Steel and composite bridges in Germany
State of the Art

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Germany

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- Typical composite road bridges with open sections and box girders
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- Composite bridges for small and medium spans
- Cable stayed bridges
- Canal bridges

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Advantages of composite bridges

- **Very slender and aesthetic bridges** due to the optimal combination . of high tensile strength of structural steel and the high compressive strength of concrete
- **High durability** of normal reinforced concrete decks due to restrictive crack width limitation.
- In comparison with steel bridges composite bridges have a **better behaviour with regard to freezing in winter.**
- Because the **low dead weight** of the composite bridges deck is, composite bridges have advantages with regard to the foundation and settlements of supports.
- Due to **innovative erection methods** composite bridges are often used for bridges over passing existent railways or highways without any restrictions for the traffic. Where existing freeways with two lanes are widened the short erection time of composite bridges avoids longer restrictions for traffic.

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Composite Bridges with open and closed cross-sections



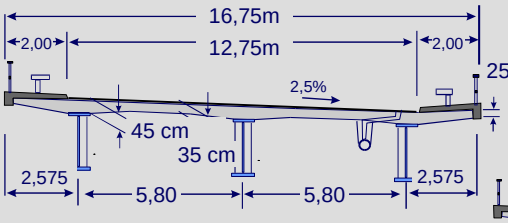
Werra-Bridge Einhausen

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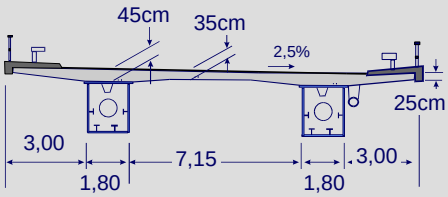
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Typical cross-sections for composite bridges

plate girder bridge with three rolled or welded main girders

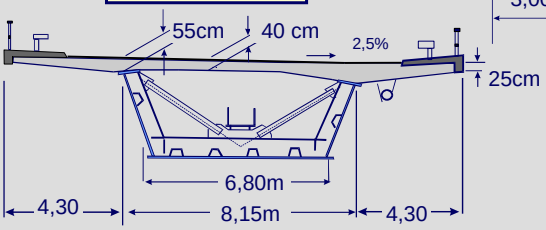


cross-section with two separated box girders



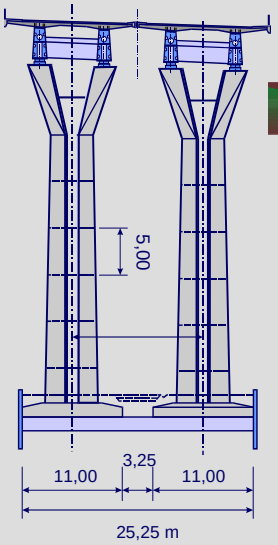
airtight welded box girders

box girder

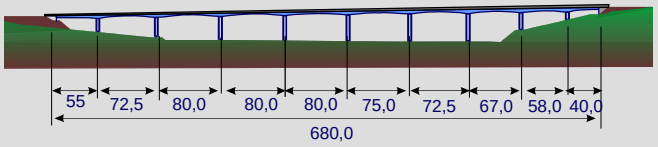


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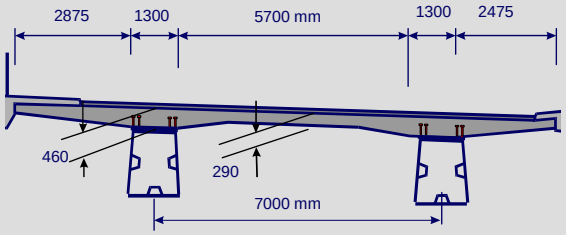
Bridge Schleusetal



view



cross-section at midspan



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Bridge Schleusetal



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Bridge Schleusetal

transportation of steel girders on site







casting of the concrete deck by moveable formwork

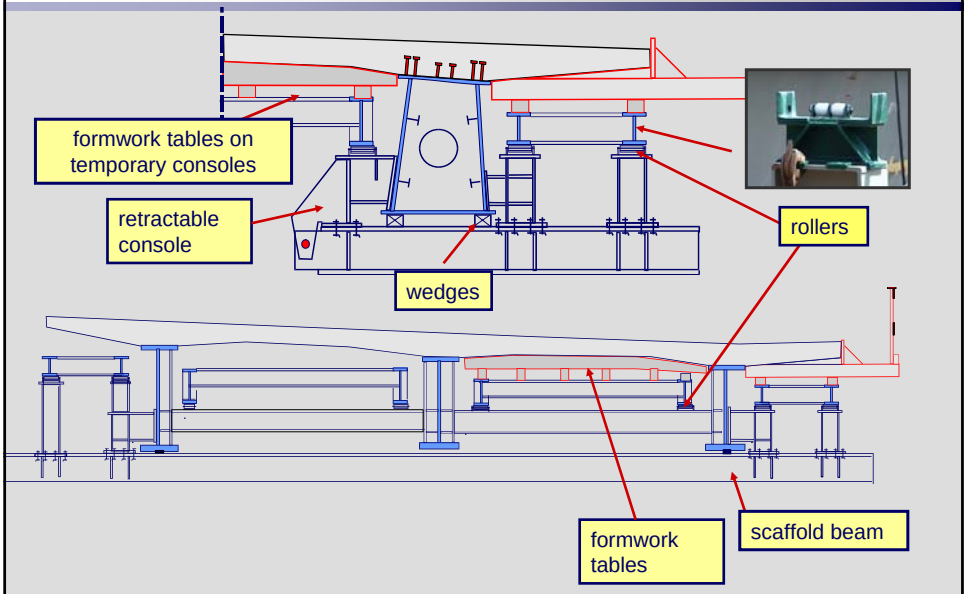


erection of steel girders by cranes

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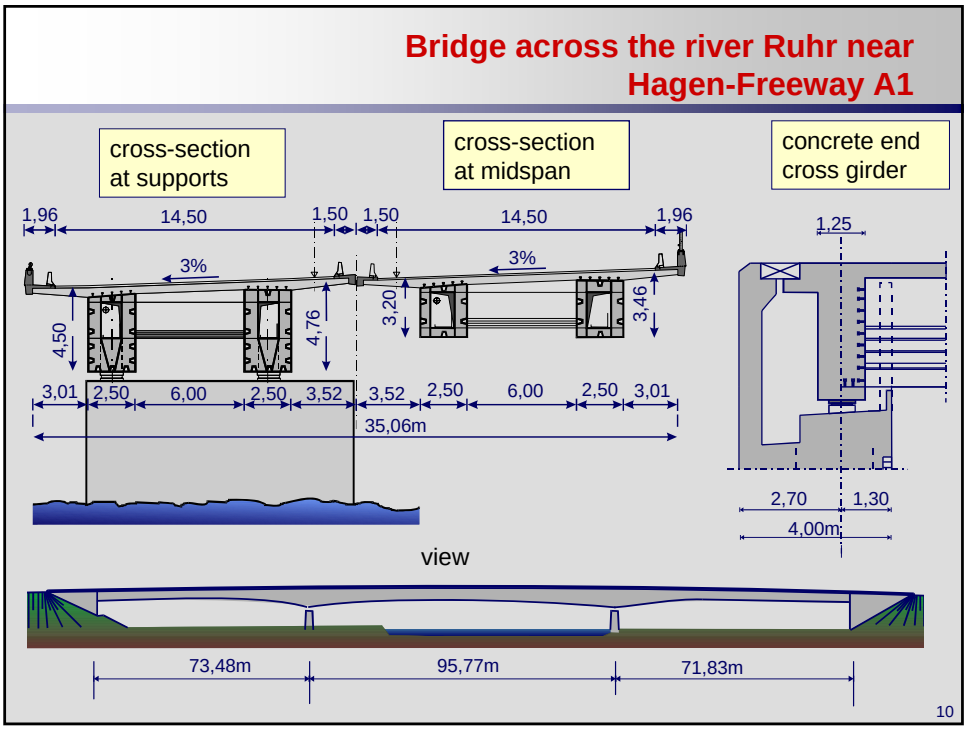
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Examples for formwork systems



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Bridge across the river Ruhr near Hagen-Freeway A1



