

# An innovative approach for the construction of small bridges

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**ABSTRACT:** In late January 2024, a new 27m-long railway bridge over the main road B25 in southern Germany was placed on its final position using the Lateral Bridge Slide Procedure (LBS). The existing bridge was built in 1931 and rehabilitated in 1977. The new bridge will allow to modernizing the railway infrastructure while also upgrading the road infrastructure (B25). The main challenge of the whole design and construction approach was to limit the disruption of the railway operations to a minimum. Having a track possession of only 10 days to demolish the existing bridge (including the abutments), place the new structure, rebuild the track and reestablish the railway operations, different alternatives were evaluated. Due to the challenging ground conditions, a ground improvement solution consisting on rigid inclusions was adopted for the foundation of both the (temporary) thrust beds and the bridge abutments. Driven ductile iron piles were used as rigid inclusions, in order to guarantee the immediate load transfer to the ground during the sliding procedure. The fast, safe and simple execution of the piles allowed for the successful installation of the inclusions within a very limited period of time (60 hours). The following technical paper presents an overview of the adopted solution, focusing mainly on the design and the execution of the ground improvement. Furthermore, additional topics such as the construction stages will be discussed.

**KEYWORDS:** railway, infrastructure, ground improvement, ductile iron piles.

## 1 INTRODUCTION

As part of a comprehensive infrastructure project, the German Railways (*Deutsche Bahn*) executed an intervention to modernize a railway overpass, built in 1931 along the railway track 5310 (Donauwörth - Treuchtlingen) over the main road B25, located at the outskirts of the Bavarian city of Donauwörth (Figure 1). This important traffic artery, which last underwent renovation works of the superstructure in 1977, required extensive repairs of the abutments, with the corresponding line closure. In coordination with the State Construction Office of Augsburg, *Deutsche Bahn* used the opportunity to modernize the entire bridge and to upgrade the main road B25, to meet current standards and to accommodate growing traffic demands.



Figure 1. Intersection of the railway track 5310 and the main road B25 (left) and view of the old railway overpass (right).

## 2 PROJECT DESCRIPTION

Both the railway track 5310 and the main road B25 are integral parts of the regional transport network, hence the main challenge of the design and construction approach for the intervention was to limit the disruption of the railway and road operations to a minimum. In this context, a constructive method was adopted, which involved building the new bridge structure next to the existing one (Figure 2) and moving it to its final position using the lateral bridge slide (LBS) procedure, once the old bridge structure was demolished.

The adopted lateral bridge sliding (LBS) procedure is an accelerated bridge construction (ABC) technique, in which the new bridge structure was constructed and then moved laterally into its final position. This procedure requires maintaining

deviations from the overall alignment (longitudinal, transversal and vertical) within tight tolerances, usually  $\leq 7\text{mm}$  (TRB, 2015).



Figure 2. Views of the new bridge structure, built to the railway track 5310 (RBM, 2024).

The new superstructure – with a self-weight of about 4,000 metric Tons - was built on temporary supports, equipped with tracks and rollers/slide bearings. Once the construction of the new bridge and the demolition of the old one were complete, the lateral slide was executed by moving the new structure on low-friction bearing pads or rollers using four simultaneously acting hydraulic jacks (two jacks per abutment) to push the structure (Figure 3).

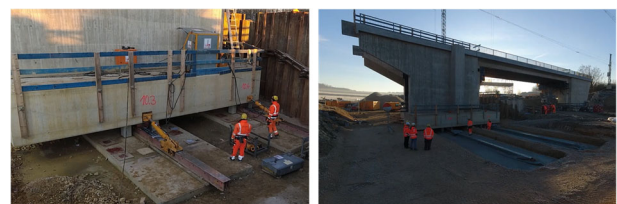


Figure 3. Lateral Bridge Slide procedure (RBM, 2024).

## 3 SUBSOIL CONDITIONS

According to LfU-Bayern (2023), the subsoil conditions in the project area are characterized by the presence of a geological unit called colorful breccia (*bunte Breccie, miXb*), a mixture of sediments (mostly silts/clays and limestone, from small fragments to blocks) that was ejected from the Ries meteorite crater, an impact structure of 26 km diameter in southern Germany (Hörz et al, 1983).

The colorful breccia is underlain by stiff to semi-solid silty clays of the upper freshwater molasses (*obere Süßwassermolasse, OSMu,F*) - extending up to depths between 11.5 m and 15.5 m below ground level - followed by the dense to very dense silty fine sands of the upper marine molasses (*obere Meeresmolasse, OMMo,S*), which extend to depths of at least 23 m below ground level (LfU-Bayern, 2025).

The natural geological sequence around the existing bridge was partially modified as a result of anthropogenic influences (i.e. construction of the existing bridge and the main road B25). The colorful breccia was partially relocated, replaced or covered by various types of infills (IBES, 2022).

