PROJECT	**Rail Baltica** SBS-Study
PURPOSE	**Prefabrication**
ANNEX 2	**Prefabrication possibilities and limits**
PERFORMANCE PERIOD	02/2019 until 09/2019
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PROJECT NUMBER INTERNAL	04119
EDITOR	Justine Bange, M.Sc.
DATE	Hannover, 27.09.2019
INDEX	a

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Technical and additional documents

Basis of assignment

[U1] Assignment order (contract) No 8/2017-120-X/X for the provision of expert services, Riga

[U2] Mini competition_SBS-Cases-R0.2

[U3] Bridge Inventory; Rail Baltica; 02.04.2019

Project-specific documents

[U4] Rail Baltica Official Website

Additional documents

[U5] DB Leitfaden Gestalten von Eisenbahnbrücken; Verfasser: Jörg Schlaich, Thomas Fackler, Matthias Weißbach (Schlaich Bergermann und Partner, Stuttgart); Victor Schmitt, Christian Ommert (SSF Ingenieure, München/Berlin); Steffen Marx, Ludolf Krontal (DB ProjektBau GmbH, Leipzig); Dezember 2008

[U6] High Speed 2 BRIDGE DESIGN REQUIREMENTS; Simon Kirby; Sadie Morgan; April 2016

[U7] Corporate Design Konzept Koralmbahn; Gestaltungsprinzipien Hoch- und Ingenieurbauten-Entwürfe; Arch. DI Christopfh Zechner, DI Robert Luger (Zechner & Zechner ZT GmbH); 10/2014

[U8] Köörna , Arno Artur/ Tarmisto, Vello Julius/ Stranga , Aivars/ Aruja**,** Endel/ Smogorzewski, Kazimierz Maciej/ Misiunas, Romuald J., Bater **,** James H. : "Estonia" at https://www.britannica.com/place/Estonia (last accessed on 15 March 2019)

[U9] Smogorzewski, Kazimierz Maciej/ Roos, Hans/ Dawson, Andrew Hutchinson/ Davies, Norman/ Wandycz, Piotr S./ Jasiewicz, Krzysztof: "Poland" at https://www.britannica.com/place/Poland (last accessed on 15 March 2019)

[U10] Interkart-Landkarten, Poster & Globen: Physikalische Landkarte Europa unter https://www.interkart.de/landkarten/europa/europa-kontinent/physikalische-landkarte-europa.html# (abgerufen am 16.03.2019)

[U11] Ril 820.2040 Schienenauszüge, Bauart und Auszugslänge/Einstellmaß; DB; 01.01.2007

[U12] Brücken aus Spannbeton-Fertigteilen; Wolfgang Rossner; Berlin: Ernst, Verlag für Architektur u. techn. Wiss., 1988

[U13] Mail: RE: Prefabrication, Transportation, loading capacity crane; Vasco Amaral; 02.04.2019

[U14] Dynamic Effects of high-speed trains (Marx, Matsumoto); work in process

[U15] Planung und Bau einer semiintegralen Eisenbahnüberführung in Walzträger-in-Beton (WiB)-Bauweise; A. Brunner, W. Frühauf, P. Kotz, T. Schantz, D. Windisch; Beton- und Stahlbetonbau Februar 2014, S. 96-106

[U16] Formdynamik an Überführungsbrücken; Michael Kleiser; Beton- und Stahlbetonbau 112, Heft 7; Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin; 2017

[U17] Leonhardt, F.: Brücken – Ästhetik und Gestaltung. Deutsche Verlags-Anstalt, Stuttgart, 1982, S. 44.

[U18] Formentwicklung einfeldriger Rahmenüberführungen anhand statisch-konstruktiver Überlegungen; Michael Kleiser; Beton- und Stahlbetonbau 112, Heft 5; Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin; 2017

[U19] Kräfte in Form bringen; Michael Kleiser, Hinko Jusufagic, Roman Pölcz, Dieter König, Christian Musil; Beton- und Stahlbetonbau 114, Heft 2; Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin; 2019

[U20] Design guidelines General requirements; Rail Baltica; 25.03.2019

[U21] Design guidelines Railway substructure, Part 1 embankments and earthworks; Rail Baltica; 02.11.2018

[U22] Design guidelines Railway substructure, Part 2 hydraulic, drainage and culverts; Rail Baltica; 25.03.2019

[U23] Design guidelines Railway substructure, Part 3 bridges, overpasses, tunnels and similar structures; Rail Baltica; 25.03.2019

[U24] Zur Gestaltung von Fertigteilbrücken; Markus Gabler, Abdalla Fakhouri, Katrin Baumann; Bautechnik 96, Heft 2; Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin; 2019

[U25] Architecture, Landscape and Visual Identity design Guidelines, Second Interim Report; Rail Baltica; 08.03.2019

[U26] Entwurf und Ausführungsplanung der Stöbnitztalbrücke; Rolf Jung, Steffen Marx, Marcus Schenkel, Rico Stockmann; Beton- und Stahlbetonbau 106, Heft 2; Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin; 2011

[U27] Grünbrückenkonstruktion aus Fertigteil-Bogensegmenten; Andrea Suffner, Torsten Schulze; Bautechnik 93, Heft 2; Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin; 2016

[U28] Ril 804.9040 Eisenbahnbrücken (und sonstige Ingenieurbauwerke) planen, bauen und instand halten Modul 804.9040 Standardisierte Rahmenbauwerke; DB; 01.09.2013

List of abbreviations

WIB	Filler beam deck (Walzträger in Beton)
CNM	Circumvalación Nimes-Montpellier; Railway line Nimes - Montpellier
HSL	High-speed line
ERTMS	European Railway Traffic Management System
VFT	Prefabricated compound part (Verbundfertigteil)

Table of content

1 Introduction

1.1 Purpose of this document

This document provides possibilities and limits of prefabricated structures.

2 Types of prefabrication for superstructure

2.1 Prestressed concrete constructions

General

Prestressed concrete constructions can be built in different ways and with different level of prefabrication and with different construction method:

- complete prefabricated construction
- prefabricated concrete and in-place concrete complement (mixed structure)
    - side-by-side → minimum gap
    - in situ concrete seal → small gap
    - in situ concrete stripes → wide gap → formwork is needed
    - in situ concrete plate → wide gap filled with prefabricated concrete plate → all topped with in situ concrete plate
- special construction method

The static proof is regulated in Eurocode.

Complete prefabricated construction

Definition: prefabricated bridges which are made only of one element from one bearing to the other bearing. Due to the high weight of the construction, this prefabrication type is mostly used for pedestrian and bicycle bridges. For single-track railway bridges box girders were used in the past.

