = 30,\text{cm}; b = 3,20,\text{m}$</td>
<td>Controlled cracking $a = 1,95,\text{m}$</td>
<td>$a = 2,60,\text{m}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 Ø 20mm according to 0,43 %</td>
<td></td>
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<tr>
<td>Crashed stone base course</td>
<td>$E_{v2} = 150,\text{N/mm}^2$</td>
<td>$E_{v2} = 150,\text{N/mm}^2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70 cm</td>
<td>30 cm</td>
<td></td>
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<tr>
<td>Frost blanket layer</td>
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<td></td>
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<tr>
<td>Layer with frost-unsusceptible material</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Subbase</td>
<td>$E_{v2} = 60,\text{N/mm}^2$</td>
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</table>

Table 1: General types of ballastless track systems with sleeper panel supported by a continuously reinforced concrete pavement on unbound base layers

Figure 5: Sleeper panel supported by a continuously reinforced concrete pavement with controlled cracking (distance $a = 1,95\,\text{m}$) and supported by an unbound base layer.

All the ballastless track systems (see fig. 5) shown in table 1 are sufficiently designed according to the procedures of [3]. The determination of the required thickness of the concrete slab supported by an unbound base layer shows, that the requirement concerning a maximum fatigue bending strength of 0,85 N/mm² for concrete slabs with free cracking would cause in general uneconomic thicknesses for the concrete slabs. A controlled cracking (e.g. see fig. 3) is therefore recommended, whereby the allowable bending stress within longitudinal direction is limited to 2,0 N/mm² for a regular crack spacing of 1,95m or 1,8 N/mm² for crack spacing 2,6 m. The acceptable stresses due to traffic load are dependent on the percentage of longitudinal reinforcement (table 1) and the respective longitudinal forces activated by cooling during winter dime. First calculations have been done based on the beam model with continuous elastic support. On the safe side no potential reduction of the bending moments by respective corner arcs below the sleeper contact area has been taken into account. Reductions of the peak values of the bending moments by corner arcs would cause reductions of the required slab thickness significantly below 30cm, which is outside of the applicability of the beam model! FEM calculation confirmed, that for given parameters - contact area of sleeper per rail seat 0,9 m x 0,3m and slab thicknesses below 30cm - the bending stresses within transversal direction will be the decisive parameter, because of getting higher than the bending stresses in longitudinal direction. For detailed investigations 2D FE-models have been created including transversal dummy joints in a distance of 1,95m or 2,60m, respectively (controlled cracking). Implementation of controlled cracking leads to a further reduction of bending stresses within longitudinal direction, whereby the designed systems of table 1 are on the safe side. This safety margin should be kept till future experiences show, that further optimisation according to slab thickness and joint spacing is possible (FE-modelling shows, that spacing of dummy joint can be increased to $a = 2,6\,\text{m}$).
The vertical contact stresses between concrete slab and unbound base layer are quite uniform. One passage of the load scheme 71 is equivalent to one load cycle. The joints are displayed only by small discontinuities within vertical stress distribution. The maximum vertical pressure under dynamic loading is $\sigma_z = 0.072$ N/mm², but contact pressures of truck tyres during construction time are $\sigma_z \geq 0.7$ N/mm², which is at least the 10-fold value! This again emphasises the requirement to limit weight and number of axle load on the unbound base layer during construction time. The maximum vertical compressive stresses for the subbase are met for $E_v = 60$ N/mm² and $2 \times 10^6$ load cycles according to [2]. Compared with concrete pavements on cement treated base course (CTB) the vertical stresses are increased based on the lower width of the concrete slab (3.20m) compared with the decisive width of the 2-layer system with a width of the CTB of 3.80m.

Important for the long term behaviour of concrete slab with controlled cracking is a durable and sufficient vertical load transfer at the joint. Cooling during wintertime by e.g. 30K will cause changes within joint width of 0.5mm to 0.6mm which requires a sufficient sealing of the joint. For concrete slabs of ballastless tracks the positioning of the dummy joint and therefore the controlled crack exactly between the rail seats is advantageous, which requires a respective lay-out of the joints. Both load distribution by the rail and sufficient load transfer at the joint activated by the longitudinal reinforcement (diameter 20mm) are decisive for the long time behaviour of the slab track.

5.3 Sleeper panels on concrete slab with dowelled dummy joints on a unbound base layer

Opposite to continuously reinforced concrete pavements (CRCP) according to [1] also concrete slabs with dummy joints but without longitudinal coupling can be investigated using the long term experiences of concrete pavements for road construction. Sealed steel dowels are inserted into the concrete within the neutral axis to handle the transfer of vertical load at the dummy joint. Decisive parameters concerning the bearing capacity within longitudinal direction are therefore traffic load and non-linear heating of the concrete slab during summer time. Tensile forces born by cooling during winter time are not transferred at the joint. Design and construction of the transversal dummy joints should be done according to [4]. The dispense of additional longitudinal reinforcement to control crack width in case of potential cracking between dummy joints should be discussed based on the design features of the chosen ballastless track system.

