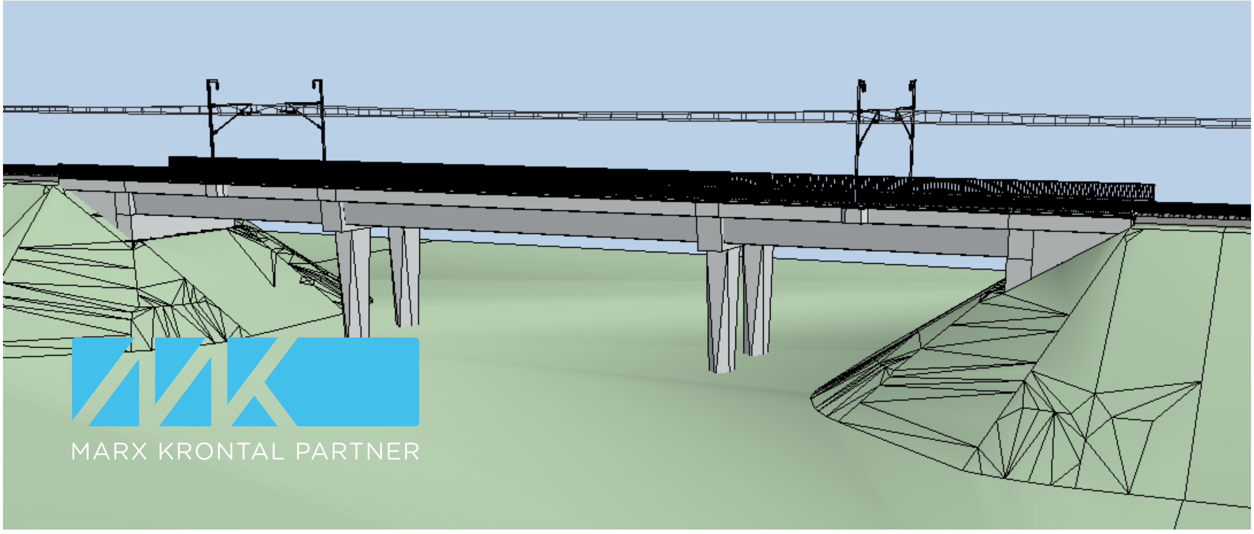

PROJECT	**Rail Baltica** SBS-Study
FINAL REPORT	**Development of preferred solution - Master Design**
CASE 2	**Justification Report Railway Viaduct**
PERFORMANCE PERIOD	07/2019 until 09/2019
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PROJECT NUMBER INTERNAL	04119
EDITOR	Justine Bange, M.Sc
DATE	Hannover, 27.09.2019
INDEX	a

Co-financed by the Connecting Europe Facility of the European Union

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

[U5] Design guidelines general requirements; Rail Baltica; 25.03.2019

Additional documents

[U6] Flue-Fluegelausbildung; Bundesanstalt für Straßenwesen bast; 12.2009

[U7] RiL804; DB Netz AG;01.11.2018

[U8] Was-Brückenentwässerung; Bundesanstalt für Straßenwesen bast; 12.2009

[U9] Marx u. Schacht: Betongelenke im Brückenbau, Bericht zum DBV-Forschungsvorhaben 279; Heftreihe Deutscher Beton- und Bautechnik-Verein E.V., Heft 18 (2010)

[U10] VDEI- Verband Deutscher Eisenbahn-Ingenieure E.V. - information Konstruktiver IngenieurBau Nr.05

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1 General

1.1 Necessity of measure, traffic routes, local boundary condition

New high-speed railway line Rail Baltica will cross small valleys and routes or rivers. A railway viaduct is the structure that carries Rail Baltica railway line over this small valleys and routes or rivers. 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 or obstacle, such as for example river or valley. A balance between local requirements, therefore needed structure and consistent design along the Rail Baltica line has to be found.

This justification report does not deal with a single building structure, but with a general solution for railway viaducts. Each railway viaduct on railway line Rail Baltica has to be planned separately considering local boundary conditions, but this report shall give a design basis for such bridge types in a general, theoretical situation.

1.2 Load assumptions

This general planning of railway viaducts does not include a static calculation, because it is depending on local boundary conditions (e.g. soil conditions) and geometric parameters of the bridge. Load assumptions for a static calculation of each bridge can be taken from design guidelines of Rail Baltica [U5].

1.3 Construction design

The main overall design concept for railway bridges and road overpasses is a straight and clear language of design.

In this planning phase superstructure is designed with a slenderness l/h of about 17.5.

Straight abutments build the end of the bridge. It two axis piers are arranged, so three bridge fields result. Piers are connected with superstructure via pier heads (see Figure 1).

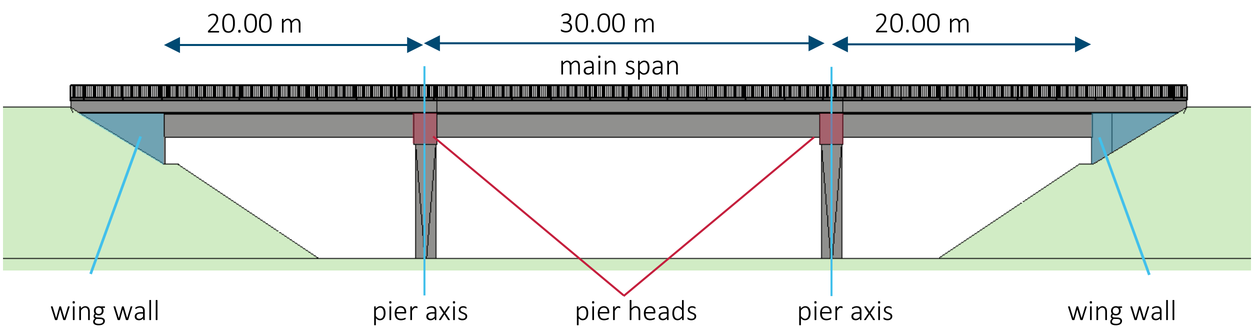

Figure 1: side view railway viaduct

Considering rural local boundary conditions this solution is a very economical solution (as shown in MCA annex 0_5). In urban situation another design could be more advantageous.

2 Soil conditions, foundation

2.1 Soil conditions

It is necessary to investigate soil conditions for each bridge. Soil investigation has to be made especially in foundation axis. For the general railway viaduct planning, good soil conditions for spread footing are assumed.

2.2 Groundwater, water pumping

Depending on groundwater level, water pumping during construction phase might be necessary. Since Baltic states are very flat countries, water pumping is often necessary. Therefore, water pumping is calculated in estimation of costs with a lump sum of 10.000 € (see estimation of costs Annex 2_1). Depending on landscape a factor (factor of difficulty) to calculate the costs depending on the amount of water pumping can be added

2.3 Footing

In this fictional design soil conditions for spread footing (as shown in Figure 2) are assumed. Calculations and construction planning are based on the idea of using spread footing.

