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|---|---|
| PROJECT | **Rail Baltica**<br>SBS-Study |
| PURPOSE | **Case Analyse** |
| ANNEX 1 | **Crossing Situations in Europe (Structures, Options and Examples)** |
| PERFORMANCE PERIOD | 02/2019 until 09/2019 |
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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] 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)

[U7] 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)

[U8] 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)

[U9] Ril 820.2040 Schienenauszüge, Bauart und Auszugslänge/Einstellmaß; DB; 01.01.2007

[U10] Mail: RE: Prefabrication, Transportation, loading capacity crane; Vasco Amaral; 02.04.2019

[U11] 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

[U12] Formdynamik an Überführungsbrücken; Michael Kleiser; Beton- und Stahlbetonbau 112, Heft 7; Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin; 2017

[U13] Leonhardt, F.: Brücken – Ästhetik und Gestaltung. Deutsche Verlags-Anstalt, Stuttgart, 1982, S. 44.

[U14] 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

[U15] 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

[U16] Design guidelines General requirements; Rail Baltica; 25.03.2019

[U17] Design guidelines Railway substructure, Part 1 embankments and earthworks; Rail Baltica; 02.11.2018

[U18] Design guidelines Railway substructure, Part 2 hydraulic, drainage and culverts; Rail Baltica; 25.03.2019

[U19] Design guidelines Railway substructure, Part 3 bridges, overpasses, tunnels and similar structures; Rail Baltica; 25.03.2019

[U20] 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

[U21] Architecture, Landscape and Visual Identity design Guidelines, Second Interim Report; Rail Baltica; 08.03.2019

[U22] 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

[U23] 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

[U24] 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 analyses typical crossing situations of the Rail Baltica railway lines and the existing infrastructure network (pedestrian paths; animal paths; roadways; railways; valleys and water lines).

Therefore, this document presents state-of-the-art solutions used in other high-speed Railway projects in Europe for typical crossing situations. Moreover, it considers the main advantages and disadvantages of the different options and how they meet the Rail Baltica Design Guidelines requirements.

# 2 Bridge design in different countries

## 2.1 Bridge design in Germany

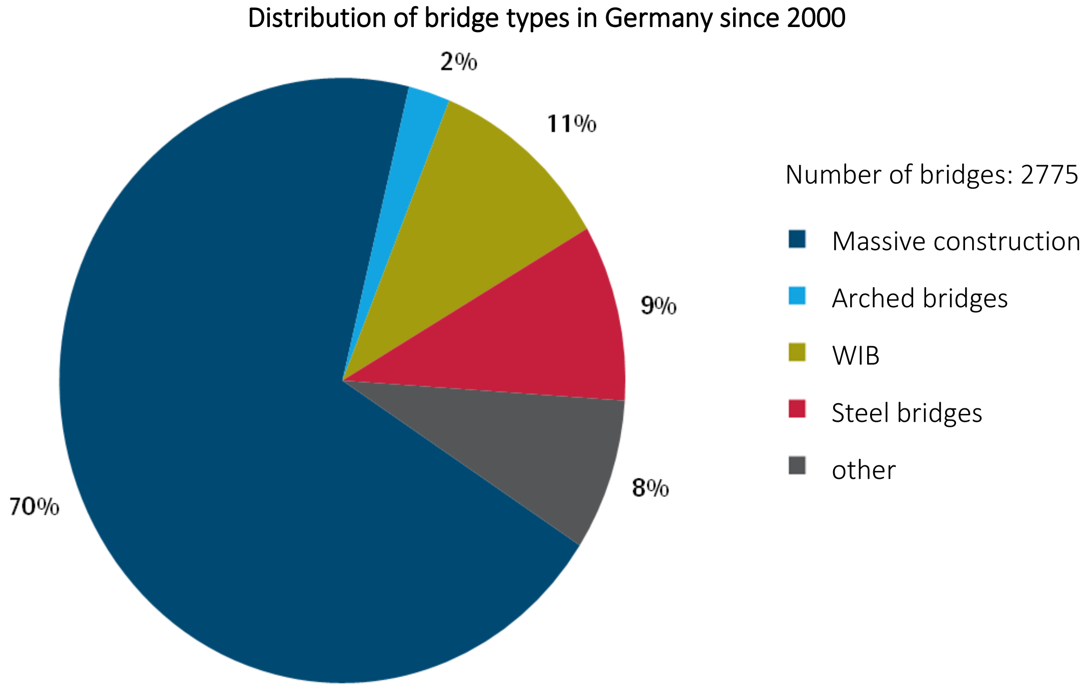



**Figure 1:** distribution of railway bridge types in Germany since 2000 [DB AG]

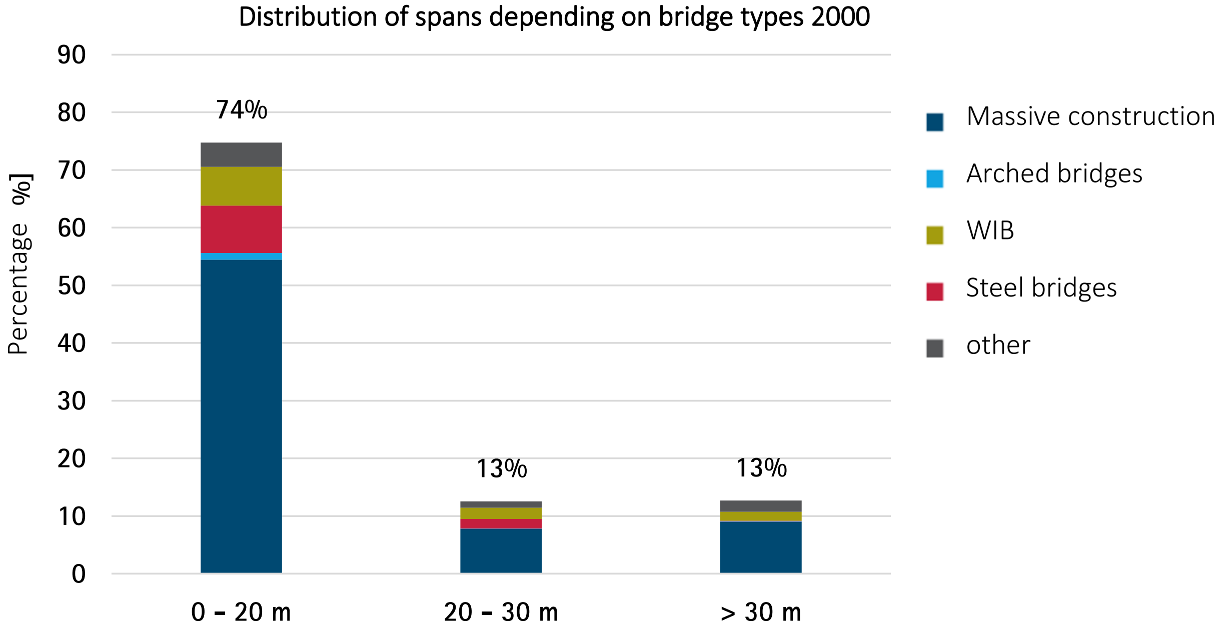



**Figure 2:** distribution of spans depending on railway bridge types in Germany since 2000 [DB AG]

## 2.2 Bridge design Railway line Nimes Montpellier (CNM) France

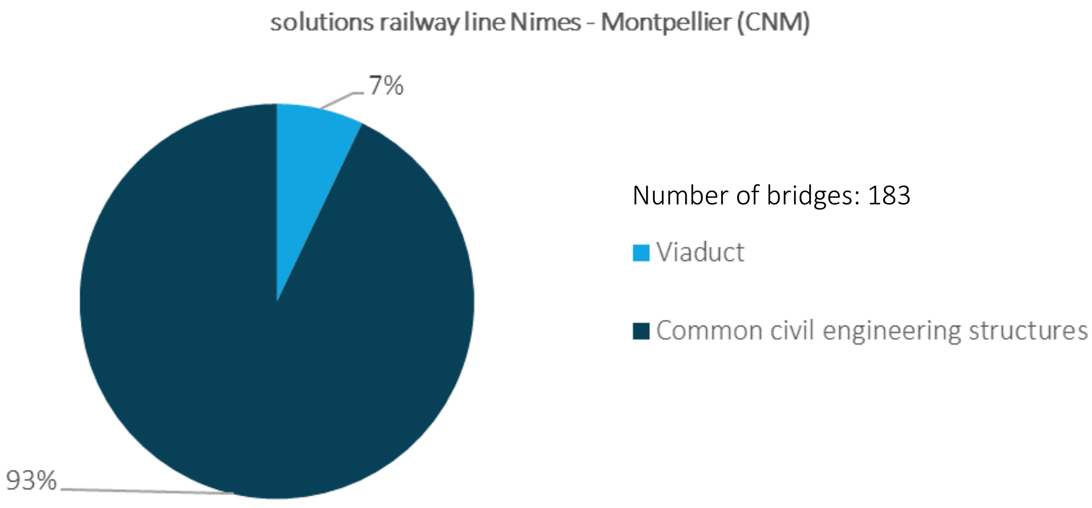



**Figure 3:** types of bridges built for CNM

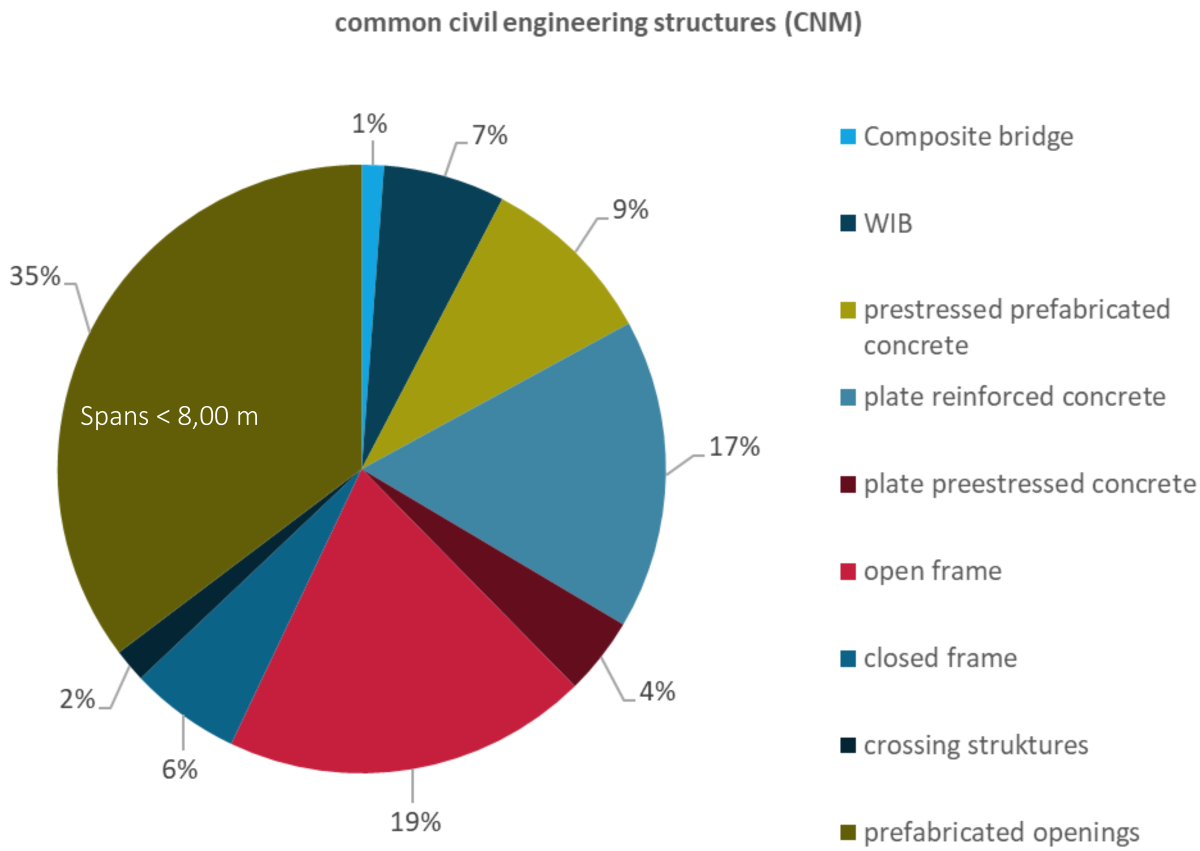



**Figure 4:** distribution of bridge types for CNM

# 3 Crossing situations

## 3.1 Introduction

The solutions for the 4 typical crossing situations of open track will be analysed and presented in this topic. The examples for each solution are from different high-speed railway projects mainly in Germany and France. In case 3 also examples from road – animal crossings are presented, because animal overpasses are not as common in railway – animal crossings. A whole table of analysed solutions for typical crossing situations is attended.