The allowable bending stresses within longitudinal direction of the slab are limited by the amount of warping stresses due to non-linear heating of the concrete slab. Unbound base layers show respective advantages due to the ability of surface deformation, which cause a harmonisation of contact stresses between the warped slab and the base layer. Based on the system “CRCP with controlled cracking (spacing a = 1.95 m) on unbound base layer ($E_v = 150$ N/mm²)” and a slab thickness of 30 cm the possibilities had been investigated to increase the joint spacing for the alternative system, which is determined by dummy joints according to [4]. It is advantageous to choose quadratic slab dimensions, here slab length $l = 3.90$ m according to the six-fold of rail seat spacing (65 cm). Figure 6 shows that the allowable bending stresses due to traffic load are limited by the warping stresses (heating during summer time). Furthermore bending of the slabs itself must be taken into account if slab length is increased.
Figure 6: Ballastless track with sleeper panels resting on a 30cm thick jointed concrete pavement: Impact of slab length on allowable and actual stresses due to traffic load.

5.4 Discrete rail seats on a continuously reinforced concrete pavement (CRCP)

Due to the small dimensions of load application area compared with slab width a two-axial bearing behaviour in longitudinal and transversal direction must be assumed. Reduction of slab width will cause an increase of bending stresses in longitudinal direction according to a beam with continuous elastic support. It must be taken into account, that load at slab edges will increase the bending stresses in longitudinal direction up to the 2-fold. This effect must be investigated in case a reduction of the slab width is aimed for. Table 2 shows ballastless track systems (fig. 7), which meet the requirements of the design procedure according to [3].

<table>
<thead>
<tr>
<th>System</th>
<th>1</th>
<th>2</th>
<th>optimisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete slab</td>
<td>$h = 36 \text{ cm}; b = 3.20 \text{ m}$</td>
<td>Controlled cracking $a = 2.60 \text{ m}$</td>
<td>$h = 34 \text{ cm}$ $a = 2.60 \text{ m}$</td>
</tr>
<tr>
<td></td>
<td>$16 \text{ } \phi 20\text{mm according to } 0.44 %$</td>
<td></td>
<td>$15 \text{ } \phi 20\text{mm (0.41 %)}$</td>
</tr>
<tr>
<td>Crashed stone base course</td>
<td>$E_{v2} = 150 \text{ N/mm}^2$</td>
<td>$E_{v2} = 150 \text{ N/mm}^2$</td>
<td>$E_{v2} = 180 \text{ N/mm}^2$</td>
</tr>
<tr>
<td>Frost blanket layer</td>
<td>$64 \text{ cm}$</td>
<td>$30 \text{ cm}$</td>
<td>$66 \text{ cm}$</td>
</tr>
<tr>
<td>Layer with frost-unsusceptible material</td>
<td>$34 \text{ cm}$</td>
<td></td>
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<tr>
<td>Subbase</td>
<td>$E_{v2} = 60 \text{ N/mm}^2$</td>
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</table>

Table 2: General types of ballastless track systems with discrete rail seats on a continuously reinforced concrete pavement on unbound base layers
For the design of single layered continuously reinforced concrete slabs with direct fixation of the rail seats a controlled cracking is required to avoid cracking at rail seats and to avoid potential loosening of bolts. In case of 0,4 to 0,5 % longitudinal reinforcement according to total cross section and a spacing of controlled cracking within 2,6m an allowable bending stress within longitudinal direction of $\sigma_{BZ,D} = 1,80 \text{ N/mm}^2$ can be estimated. Further reductions of transversal crack spacing has no impact on the required slab thickness due to the fact, that the allowable bending stress within transversal direction is limited by the given stress level caused by the non-linear temperature gradient during summertime heating. In case $E_v = 180 \text{ N/mm}^2$ is required according to [7] the slab thickness can be reduced in accordance with [3] to 34 cm.

5.5 Discrete rail seats on concrete slabs with doweled transversal joints on unbound base layer

According to chapter 5.3 it can also be thought about concrete slabs with discrete rail seats and doweled joints on unbound base layers. At least a constructive reinforcement should be installed within the single slabs. Figure 8 shows, that joint spacing for a 30cm thick concrete slab in a width of 3,20m should be limited to a maximum of 4,55m according the 7-fold of rail seat spacing. It is recommended to choose a joint spacing of 3,90m (6-fold of rail seat spacing).
6. Conclusions

According to thickness design and constructive features ballastess track systems with asphalt or concrete pavements on unbound base layers are possible solutions. But the abandonment of the treated base layer will have an impact on the construction procedures and constructive details for each ballastless track supplier compared with the original design using an asphalt or cement treated base layer. For each solution the decision towards unbound base layers will depend on the potential economic benefits. For further development of these alternative designs the experiences born during the installation and by monitoring during service life on test sections will be very important.

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References