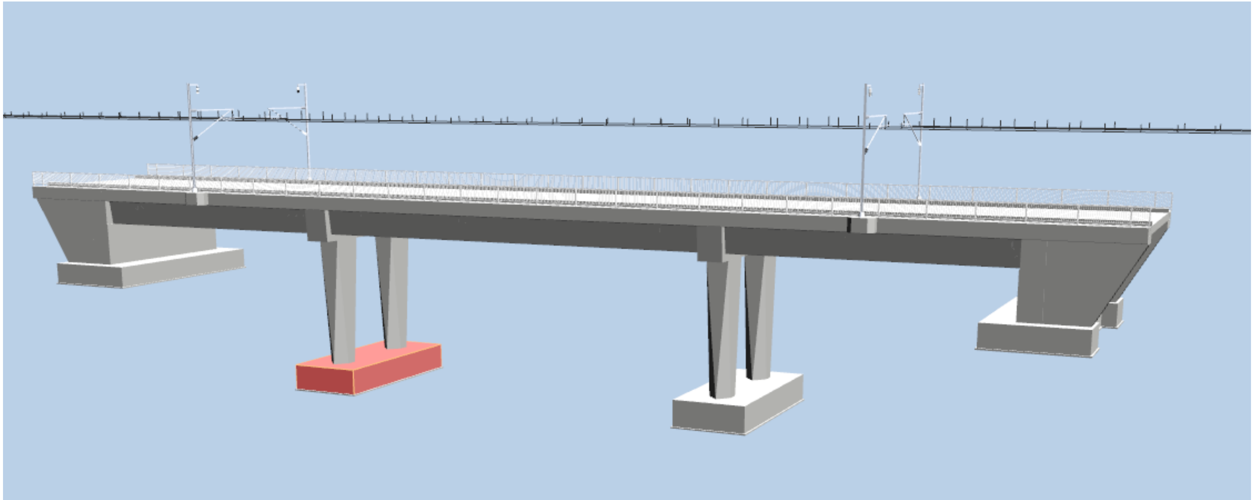

Figure 2: spread footing for railway viaduct

For other soil conditions also spread footing with previous soil improvement or deep foundation, as shown in Figure 3, is thinkable.

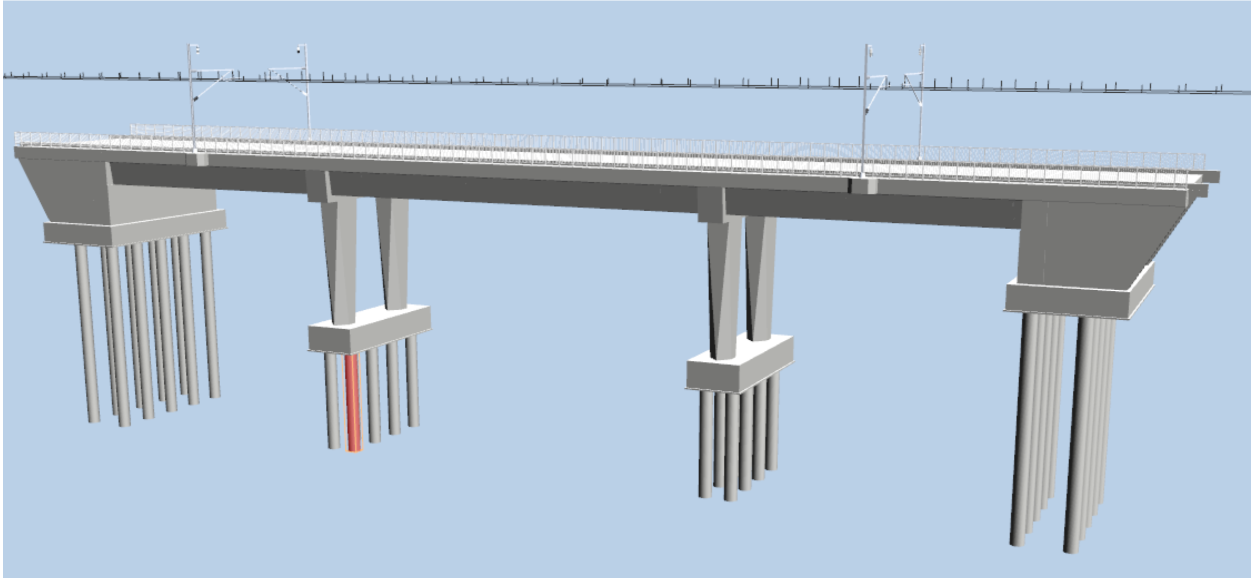

Figure 3: deep foundation for railway viaduct

2.4 Investigation regarding contamination and explosive ordnance

For general railway viaduct planning no investigation regarding contamination and explosive ordnance is included in calculations. Depending on local boundary conditions the expense for these investigations has to be taken into account.

3 Substructure

3.1 Abutment, wing walls, backfill

Abutments and wing walls (east and west) are based on a 1.50 m thick, spread footing which is set on a granular subbase.

Abutment and wing walls shall be constructed with concrete C 30/37. Reinforcing steel type B 500 B has to be used.

Wing walls have a constant thickness of 1.00 m and a length of about 5.50 m. They are designed according standard drawings by the German Federal Ministery of Transport, Building and Urban Development RiZ Flü 1 (Picture 1) [U6].

The angle of wing walls can be differ depending on landscape situation. For railway viaducts angle of wing walls do not have such a big influence on design and visual impact as for underpasses.

There are three main kinds of wing walls:

- Angled wing walls: building more difficult, construction time is longer than parallel wing walls, most economical solution in comparison to parallel and perpendicular wing walls
- Parallel wing walls: easy to build, construction can be done in a short time, wing wall does not disturb existing embankment, but not most economical arrangement

- Perpendicular wing walls: building less difficult than angled wing walls, continuous alignment with bridge deck which can be used to support railings, disturb existing embankment

In this theoretical case perpendicular wing walls are chosen, because it is the best compromise considering all three components building difficulty, construction time and visual appearance. Depending on landscape also angled wing walls or parallel wing walls can be advantageous.

According Ril 804 [U7] backfill needs a special quality for railway bridges. Therefore, two areas of backfill are needed (see Figure 4). In the first backfill area (directly behind abutment wall; chequered area) a qualified soil improvement is necessary. In the second backfill area (striped area) a layer wise backfill with layer thickness ≤ 30 cm is necessary.

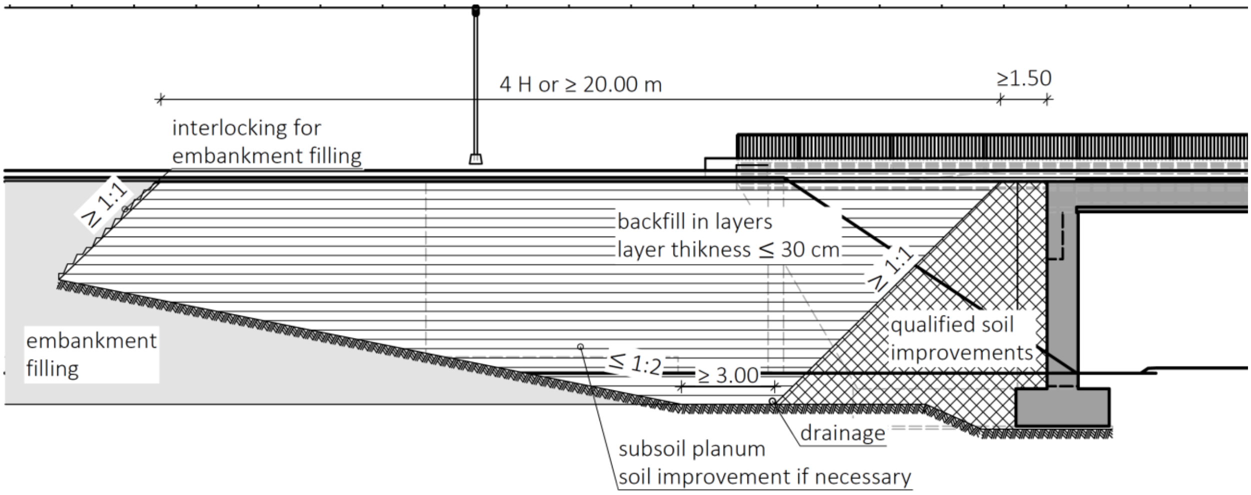

Figure 4: backfill for high-speed railway lines according Ril 804 [U7]

3.2 Piers

Superstructure is connected via pier heads to substructure (see Figure 5). Two piers for each pier axis (20 + 30) are arranged. The main geometry can be taken of drawing Annex 2_2_001 and Annex 2_2_002.