For the track types inner-city location and big river crossings individual solutions have to be found but the bridge design should be constant over the whole railway line. Therefore, engineers' competitions can be a great opportunity to get an innovative solution.

## 3.2 Case 1 Underpass

### 3.2.1 Description

When the Rail Baltica line crosses over another route the structure that carries it is termed an Underpass. Typical Underpasses are short (horizontal clearance 10 – 20 m) and often single-span (longer multi-span underpasses are called "rail viaducts" and are covered separately in this report). The demanded vertical clearance by Rail Baltica is 5,00 m in Germany the required minimum vertical clearance is 4,50 m. Required minimum thickness of construction by Rail Baltica is 1,50 m. [U2]

The key considerations for typical underpasses are:

- Safety for Rail Baltica line and infrastructure below Rail Baltica line
- Integration of bridge into landscape
- Integration of security fencing into bridge and landscape

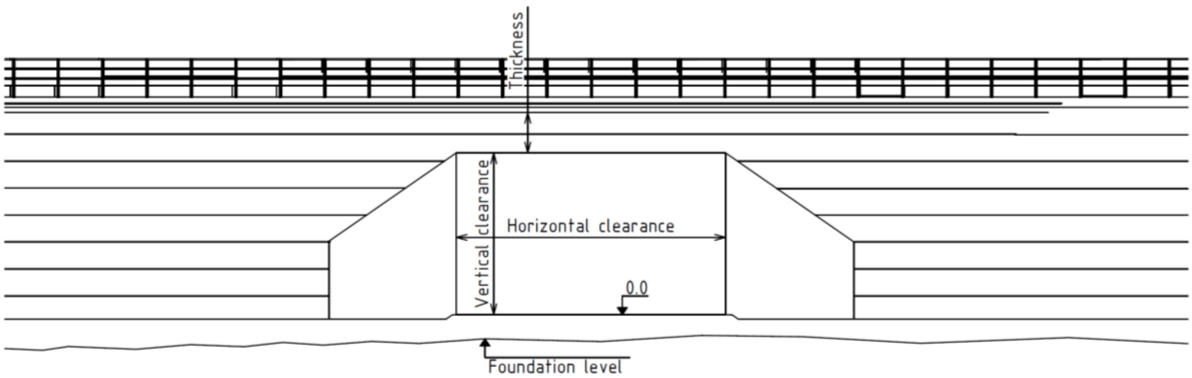



**Figure 5:** Longitudinal view - Case 1 [U2]

### 3.2.2 Structures

Figure 6 and Figure 7 show the percentage distribution of all underpasses analysed by us(see annex). This figure does not represent the percentage distribution for all common railway underpasses because the analysed bridges were chosen arbitrary.

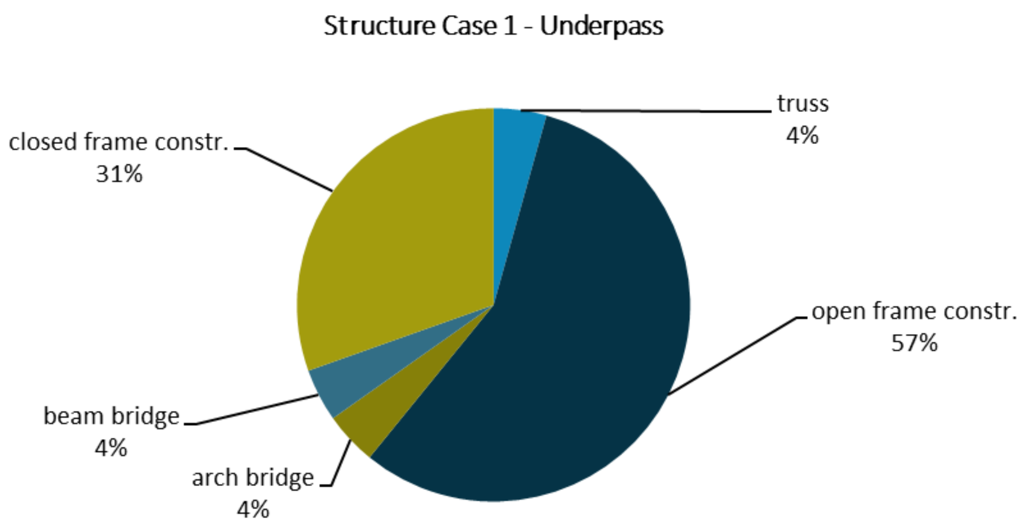



**Figure 6:** common civil engineering structures for underpasses – results of analysis real bridge designs

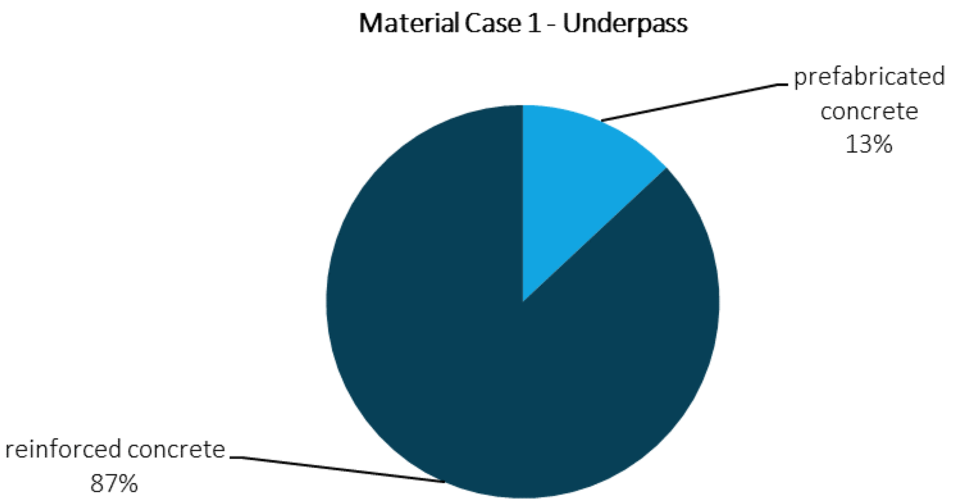



**Figure 7:** commonly used material for underpasses - results of analyses real bridge design

## Open frame construction

Material: reinforced concrete

Definition: monolithic attachment between plate and walls or abutments

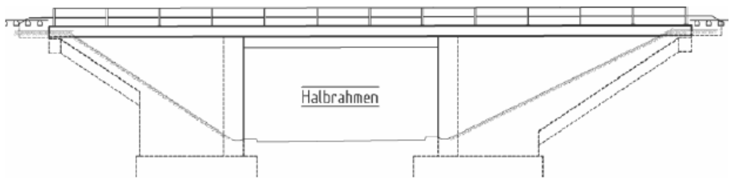



**Figure 8:** open frame bridge

Production: concrete formwork, cast-in-place concrete

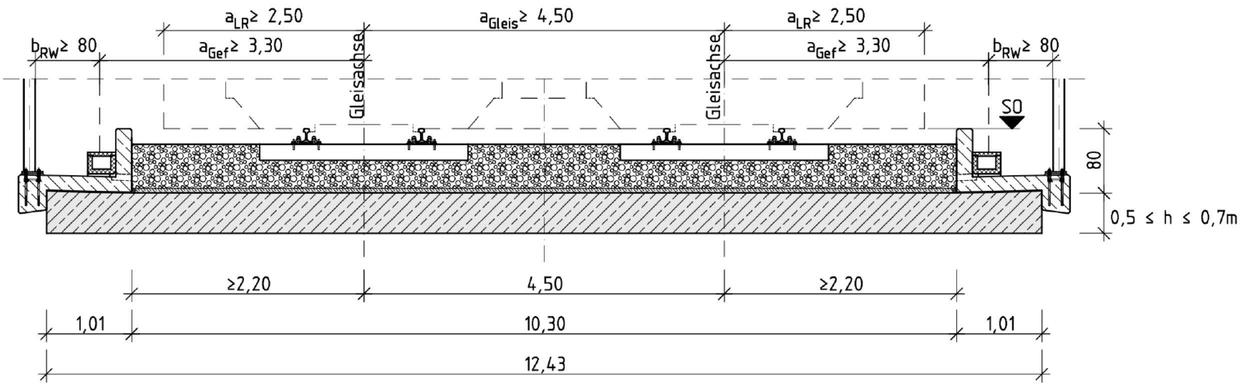
Possibility of prefabrication: partly

Advantage:

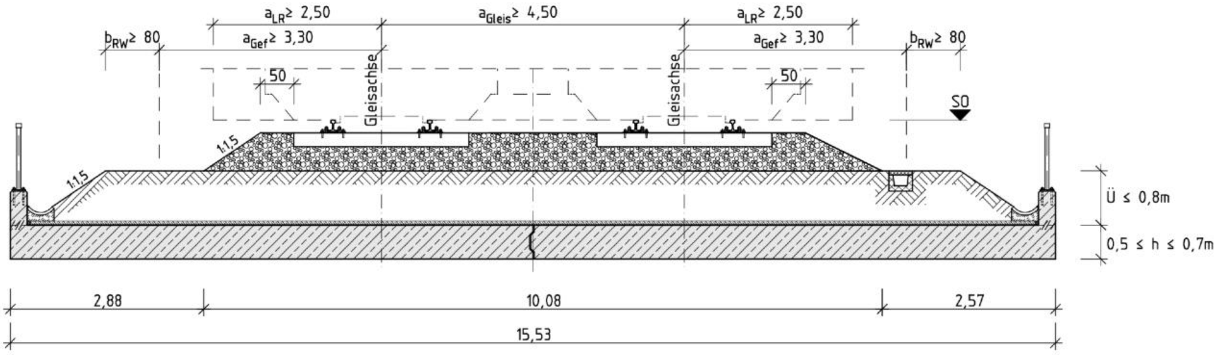
- stiff construction → deflection and vibration are reduced, fewer expansion joints are required
- suitable for crossing with pipes or streams
- no bearings are required

Disadvantage:

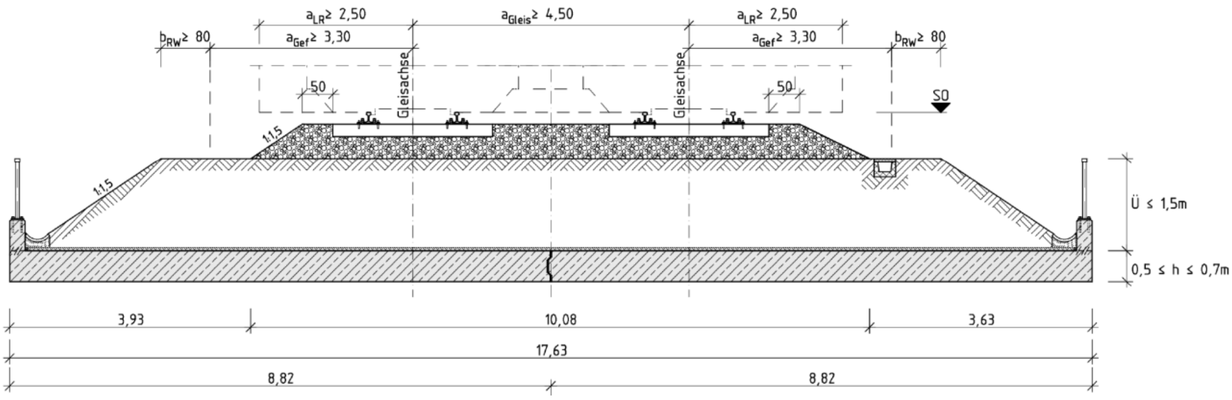
- no prefabrication
- not suitable on unstable ground or when high ground water level is present




Ü = 0,00 m




Ü ≤ 0,80 m




Ü ≤ 1,50 m

**Figure 9:** typical crossing sections for frames depending on covering layer [U24]

## Closed frame construction

Material: reinforced concrete

Definition: monolithic attachment between plate, foundation and walls or abutments

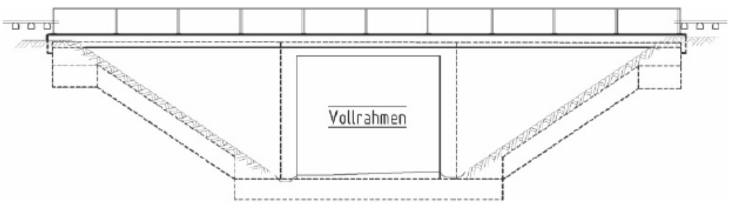



**Figure 10:** closed frame bridge

Production: make foundation, concrete formwork, cast-in-place concrete

Possibility of prefabrication: partly

Advantage:

- stiff → deflection and vibration are reduced, fewer expansion joints are required

- can be used for difficult ground conditions
- no bearings are required

Disadvantage:

- no prefabrication
- not useable for crossings with pipes or streams
- only economical for small span max. 6,00 m