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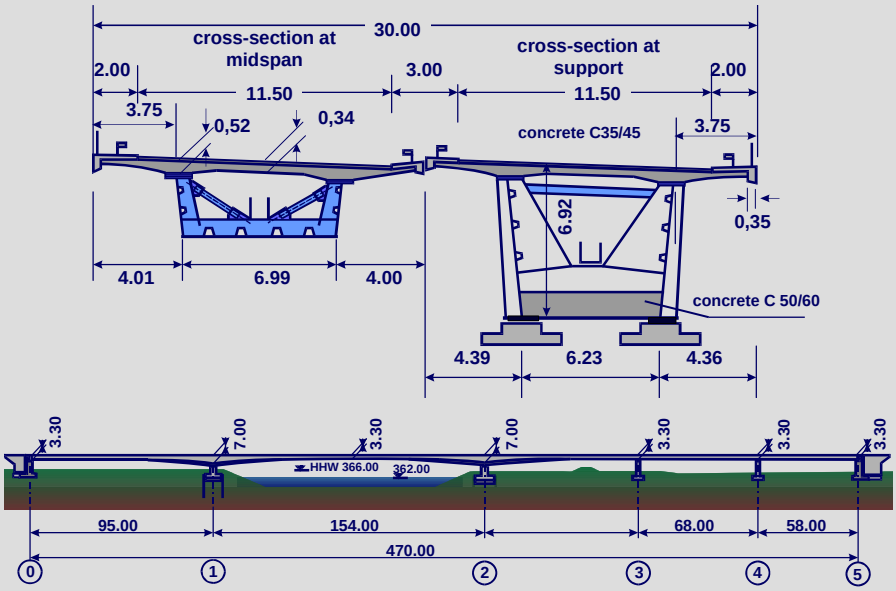
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Bridge across the river Ruhr near Hagen-Freeway A1



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Bridge Neuötting -Double composite box girder



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Double composite bridge Neuötting



box girder with double composite action at internal supports





composite bottom flange

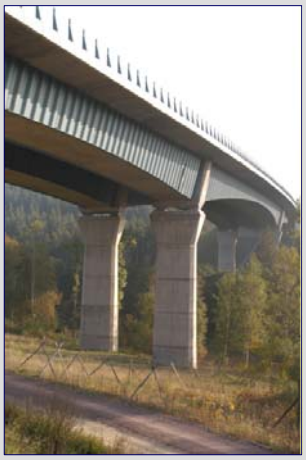
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Box girders with corrugated webs



Bridge Altwipfergrund

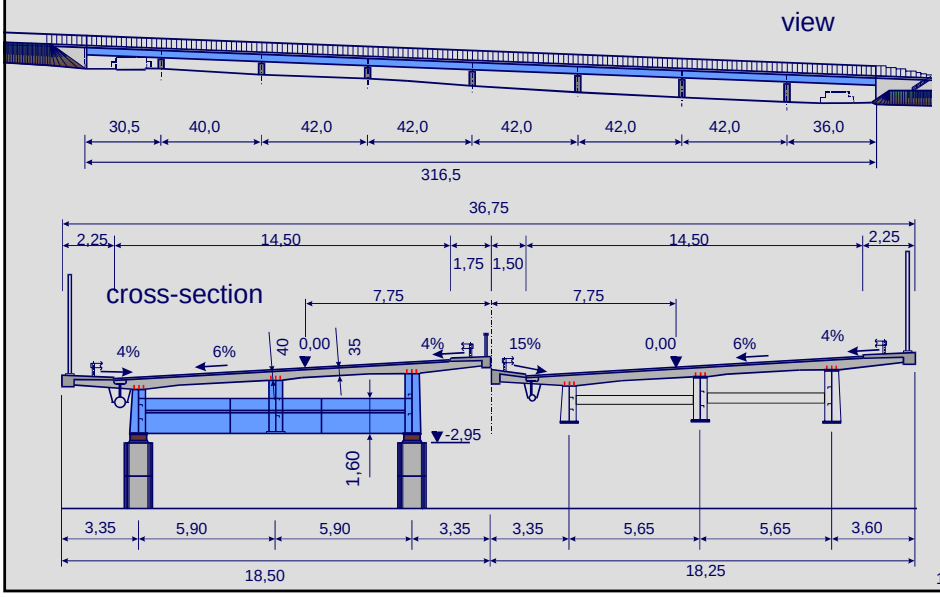




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Bridge Langerfeld – Freeway A1



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Langerfelder Bridge – Highway A1



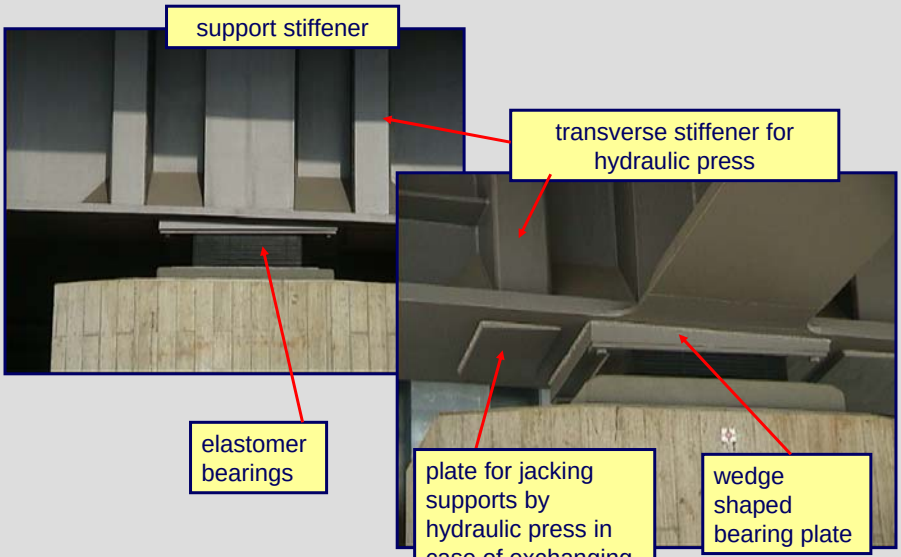




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Langerfelder Bridge – Highway A1
Detailing at internal supports



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Composite box girders with wide cantilevering concrete decks



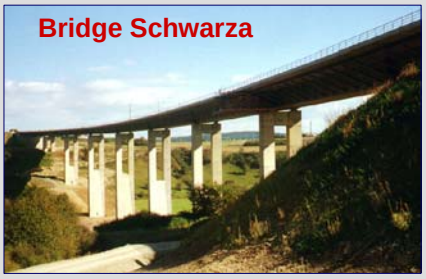
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Composite box girders with wide concrete decks



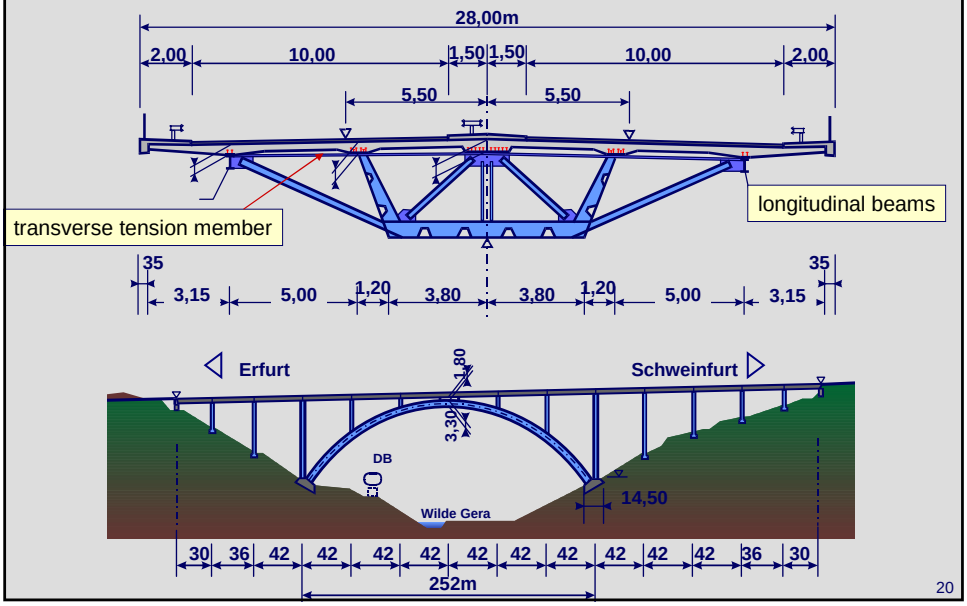






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Bridge Wilde Gera



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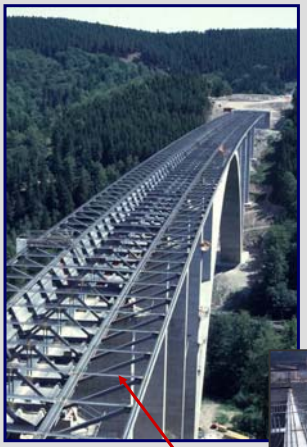
Bridge Wilde Gera