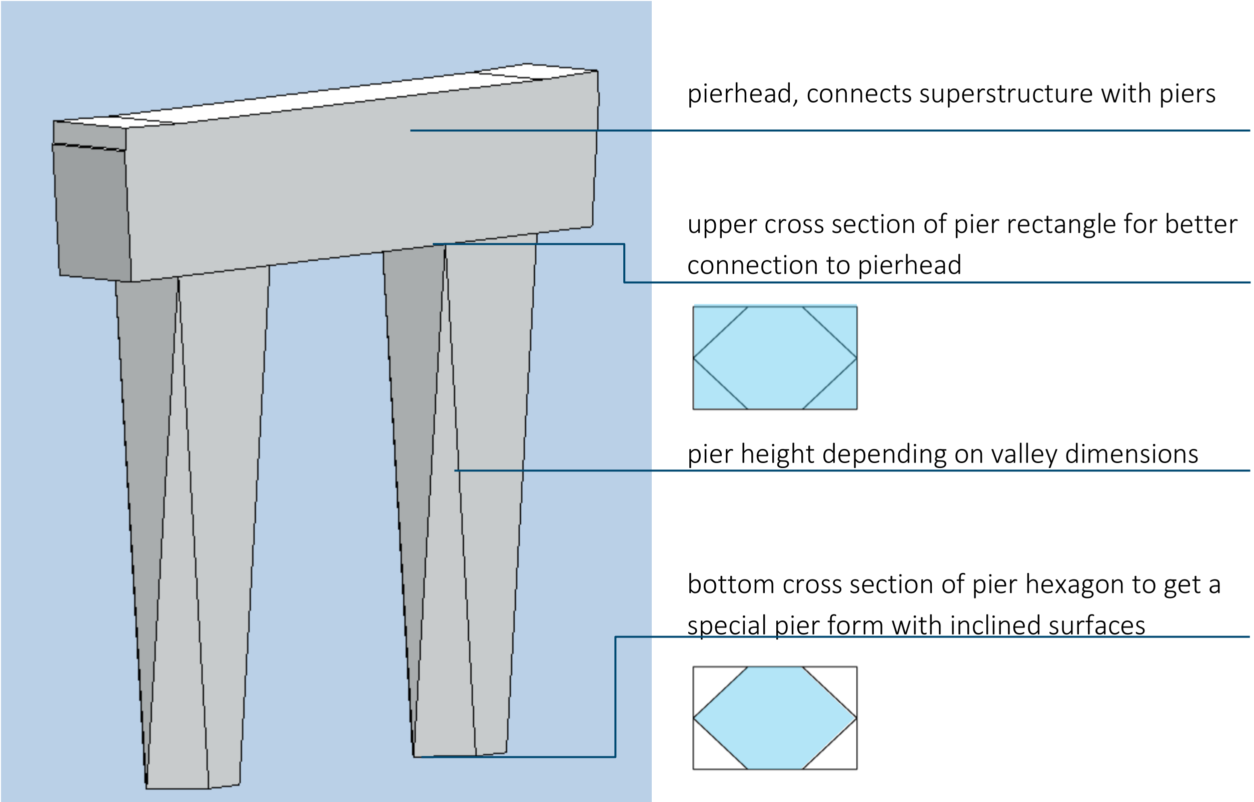

Figure 5: pair of piers with pierhead

Foundation of piers is described in chapter 2.3.

Aim of the bridge design of railway viaducts for Rail Baltica is to reduce maintenance and thus to avoid bearings. That is why a frame impact is generated for railway bridges. Therefore, connection between superstructure and piers have to be weak. Thus, concrete hinges need to be installed (see Figure 6).

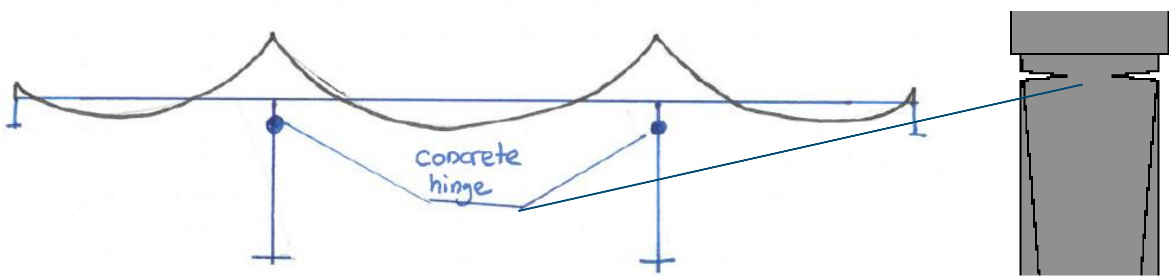

Figure 6: principle of railway viaduct structure (left) and principle of concrete hinge (right)

Reinforcement for concrete hinges have to be planned according [U9], compare Figure 7. Principle is also shown in drawing Annex 5_0_001_C1+C2_detail plan railway bridges".

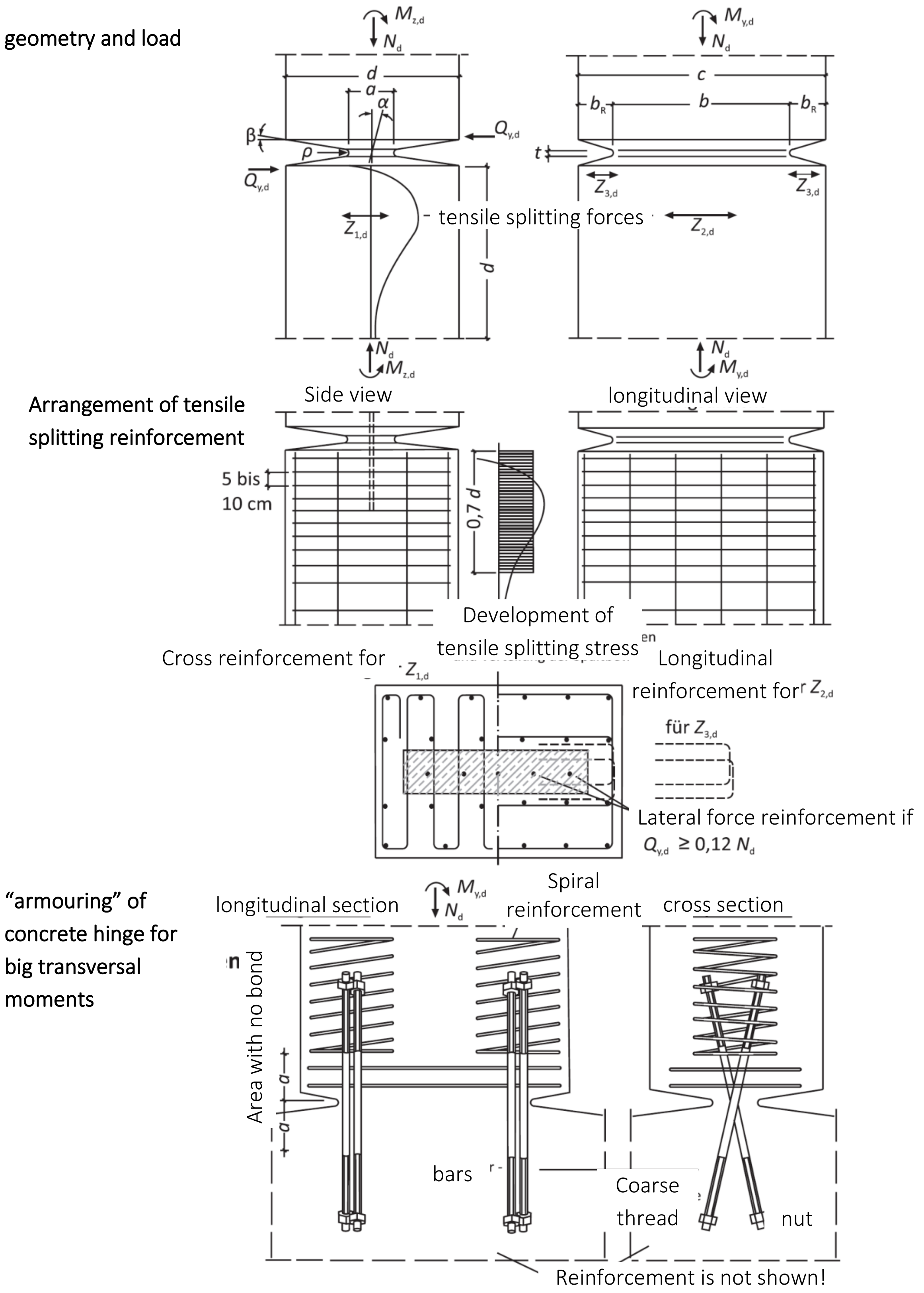

Figure 7: Concrete hinges [U9]

Designation of used letters in Figure 7.