<u>Plate; single or multi T-beam</u>

Material: reinforced concrete

Definition: monolithic construction as plate, single or multi tee-beam

Spans: plate conventional reinforcement: up to 15 m

prestressed: up to 25 m

T-beam conventional reinforcement up to 20 m

Prestressed: up to 40 (sometimes up to 50) m

Production: concrete formwork, cast-in-place concrete

or lift in single tee-beams of multi-tee beam bridge and cast-in-place concrete plate

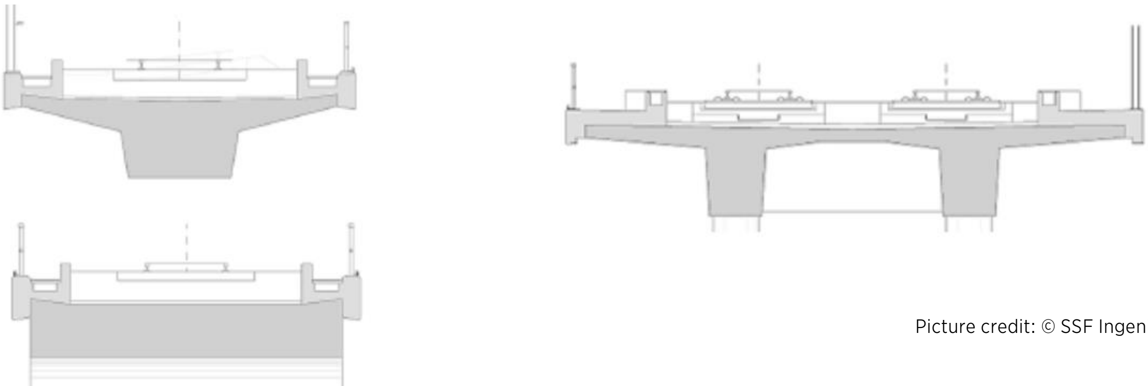
Possibility of prefabrication: partly for multi tee-beam depending on span

Advantage:

- Helpful for short spans
- T-Beam: Beam and slab are cast monolithically so the flange also takes up the compressive stresses

Disadvantage:

- formwork is needed for plate and single T-beam



Picture credit: © SSF Ingenieure

**Figure 11:** cross sections single tee-beam, double tee beam and plate

Steel composite construction

Material: mixed Constructions with composite precast girders

Definition: monolithic construction as single or multi tee-beam construction with open or closed profile sections. For spans ≥ 30 m

Production: lift in steel girders; lay prefabricated concrete plates, casting with concrete

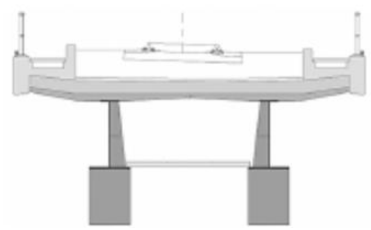
Possibility of prefabrication: partly

Advantage:

- lighter construction than concrete girders
- higher span width possible:
  - reduces masses for substructure
  - smaller conflict potential with “crossing partner”
- no formwork is needed
- partly prefabrication, fast and easy assembly
- depending on construction carriageway slab could be changed
- concrete slap has a higher mass than steel orthotropic deck → fewer vibration

Disadvantage:

- steel structure is usually more expensive in terms of material in comparison to concrete girder
- corrosion protection is needed



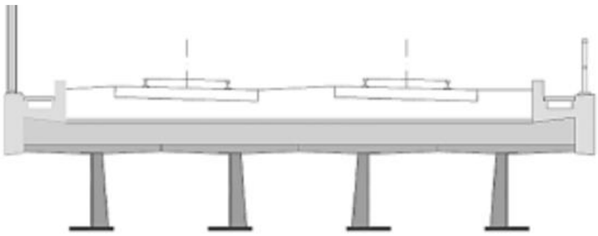


**Figure 12:** cross sections composite construction

Picture credit: © SSF Ingenieure

### 3.2.3 Options

Additional conceivable structures in literature

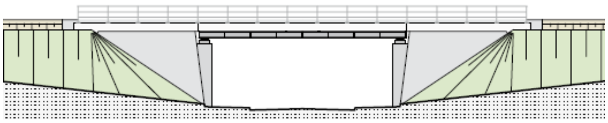


**Figure 13:** trough bridge; steel [U5]

Material: steel

Production: lifting in prefabricated steel construction

Possibility of prefabrication: partly

Advantage: slightly slanting position of abutment opens the view passage, partly prefabrication, fast construction

Disadvantage: corrosion protection, bearing, higher costs of steel, transportation of large and heavy structural elements

→ higher maintenance

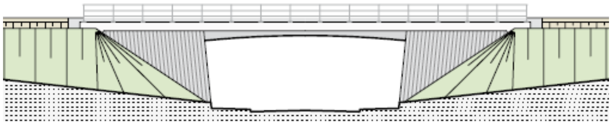


**Figure 14:** frame construction; steel composite [U5]

Material: steel composite

Production: lift in steel girders; lay prefabricated concrete plates, casting with concrete

Possibility of prefabrication: partly

Advantage: slender construction, slightly slanting position of abutment opens the view passage, partly prefabrication, fast construction

Disadvantage: corrosion protection, bearing, higher costs of steel, transportation of large and heavy structural elements

→ higher maintenance

## Position in embankment

Depending on topographic situation the structure can either be located full in the embankment or partly.


**Figure 15:** poor abutment design

- Substantial concrete abutments
- Retaining walls


**Figure 16:** refined of abutment design

- Bank seat abutments
- Visible extant of concrete abutment minimised

## Form of integral bridge ends and abutment types for frame bridges

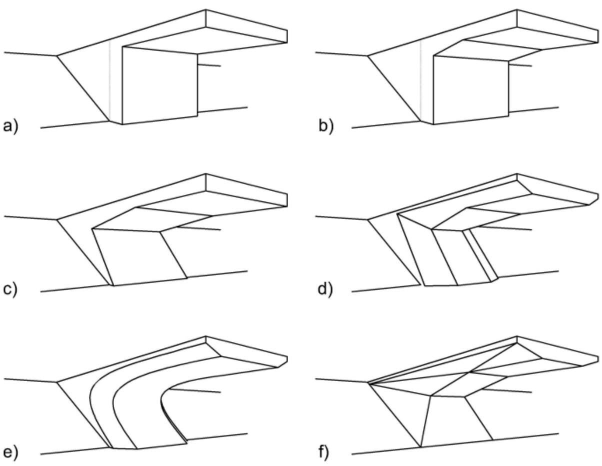



**Figure 17:** Comparison of form approaches of integral bridge ends with different [U12]

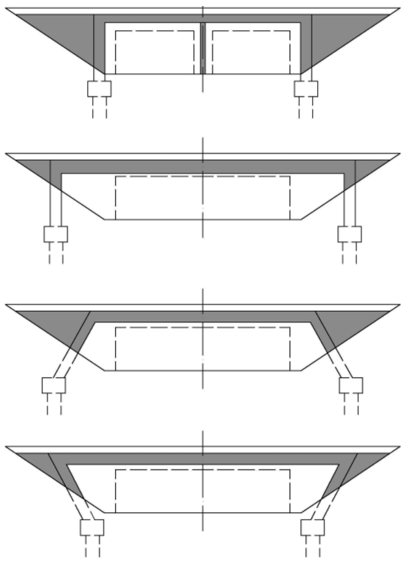


**Figure 18:** different abutment types [U14]

## Angle for wings of the abutments

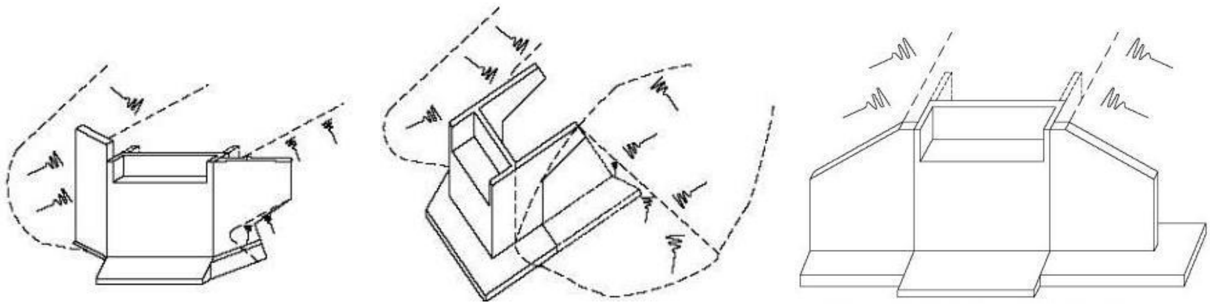
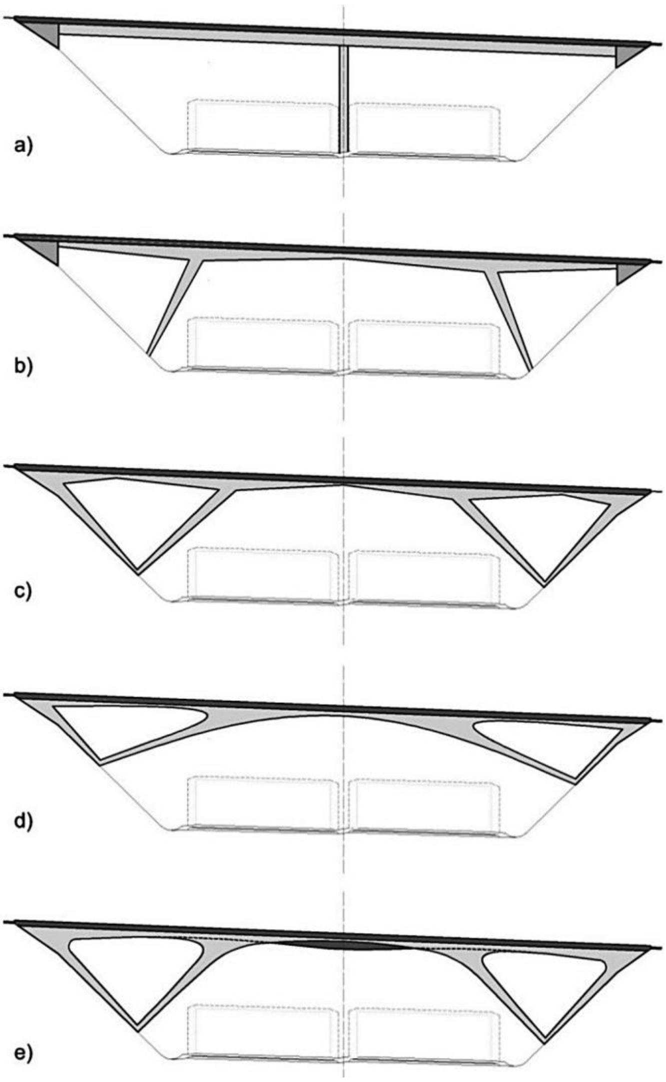


**Figure 19:** different orientation of wing walls

## Angle of inclination and shape




Dreary design

Calm design, slightly inclined struts

Suspenseful design, edgy forms, flat struts and additional counter struts to direct the horizontal forces into the ground

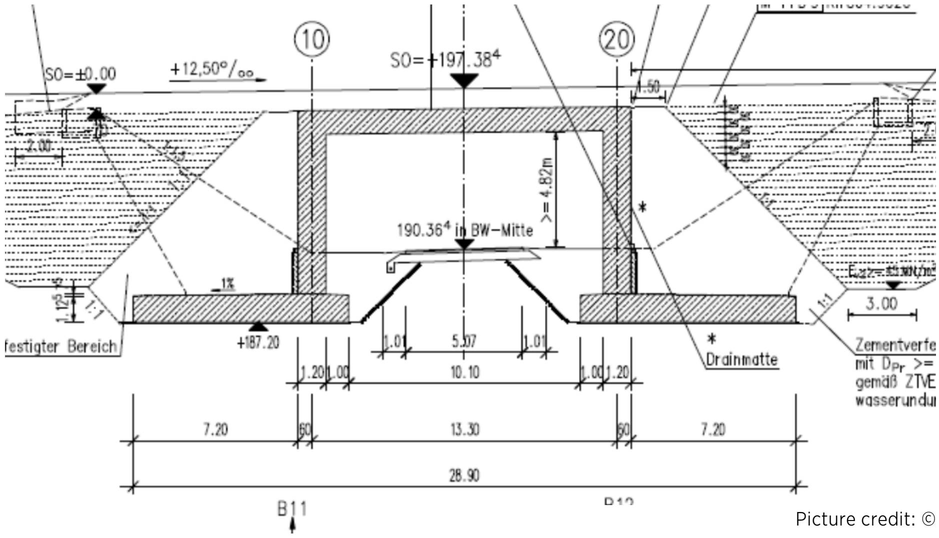
Dynamic suspenseful design, flat widened struts which are opposed to the embankment