EXAMPLES FOR SINGLE-TRACK RAILWAY BRIDGES

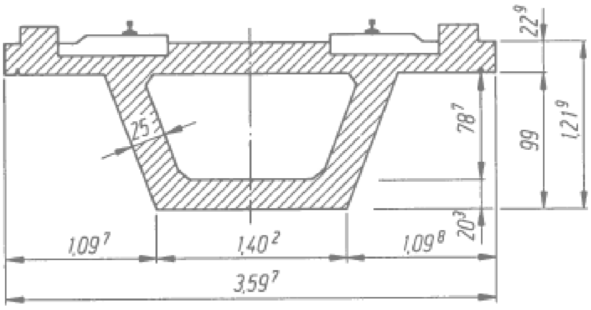


Figure 1: trapezoidal box girder; elevated track USA [U12]

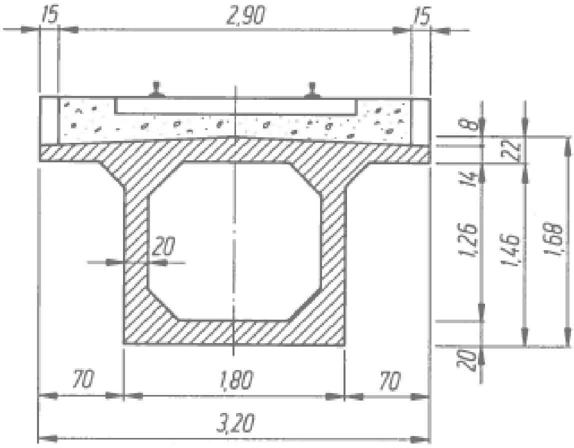


Figure 2: single-celled box girder Japan (span 22,30 m) [U12]

Prefabricated and cross tensed up construction

Definition: Prefabricated prestressed girders which are cross tensed can be used for spans around 25 m.

EXAMPLES FOR ROAD BRIDGES

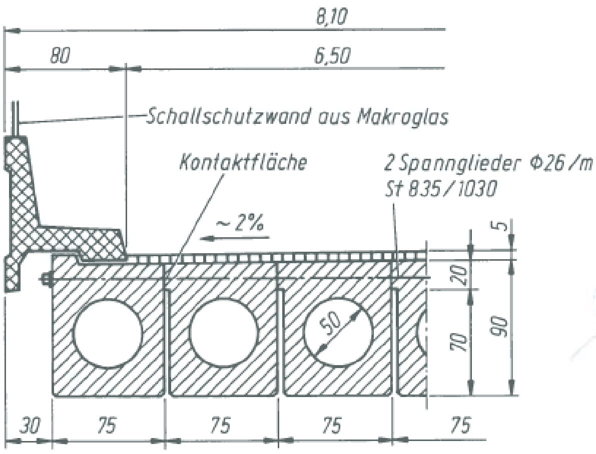


Figure 3: anisotropic structure with contact area [U12]

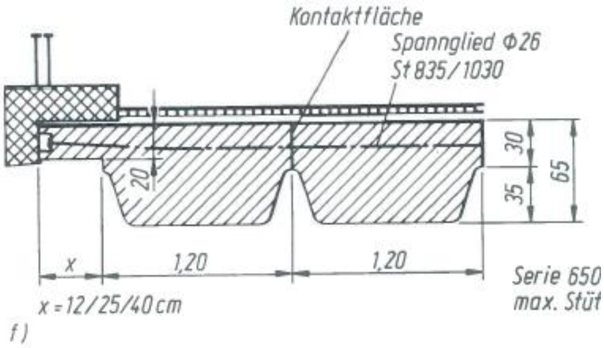


Figure 4: orthotope structure with contact area [U12]

EXAMPLES FOR RAILWAY BRIDGES

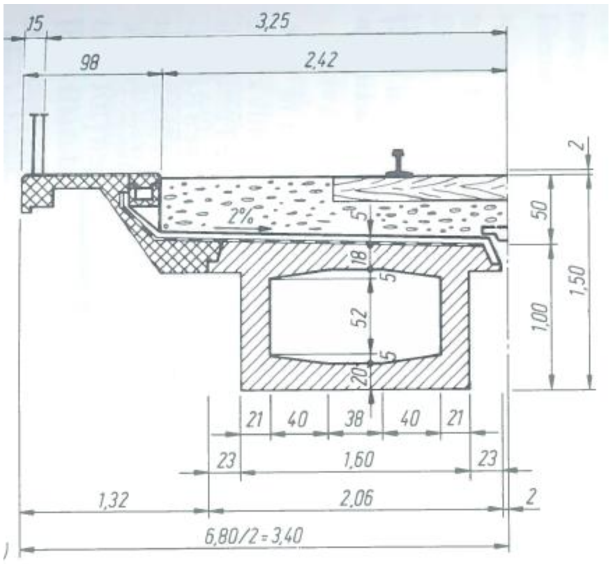


Figure 5: box girders (spans 11,20 m and 14,20 m) [U12]

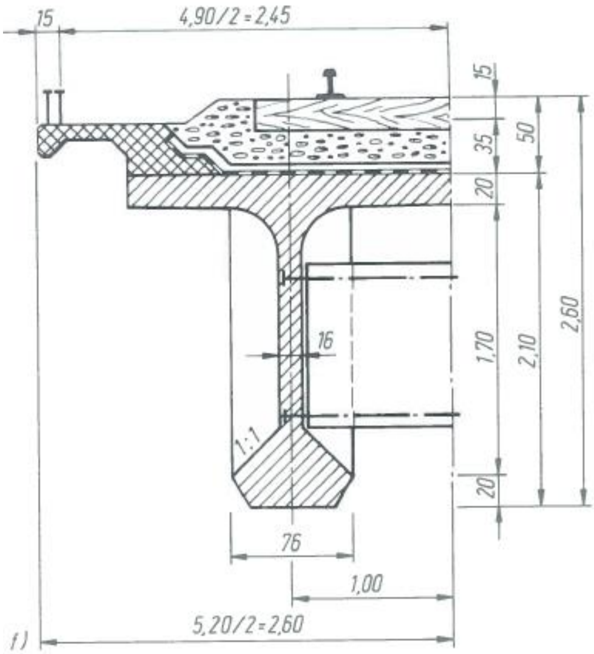


Figure 6: t-profile with strengthened lower boom [U12]

Prefabricated concrete and in-place concrete complement (mixed structure)

Definition: The mixed structure between prefabricated concrete and in-place concrete complement is the most common structure for prefabricated prestressed concrete constructions. The mixed structures can be classified dependent on the distance between the prefabricated concrete parts:

- side by side: lay the girders side by side (only very small gap) and connect them by shear connectors with a continuous in-place concrete plate. (Figure 7; Figure 8)
- in-situ concrete seal: lay the girders with a small gap and fill it with in-situ concrete (Figure 9; Figure 10)
- in-situ concrete stripes: wider distance between girders which has to be filled with in-situ concrete. Therefore, formwork is necessary. Thus, advantage in comparison to normal in-place concrete structures is lost.
- In-situ concrete plate: wide distance between girders which are filled with prefabricated concrete plates and connected with a continuous in-place concrete plate. (Figure 11)