GEOMETRY		FORCES AND MOMENTS	
a	concrete hinge width	N	normal force
b	concrete hinge length	β	torsion
d	width of object connected to concrete hinge	M_Z	moment around y-axis
c	length of object connected to concrete hinge	M	moment around z-axis
t	Concrete hinge height	Q	lateral force
b_R	notch of front surface	Z_1	tensile splitting forces
β	inclination of main notch	Z_2	tensile splitting forces
ρ	Radius of notch smoothing	Z_3	tensile splitting forces

3.3 Visible surfaces

For bridge design the interaction of surfaces is a big factor. Care should be taken for a good interaction between surfaces of superstructure and substructure. The visible surfaces of superstructure are mainly very smooth due to prefabrication. To contrast visible surfaces of substructure from the smooth superstructure surfaces different ways of formwork can be used:

- Formwork panels
- Planed planks
- Non-planed planks

Also, orientation of formwork can be used to produce a significant surface. We advise <u>against</u> colouring of concrete parts to get a contrast of surfaces. Concrete elements get an unnatural look. Furthermore, coloured surfaces may attract unauthorized graffiti artists. Additionally, costs per cubic metres concrete will increase about 10-20 %.

4 Superstructure

4.1 Load-bearing structure

Superstructure is a three-span plate construction. The slab construction is made out of two components: the prefabricated girders (+ prefabricated plates) and an in-situ concrete deck. The prefabricated elements could either be U-profile girders (Figure 8 left) or I-profile girders (Figure 8 right) with an additional prefabricated plate (length 2-2.50 m). Span is 30.00 m with constant construction height of 2.20 m. Relation of span to height is l/h = 13.6.

Due to small bridge height accessibility for inspection is possible from below with lifting platform. Voids of U-beam girders cannot be inspected. Surfaces of voids are not confronted with environmental influences, thus, no exposure.

standard cross section with prefabricated U-beam elements | Alternativ standard cross section with prefabricated I-beam elements

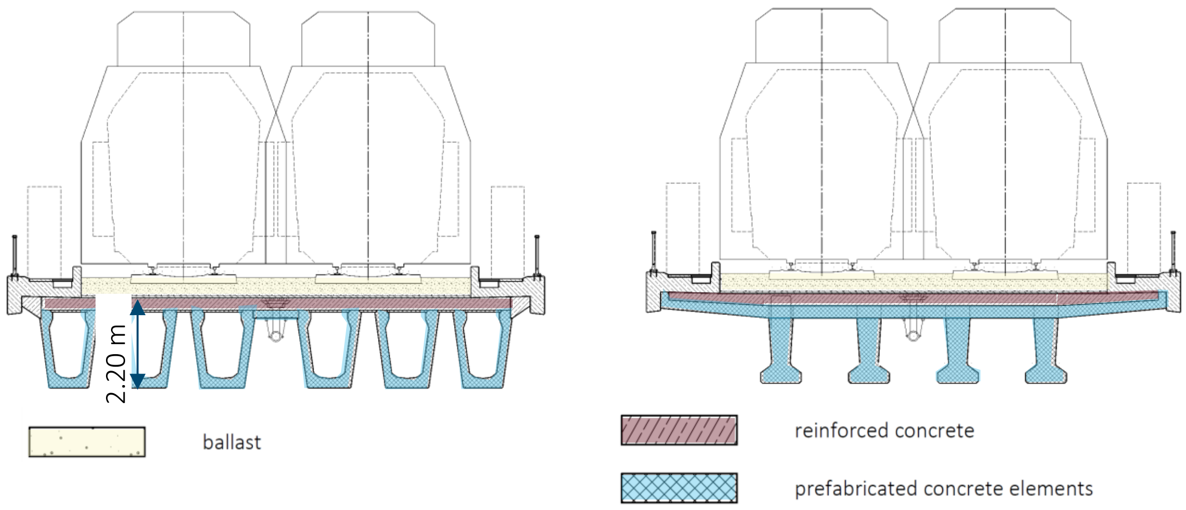

Figure 8: standard cross section U-beam (left) and I-beam as alternativ (right)

For both variants of cross sections prefabricated girders which are pretensioned in prestressing bed are used. The advantage of prestressing bed method is no anchor points are needed.

Superstructure materials are:

- Concrete
- Reinforcing steel
- Prestressed strands

Characteristic values of building material depend on static proof and exposure class. Exposure classes can be assumed for railway bridges as shown in Figure 9 for railway bridges crossing streets, cycle- and pedestrian routes and railway lines. Figure 10 shows exposure classes for railway bridges crossing water.

With estimated exposure class minimum compressive strength can be estimated with Table 1.

Minimum characteristic values for railway viaducts are listed in drawing Annex 2_2_002.

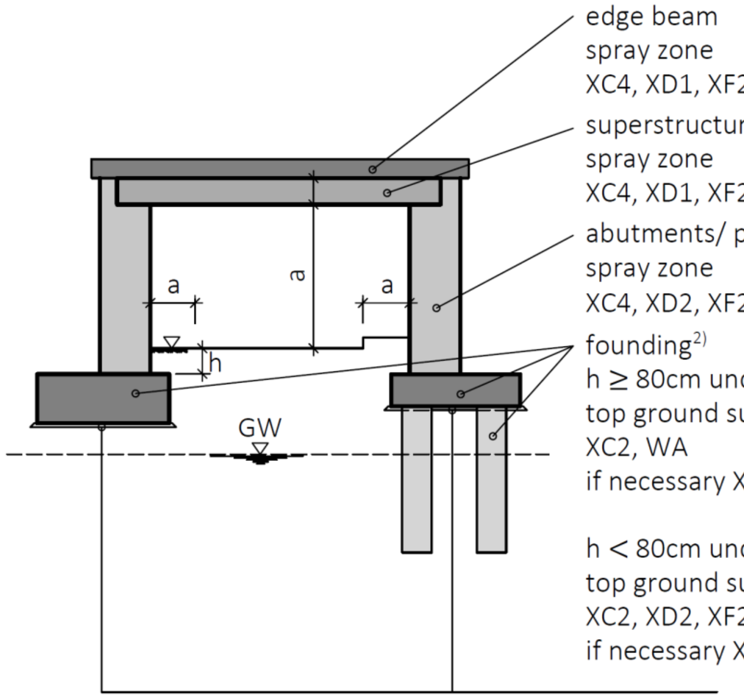

Figure 9: exposure classes for railway bridges crossing streets, cycle- and pedestrian routes and railway lines according [U10]