Chosen design, building ground load is smaller than in d) but dynamic design is still present

**Figure 20:** Different conceptual design options [U15]

### 3.2.4 Examples

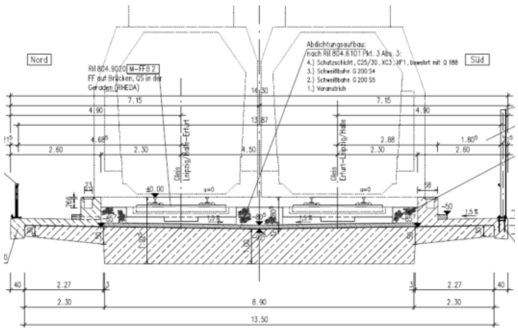
## Case 1 Underpass




Picture credit: © DB AG VDE 8

**Example 1 - open frame construction**

Bridge: EÜ Wirtschaftsweg Krautheim- Heyeberg



Picture credit: © DB AG VDE 8

| | |
|---|---|
| Type: | Railway Bridge |
| Line / built | HS between Leipzig and Erfurt / 2010 |
| speed | 300 km/h |
| country | Germany |
| Construction | Open Frame |
| Span | 13,30 m |
| Dimensions | Vertical Clearance 4,82 m<br>Thickness 1,00 m |

Advantage: stiff construction, standard solution

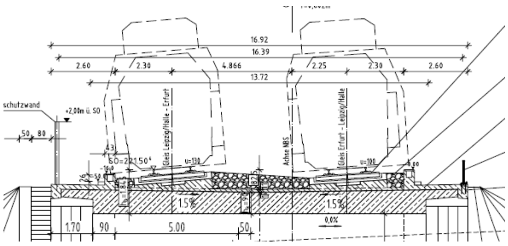
Disadvantage: no prefabrication, not suitable on unstable ground or when high ground water level is present

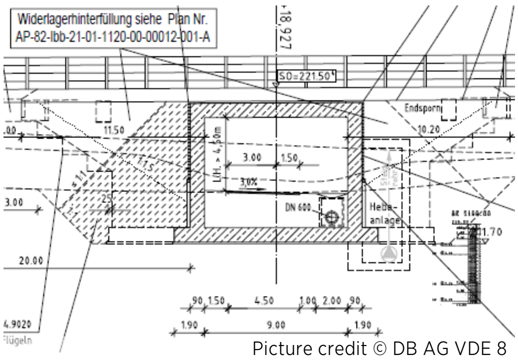

Picture credit © DB AG VDE 8

## Example 2 - closed frame construction

Bridge: EÜ Essleben - Herrengosserstedt

| | |
|---|---|
| Type: | Railway Bridge |
| Line / built<br>speed<br>Country | HS between Leipzig and Erfurt / 2010<br>300 km/h<br>Germany |
| Construction | closed frame |
| Span | 9,90 m |
| Dimensions | Vertical Clearance 4,50 m<br>Thickness 0,90 m |

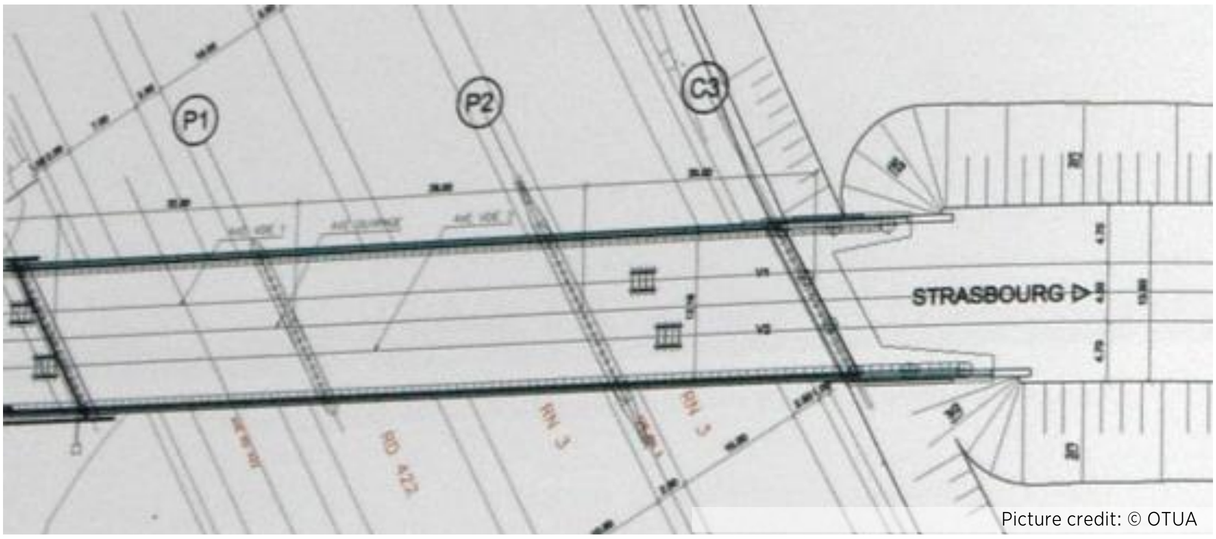

Picture credit © DB AG VDE 8



Picture credit © DB AG VDE 8

Advantage: stiff, can be used for difficult ground conditions

Disadvantage: no prefabrication, opening seems small because of substantial concrete abutments, more material than open frame construction

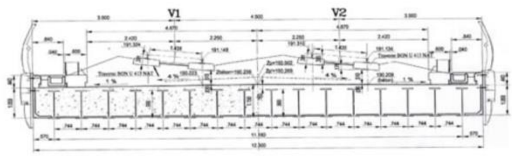


Picture credit: © OTUA

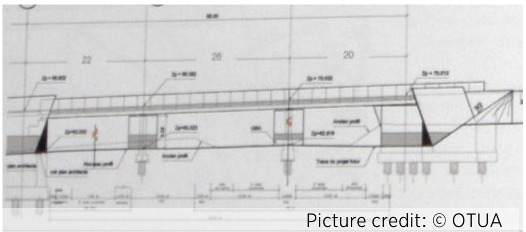
### Example 3 - filler beam deck bridge

Bridge: bridge over RN3 at Claye-Souilly

| | |
|---|---|
| Type: | Railway bridge |
| Line / built | Claye-Souilly / 2004 |
| speed | 300 km/h |
| country | France |
| construction | Filler beam deck bridge |
| Span | 22 m, 26 m, 20 m |
| Dimensions | Vertical Clearance 3,85 m<br>Thickness approx. 1,0 m |



Picture credit: © OTUA

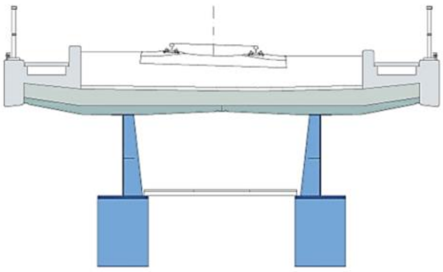

Picture credit: © OTUA

Advantage: possibility of partly prefabrication; very slender design; construction under traffic is possible, robust construction

Disadvantage: bad dynamic properties; subjected to resonance due to high slenderness; no integral construction possible


**Example 4 – Steel Composite Bridge**

Bridge: EÜ Saaleflutbrücke



Picture credit © SSF AG

| | |
|---|---|
| Type: | Railway bridge |
| Line / built | between Halle and Erfurt / 2008 |
| speed | 160 km/h |
| Country | Germany |
| Construction | Steel composite bridge |
| Span | 32,50 m |
| Dimensions | Vertical Clearance > 5,00 m<br>Thickness 1,95 / 3,15 m |

Advantage: partly prefabrication, haunched main girders increase the slenderness in field

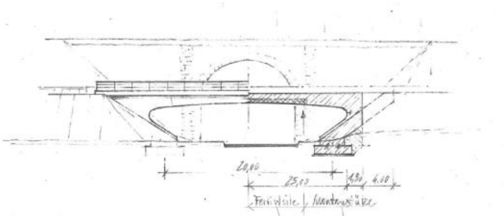
Disadvantage: high lifting weight, high requirements to transport condition

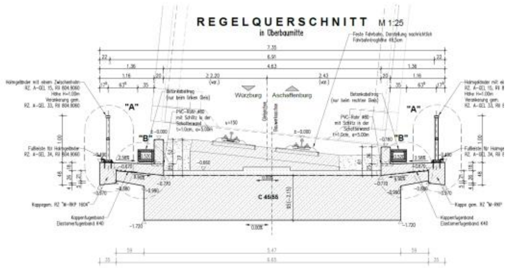

Picture credit © DB Netz AG

**Example 5 – open frame construction**

Bridge: EÜ over B26

| | |
|---|---|
| Type: | Railway bridge |
| Line / built speed | between Würzburg und Aschaffenburg |
| Country | Germany |
| Construction | Open frame construction reinforced concrete |
| Span | 24,65 m |
| Dimensions | Vertical Clearance > 4,70 m<br>Thickness 0,95 / 2,15m |


Picture credit © DB Netz AG



Picture credit © DB Netz AG

Advantage: stiff construction, haunched superstructure increase the slenderness in field, no bearings, low maintenance

Disadvantage: no prefabrication

## 3.3 Case 2 Rail Viaduct

### 3.3.1 Description

Rail Viaducts should be seen as an important representative of Rail Baltica. The main purpose of these structures is to allow the Rail Baltica line to cross over other infrastructure. A balance between local requirements, therefore needed structure and consistent design along the Rail Baltica line has to be found. Spans around 15 – 30 m shall be considered and vertical clearance of 7,00 m.

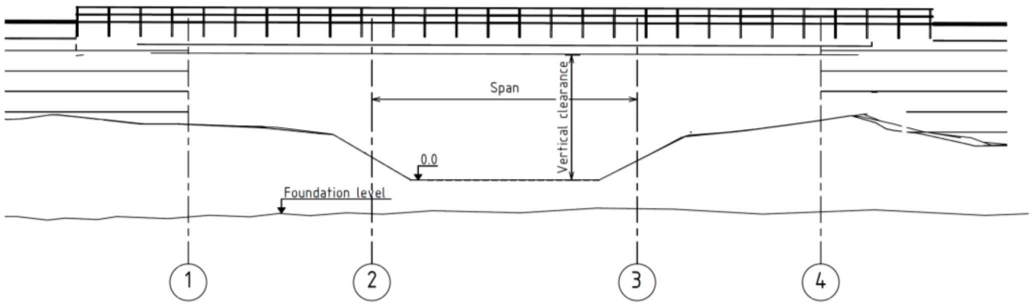



**Figure 21:** Longitudinal view - Case 2 [U2]

### 3.3.2 Structures

Figure 22 and Figure 23 show the percentage distribution of all rail viaducts analysed by us (see attached table). This figure does not represent the percentage distribution for all common rail viaducts because the analysed bridges were chosen arbitrary.