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Bridge Wilde Gera – Highway A71







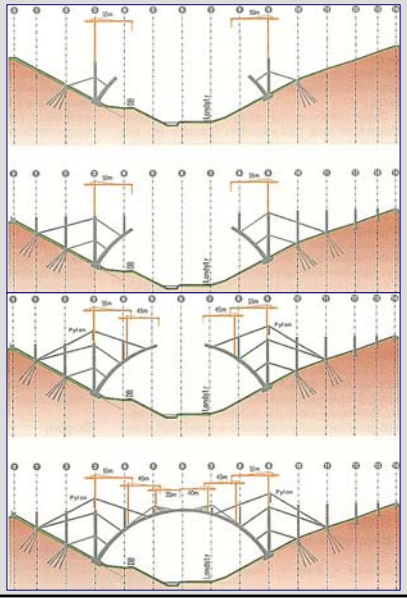
transverse steel tension members

transverse frames

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Bridge Wilde Gera – Highway A71







cantilever erection of the arch

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Bridge Wilde Gera – Highway A71



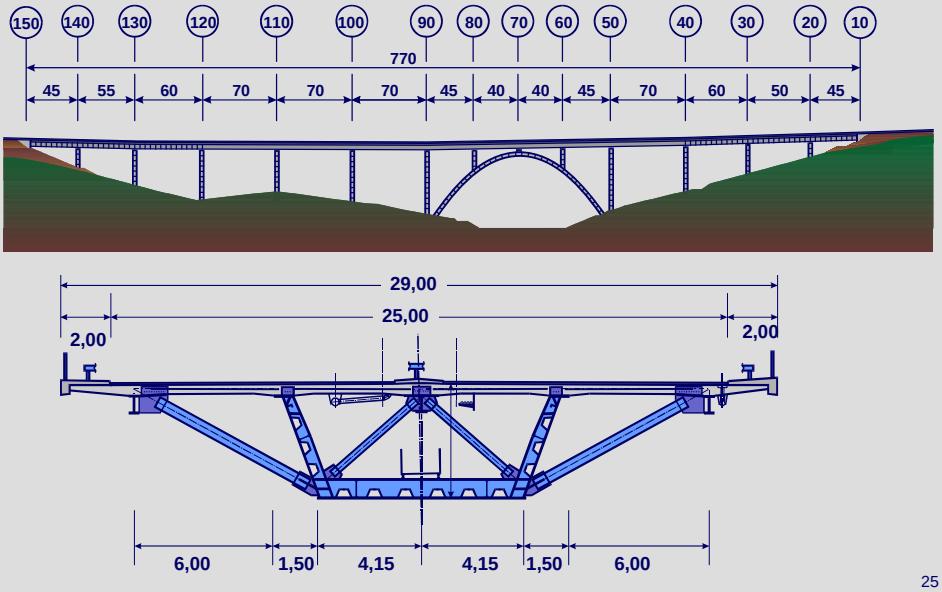


Bridge girder during launching

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Bridge Albrechtsgraben - Highway A71



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Bridge Albrechtsgraben - Highway A71





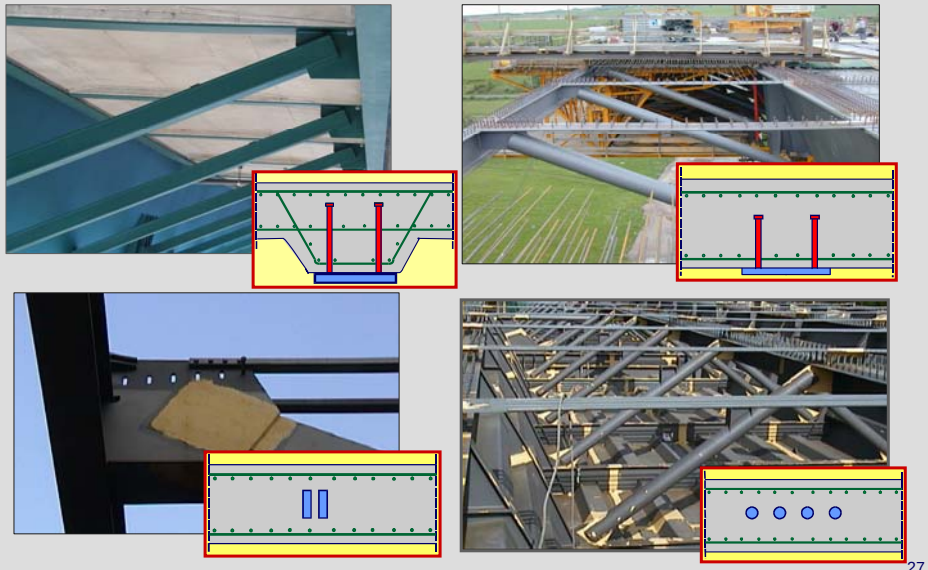




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Different detailing of transverse tension members



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Joints between the longitudinal girders/box girders and the transverse tension members





Bridge Schwarza

Bridge Albrechtsgraben

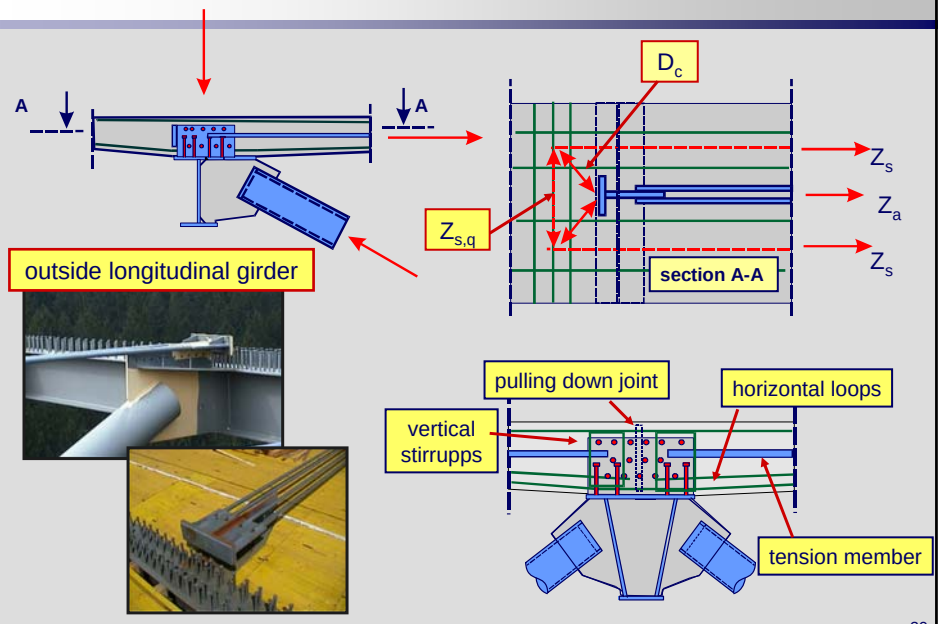




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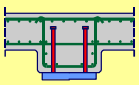
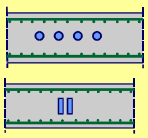
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Detailing of the transverse tension members