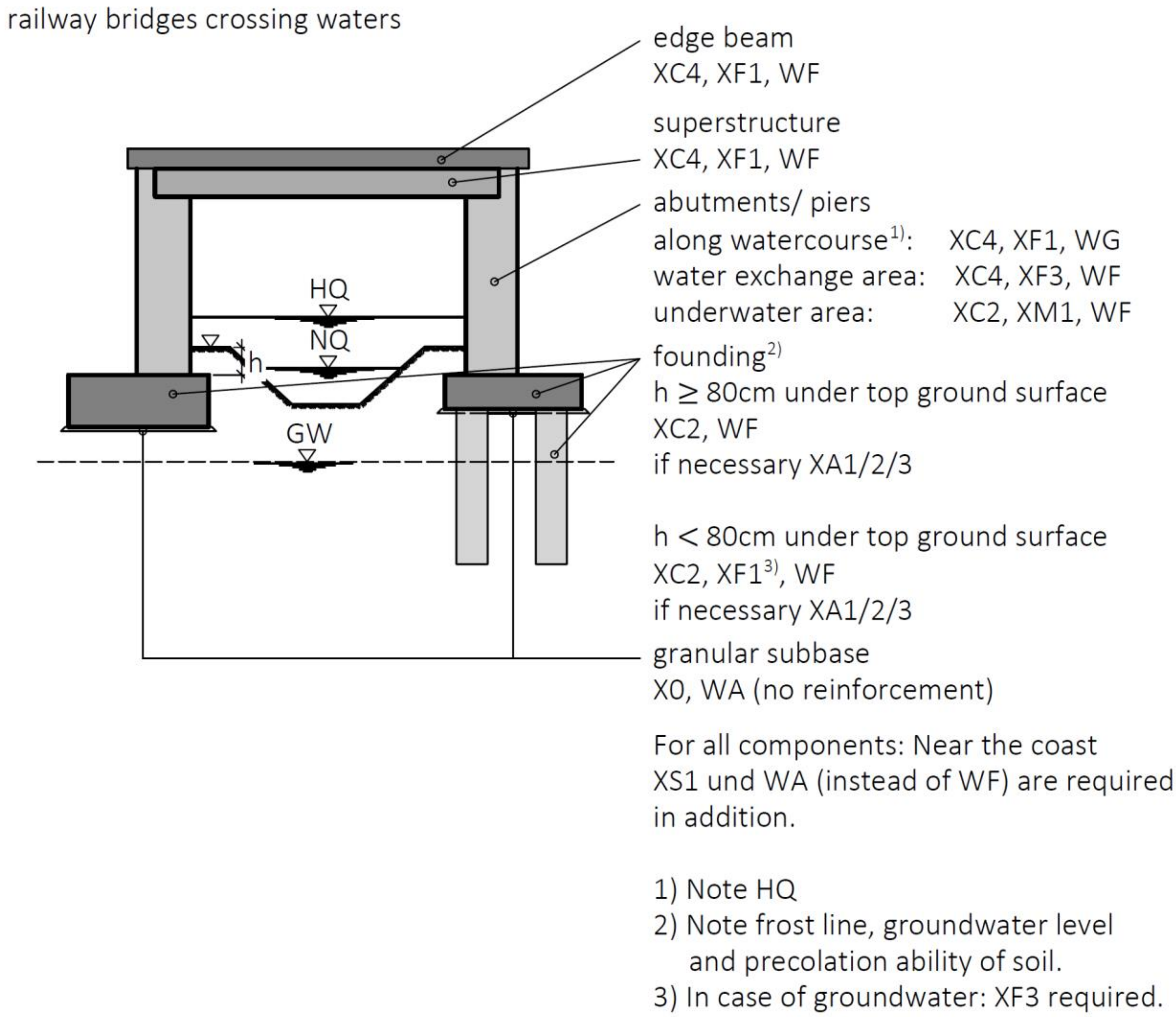

Figure 10: exposure classes for railway bridges crossing waters according [U10]

Table 1: minimum compressive strength class due to exposure classes according [U10]

	Civil engineering railway bridges components reinforced [1,6]	exposure classes X0	XC				XD			XS			XF				XA			XM			humidity class	minimum com-pression strenght class f_{ck}	concr. cover [3] c_{nom} [mm]	comment
		no risk	carbonation 1	2	3	4	chloride 1	2	3	chloride/ sea 1	2	3	frost 1	3	frost/de-icing chemical 2	4	chemical attack [11] 1	2	3	wear 1	2	3	W			
1	granular subbase	X																						C 12/15	-	no reinforcement
2	founding*			X				X^{5*}		X^{7}			X*	X**	X^{5*}								WF/ WA [7]	C 25/30 [1,3] C 30/37 [4,5,7]	55	* from 0,8 m under top ground surface XD/ XF are not required in general. Note frost line, ground-water level and pre-colation ability of soil!
3	founding* weak chemical attack			X				X^{5*}		X^{7}			X*	X**	X^{5*}		X^{2}						WF/ WA [7]	C 25/30 [1,3] C 30/37 [4,5,7]	55	
4	founding* moderate chemical attack			X				X^{5*}		X^{7}			X*	X**	X^{5*}			X^{2}					WF/ WA [7]	C 30/37 [4,5,7]	55	
5	founding* strong chemical attack			X				X^{5*}		X^{7}			X*	X**	X^{5*}				X^{2}				WF/ WA [7]	C 35/45 [2]	55	** XF3 in case of groundwater
6	abutments/ piers frost, no de-icing salt risk					X				X^{7}			X										WF/ WA [7]	C 25/30 [2] C 30/37 [7]	45/55 [9]	
7	abutments/ piers frost, de-icing salt risk [5]					X		$X^{4,10}$	X	X^{7}					$X^{4,10}$	X^{13}							WA	C 30/37 [4,10] C 35/45 [2]	45/55 [9]	spray zone
8	abutments/ piers close to the water [12]- frost					X				X^{7}			X										WF/ WA [7]	C 25/30 [2] C 30/37 [7]	45/55 [9]	
9	abutments/ piers close to the water [12]- frost, water exchange area					X				X^{7}				X									WF/ WA [7]	C 30/37 [4]	45/55 [9]	
10	abutments/ piers close to the water [12]- underwater area		X							X^{7}										X			WF/ WA [7]	C 30/37 [2]	45/55 [9]	
11	superstructure frost, no de-icing salt risk					X				X^{7}			X										WF/ WA [7]	C 25/30 [2] C 30/37 [2,7]***	45	***prestressed concrete [3]
12	superstructure frost, de-icing salt risk [5]					X	X			X^{7}					X								WA	C 30/37 [4]	45	spray zone
13	edge beam frost, no de-icing salt risk					X				X^{7}			X										WF/ WA [7]	C 25/30 [2] C 30/37 [7]	35/25 [8]	
14	edge beam frost, de-icing salt rsik [5]					X	X			X^{7}					X								WA	C 25/30LP [2,4] C 30/37 [7]	35/25 [8]	spray zone

[1] Ril 804.4201/ 4301 (01.05.2003)
[2] DIN-Fb 100 (2001) 4.1; T. 2; T. F.2
[3] DIN-Fb 102 (2003) 3.1.4; T. 4.101
[4] ZTV-ING (3-1; 07/06) section 4
[5] a < 10 m de-icing salt risk [1]
[6] w/z-value ≤ 0,5 [1]
[7] WA/ XS only near the coast
[8] contact to concrete
[9] contact to soil
[10] constructive measures for discharge of de-icing salt water, otherwise XD3/ XF4
[11] sulphate for XA must be stated explicitly
[12] no seawater
[13] only earth-moist concrete [2] (w/z-value ≤ 0,4)

4.2 Bearings, joints, expansion joints

In this example railway viaducts are planned as integral bridges; thus, no bearings and joints are needed. Only dummy joints / controlled crack joints in abutments according Annex 5_0_002 have to be planned.

For longer viaducts with bridge length > about 60 m semi-integral constructions are necessary. Therefore, bearings and joints are needed.