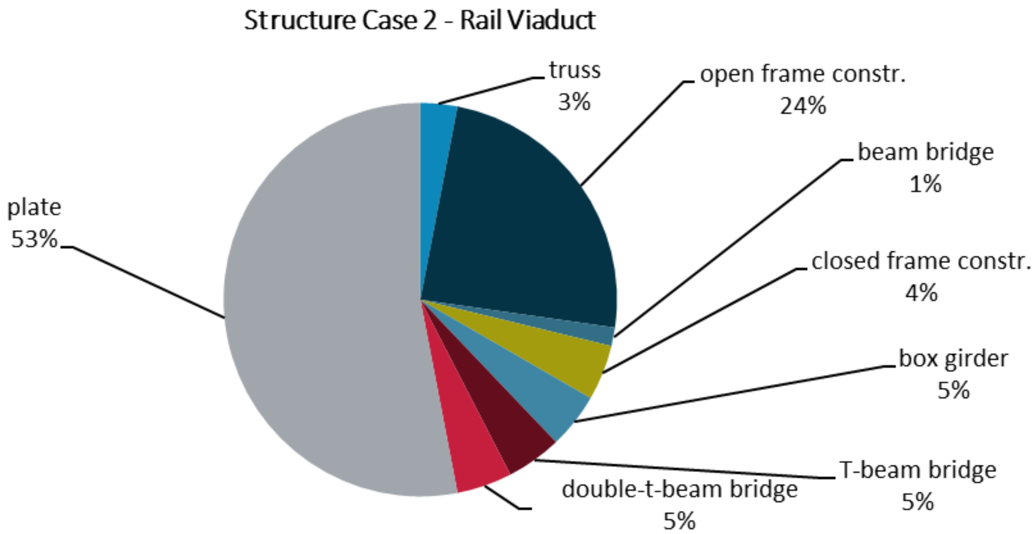



**Figure 22:** common civil engineering structures for rail viaducts – results of analysis real bridge designs

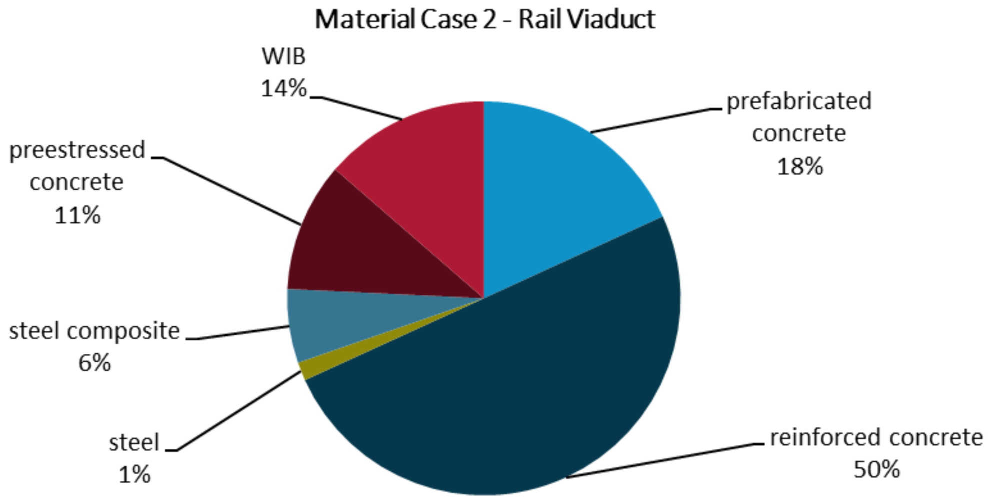



**Figure 23:** commonly used material for rail viaducts - results of analyses real bridge design

## Plate; filler beam deck (WIB)

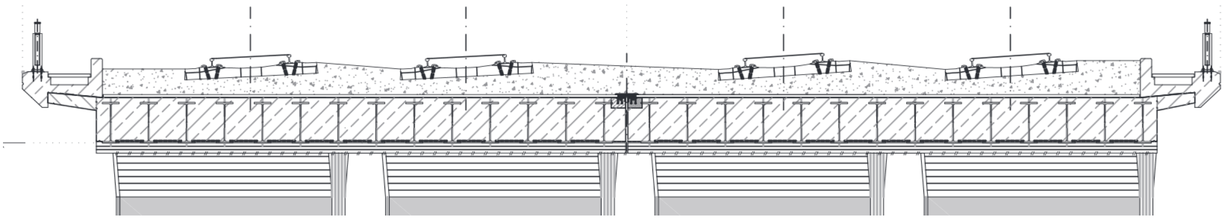


**Figure 24:** cross section filler beam bridge (WIB) [U11]

Material: rolled steel girders and reinforced concrete

Definition: composite construction, multiple rolled steel girders (longitudinal members) and reinforced concrete (cross members)

Production: (Figure 25 - Figure 27) Installation of rolled iron girders, reinforcement on site, concrete bridge deck

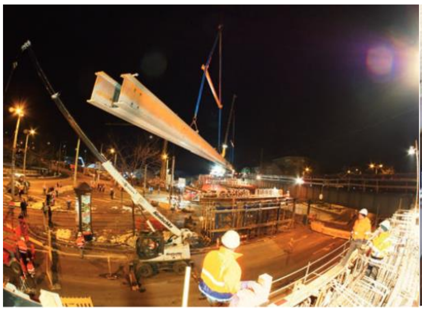


**Figure 25:** Installation of the rolled iron girders [U11]

**Figure 26:** Installation of reinforcement on site [U11]

**Figure 27:** Overall view of the new bridge [U11]

Possibility of prefabrication: partly

Advantage:

- possibility of partly prefabrication
- very slender design
- construction under traffic is possible

Disadvantage:

- bad dynamic properties
- static proof with technical approval not with Eurocode

T-beam; double-t-beam

| | | |
|---|---|---|
| Material: | reinforced concrete + prestressed concrete | |
| Definition: | monolithic construction as plate, single or multi tee-beam. | |
| Spans: | plate | conventional reinforcement: up to 15 m |
| | | prestressed: up to 25 m |
| | T-beam | conventional reinforcement up to 20 m |
| | | Prestressed: up to 40 (50) m |
| Production: | concrete formwork, cast-in-place concrete | |

Possibility of prefabrication: no; bridge parts are too heavy

Advantage:

- Helpful for short spans
- T-Beam: Beam and slab are cast monolithically so the flange also takes up the compressive stresses

Disadvantage:

- formwork is needed for plate and single T-beam

Open frame construction, multi-span

Material: reinforced concrete

Definition: monolithic attachment between plate and walls or abutments

Production: concrete formwork, cast-in-place concrete

Possibility of prefabrication: no; bridge parts are too heavy

Advantage:

- stiff construction → deflection and vibration are reduced, fewer expansion joints are required
- standard
- good dynamic properties
- no bearing

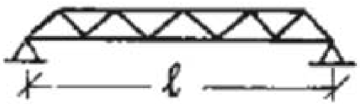
Disadvantage:

- no prefabrication or if partly prefabrication connection points are difficult

<u>Truss</u>

Material: steel

Definition: structure of monolithicly connected elements usually forming triangular units




Production: prefabrication of bridge parts (upper chord, strut, top lateral bracing, diagonal member, vertical member lower chord), depending on dimensions partly or full connection of bridge parts in factory, transportation to site, lifting in or slide in

Possibility of prefabrication: partly depending on dimensions

Spans: economical for spans between 50 m and 90 m

Advantage:

- wide spans are possible

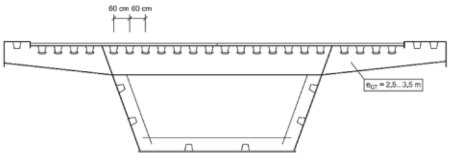
Disadvantage:

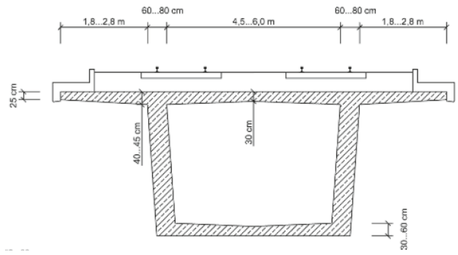
- steel construction more expensive than concrete or composite construction
- bearing necessary
- corrosion protection necessary → high level of maintenance

Box girder, steel or concrete

Material: steel or concrete

Definition: shape of a hollow box for main girders




Production: concrete: either concrete formwork and cast-in-place concrete

or prefabrication of superstructure parts and installation by using cranes

or incremental launching

steel: partly prefabrication of superstructure parts and installation by using cranes

Possibility of prefabrication: partly

Spans: economical for spans ≥ 100 m (steel) / ≥ 50 m (concrete)

Advantage:

- high spans are possible

Disadvantage:

- steel box → corrosion protection → high level of maintenance
- bearing necessary

### 3.3.3 Options

As mentioned for Case 1 the position of the abutment in the embankment and the angle of wings are options for bridge design (3.2.3).

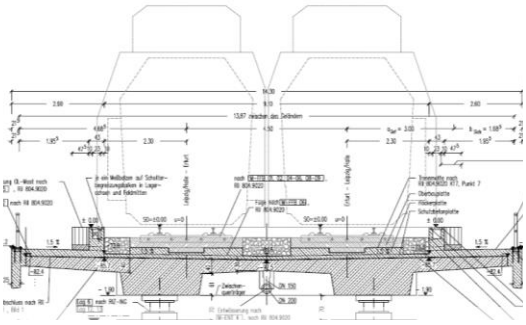
### 3.3.4 Examples

## Case 2 Rail Viaduct

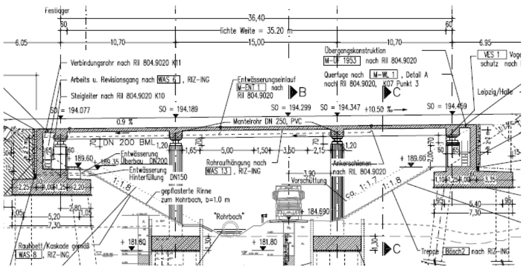
Picture credit: © DB AG VDE 8

**Example 1 - double T-beam cross section**

Bridge: EÜ Hardisleben - Teutleben



Picture credit: © DB AG VDE 8

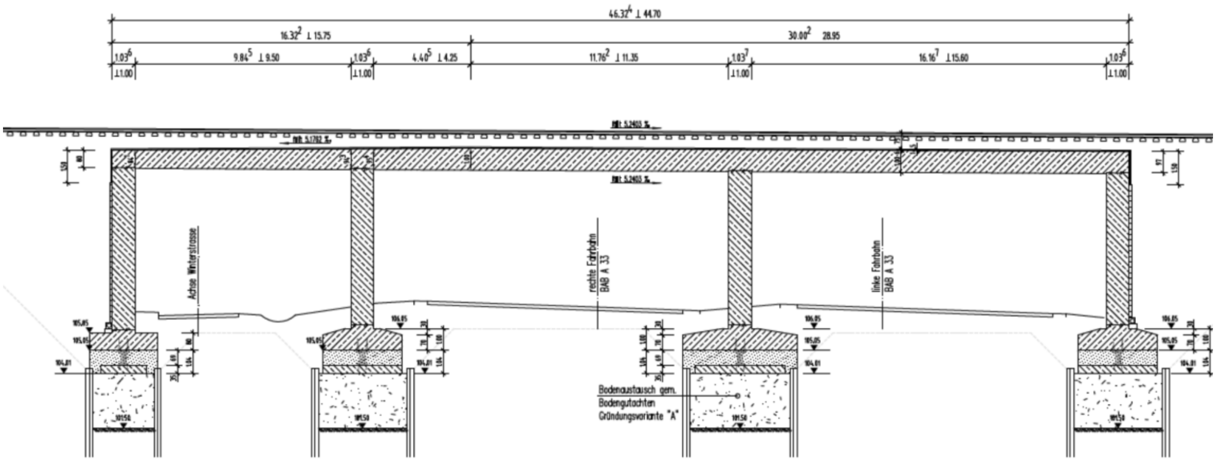


Picture credit: © DB AG VDE 8

| | |
|---|---|
| Type: | Railway Bridge |
| Line / built | EÜ between Leipzig and Erfurt / 2010 |
| speed | 300 km/h |
| Country | Germany |
| Construction | double T-beam construction, prestressed concrete |
| Span | 15,0 m |
| Dimensions | Vertical Clearance 9,6 m<br>Thickness 1,10 m |

Advantage: Minimised visible extant of concrete abutment

Disadvantage: bearings → higher maintenance



Picture credit © DB AG

### Example 2 Semi-integral

Bridge: - EÜ BAB A33 Bielefeld

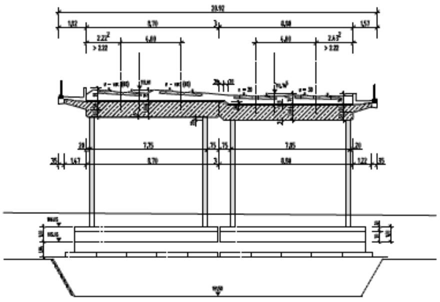
Type: Railway Bridge

Line / built speed Country: 1700 between Hannover and Hamm and 2990 Minden Hamm / 200 km/h Germany

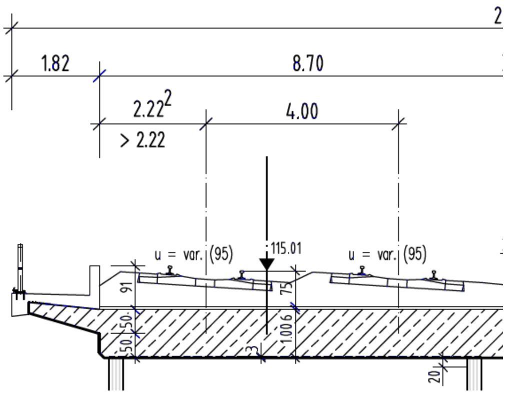
Construction: Frame

Span: 16,6 m

Dimensions: Vertical Clearance 4,70 m
Thickness 1,00 m



Picture credit © DB AG




Picture credit © DB AG

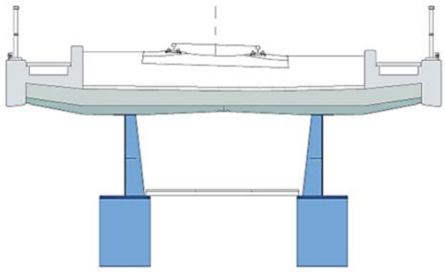
Advantage: monolithic bond between superstructure and substructure, no bearings, low maintenance