SIDE-BY-SIDE

EXAMPLE FOR A ROAD BRIDGE

EXAMPLE FOR A RAILWAY BRIDGE

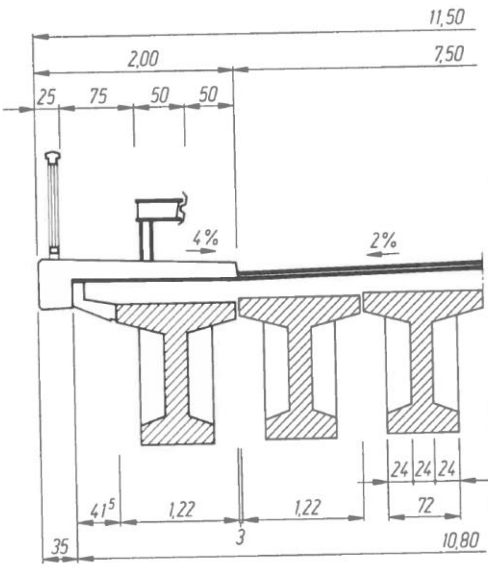


Figure 7: side by side; I-cross section, two-span beam [U12]

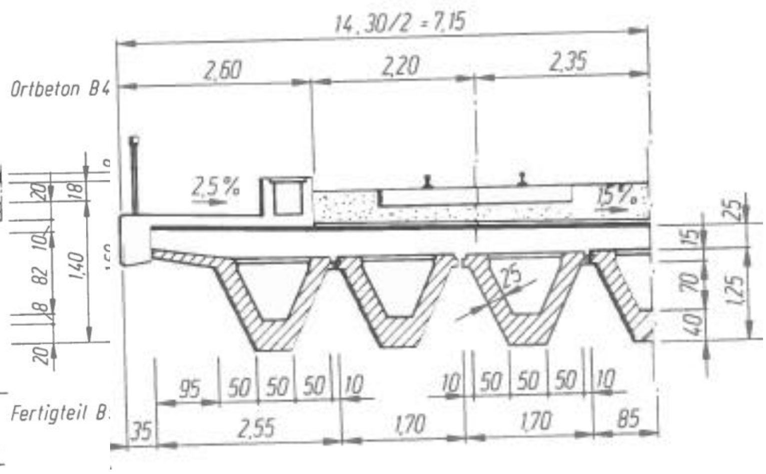


Figure 8: side-by-side; V-cross section [U12]

IN-SITU CONCRETE SEAL

EXAMPLE FOR A ROAD BRIDGE

EXAMPLE FOR A RAILWAY BRIDGE

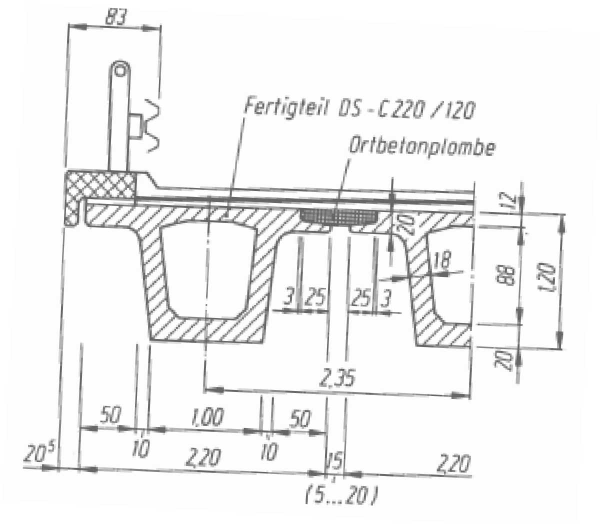


Figure 9: in-situ seal, box girders [U12]

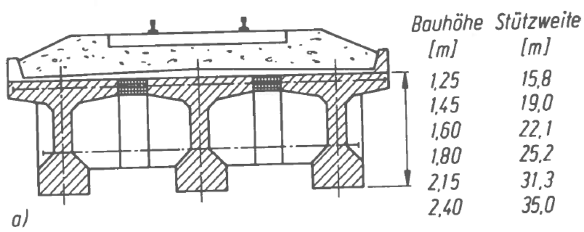


Figure 10: in-situ seal, single track (spans 15,8 – 35 m) [U12]

IN-SITU CONCRETE PLATE

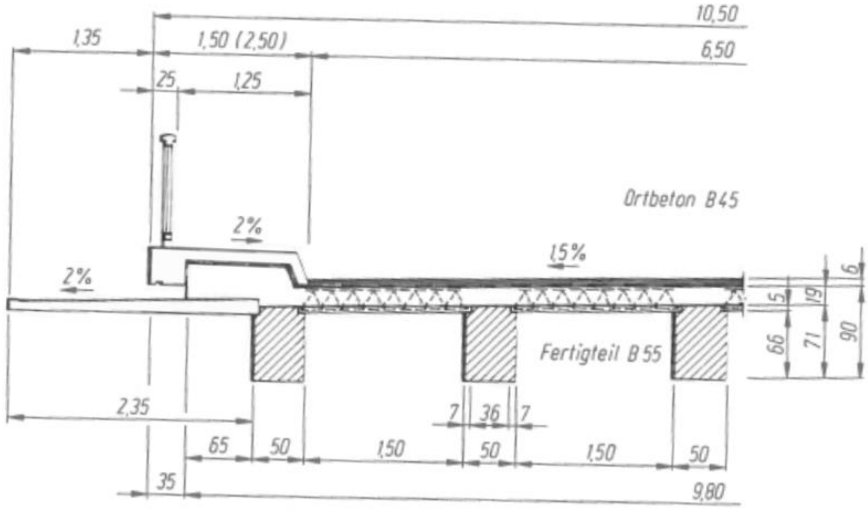


Figure 11: railway underpass, rectangular cross section, integrated framework [U12]

Special construction method

Definition: prefabricated concrete constructions which cannot be built by standard lifting devices. These constructions need special devices or methods to be build up e.g. floating crane, launching gantry, beam launchers, heavy load tire trolleys.

2.2 Steel composite construction

Steel composite constructions are partly prefabricated solutions. The static proof is regulated in Eurocode.

<u>TTT-partly prefabricated construction</u>

The TTT-partly prefabricated structure solution uses prefabricated steel and concrete parts which are assembled on side. Figure 12 shows a cross section for this structure type.