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Acessment of different solutions for transverse tension members

	geometry of the concrete slab	internal forces in the tension member	connections
	a constant depth of the slab over the total width of the bridge deck is required, uni-axial load transfer in transverse direction	high stresses due to local concentrated wheel loads (Fatigue resistance)	economical simple connections with the top flanges of the box girder and the secondary longitudinal girders
	haunched concrete slab, expensive formwork, bi-axial load transfer in transverse and longitudinal direction	higher stresses due to local loads. Resistance of the tension member to normal forces, bending moments and vertical shear should be considered	
	slabs with constant depth and haunches in longitudinal direction are possible, uni-axial load transfer in transverse direction	no significant stresses in the steel tension member due to local loads	complicate connection caused by the eccentricity between the tension member and the top flanges of the box girder

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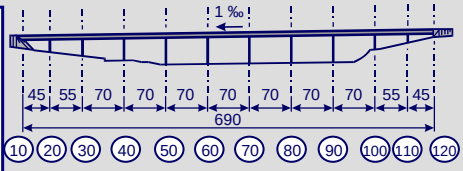
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Sequense of casting of concrete

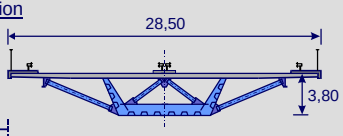
Method I : continuous in one direction

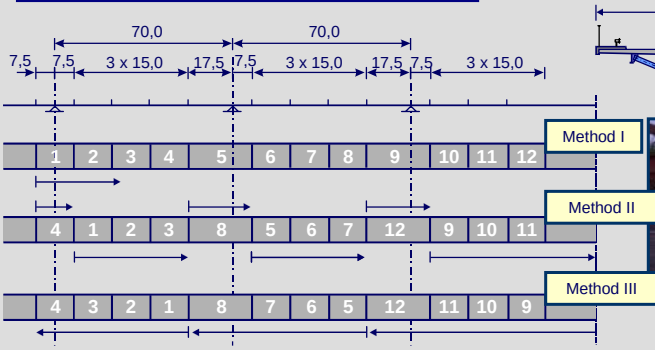
Method II: continuous in one direction but regions at internal supports are casted in a second step after the concrete in mid-span regions is effective

Method III: span-wise in reverse direction



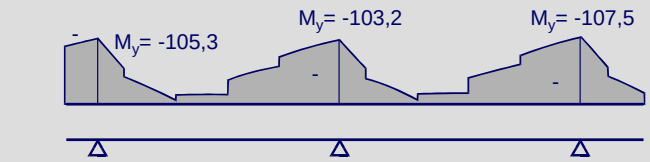
cross-section



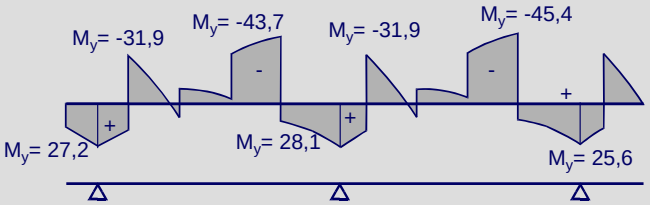




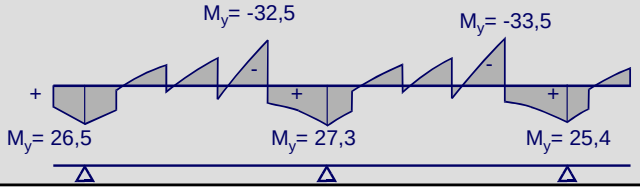
bending moments acting on the composite section due to dead weight of concrete



Method I



Method II

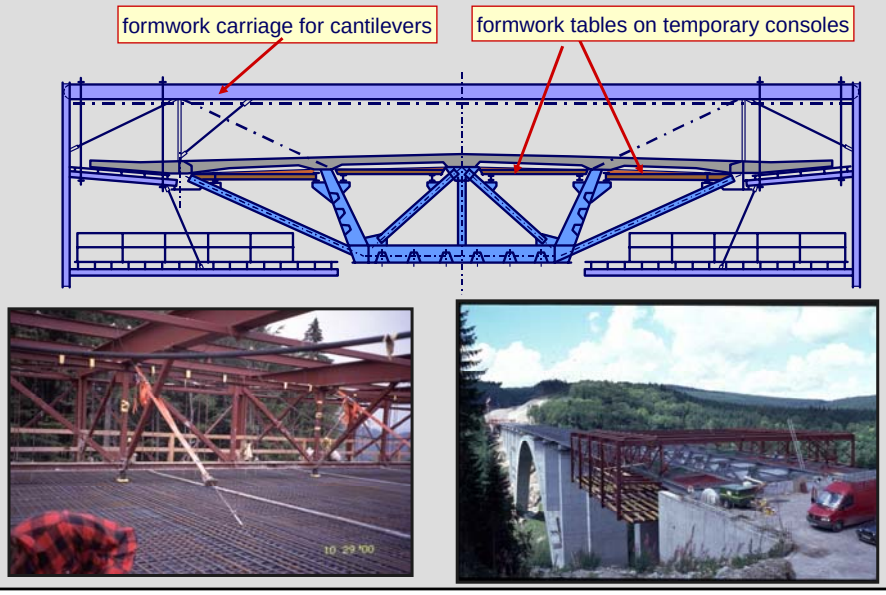


Method III

[M_y in MNm]

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Formwork carriage running on the top of the deck



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Formwork carriage running on the top of the deck

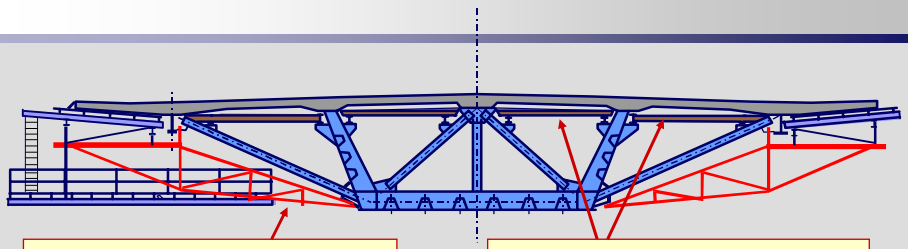


Bridge Wilde Gera

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Formwork underneath the concrete deck



formwork carriage for outer cantilevers

formwork tables on temporary consoles





Bridge Albrechtsgraben

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Formwork underneath the concrete deck (system Kirchner)









Bridge Schwarza

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Exchange of concrete decks



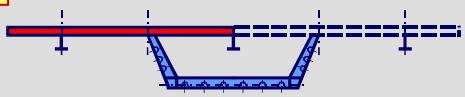
Normally it is a general requirement in Germany to have separate bridges for each traffic direction in order to be able to divert the full traffic on the remaining bridge in case of major maintenance work on the other. The concrete deck is the most vulnerable part of a bridge section. With regard to the expected intensive increase of road traffic and local wheel loads in future, the concrete deck must be regarded as a wearing part in contrast to the steel structure with implication of different lifetimes of the concrete deck and the steel structure.

In case of one main composite box girder for both traffic directions the flow of traffic has to be maintained in both directions just on one half of the bridge during a future replacement of the bridge deck. For this procedure the bridge deck will be partially cut out with high-pressure water method and will be replaced by a new bridge deck. During this procedure significant additional stresses result in the superstructure, which have to be considered during design and construction.