Picture credit © SSF AG

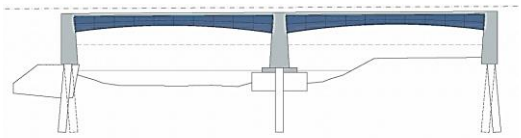
**Example 3 – Steel composite bridge**

Bridge: EÜ über die Saale

| | |
|---|---|
| Type: | Railway Bridge |
| Line / built | between Halle and Erfurt / 2008 |
| speed | 160 km/h |
| Country | Germany |
| Construction | Steel composite Frame |
| Span | 32,50 / 32,50 m |
| Dimensions | Vertical Clearance > 5,00 m<br>Thickness 1,95 / 3,15 m |



Picture credit © SSF AG



Picture credit © SSF AG

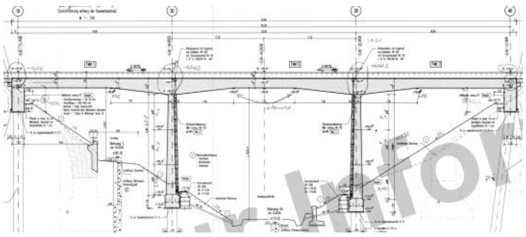
Advantage: partly prefabrication, haunched main girders increase the slenderness in field

Picture credit © DB AG

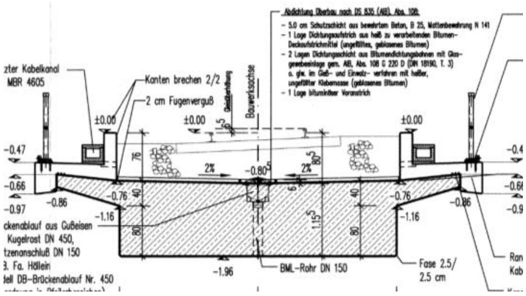
**Example 4 – frame bridge**

Bridge: EÜ Nesselgrundbrücke

| | |
|---|---|
| Type: | Railway Bridge |
| Line / built | Near Dresden / 1999 |
| speed | 160 km/h |
| Country | Germany |
| Construction | Semi-integral |
| Span | 22,50 m |
| Dimensions | Vertical Clearance > 5,00 m<br>Thickness: 1,20m |



Picture credit © DB AG



Picture credit © DB AG

Advantage: haunched main girders increase the slenderness in field

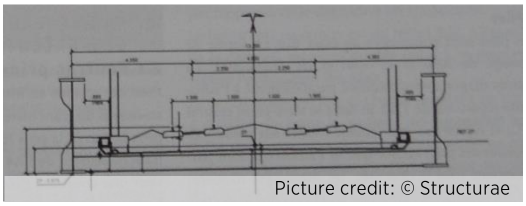

Picture credit: © Structurae

**Example 5 – Twin girder composite deck**

Bridge: Viaduc de l 'Orxois

| | |
|---|---|
| Type: | Railway bridge |
| Line / built<br>speed | between Marigny-en-Orxois and Lucy-le-Bocage / 2008<br>350 km/h |
| Country | Germany |
| Construction | Twin girder composite deck |
| Span | 30,0 / 40,0 m |
| Dimensions | Vertical Clearance ≈ 5 m<br>Thickness 3,3 m – 4,20 m |


Picture credit: © Structurae


Picture credit: © Structurae

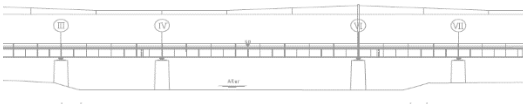
Advantage: small railway height

Disadvantage: massive construction, height amount of steel, maintenance vs. corrosion protection


Picture credit © Schwinge/Panier

### Example 6 - steel trough bridge

Bridge: EÜ Allerbrücke bei Verden


Picture credit © DB AG

| | |
|---|---|
| Type: | Railway Bridge |
| Line / built | Wunstdorf - Bremen / 2015 |
| speed | max. 300 km/h |
| Country | Germany |
| Construction | Steel trough bridge |
| Span | 32,52+48,68+49,68+80,0+49,71+48,81+37,8<br>8+27,20=374,58 m |
| Dimension: | Vertical Clearance > 5,00 m<br>Thickness 3,35-7,70 m |

Advantage: very slender construction

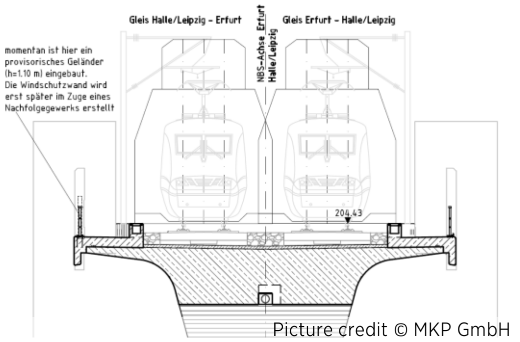
Picture credit: © MKP GmbH

**Example 7 – semi-integral, prestressed concrete**

Bridge: Scherkondetalbrücke

| | |
|---|---|
| Type: | Railway bridge |
| Line / built speed | 5919 NBS Erfurt – Leipzig/Halle/ 300 km/h |
| Country | Germany |
| Construction | Semi-integral, prestressed concrete |
| Span | 44,0 m |
| Dimension: | Vertical Clearance 34,00 m<br>Thickness 2,00 / 3,50 m |

Picture credit © MKP GmbH




Picture credit © MKP GmbH

Advantage: monolithic connection superstructure with substructure; slender and continuous superstructure, no bearings, no joints, low maintenance

Disadvantage: technically demanding

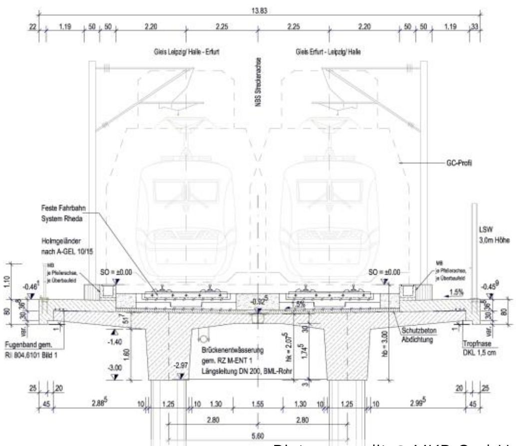
Picture credit: © MKP GmbH

### Example 8 – frame bridge double t-beam cross section

Bridge: Gänsebachtalbrücke

| | |
|---|---|
| Type: | Railway Bridge |
| Line / built speed | 5919 Großbrembach -Saubachtal/ 360 km/h |
| Country | Germany |
| Construction | frame bridge double t-beam cross section |
| Span | 24,0 m |
| Dimension: | Vertical Clearance 20,00 m<br>Thickness 3,00 m |

Picture credit © MKP GmbH



Picture credit © MKP GmbH

Advantage: monolithic connection superstructure with substructure; slender and continuous superstructure, no bearings, no joints, low maintenance

Disadvantage: technically demanding


Picture credit: © Structura ingenieure

## Example 9 – integral solution

Bridge: EÜ Glinicker Weg

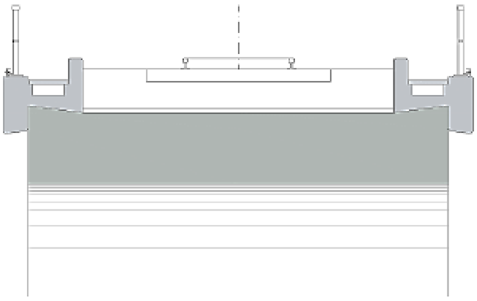
Type: Railway bridge

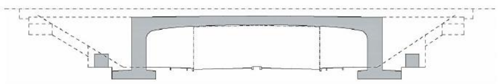
Line / built speed Country: 6144 Berlin-Adlershof Abzw. – Berlin Wendenheide/ 100 km/h Germany

Construction: Frame, reinforced concrete

Span: 26,20 m

Dimension: Vertical Clearance 4,70 m
Thickness 1,0/ 1,75 m
Slenderness l/26 / l/15


Picture credit © ssf ingenieure


Picture credit © ssf ingenieure

Advantage: wide opening, stiff construction

Disadvantage: Need of formwork for construction

## 3.4 Case 3 Animal overpass

### 3.4.1 Description

| CASE 3 | ANIMAL OVERPASS |
|---|---|
| HORIZONTAL CLEARANCE [M] | 12.50 (CASE 3.1)<br>OR<br>23 (2 X 5.25+12.50) (CASE 3.2) |
| FOUNDATION LEVEL [M] | -4.50 OR -20.00 |
| NATURAL GROUND LEVEL [M] | -2.50 |
| VERTICAL CLEARANCE [M] | 6.70 |
| SOIL DEPTH [M] | 1.50 |
| B MIN [M] | 50.00 |
| ALFA [°] | 14 |

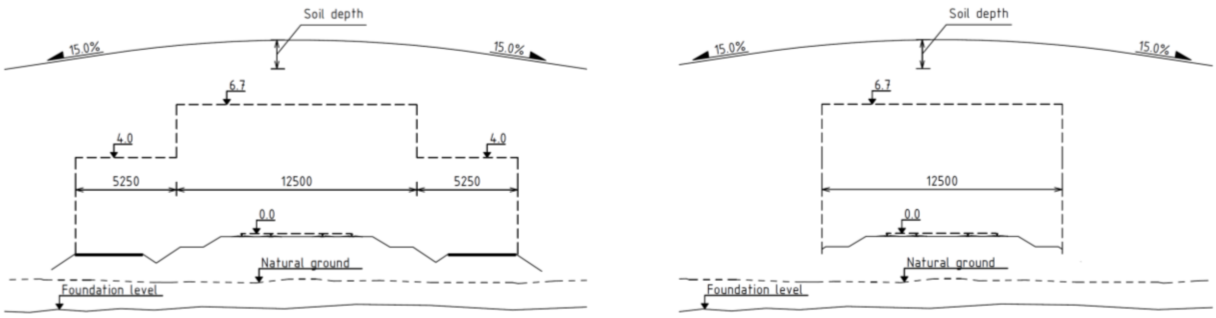



**Figure 28:** Section A-A - Case 3.1 (left) and Case 3.2 (right) [U2]

### 3.4.2 Structures

Figure 29 shows the percentage distribution of all animal overpasses analysed by us (see annex). This figure does not represent the percentage distribution for all common animal overpasses because the analysed bridges were chosen arbitrary.

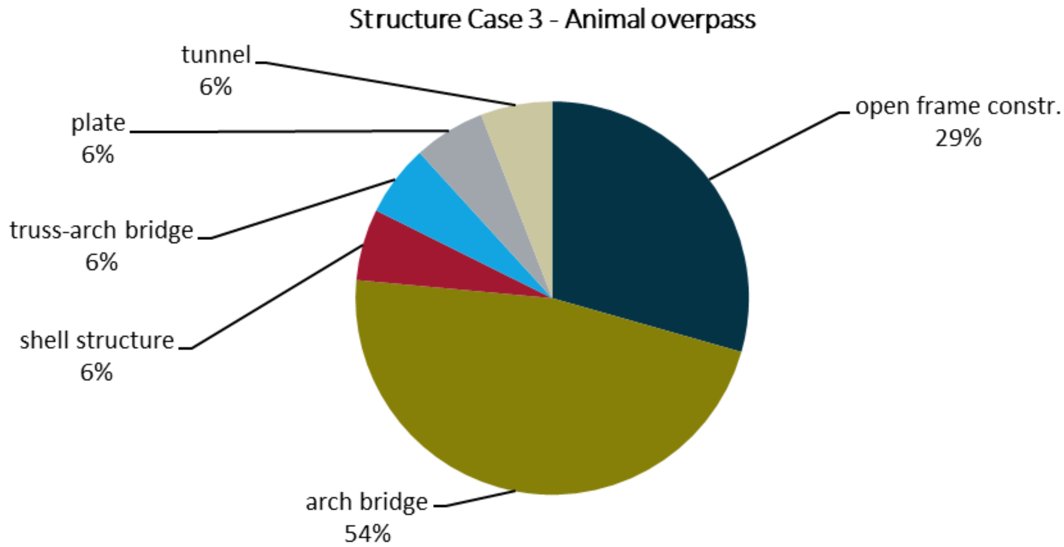



**Figure 29:** common civil engineering structures for animal overpass – results of analysis real bridge designs

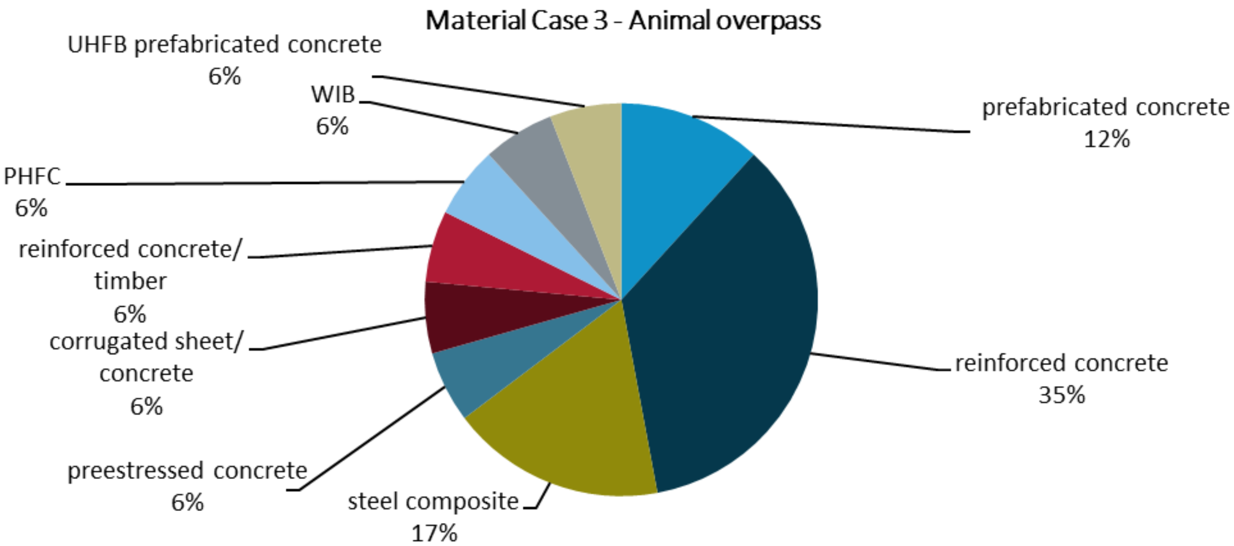



**Figure 30:** commonly used material for animal overpass - results of analyses real bridge design

Shell structure

Material: reinforced concrete

Definition: three-dimensional solid whose thickness is very small

Production: concrete formwork, cast-in-place concrete plane on flor, blow construction up, concrete layers on top