Examples for expansion joints are shown in Figure 11 and Figure 12.

small joints for semi-integral railway viaducts

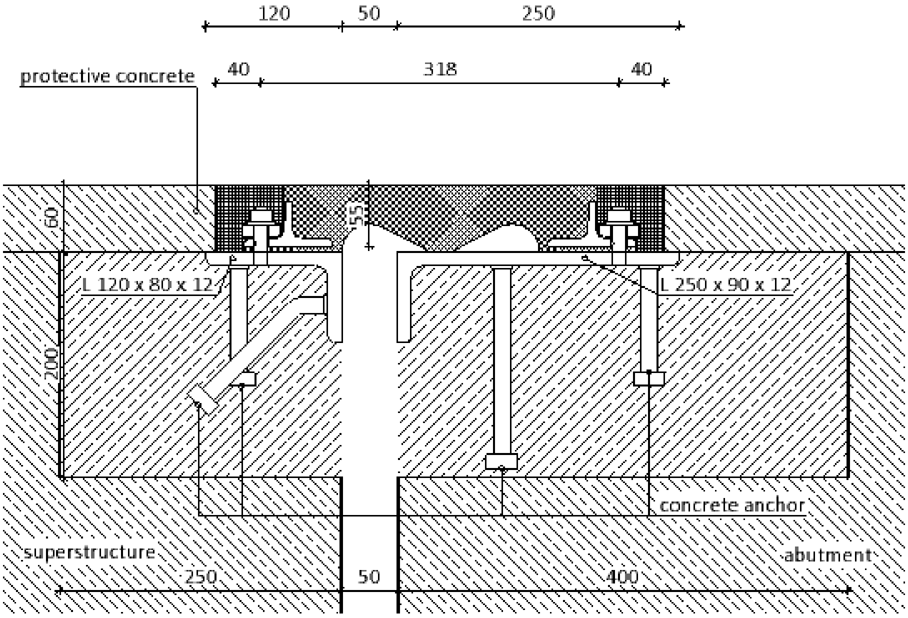

Figure 11: small joints for semi-integral railway viaducts according M-ÜF 1934 [U7]

large joints for semi-integral railway viaducts

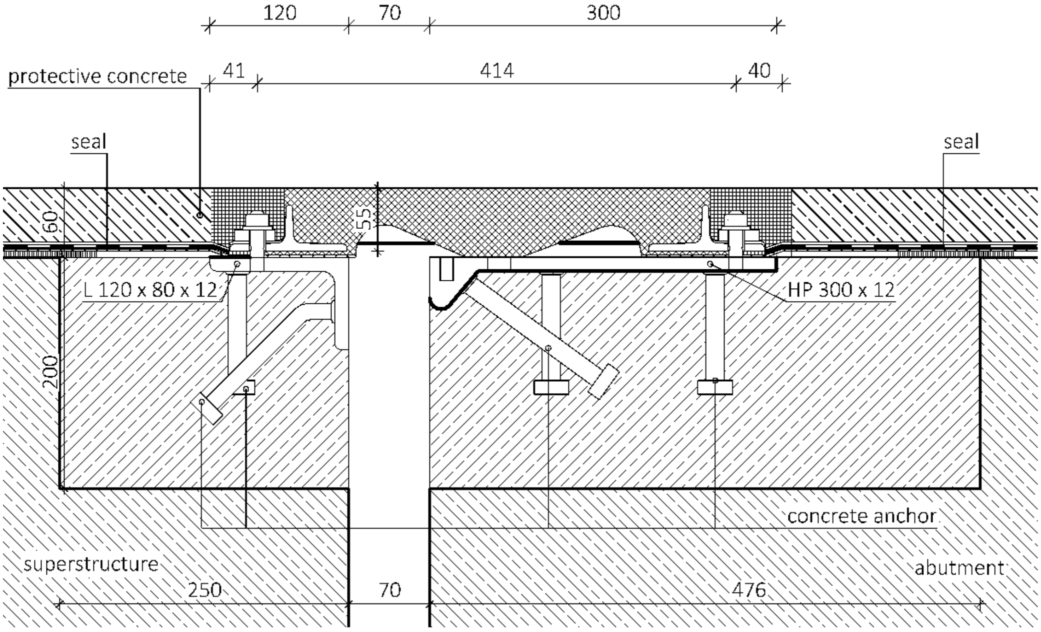

Figure 12: large joints for semi-integral railway viaducts accoring M-ÜF 1937 [U7]

4.3 Waterproofing, covering

Waterproofing design is the same principle than for underpasses. Detailed principles of waterproofing and covering are shown in Annex 5_0_001.

4.4 Corrosion protection, protection against environmental influences

Railings and other equipment parts made of steel (e.g. noise cancelling walls, protection systems), need a coating system against corrosion.

5 Drainage system

5.1 Superstructure

Drainage planning needs to ensure sufficient drainage of track lane. Drainage system in cross section is shown in Figure 13.

Bridges with bridge length less than 30 m – even without longitudinal incline – can be built without particular drainage system in superstructure.

Railway viaducts with bridge length more than 30 m have to be drained with following drainage elements according Ril 804.1101 [U7]:

- pipes not smaller than DN 200
- longitudinal incline of pipes at least 0.9 %
- drain pipes in longitudinal direction has to be placed with a distance about 30 m; in transversal direction they have to be placed between track axis
- local 1.5 % longitudinal and transversal inclination near drain pipes
- water drains are placed on piers and abutments

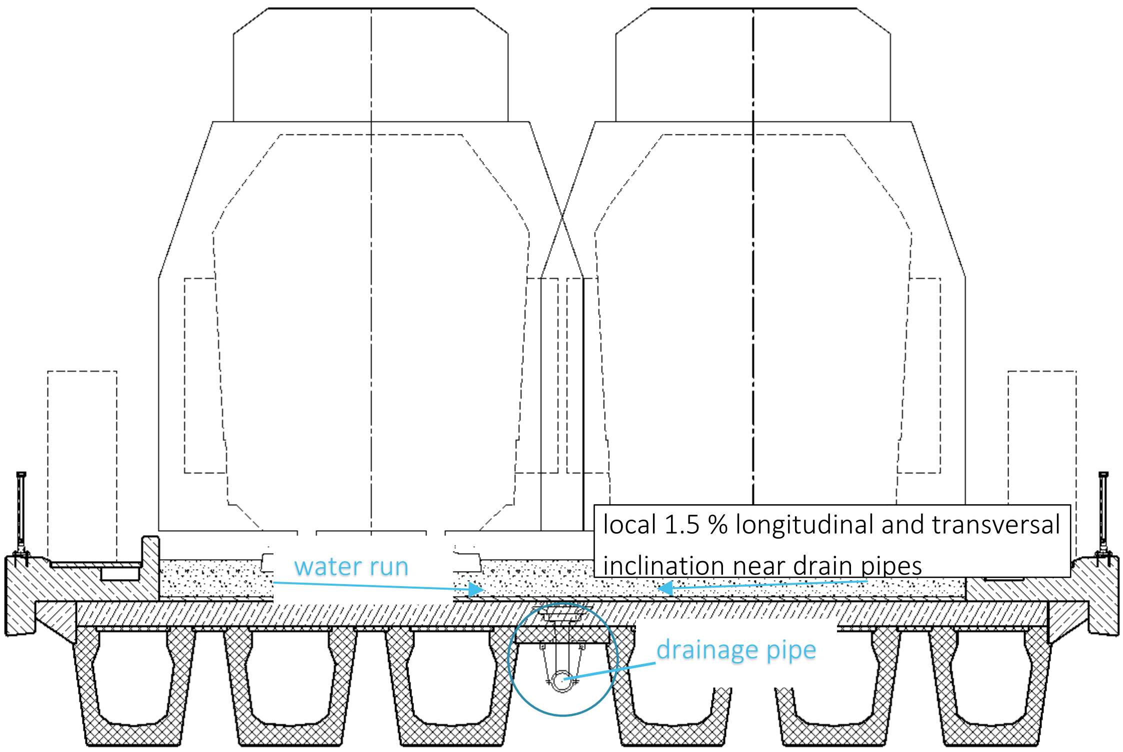

Figure 13: drainage system in cross section; Case 2 - Railway Viaduct –

5.2 Abutments

Drainage takes place in drainage walls along abutments (see Figure 14). Therefore, drainage walls have to be included in drainage planning and have to be calculated to define dimensions of run pipe.