- Red: box steel girder
- Grey: prefabricated concrete plate as cross beams and
- Blue: prefabricated concrete plate as flange
- Light blue: in-cast concrete

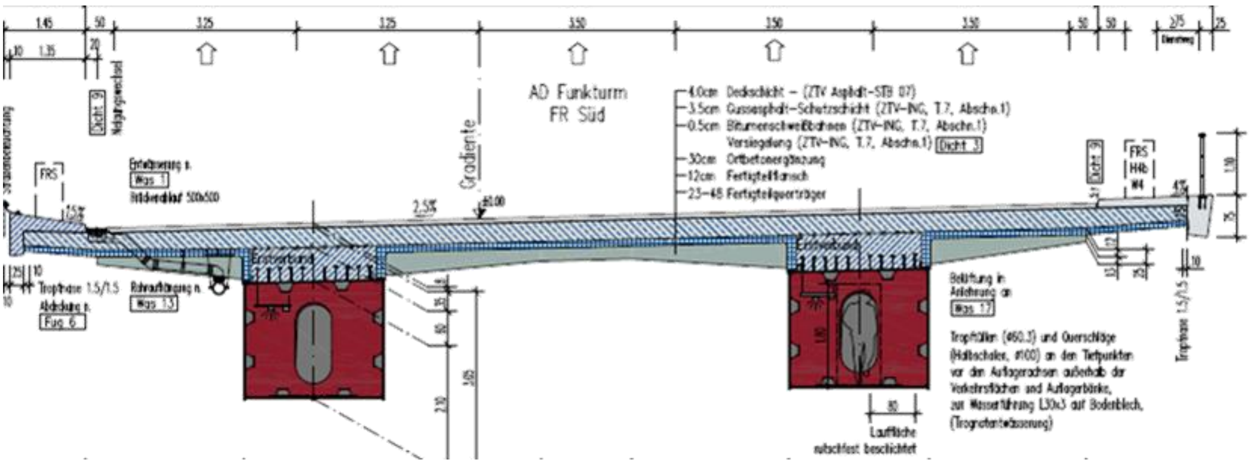


Figure 12: cross section example TTT-prefabricated parts [ssf ingenieure]

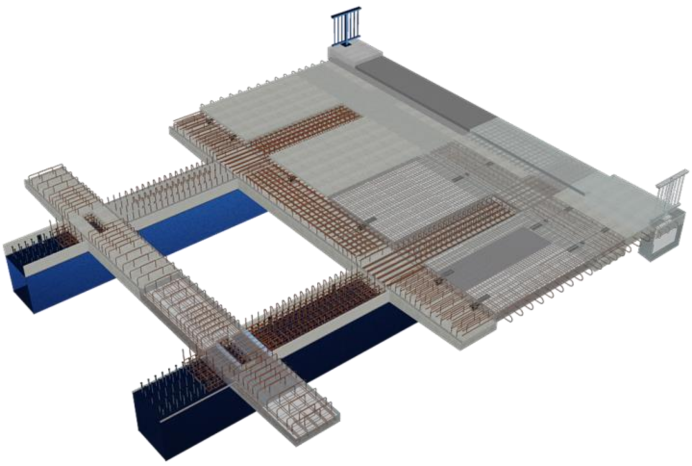
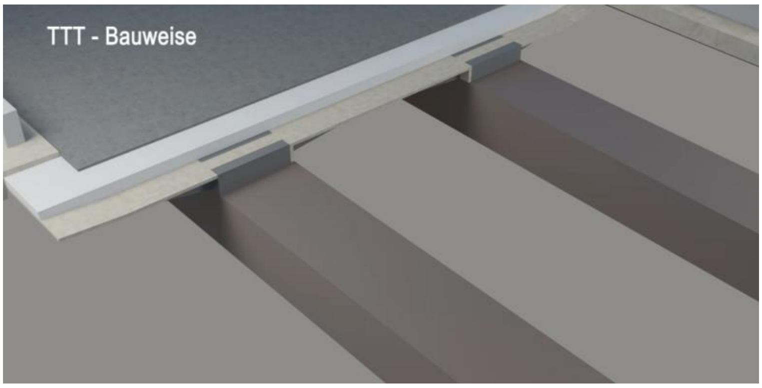
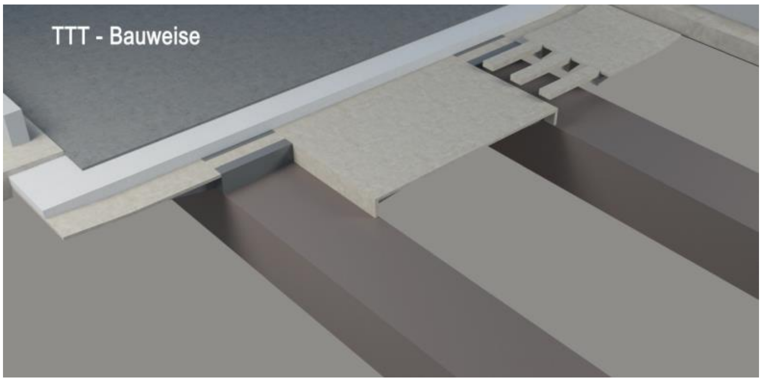


Figure 13: System of TTT-prefabrication

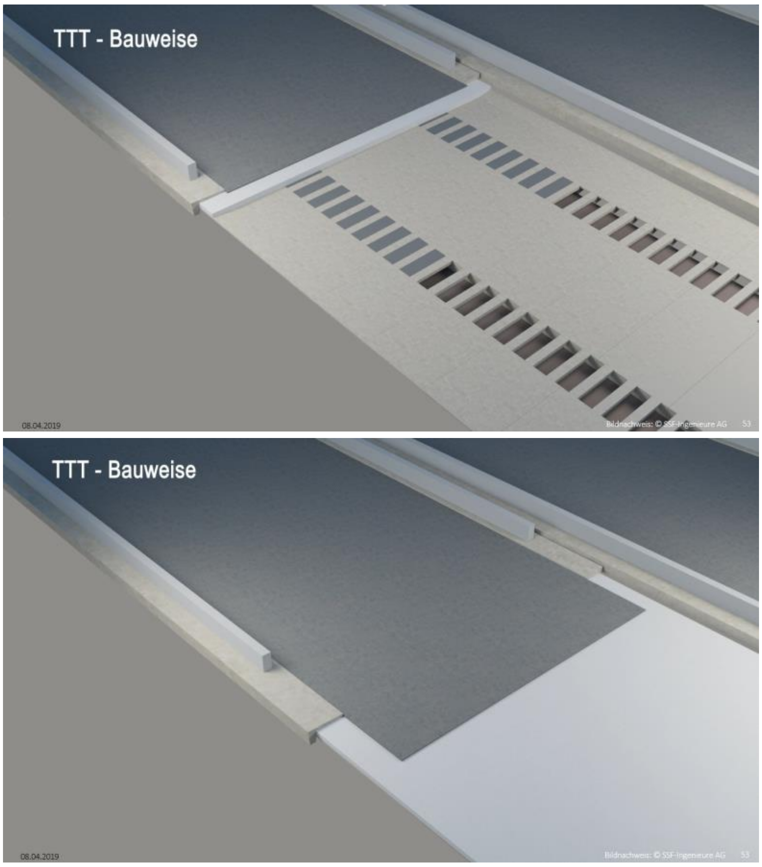
In the following figure (Figure 14)the building procedure for a TTT-partly prefabricated superstructure is shown:



- Lay box girder or other steel construction



- Lay prefabricated concrete plates between box girders.
- Lay prefabricated concrete plates for cantilever wings and adjust these.