Possibility of prefabrication: no

Advantage: innovative, light construction

Disadvantage: no prefabrication, not useful for existing crossings where the availability has to be guaranteed

Frame structure with filler beams (WIB)/ prefabricated composite construction

Material: steel girders in concrete (filler beam bridges)

Definition: prefabricated WIB girders combined with concrete plate

Production: lift in prefabricated WIB girders, cast-in-place concrete plate

Possibility of prefabrication: partly

Advantage: possibility of partly prefabrication, very slender design

Disadvantage: bad dynamic properties, static proof with technical approval not with Eurocode

Arch bridge cast-in-place concrete

Material: reinforced concrete

Definition: three-dimensional solid whose thickness is very small

Production: concrete formwork, cast-in-place concrete

Possibility of prefabrication: no

Advantage: standard, slender construction

Disadvantage: no prefabrication, cannot be used for underpass or railway viaduct

Three-hinged-Arch bridge prefabricated parts

Material: prefabricated concrete parts

Definition: three-dimensional solid whose thickness is very small

Production: lifting in concrete parts and fill gaps

Possibility of prefabrication: partly

Advantage: slender construction, partly prefabrication

Disadvantage: cannot be used for underpass or railway viaduct

### 3.4.3 Options

Animal underpass

To ensure ecological passage also animal underpasses are conceivable e.g. Stöbniztalbrücke or Gänsebachtalbrücke. This option is a perfect opportunity for crossing situations with characteristic pass ways of wild animals in small valleys.


**Figure 31:** Example integral bridge EÜ Stöbnitztalbrücke VDE 8.2


**Figure 32:** Example integral bridge EÜ Scherkondetalbrücke VDE 8.2

### 3.4.4 Examples

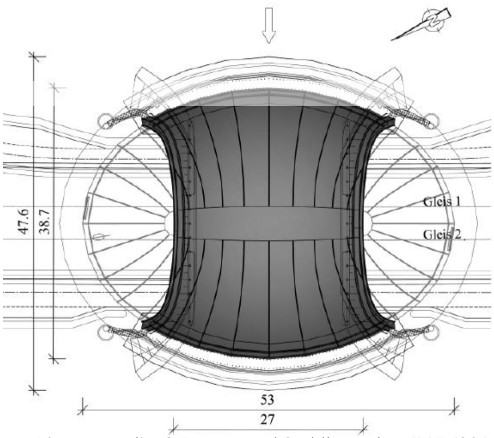
## Case 3 Animal overpass


Picture credit: © TU Wien

**Example 1 - Pneumatic Forming of Hardened Concrete (PFHC)**

Bridge: Animal Overpass AM2

| | |
|---|---|
| Type: | Animal overpass |
| Line / built speed | Aich - Mittlern / 2017 up to 250 km/h |
| country | Austria |
| Construction | shell structure, Pneumatic Forming of Hardened Concrete |
| Span | 27 m |
| Dimensions | Vertical Clearance 8,9 m<br>Thickness 0,45 m |



Picture credit: © Beton- und Stahlbetonbau 113 (2018)


Picture credit: © Beton- und Stahlbetonbau 113 (2018)

Advantage: light construction

Disadvantage: no prefabrication, not useful for existing crossings


**Example 2 - sectional girders in concrete (WIB) / prefabricated composite construction**

Bridge: Animal Overpass A 14 Karstädt



| | |
|---|---|
| Type: | Frame bridge for road crossing |
| Line / built speed | Karstädt / 2015 |
| Country | Germany |
| Construction | Sectional girders in concrete (WIB) / prefabricated composite construction |
| Span | > 38,25 m |
| Dimensions | Vertical Clearance approx 4,70 m |

Advantage: possibility of partly prefabrication, very slender design

Disadvantage: bad dynamic properties, static proof with technical approval not with Eurocode, vertical clearance is too small for railways to pass through


Picture credit: © Klähne Ingenieure

**Example 3 - Cast-in-place concrete arch bridge**

Bridge: Animal Overpass A 14 BW21Ü5

| | |
|---|---|
| Type: | Frame bridge for road crossing |
| Line / built speed | Karstädt / 2016 |
| Country | Germany |
| Construction | Cast-in-place concrete arch bridge |
| Span | 42,55 m |
| Dimension | Vertical Clearance approx. 4,70 m<br>Thickness 0,8 m – 1,20 m |


Picture credit: © Klähne Ingenieure


Picture credit: © Klähne Ingenieure

Advantage: standard, slender construction

Disadvantage: no prefabrication, vertical clearance is too small for railways to pass through


Picture credit: © Landesbetrieb Straßenwesen Brandenburg

**Example 4 – three-hinged arch bridge with prefabricated prestressed concrete elements**

Bridge: Animal Overpass A 11 Uckermark

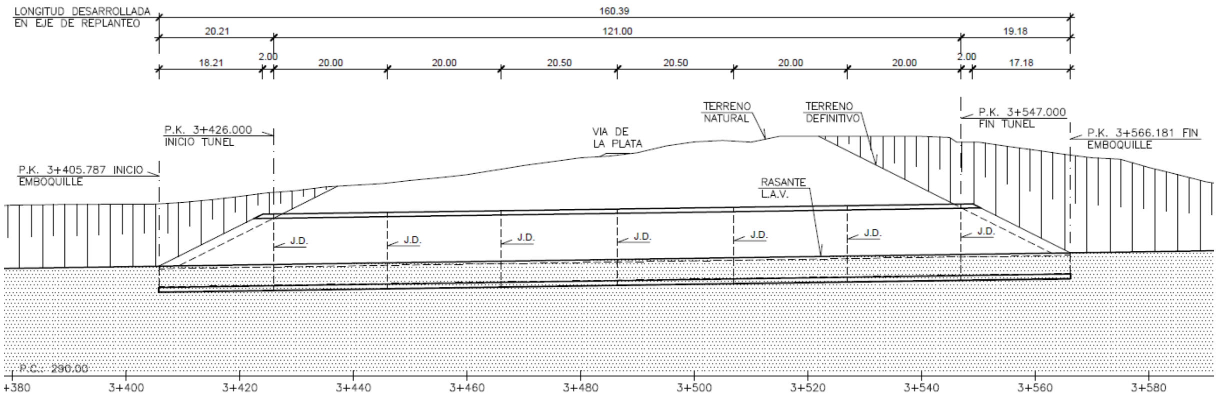
| | |
|---|---|
| Type: | three-hinged arch bridge for road crossing |
| Line / built speed | A11 Uckermark |
| Land | Deutschland |
| Construction | 48 prefabricated and prestressed superstructure parts, placed on abutments and support frame |
| Span | 36,3 m |
| Dimensions | Vertical Clearance approx 7,80 m |


Picture credit © Landesbetrieb Straßenwesen Brandenburg


Picture credit: © Landesbetrieb Straßenwesen Brandenburg

Advantage: slender construction, partly prefabrication

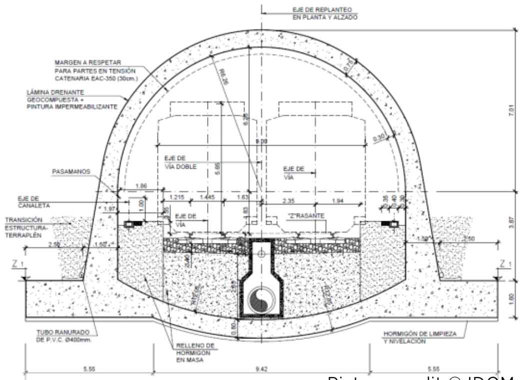
Disadvantage: cannot be used for underpass or railway viaduct




Picture credit: © IDOM

### Example 5 – reinforced concrete tunnel/ "landscaping bridge"

Bridge: estructuras falso tunel via de la plata



Picture credit © IDOM

| | |
|---|---|
| Type: | tunnel |
| Land | Spain |
| Construction | Reinforced concrete tunnel |
| Span | 9,42 m |
| Dimensions | Length: 121 m<br>Thickness: 0,75 m |

Advantage: utilising the compressive strength of concrete in resisting the loading by means of arch acting and the base is wide enough for traffic

Disadvantage: difficult to construct

## 3.5 Case 4 Road overpass

### 3.5.1 Description

According to Bridge Inventory of Rail Baltica project [U3] most of the needed bridges are road overpasses. Road overpasses enable motor vehicle, pedestrian and cyclist to cross Rail Baltica. Therefor a width of 12,00 m shall be provided. A vertical clearance of 6,70 m must be provided for high-speed trains. Typical occurring spans for Rail Baltica are between 20 – 30 m. [U2]

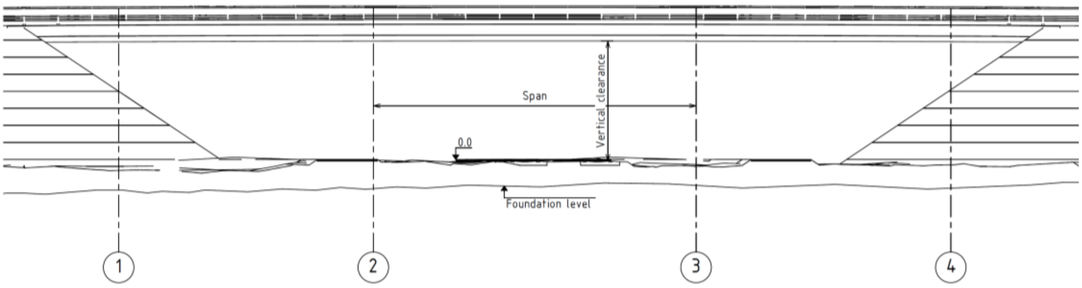



**Figure 33:** Longitudinal view - Case 4 [U2]

### 3.5.2 Structures

Figure 34 shows the percentage distribution of all road overpasses analysed by us (see annex). This figure does not represent the percentage distribution for all common road overpasses because the analysed bridges were chosen arbitrary.