The highly heterogeneous infills (soft to stiff sandy, clayey silts or loose silty sands) present variable mechanical properties, which could lead to differential settlements of shallow foundations placed directly on them, hence special measures such as extensive soil replacement are often recommended.

The subsoil profile at the specific project area is schematically presented in Figure 4 and the geotechnical properties of the identified soil units are summarized in Table 1.

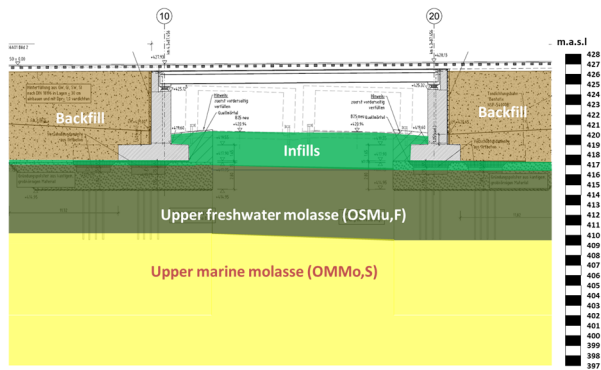


Figure 4. Subsoil profile at the project area (modified after IBES, 2022).

Table 1. Geotechnical parameters of the soil units (IBES, 2022).

Parameter	Infills	Upper freshwater molasses (OSMu,F)	Upper marine molasses (OMMo,S)
$\gamma / \gamma' (\text{kN/m}^3)$	18/10	20/10	21/11
$\phi (^{\circ})$	25 - 30	15 - 17.5	27.5 - 32.5
$c (\text{kN/m}^2)$	0 - 2	8 - 25	2 - 5
$E_s (\text{MN/m}^2)$	5 - 20	4 - 10	40

The use of shallow abutment foundations on the infills and the upper freshwater molasses (OSMu,F) was discarded, due to the aforementioned risk of differential settlements. In this context, the preliminary assessment for the new bridge structure required the transfer of the loads from the abutments (axis 10 and 20, Figure 4) to the more competent strata, preferably to the upper marine molasses (OMMo,S).

#### 4 GROUND REINFORCEMENT

Due to the heterogeneous ground conditions present in the project area (Figure 4), which could lead to differential settlements during the lateral slide operation, it was decided to carry out ground reinforcement with rigid inclusions (RI) to transfer the loads to the deeper layer of marine molasses (OMMo,S) and to reduce the settlements to 10 mm or less.

Due to the very tight time schedule (10 days of track possession), the rigid inclusions needed to be installed within 60 hours. Under these conditions, the most suitable, fast and

cost-effective solution was provided by non-grouted ductile iron piles (DIPs), due to the flexibility, large adaptability and installation speed. In addition, the non-grouted piles can be fully loaded immediately after the pile driving works are completed.

DIPs are low vibration, driven, full-displacement piles, installed using a medium-sized excavator and a hydraulic breaker hammer with a modified shank that seats into the pile socket (bell) for driving, using the hammer's percussive energy. The hydraulic hammers typically range from 1,200 kg to 2,500 kg and operate at frequencies ranging from 250 to 500 blows per minute, delivering much higher frequency than traditional high-impact, low-frequency driven piling systems (Lopez and Steinlechner, 2023).

DIPs are used to transfer loads from the superstructure into the lower soil layers and/or to limit deformations according to the principles of executing geotechnical works and have the flexibility to be installed to transfer the loads developing skin friction and/or end-bearing capacity (Lopez and Steinlechner, 2023). For the project, end-bearing non-grouted ductile iron piles (DIP) were adopted and their execution is schematically presented in Figure 5.

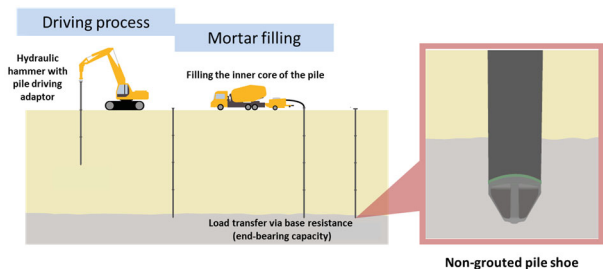


Figure 5. Execution of end-bearing (non-grouted) ductile iron piles (after Lopez and Steinlechner, 2023)

#### 5 DESIGN CONSIDERATIONS

##### 5.1 Construction stages

Three constructions stages were considered for the design of the ground reinforcement:

- Temporary: lateral sliding process: self-weight of the new bridge structure (reinforced concrete only: about 4,000 metric tons), distributed over four reinforced concrete thrust beds.
- Temporary: construction of the new overpass: self-weight of the new bridge structure, including the backfilling of the abutments as well as the new track (ballast, sleepers and rails) and the dynamic effects from compaction.
- Permanent: service life of the bridge (100 years) (Holst and Holst, 2013): self-weight of the new bridge structure, including the backfilling of the abutments as well as the new track (ballast, sleepers and rails). Longitudinal vertical traffic loads for a design speed of 160 km/hour (load models LM 71 and HSLM A1-10). Longitudinal horizontal traffic loads (start-up and breaking loads) and transversal horizontal traffic loads (lateral impact)

##### 5.2 Updated subsoil models

In 2023, additional cone penetration tests (CPT) were carried out at the vicinity of the new abutments (axis 10 and 20, Figure 4). With the results of the CPTs, the soil profiles (subsoil models) for the design of the reinforcement were updated and are schematically presented on Figure 6 and 7.

A granular load transfer platform (LTP) with a uniform thickness of 1.3m and reinforced with a geogrids was considered for the efficient load transfer onto the inclusions

via arching effect. Steel plates (400mm x 400mm x 30mm) were used at the top of the pile to aid in the effective load transfer from the LTP to the pile. The rigid inclusions needed to reach the dense to very dense upper marine molasses (OMMo,S) in order to minimize the settlements, resulting in an average length of 10 m (Figure 8).

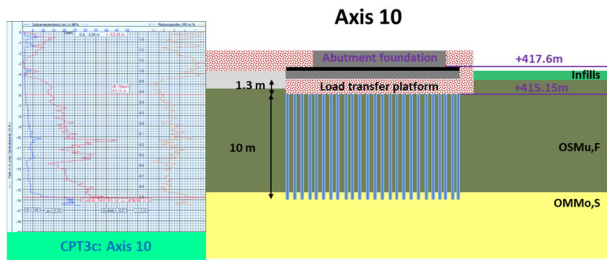


Figure 6. Updated subsoil model for Axis 10

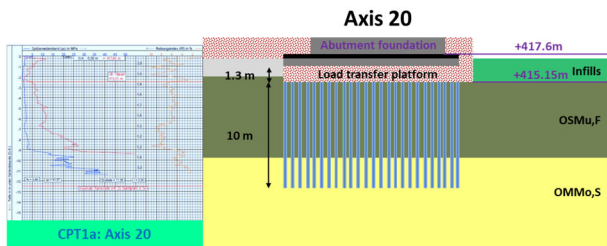


Figure 7. Updated subsoil model for Axis 20

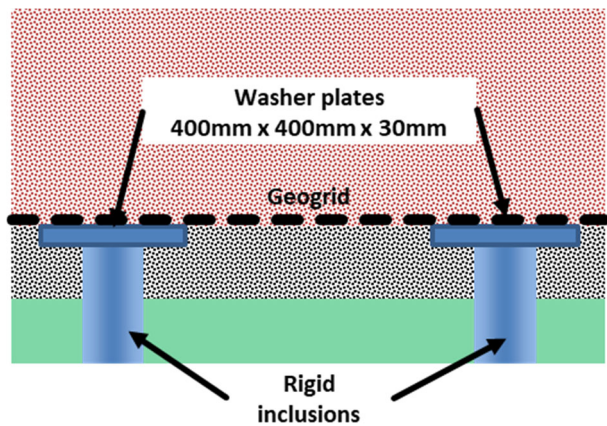


Figure 8. Pile head connection (schematic)

The abutments have an asymmetrical shape, leading to a variable distribution of the rigid inclusions along the temporary thrust beds. The thrust beds beneath the girder supports (bearing plates) have the largest concentration of elements (Figure 9 and 10). An area replacement ratio of 30% was considered for the project (ZPP, 2023).

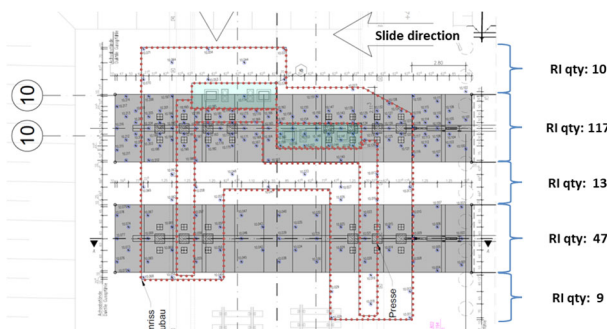


Figure 9. Plan view with the distribution of RIs for the abutment at Axis 10 (modified after Max Bögl, 2023)

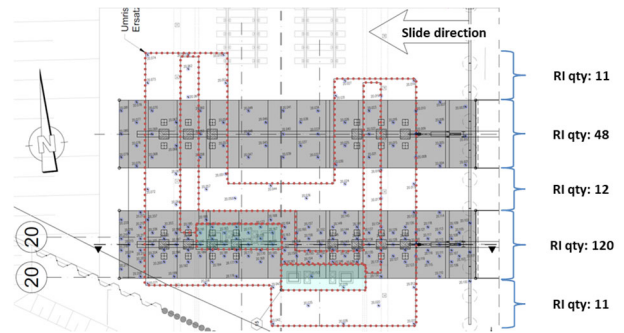


Figure 10. Plan view with the distribution of RIs for the abutment at Axis 20 (modified after Max Bögl, 2023)

Following a conservative approach, it was adopted that the ductile iron piles (DIP) that constitute the rigid inclusions would receive 100% of the resulting loads acting on the abutments' foundations.