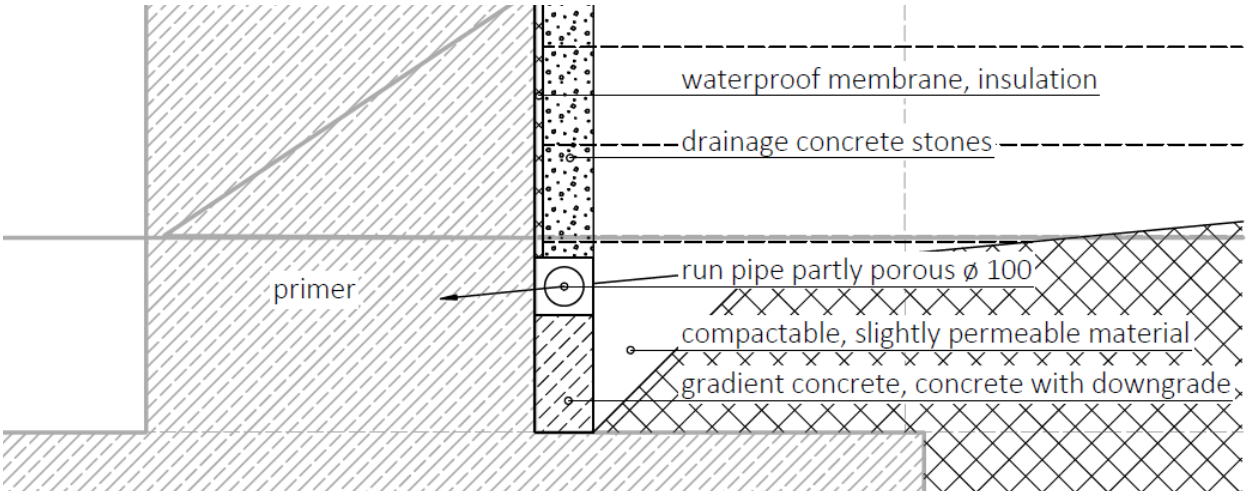

Figure 14: Detail E: drainage system abutment

6 Restraint and protection systems

Railings

As railings bar railings with a bar distance of less than 120 mm are planned. For further geometrical details see Annex 5_0_001. The main principle of bar railings is shown in Figure 15.

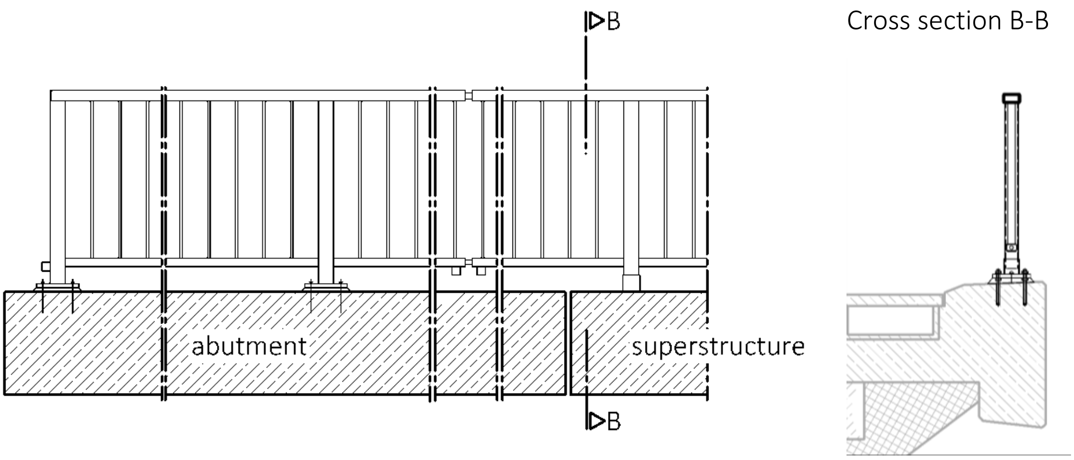

Figure 15: railing railway bridges according Ril 804 [U7] A-GEL-12

Noise protection walls

For general railway viaduct planning no noise protection walls are included in calculations. They should be planned if local boundary conditions require noise protection. Centre distance for noise barrier on bridge is ≤ 2.50 m. In embankment area a center distance of ≤ 5.00 m is necessary.

7 Accessibility

Accessibility for inspection is possible from below with lifting platform.

Accessorily via embankment stairs could be also possible. We advise against embankment stairs, because this enables unauthorized access to railway bridges. If embankment stairs are wanted, we advise to include them in emergency escape route planning (stair width large enough etc.).

Voids of U-beam girders cannot be inspected. Surfaces of voids are not confronted with environmental influences, thus, no exposure.

8 Other equipment

Grounding

All solid construction components have to be equipped with an inner grounding. All steel construction components (noise protection wall, parapets, …) need grounding connections and need to be connected to railway earthing.

Catenary masts

Catenary masts have to be placed every 50 m. So, catenary masts have to be installed on railway viaducts. Therefore, overhang bracket for catenary masts have to be installed.

On plan view in Figure 16 it is shown that only in the area of catenary masts the cross section is widened to carry the catenary masts.

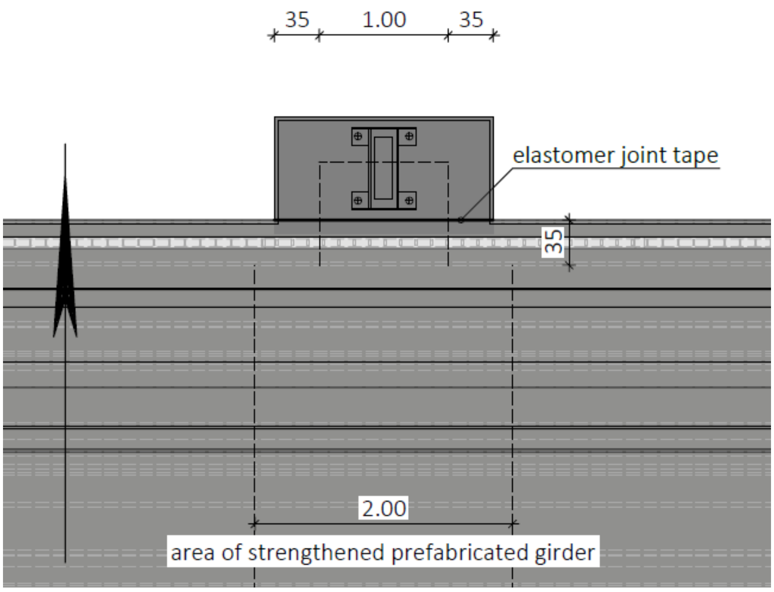

Figure 16: detail L plan view; overhang bracket for catenary masts

For this additional overhang the prefabricated girder has to be strengthened as shown in Figure 17.