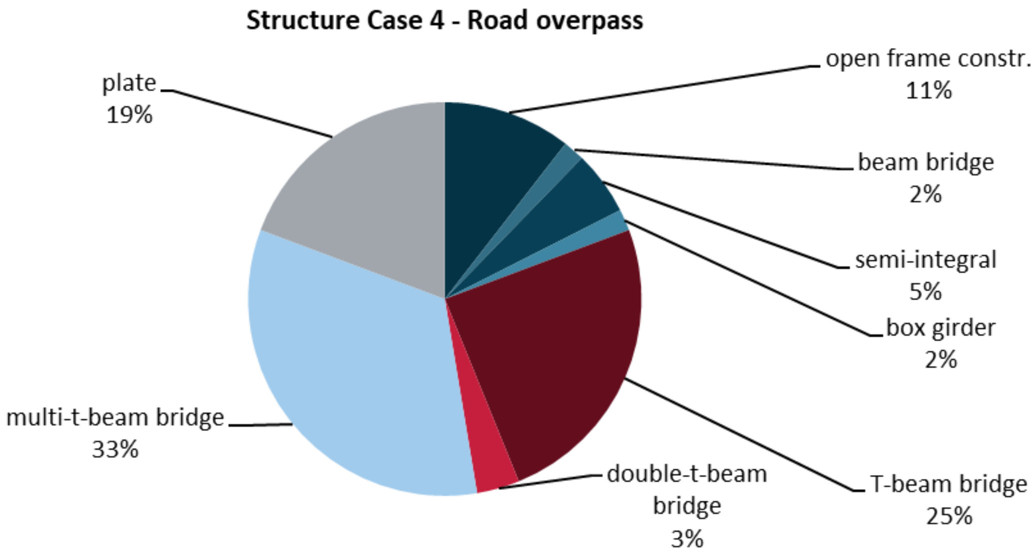



**Figure 34:** common civil engineering structures for road overpasses – results of analysis real bridge designs

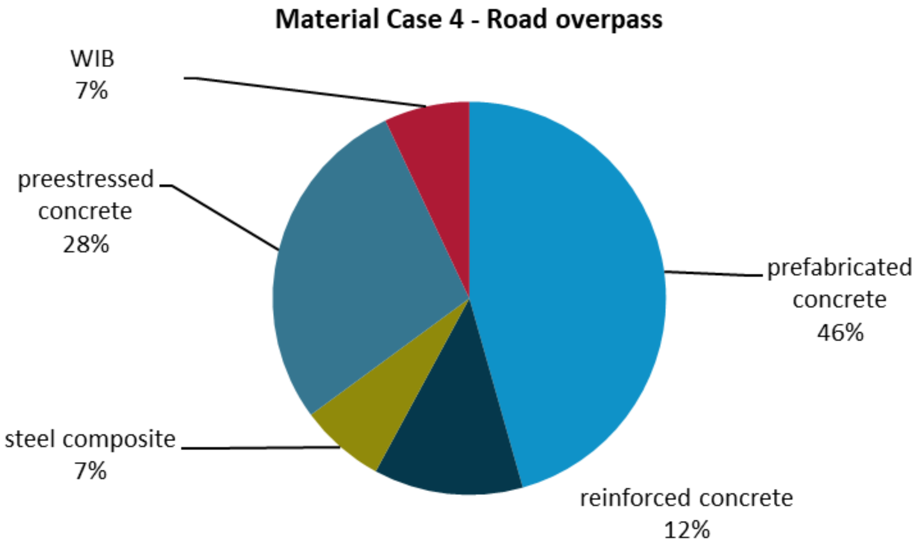



**Figure 35:** commonly used material for road overpass - results of analyses real bridge design

Structure types are similar to Case 2 Rail Viaduct. See information about structures above in chapter 3.3.2.

### 3.5.3 Options

As mentioned for case 1 the position of the abutment in the embankment and the angle of wings are options for bridge design (3.2.3).

For Road overpasses parapets have to be installed:

- to protect the Railway from accidental offloading of lorries/tracks circulating above Rail Baltica
- to protect pedestrians from the High Voltage required for Rail Baltica operations
- to provide a high aesthetic quality


**Figure 36:** Parapets to protect Railway and pedestrians

### 3.5.4 Examples

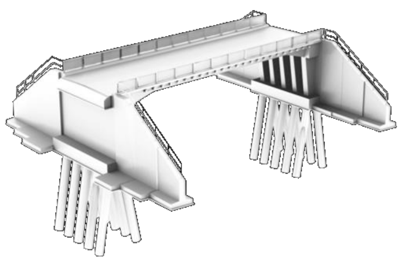
## Case 4 Road overpass


Picture credit: © Jörg Heckenkamp ruhrnachrichten.de

**Example 1 – two precast bridges, same design**

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


Picture credit: © Leitheiser

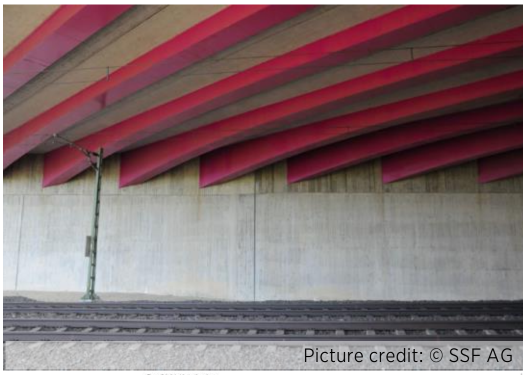
Advantage: high percentage of prefabrication

Picture credit: © SSF AG

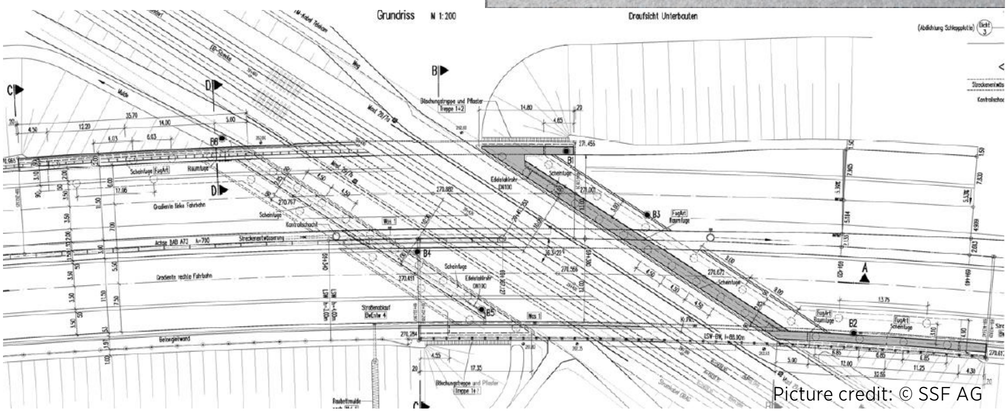
### Example 2 – oblique construction 36 gon

Bridge: Example oblique-angled construction

| | |
|---|---|
| Type: | Road overpass |
| Line / built speed country | A 73 crossing 5100 Bad Staffelstein-Lichtenfels/ Railway speed 160 km/h Germany |
| Construction | Composite bridge |
| Span | 24 m |



Picture credit: © SSF AG




Picture credit: © SSF AG

Advantage: partly prefabrication

Disadvantage: higher parapet over high-voltage line brings discontinuity in comparison to other parapet along the bridge


Picture credit: © Klähne ingenieure

**Example 3 – steel composite bridge, two box girders**

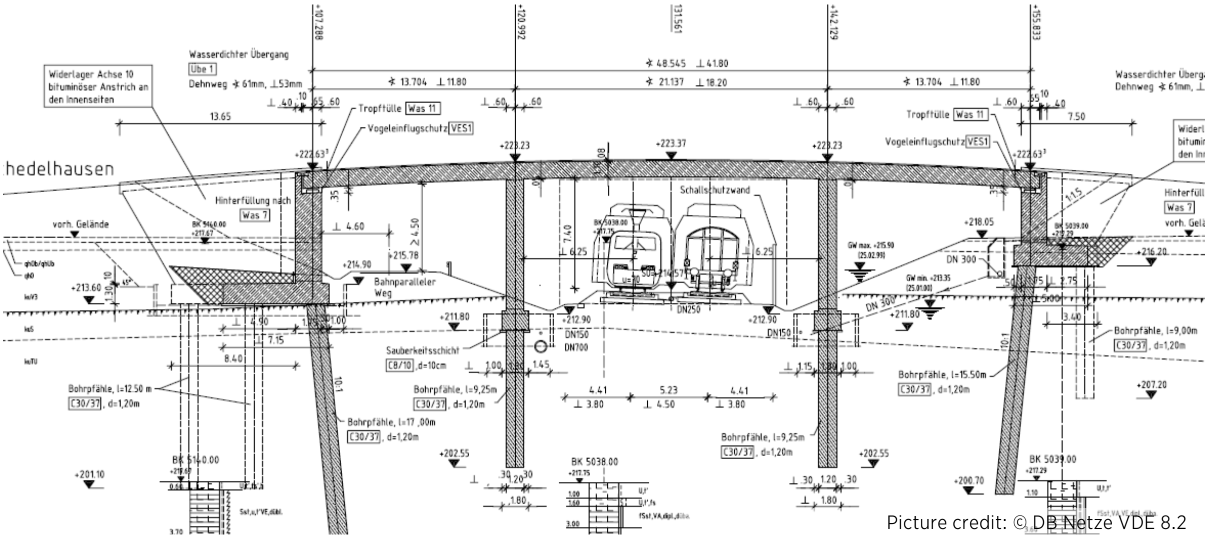
Bridge: Bridge K 59


Picture credit: © Klähne Ingenieure

| | |
|---|---|
| Type: | Road overpass |
| Line / built speed country | K 59<br>Germany |
| Construction | Steel composite, two box girders |
| Span | 30 m |
| Dimensions | Constant construction height<br>15 cm precast carriageway slab<br>30 cm cast-in-place concrete complement |

Advantage: high percentage of prefabrication

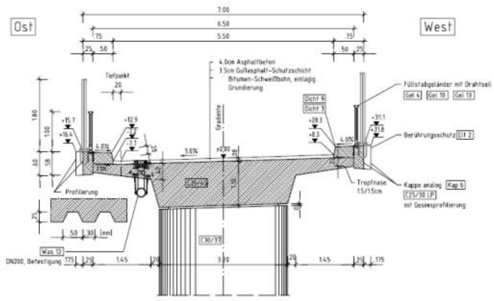
Disadvantage: corrosion protection needed for steel girders



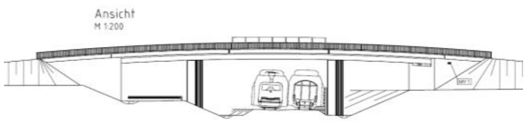

Picture credit: © DB Netze VDE 8.2

### Example 4 – semi integral prestressed bridge

Bridge: Ballstedt-Vippachedelhausen




Picture credit: © DB Netze VDE 8.2




Picture credit: © DB Netze VDE 8.2

| | |
|---|---|
| Type: | Road overpass |
| Line / built speed | 5919 |
| country | Germany |
| Construction | Semi integral bridge, prestressed concrete |
| Span | 21,14 m |
| Dimensions | construction height: 1,10 m<br>Vertical Clearance 7,40 m |

Advantage: monolithic connection, no bearings for connection to piers

Disadvantage: cast-in-place concrete, no prefabrication

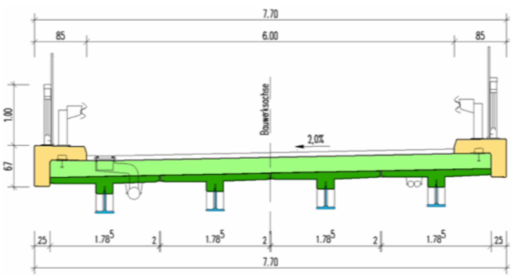
Picture credit: © ssf ingenieure

### Example 5 – frame bridge VFT-WIB, concrete hinge connection pile-superstructure

Bridge: Road bridge Kratzerau

| | |
|---|---|
| Type: | Road overpass |
| Line / built speed | ÖBB Salzburg-Wörgel |
| country | Austria |
| Construction | Integral construction, cross section: VFT-WIB |
| Span | 19,5 m |
| Dimensions | Vertical Clearance 7,50 m |

Picture credit: © ssf inenieure




Picture credit: © ssf ingenieure

Advantage: partly prefabrication

Disadvantage: corrosion protection for steel girders

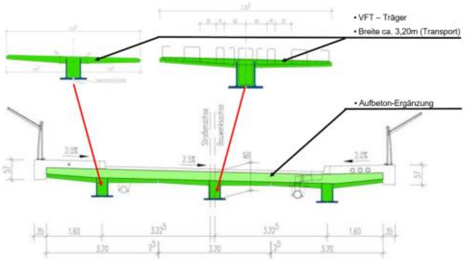

Picture credit: © ssf ingenieure

**Example 5 – frame bridge VFT-WIB, integral**

Bridge: Road bridge Pöking


Picture credit: © ssf inenieure

| | |
|---|---|
| Type: | Road overpass |
| Line / built speed | 5504 Starnberg-Possenhofen/ 120 km/h |
| country | Germany |
| Construction | Integral construction, cross section: VFT-WIB |
| Span | 16,6 m |
| Dimensions | |



Picture credit: © ssf inenieure


Picture credit: © ssf ingenieure

Advantage: high percentage of prefabrication

Disadvantage: corrosion protection for steel girders

## 3.6 Conclusion

Obviously, there are many different bridge designs for all of the four mentioned cases. As shown in the study case the bridge design differs in terms of:

- Structure/ Bridge types
- Design of connection points
- Material
- Possibility of prefabrication
- Abutment design
- Pier design
- Architectural design

The options show that with preliminary consideration the bridge design can be not only successful regarding to functionality and durability but also regarding to aesthetic implications.

## Final leaf

Hannover, 27.09.2019