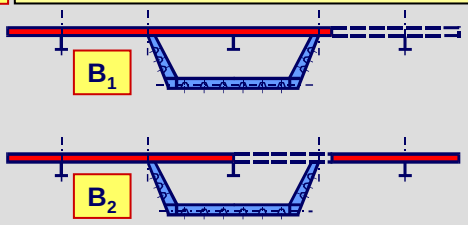
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Different possibilities for the exchange of the concrete slab

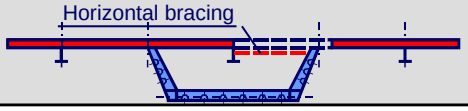
A exchange of one half of the deck



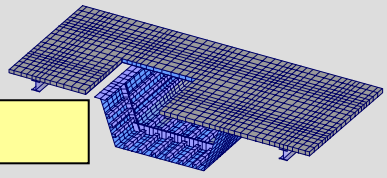
B exchange over a quarter of the bridge in two steps



C exchange of one half of the deck with additional horizontal bracing



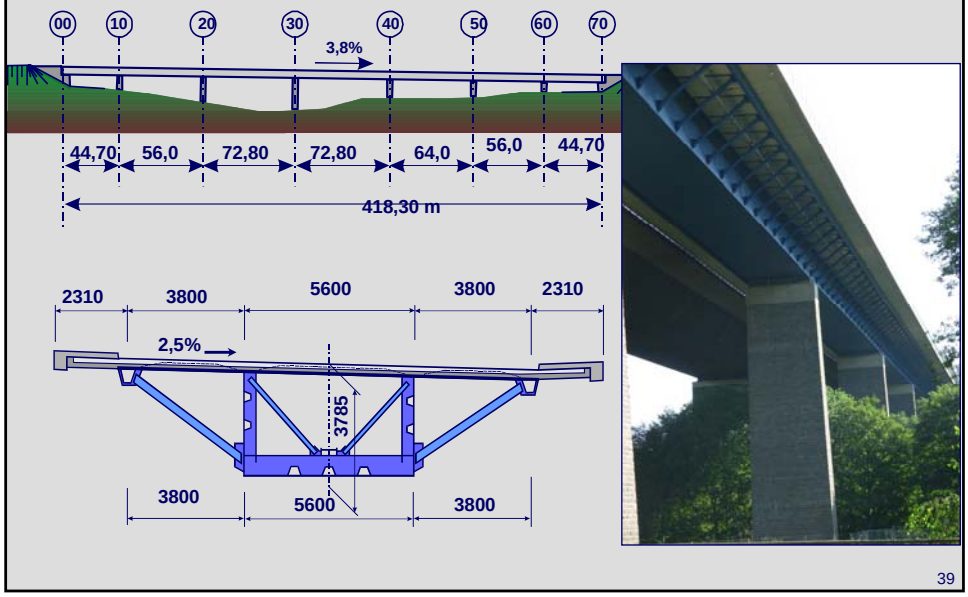
The width of the span is the most important factor for choosing the different methods. Method *A* can only be used for spans up to 50 m. Methods *B* or *C* are possible for the exchange of the concrete deck of bridges with larger spans of up to 100 m.



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Bridge Oehde – Freeway A1



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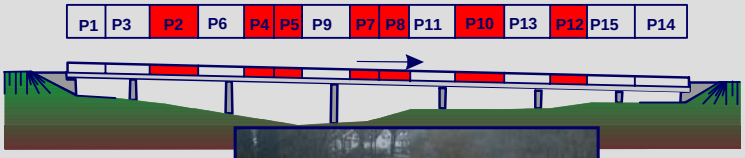
Bridge Oehde – Freeway A1



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Bridge Oehde – Freeway A1





concrete deck with partially prefabricated concrete elements



launching of the bridge with partially prefabricated concrete elements

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Composite bowstring arches



Saalebridge Besedau

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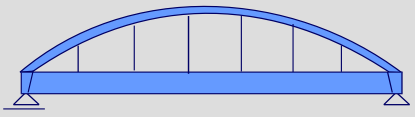
Composite bow string arches



Composite bow string arches with concrete decks are an often used system where the construction depth is limited e.g. for bridges over canals and rivers.The reinforced concrete deck is connected with the steel structure by horizontal bracings at the end of the bridge and is acting as a tension member in the main system.

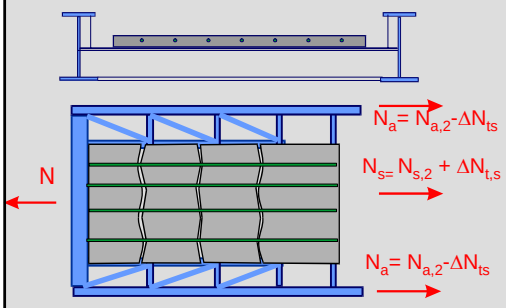
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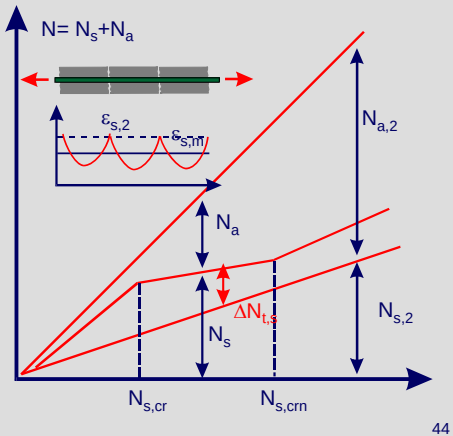
Normal forces in the concrete tension member



For the normal forces in the concrete member the effects of tension stiffening of concrete between cracks should be considered.

The concrete member acts as a tension member in the main system.





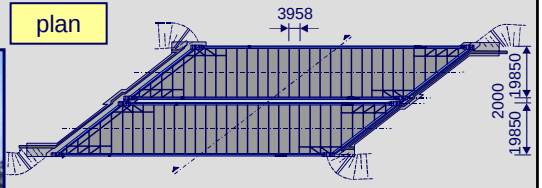
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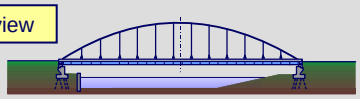
Bridge Ladbergen near Ladbergen– Highway A1



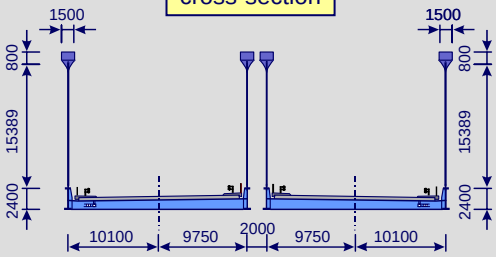
plan



view



cross-section





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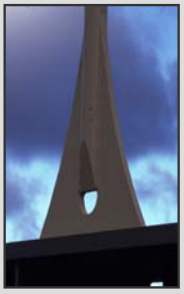
Detailing of composite bowstring arches







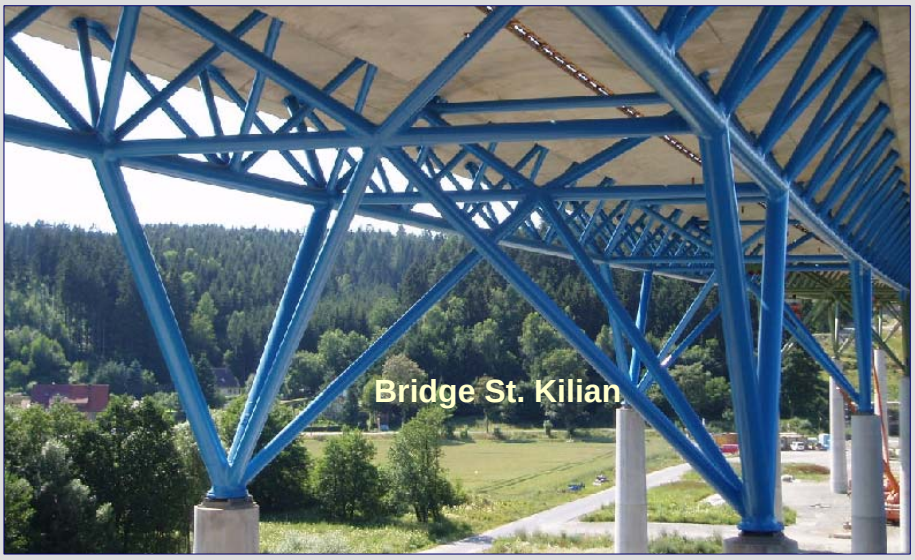




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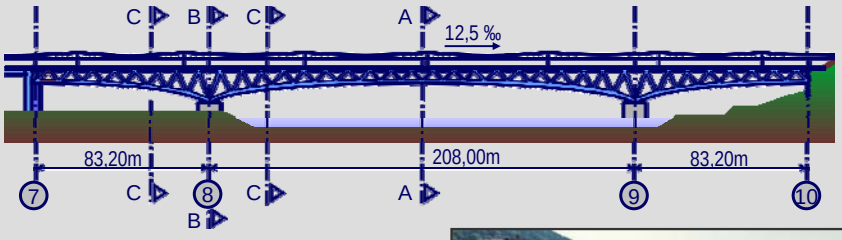
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Composite trusses