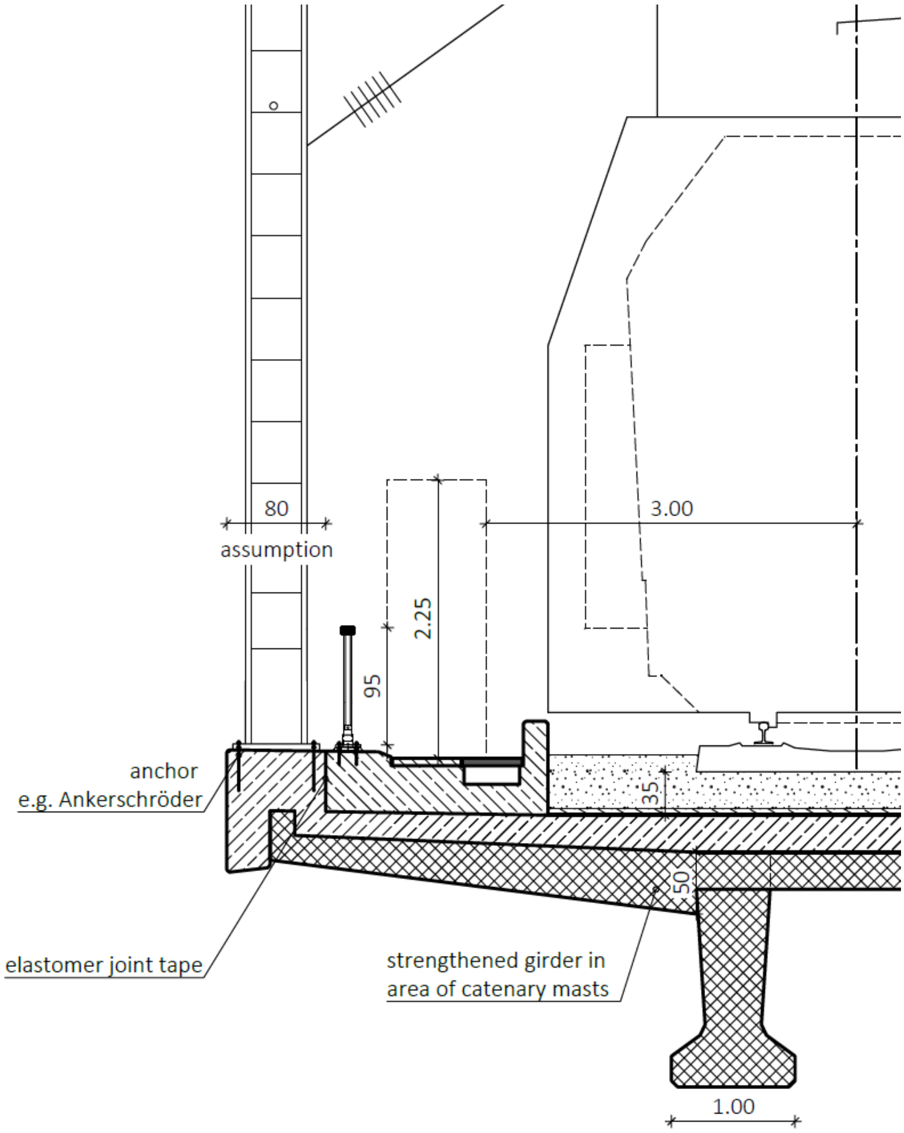

Figure 17: Detail L: cross section; overhang bracket for catenary masts

9 Construction, construction period

9.1 Construction process, construction period

Construction process	duration	comments
1 PREPARATORY WORKS	2-3 WEEKS	
Access/ access road to construction site		depending on region and landscape situation
If necessary, redirect "crossing partner"		depending on traffic situation
Set site area		
2 EARTHWORK		
Produce planum	1-6 WEEKS	depends strongly on landscape situation
Build embankment	1-6 WEEKS	depends strongly on landscape situation
Pit excavation for spread footing of abutments and piers	incl. in founding	depending on local conditions either open excavation or sheeting
Backfill layer wise	incl. in abutment	layer thickness around 30 cm in a high-quality consolidation
3 FOUNDING FOR ABUTMENTS AND PIERS	4-6 WEEKS PER FOUNDING AXIS INCL. PIT EXCAVATION DEPENDS ON TYPE OF FOUNDATION	
Abutment		
(pit excavation see earthwork)		
Granular subbase (abutment)		
Spread footing, foundation slab (abutment)		
- formwork		
- place reinforcement		incl. starter bars for abutment walls
- pouring concrete		
deep foundation as option instead of spread footing (abutment)	+ 2 WEEKS PER AXIS	
- insertion of foundation piles		depending on soil condition either bored piles, displacement piles, driven pile incl. starter bars for foundation slab
- formwork foundation slab		
- place reinforcement for foundation slab		incl. starter bars for abutment walls
- pouring concrete for foundation slab		
(Backfill layer wise see earthwork)		
piers		one pier foundation per pier axis
(pit excavation see earthwork)		

Granular subbase (piers)		
Spread footing (piers)		
- formwork		
- place reinforcement		incl. Starter bars for piers
- pouring concrete		
deep foundation as option instead of spread footing (piers)	+2 WEEKS PER AXIS	
- insertion of foundation piles		depending on soil condition either bored piles, displacement piles, driven pile incl. starter bars for foundation slab
- formwork		
- place reinforcement for foundation slab		
- pouring concrete for foundation slab		
4 SUBSTRUCTURE		
Abutment	5-7 WEEKS PER ABUTMENT AXIS INCL. BACKFILL	
Geometry as shown in drawing annex 2_2_001/002		in-situ concrete to ensure integral connection to superstructure, in this example perpendicular wing walls
abutment wall until construction joint		
- formwork		
- place reinforcement		incl. starter bars for abutment wing walls and superstructure connection
- pouring concrete		
abutment wing walls		
- formwork		
- place reinforcement		
- pouring concrete		
Piers	1-2 WEEKS PER PIER AXIS	
Geometry as shown in drawing annex 2_2_001/ 002		In-situ concrete to ensure integral connection to superstructure, pier head to ensure integral connection to superstructure, incl. concrete hinge
piers		
- formwork		+ prepared formwork for concrete hinge
- place reinforcement		incl. starter bars for pierhead
- pouring concrete		

pierheads		after superstructure elements are placed!
- formwork		
- place reinforcement		incl. starter bars for superstructure connection
- pouring concrete		
5 SUPERSTRUCTURE		
support structure	ABOUT 3 WEEKS	
- build support structure		if necessary, founding for support structure
- dismantling support structure		
superstructure		
prefabricated concrete elements	12-16 WEEKS INCL. CURING TIME	
- produce prefabricated concrete elements		in precast factory
- transport prefabricated concrete elements to side		
- place prefabricated concrete elements		on support structure and on abutment walls
in-situ concrete for superstructure and connection area	4-5 WEEKS	
- formwork for connection area + waterproofing bridge end		connection area between superstructure and substructure, waterproofing bridge end according Detail C, Annex 5_0_001
- place reinforcement for in-situ superstructure and connection area		
- pouring concrete		
- let concrete dry	+14 DAYS	
6 EQUIPMENT		
Waterproofing edge beam	8-9 DAYS	
- layer wise following Detail A (Annex 5_0_001)		
Build in-situ concrete edge beams	4-5 WEEKS	with anchoring for railing, for catenary masts and, if necessary, for noise protection barrier
- install temporary formwork consoles		
- formwork		
- place reinforcement		
- pouring concrete		
protective concrete + waterproofing superstructure between edge beams	2-3 WEEKS	
- reinforced protective concrete		
- layer wise following Detail B (Annex 5_0_001)		
Drainage system abutment	1 WEEK PER ABUTMENT	

- following Detail E drainage (Annex 5_0_001)		
Installation of catenary masts on brackets for catenary masts	2-3 DAYS	
Grounding, railing, cable-duct, joints, etc.	5-6 WEEKS	
- inner grounding		
- grounding of steel construction components to railway earthing		
- railing following Detail railing (Annex 5_0_001)		
- cable duct		
- if necessary: joints		
- if necessary: noise protection barrier		
Provide track (track geometry, ballast, sleepers, ...)		inkl. cables, overhead cable etc.
- has to be provided with whole railway line		
7 LANDSCAPING	1-6 WEEKS	
Depending on local boundary conditions		
8 FINALIZING WORK	2-3 WEEKS	
Clearing construction site		

ALL INFORMATION ABOUT DURATION ARE ROUGH REFERENCE VALUES.
DURATION FOR PREPARATION, TRANSPORT AND LANDSCAPING DEPENDS STRONGLY ON LANDSCAPE SITUATION.

9.2 Protective measures

Work for waterproofing might be problematical if ambient temperature is too low. Therefore, waterproofing either has to take place when it is not too cold for the waterproofing material (the manufacturer's details are to be observed) or a waterproofing material for the special ambient temperature while waterproofing apply phase has to be planned in detailed design for the specific structure. Waterproofing work can be started 2 weeks after concreting.

10 Costs

The costs are roughly estimated. A list with costs and quantities can be seen in Annex 2_1_001 for U-beam girder and in Annex 2_1_002 for alternative cross section with I-beam girder.

Final leaf

Hannover, 27.09.2019