### 5.3 Internal load bearing capacity of the rigid inclusions

After finishing the pile driving works, the internal core of the ductile iron pile pipe was filled with neat grout (resistance class C20/25). For the temporary cases, the internal load bearing capacity of the pile elements was conservatively defined only by the mechanical and geometrical properties of the ductile iron pipe itself (cross-section: with an effective diameter  $D_{eff}$  and an effective wall thickness  $t_{eff}$ ), without considering the contribution of the grouted core (Figure 11).

For the permanent case, the composite cross-section including both the ductile iron pipe and the grout were taken into account, considering a corrosion loss of the ductile iron pipe's "outer skin" ( $r_o$ ) (Figure 11). The values for  $D_{eff}$  and  $t_{eff}$  correspond to the nominal values for the diameter and wall thickness ( $D$  and  $t$ ), informed in DIBt (2022).

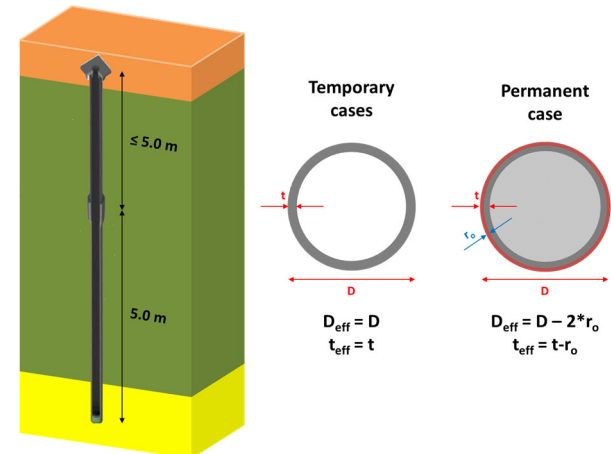


Figure 11. Cross-section considerations for the temporary and permanent cases

The required pile reinforcement is presented in Table 2.

Table 2. Pile reinforcement

Abutment	Axis 10	Axis 20
Pyle type	170/10.6	170/10.6
Amount of piles	217	220
Length (m)	10	10
	Temporary cases	
Internal load-bearing capacity (design) (kN)	1540	1540
	Permanent cases	
	1469	1469

#### 5.4 External load bearing capacity of the rigid inclusions

As previously mentioned, the piles needed to reach the dense to very dense sandy upper marine molasses (OMMo,S), where they were expected to develop the required geotechnical capacity to minimize the settlements of the new bridge structure. Based on experience in the local subsoil conditions, it was expected that the load transfer would occur mainly in end-bearing. The mobilization of the end-bearing capacity of DIPs is usually reached when the pile head deflection is less than 30 mm during a continuous driving time of 60 seconds (TRM, 2022), provided that the hydraulic hammer is working at full performance.

## 6 EXECUTION

The contractors had a track possession period of only 10 days (January 22 – February 1, 2024) to demolish the existing bridge, move the new bridge to the position of the old one, rebuild the track and reestablish the railway operations. A total of 398 DIPs (total length of around 4,000 lineal meters) for the ground reinforcement were successfully installed by the German company Carl Heuchel GmbH & Co. KG in the time from January 25 to 27, 2024 (60 hours). Figure 12 shows some impressions from the pile driving works.



Figure 12. Installation of the DIPs for the ground improvement (courtesy of Carl Heuchel GmbH & Co. KG)

## 7 FINAL REMARKS

After installing the last DIP (including the grouting of the inner core) and placing the head plates, the load transfer platform (LTP) was installed on January 27, followed by the construction of the temporary reinforced concrete thrust beds with the sliding rails. The lateral sliding procedure took place on January 28, lasting 3 hours.

Once that the new bridge structure reached its final position, the backfilling of the abutments and the construction of the new tracks were finished on January 31. With an estimated investment of 12,000,000 €, the new railway

overpass over the main road B25 in Donauwörth (Bavaria) was reopened to traffic on February 1, 2024 (Figure 13).



Figure 13. Reopening of the track 5310 to traffic on February 1, 2024 (RBM, 2024)

## 8 ACKNOWLEDGEMENTS

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