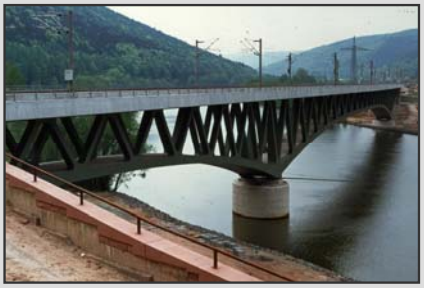
47

Composite truss bridge with double composite action – Bridge Nantenbach across the river Main



view

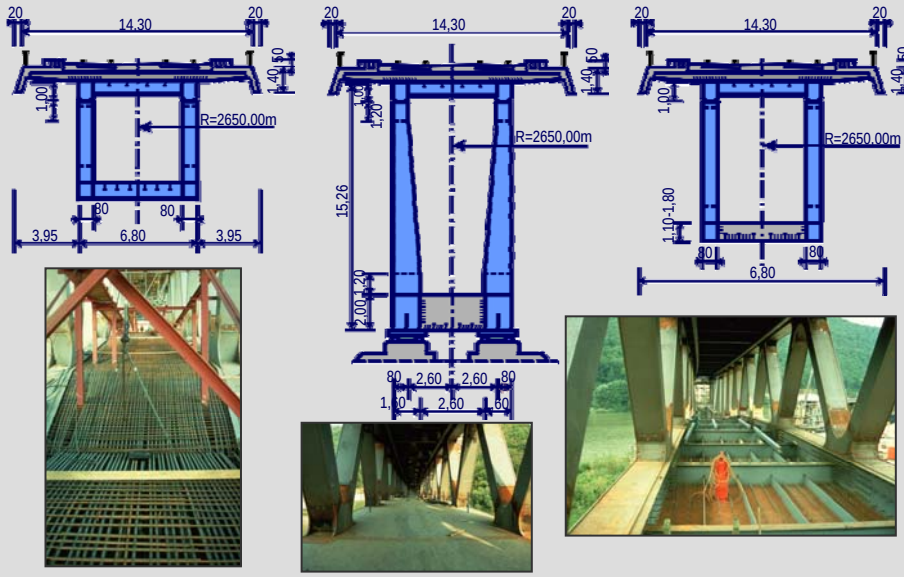




48

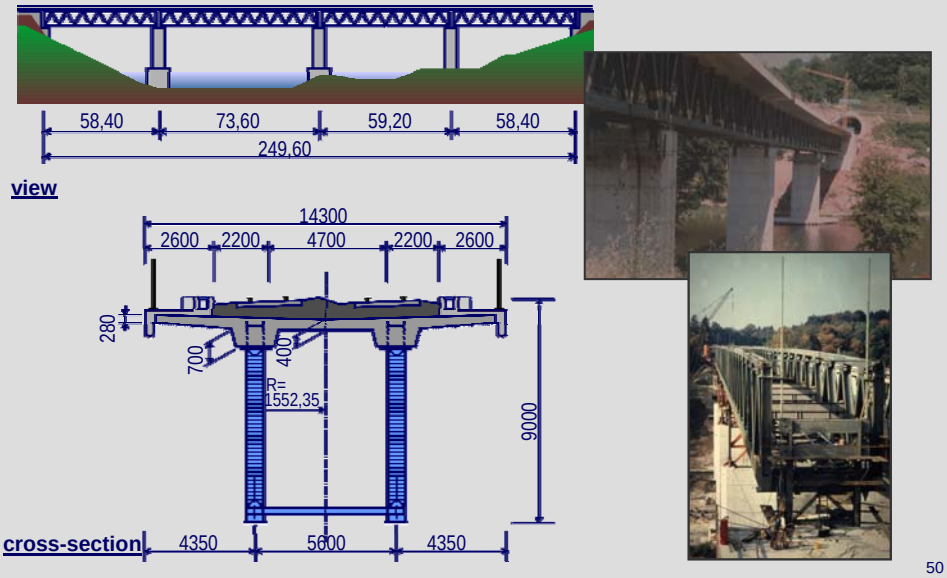
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Composite truss bridge with double composite action – Bridge Nantenbach across the river Main



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Composite truss bridge Kragenhofer



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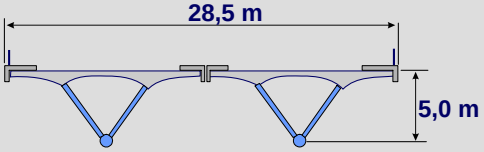
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Bridge St. Kilian









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Bridge St. Kilian







steel trusses with hollow sections and cast iron nodes



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Composite bridges for small and medium spans



Bridge Oberhartmannsreuth

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Composite bridges with rolled sections for small an medium spans





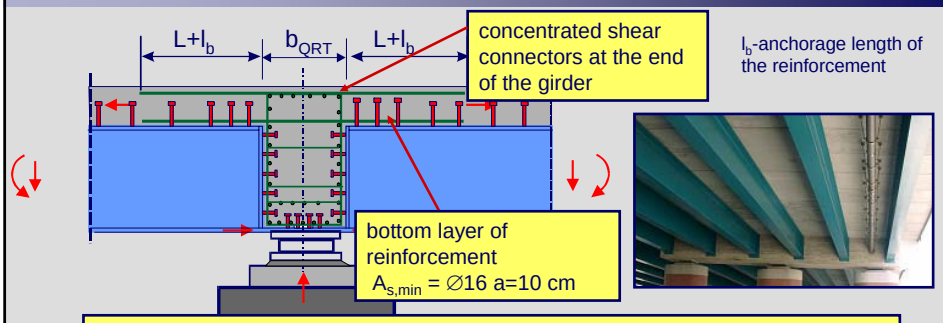
Advantages

- short construction time
- simple erection method because of no steelwork on site.
- steelwork only in the shop
- small total depth of the composite section
- concrete slab without any pre-stressing

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Longitudinal reinforcement at internal supports



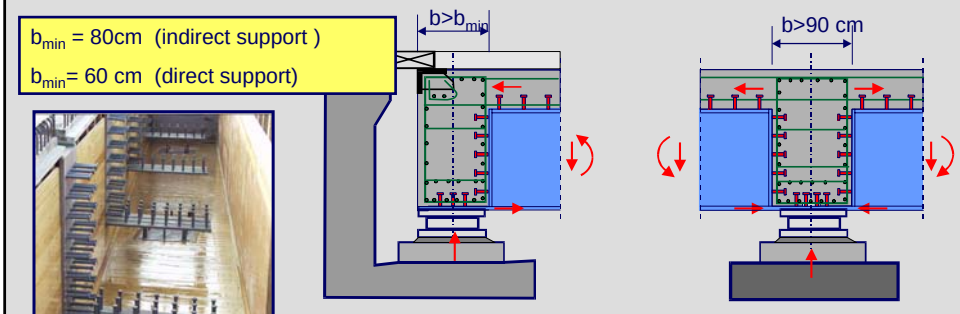
- The longitudinal reinforcement at internal supports should be placed over a length not smaller than L= 0,15 L_{St} where L_{St} is larger span length adjacent to the support considered.
- at the end of the steel girder the number of shear connectors should be increased due to local introduction of the tensile force in the reinforcement in the composite section.
- In case of sagging bending moments at internal supports due to temperature effects, traffic loads and settlements of supports for the tensile forces in the bottom flange a connection by steel plates or studs in combination with loops is required.

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Detailing of transverse supporting beams in concrete

b_{min} = 80cm (indirect support)

b_{min}= 60 cm (direct support)





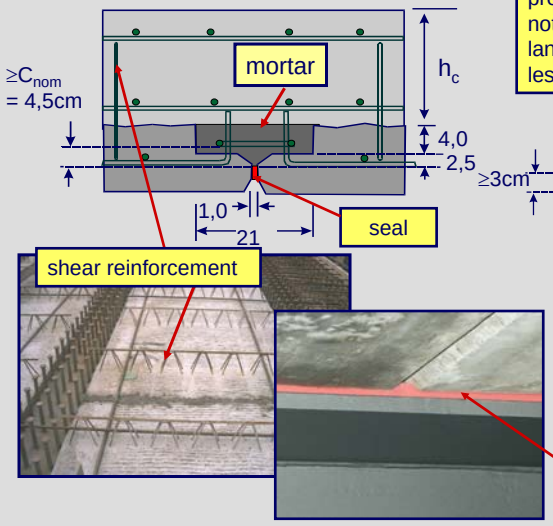


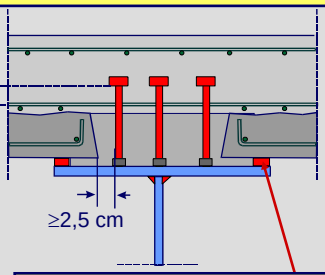
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Detailing of partially prefabricated concrete elements

the depth of the concrete above the prefabricated elements $\mathbf{h_c}$ should be not less than 20 cm within the traffic lanes. in other regions $\mathbf{h_c}$ should not be less than 15 cm.