– Fill gaps with in-situ concrete
→ connect box girders and prefabricated concrete plates.

– Concrete bridge deck
– Road surface
– Concrete cap

Figure 14: TTT-partly prefabricated superstructure building procedure [ssf ingenieure]

2.3 Preflex girder and filler beam bridges

Preflex girder, also called as double steel-composite construction, and WIB (filler beam bridges) constructions are half prefabricated very slender constructions. The static proof is based on technical experiments and technical approval but not with Eurocode. The technical approval is not suitable for frame constructions. Therefore, a specific individual approval has to be requested.

Following steps have to be done to build a Preflex girder:

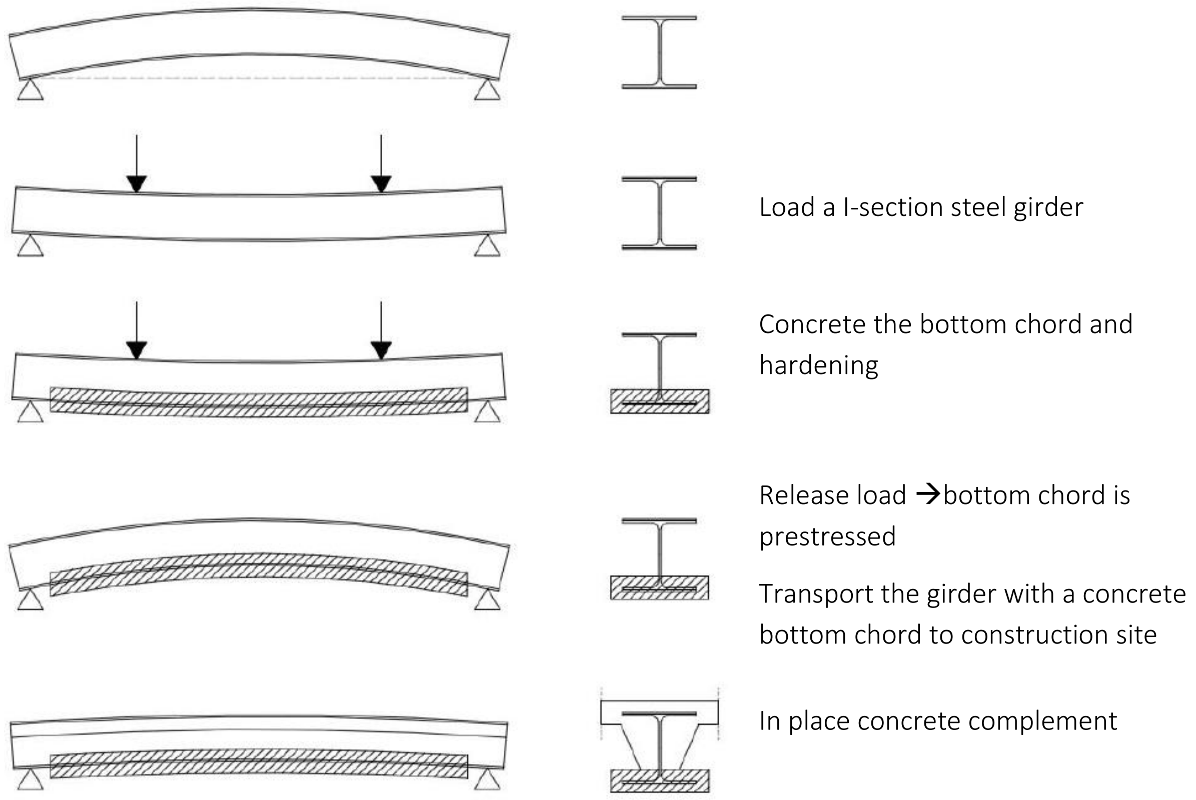


Figure 15: Preflex girder principle [C+P Brückenbau GmbH & C. KG, Bad Homburg]

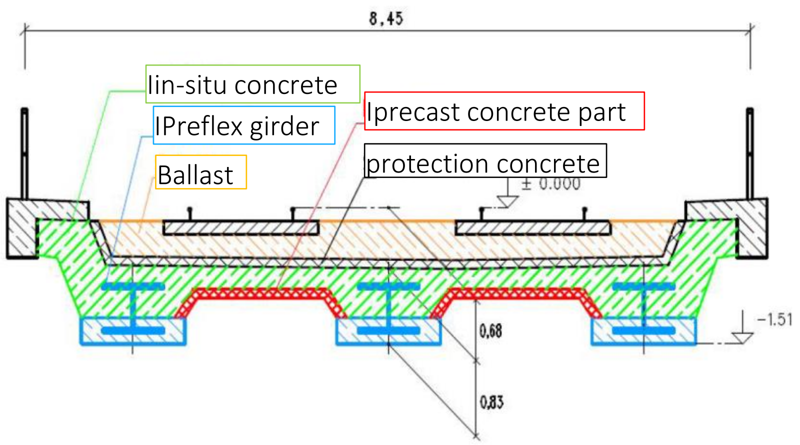


Figure 16: railway bridge cross section with Preflex girder [C+P Brückenbau GmbH & C. KG, Bad Homburg]

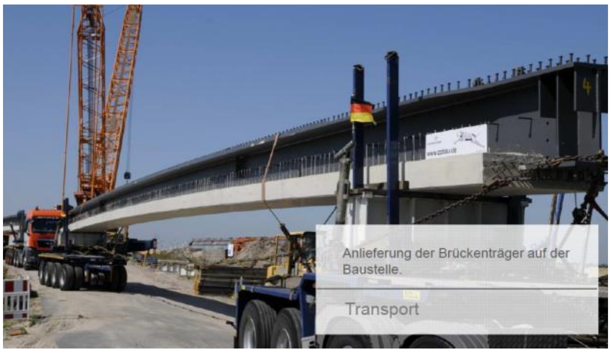


Figure 17: Transport [C+P Brückenbau GmbH & C. KG, Bad Homburg]

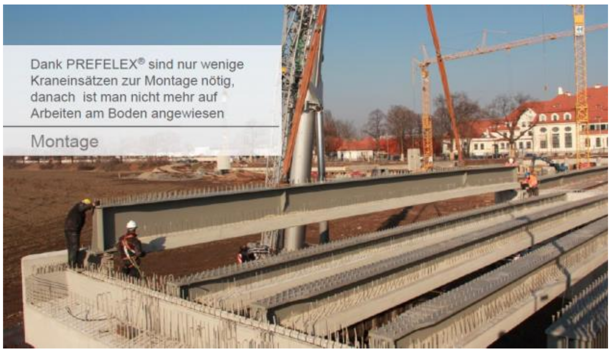


Figure 18: Installation [C+P Brückenbau GmbH & C. KG, Bad Homburg]

Figure 19: cross girder before installation [C+P Brückenbau GmbH & C. KG, Bad Homburg]

For single span railway bridges the slender construction leeds to dynamic problems. Also, a continuous beam construction with Preflex girder or WIB construction is very difficult. Thus, this type of construction is mainly suitable for small road overpasses or non-high-speed railway bridges.