Elastomeric support strips with a thickness of 2 cm and a width of 3 cm. The minimum value of pressing should be 3-5 mm and the maximum value should not exceed 10 mm.

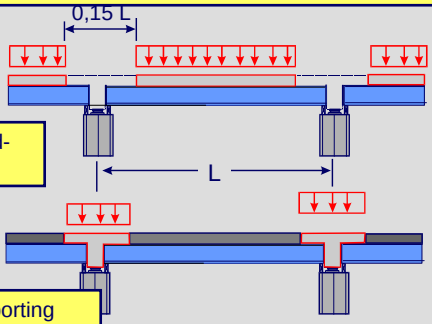
Casting of concrete



in case of smaller span length the transverse supporting beams and the concrete slab should be casted in one operation.

in case of larger span length or for bridges with a big total length at first the midspan regions and subsequently the internal supports and the transverse supporting beams should be casted.





casting of mid-span regions

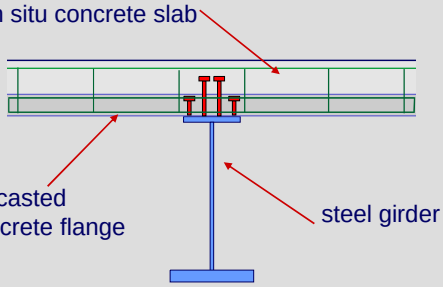
casting of supporting beams and the slab at internal support

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VFT-Bridges with welded or rolled I-sections



steel girder in the shop





installation by crane

transport on site

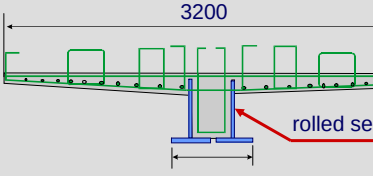


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VFT-Filler beams









shear connection

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VFT-Filler beams



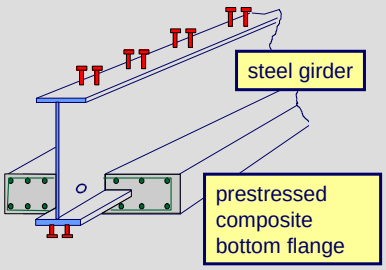






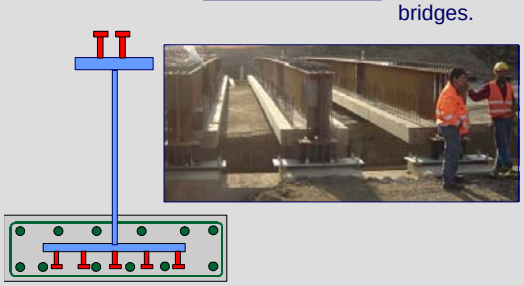
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Preflex - Beams



The Preflex-Beam is a girder with a pre-stressed composite bottom flange where the pre-stressing is applied by elastic bending of the steel girder.

The pre-stress causes a higher bending resistance and a high flexural stiffness. Therefore the deflections under serviceability conditions very small. This type of beam is often used for railway and road bridges where the available construction depth is highly restricted. Ratios of span to structural depth up to 45 are possible for road bridges.

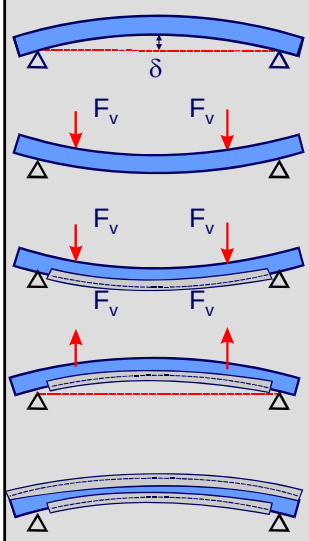


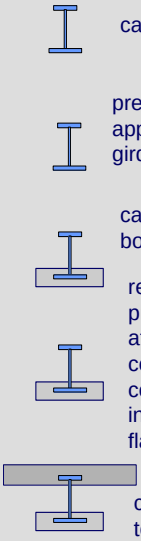


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Preflex Girders – pre-stressing of the concrete bottom flange





campered steel girder

pre-stressing forces F_v applied to the steel girder (elastic bending)

casting of the concrete bottom flange

removing of the prestressing force F_v after hardening of concrete causes compressive stresses in the concrete bottom flange

casting of the concrete top flange on site





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Composite bridge with Preflex-Girders





Hermann-Lieberum Bridge in Leipzig

continuous beam, span 33 m and construction depth 130 cm



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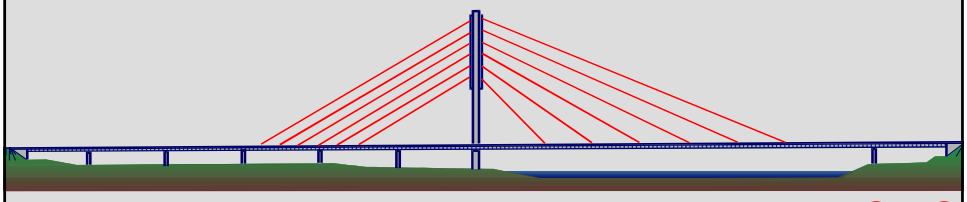
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Cable stayed bridges



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cable stayed bridge Wesel across the river Rhein



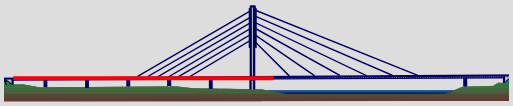




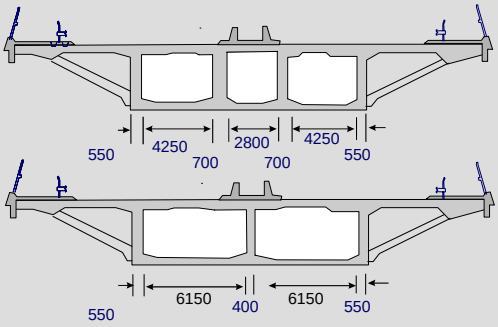
66

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Cable stayed bridge Wesel across the river Rhein



cross-section axes 10 - 70

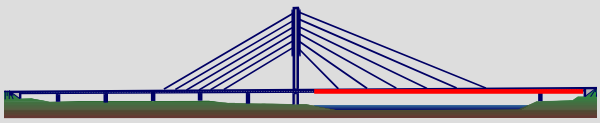




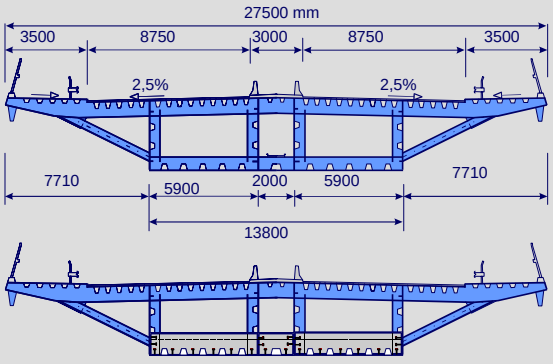


67

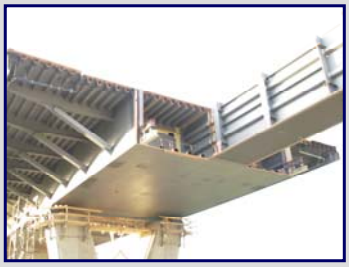
Cable stayed bridge Wesel across the river Rhein



cross-section axes 70 - 90







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Joint between the steel and the concrete section – concrete end cross girder