3 Prefabrication for substructure

3.1 Full prefabricated parts

Figure 20 shows the connection of a full prefabricated pier element to footing. A full prefabricated pier element is reinforced. Only the connection points between the prefabricated parts need to be done.

Picture credit: © Marcos Sanchez Arup [U24]

Picture credit: © Marcos Sanchez Arup [U24]

Figure 20: Connection of prefab pier elements to footing in a M50 extension bridge in Ireland

In Figure 21 a roughly 42 Tons heavy abutment piece is shown. The main tasks by prefabricated parts is not only to build and lift them, but also to deliver them without damage to site.

Figure 21: prefabricated abutment part [Precast of Maine]

3.2 Prefabricated covering parts

Prefabricated covering parts, like used for the new bridge Lennetalbrücke near Hagen, are a useful method to guarantee a high surface quality. In Figure 22 the finished piers (left) and the covering pier parts (right) are shown. After placing the covering pier parts, reinforcement is added and the covering is filled with in-situ concrete. The advantage is a smaller lifting weight than full prefabricated parts.

Figure 22: prefabricated covering pier parts for Lennetal bridge near Hagen

Another example for prefabricated covering parts for piers is the Albeins bridge in South Tyrol. Two non-load bearing half-shells were produced and transported to site. The assembly is directly done after transportation to avoid storage on site. The half-shells are connected with foundation plate by threaded bars. After Lifting the reinforcement cage the pile is concreted with self-compacting concrete.

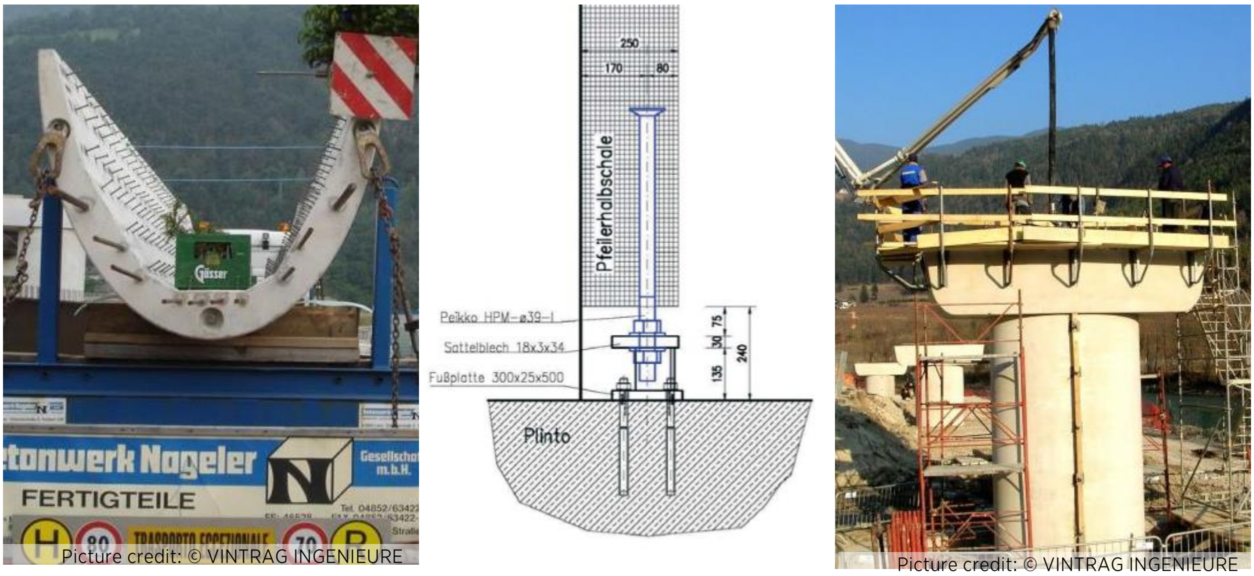


Figure 23: partly prefabricated concrete pile with non-load bearing half shells [VINTRAG INGENIEURE]

3.3 Examples

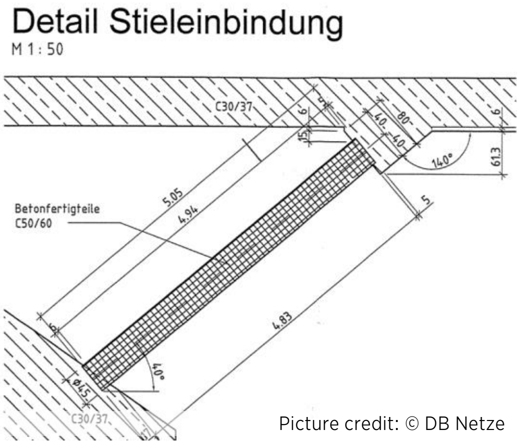

Picture credit: © MKP GmbH

Example 1 – prefabricated, inclined struts

Bridge: Rail Viaduct Vechelde

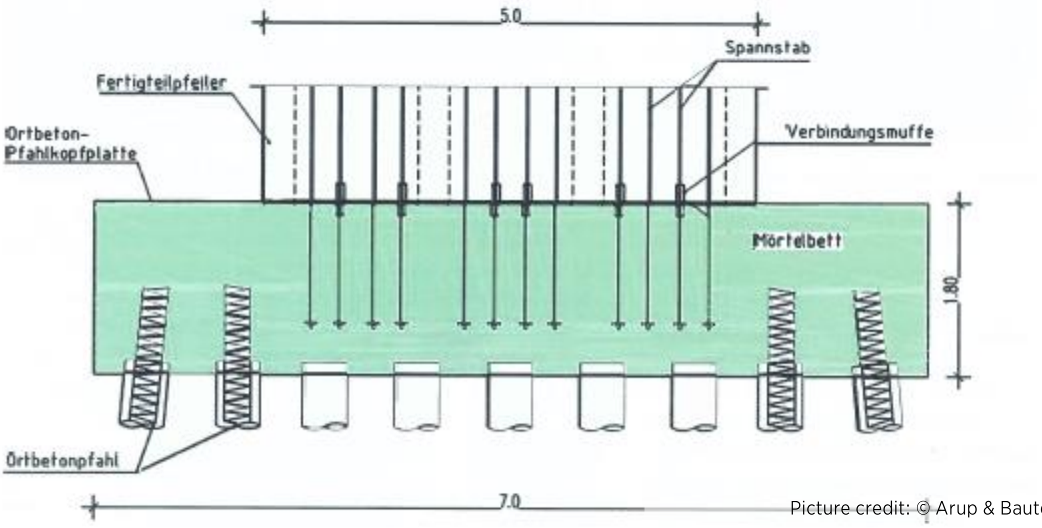
Type	Railway bridge
Line / built speed	1730 Hannover -Braunschweig / 160 km/h
Country	Germany
Construction	Open frame construction
Span	14 m
Dimensions	Vertical Clearance 4,70 m Thickness 0,86 m


Picture credit: © MKP GmbH



Picture credit: © DB Netze

Prefabricated strut

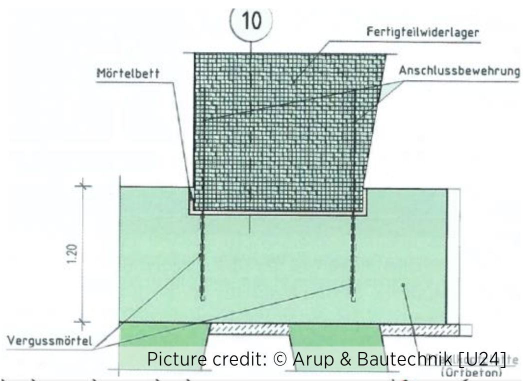


Picture credit: © Arup & Bautechnik [U24]

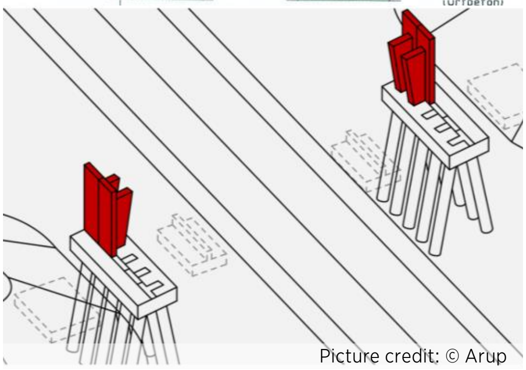
Example 2 – prefabricated substructure with cast-in-place piles

Bridge: Precast bridge Stiegenkamp and Nordbecker Damm

Type:	Road overpass
Line / built speed	L 518
country	Germany
Construction	Frame construction, prefabricated
Span	24,6 m / 24,1 m
Dimensions	Slenderness: l/43 / l/37,7



Picture credit: © Arup & Bautechnik [U24]



Picture credit: © Arup

Connection of prefabricated abutment elements to footing

4 Possibilities of prefabrication

4.1 Time saving

With traditional bridge construction, foundations for piers and abutments must be built first. Pier columns and caps must be built before beams and decks are placed. With prefabricated bridge elements these components can be fabricated concurrently and be transported to site as needed.

Due to fabrication in a climate-controlled environment weather does not affect time schedule of construction.

Fast construction on site ensures less traffic obstruction for “crossing partners”.

4.2 Quality control

Precast elements ensure:

- Surface quality
- Aesthetic
- Quality of execution

Long-term durability for prefabricated bridge parts due to higher quality materials used.

4.3 Environmental

Often environmental permitting requirements limit onsite construction, for example, to certain seasons of the year. These limitations lead to less available calendar days for construction. Prefabrication in fabric does not have to adhere to those limitation. Thus, prefabrication and accelerated construction can keep a project on schedule even with fewer available working days and other environmental limitations at the site.

4.4 Saving auxiliary construction on site

Producing in a prefabrication factory reduces auxiliary construction on site such as:

- Formwork
- Supporting scaffolding

5 Limits of prefabrication

5.1 Transportation

Construction with prefabricated bridge parts means not only to make them in a quality-controlled surrounding, but also to transport them from precast factory to construction site.

Existing infrastructure

Following maximum vehicle parameters are allowed in the Baltic countries [U13]:

Length:

– Vehicle – 12 m
– Trailer – 12 m
– Vehicle with trailer - 18,75 m
– Auto train with more than one link – 25 m

Weight:

– Double axle vehicle – 18 t.
– Triple axle vehicle – 25 t.
– Four axle vehicles with two paired driven axles and pneumatic suspension (with limit to one axle 9,5 t.) – 32 t.
– More than three axles and more than one link auto train – 40 t.
– Double axle trailer – 18 t.
– Triple axle trailer – 24 t.
– More than three axles trailer – 30 t.
– Other vehicle and trailer combinations do not exceed 40 t.

Width:

– Vehicle - 2,55 m

Height:

– Vehicle - 4,0 m
– Trailer - 4,0 m

Construction road

For all bridge structures a construction road has to be build. For the delivery these roads have higher requirements for the design due to high weights and great lengths of delivery vehicle.

5.2 Lifting equipment

Installing the prefabricated bridge parts requires cranes. An example for one of the biggest cranes that can be used is shown in Figure 24. The figure pictures the load capacities depending on lifting height.