joint with overlapping steel plates and headed studs



concrete end cross girder

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concrete end cross girder



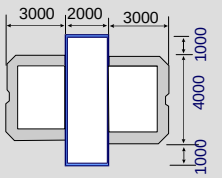


70

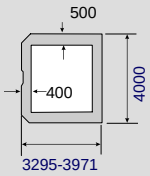
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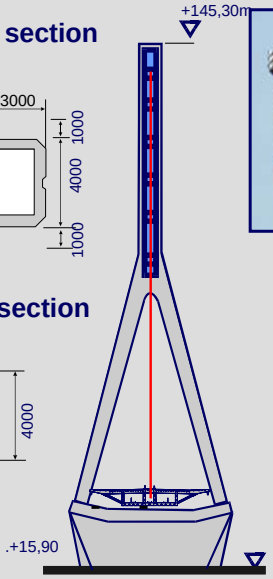
Pylon in high strength concrete

composite section



concrete section

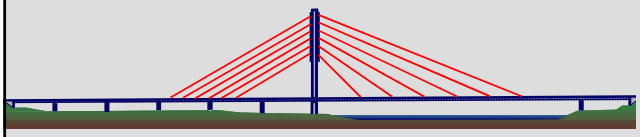






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cables





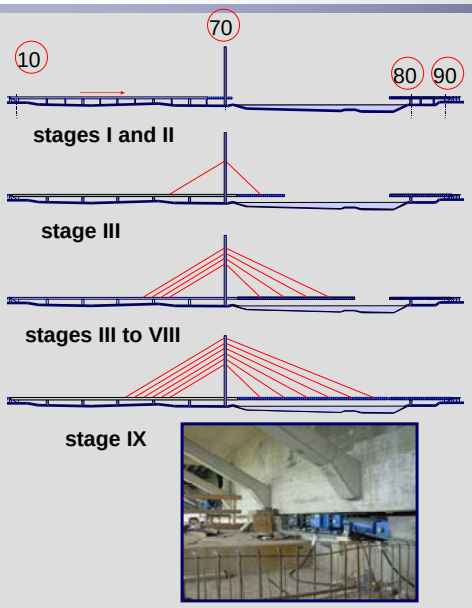


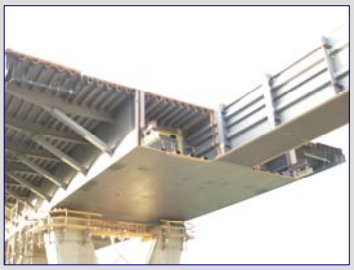
Use of parallel strand cables of galvanized waxed and PE-coated strands instead of traditionally used fully locked coil ropes.

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erection stages







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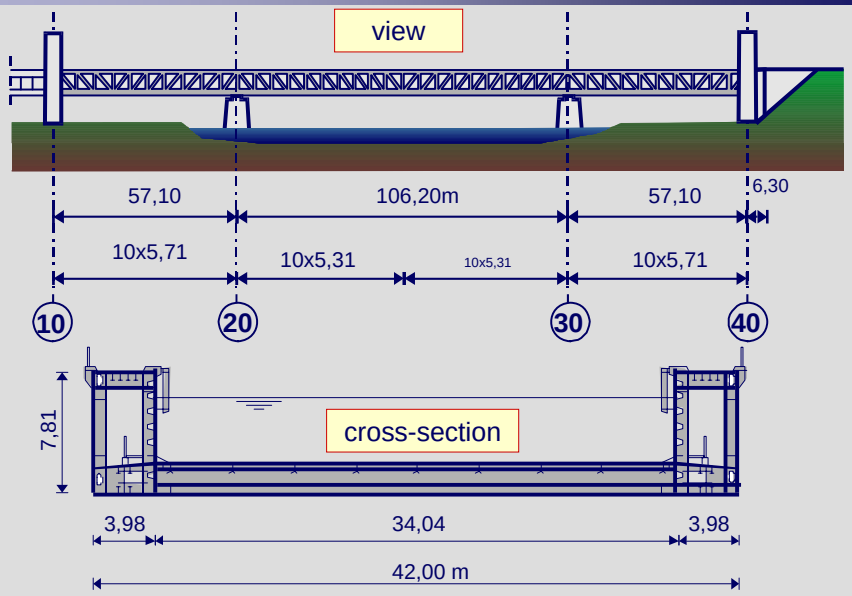
Canal bridges



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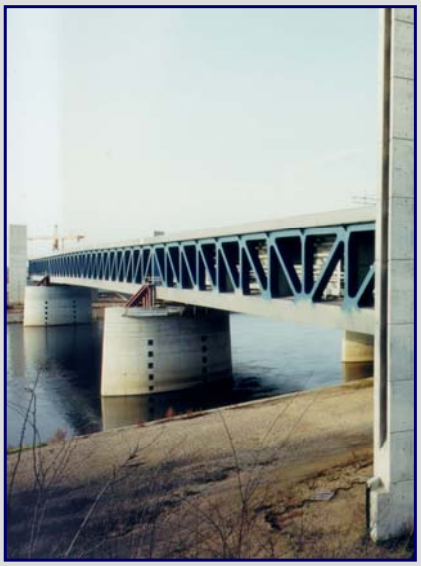
Canal bridge Magdeburg



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Canal bridge Magdeburg





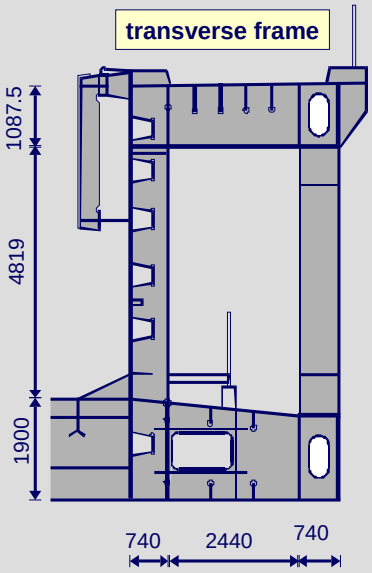
total length 228 m
span length 57,1 m – 106,2 m – 57,1 m
Structural steel 9.500 t

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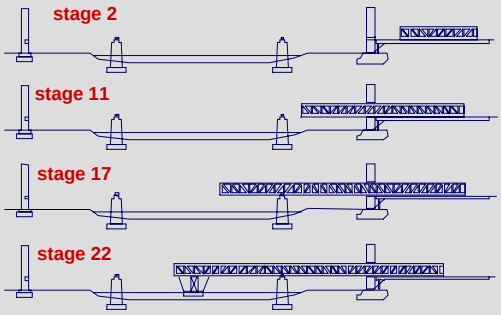
Canal bridge Magdeburg





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Launching of the bridge





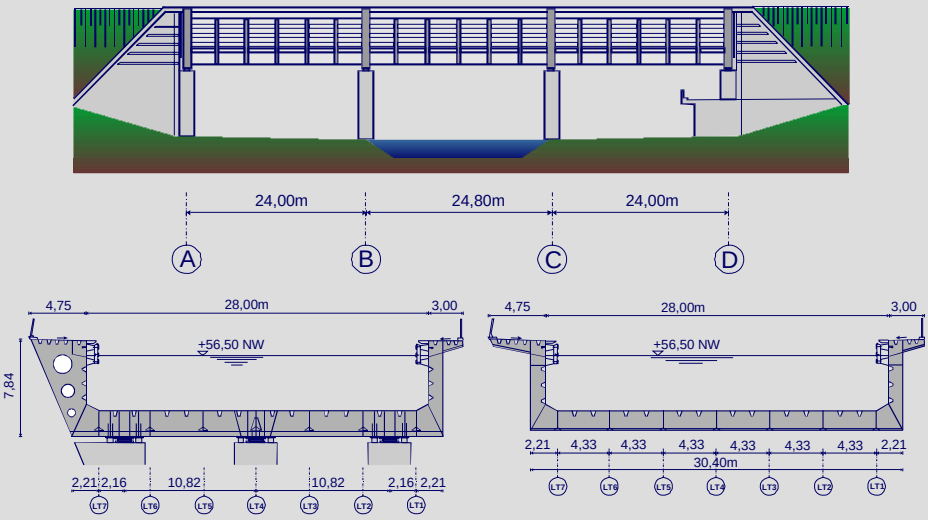




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Canal-bridge Lippe



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Canal-bridge Lippe



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Thank you very much for your attention





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