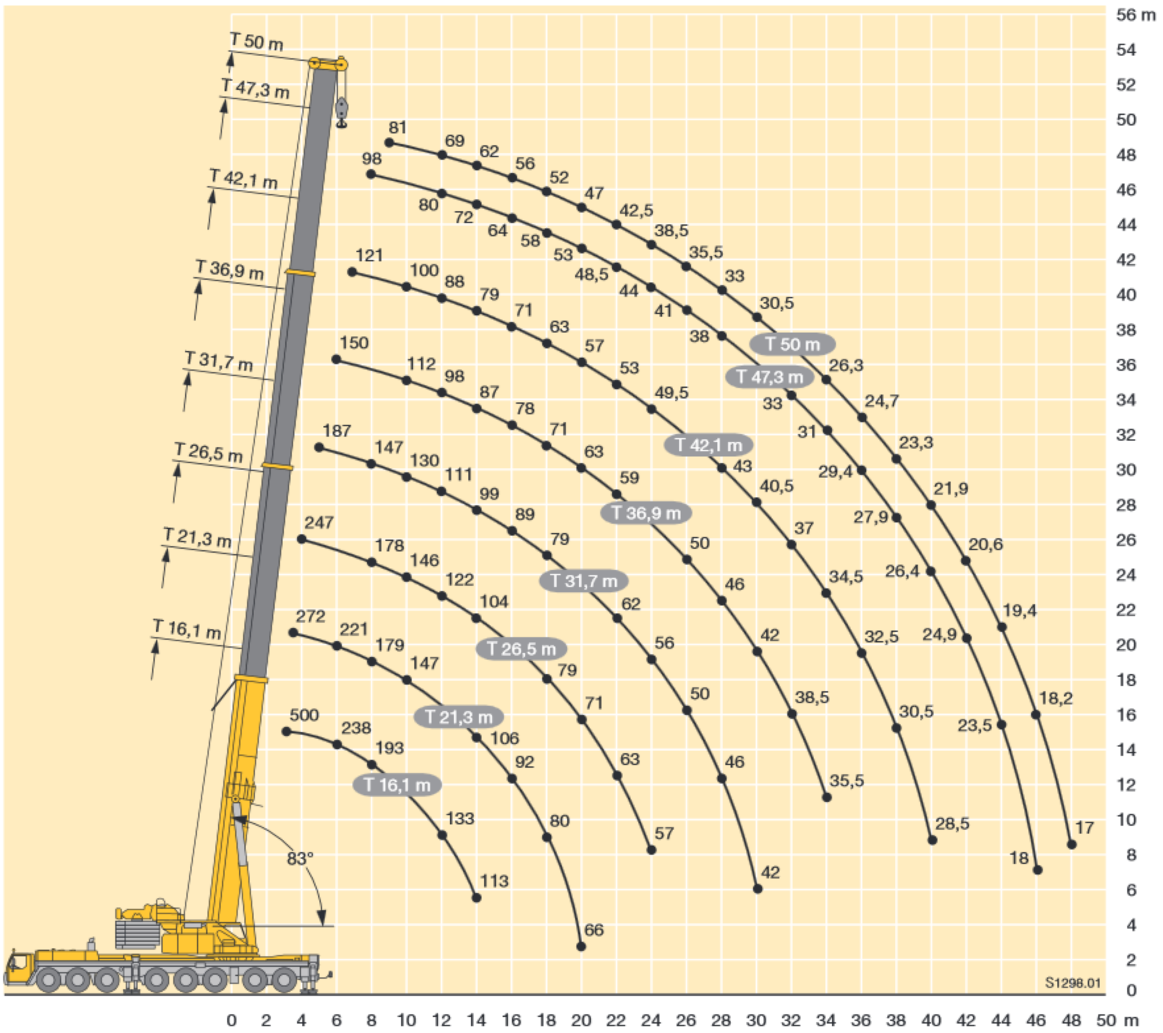


Figure 24: Lifting capacities depending on lifting height [http://strelelogistics.com]

Depending on span and weight of prefabricated bridge parts a launching gantry is sometimes necessary.

Figure 25: Launching gantry [www.directindustry.com]

5.3 Connection points

Due to lifting weight limitations a half prefabrication solution is mostly required. Prefabricated bridge parts must be assembled and connected with connection points.

Even if the prefabrication level is high. There are always connection points necessary. These connections are, mostly, built with in-cast concrete especially for integral structures.

The connection points, joints, have to fulfil special requirements due to the usage for high speed railway lines. Especially limits for fatigue resistance and vibration amplitudes have to be fulfilled. Joints always interrupt the support structure system. Which is negative for high-speed-railway systems. Therefore, integral connection points should be designed. Integral connection points between superstructure and substructure could be built like the frame joints for Stöbnitztalbrücke shown in Figure 26. Such integral joints raise the level of durability. A good and durable standard solution for connection points has to be taken into account for the next design step.

Still, connection points can also be a possibility for small tolerances. With connection points slight deviations in geometry can be compensated.

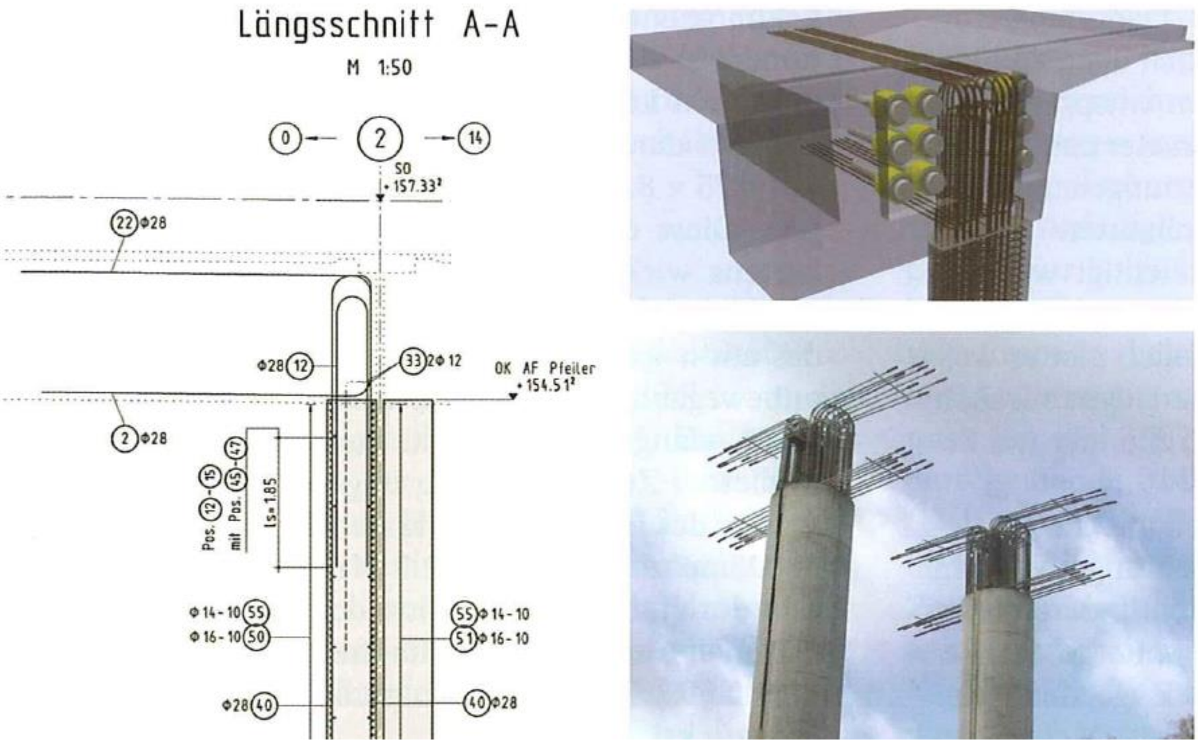


Figure 26: Frame Joint [U26]

5.4 Usage for high speed railway lines

Not all types of prefabrication structures presented in chapter 2 can be used for railway viaducts. Because of the high necessary stiffness and the design requirements for high speed railways following prefabrication structures should **only be used for road overpasses** or non-high-speed railway bridges:

- Preflex girders
- WIB (Sectional girders in concrete)

5.5 Span depending

The possibility of prefabricated bridge parts also depends on span length. The shorter the span, the easier it is to use a high level of prefabrication due to transportation and lifting requirements.

6 Conclusion

Precast elements ensure surface quality, aesthetic and quality of execution. Still, connection points on site are necessary due to transportation capacity and lifting equipment. Connection points are always a big challenge for the durability of bridges. Therefore, the standard connections have to be designed carefully with the main aspect of durability as basis.

Final leaf

Hannover, 27.09.2019