Eckhard Held, Stefan Kimmich, Roland Sauer
RIB Engineering GmbH Stuttgart

# Innovative Bridges with Short Construction time in Modular Design

**Eckhard Held**
Team Leader Bridge Cons.

*Technical Academy Esslingen - 4. Bridge Colloquium*

# Innovative Bridge with Short Construction time in Modular Design

# Overview

1. Introduction

2. Advantages of the Modular Design

3. Bridge types in Modular Bridges
   *2.1 Composite Concrete Bridges*
   *2.2 Steel Composite Bridges in VFT-Construction*
   *2.3 WIB-Bridges*

4. Examples of Replacement New Buildings
   *3.1 Concrete Composite*
   *3.2 Steel Composite*
   *3.3 WIB-Bridge*

5. Summary and Conclusion

# Introduction

## Bridges in modular Construction

- Small and medium Spans (10 m to 45 m)
- Innovative Composite Structures with a High degree of Prefabrication
- Frame Bridges in Composite Construction as Overpass Structures
- Predominantly used for Replacement of new Buildings
- High Demand along Federal Highways, National Highways, Railroad lines

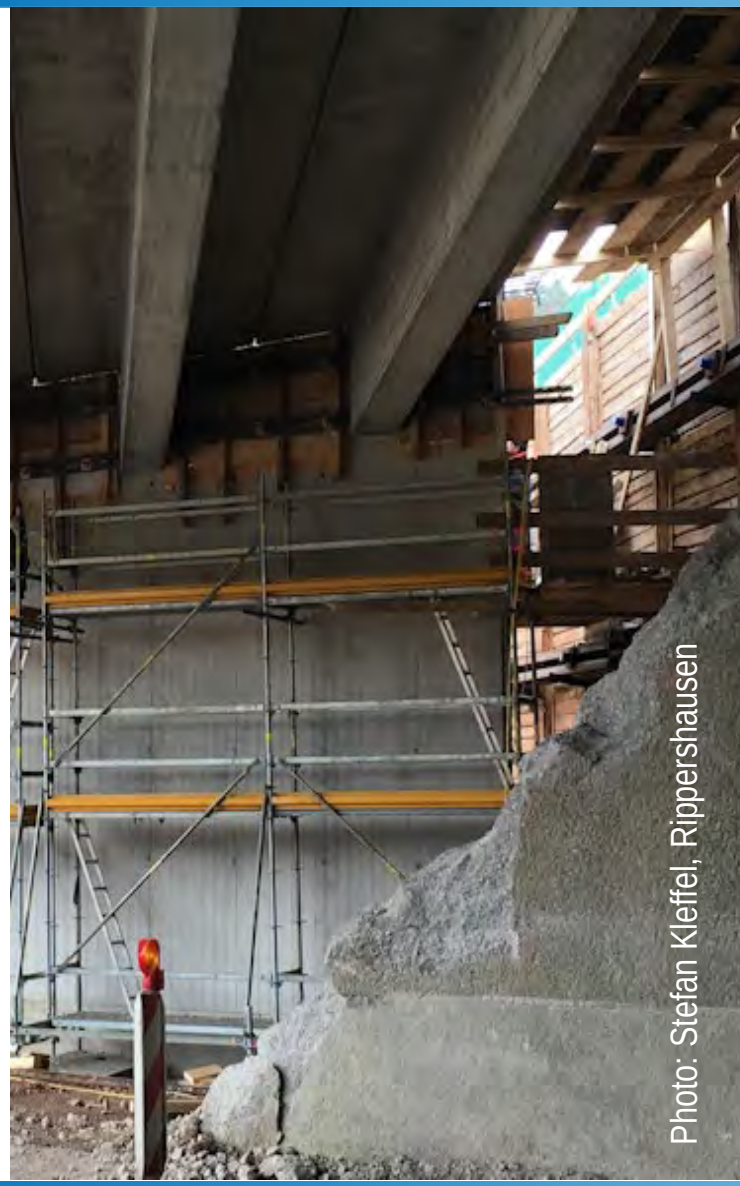


Photo: Stefan Kleffel, Rippershausen

# Advantages of the Modular Design

- Construction with Short Construction times
- Minimal Traffic obstructions and thus fewer Traffic jams
- High Quality Standard via Prefabrication of the Prefabricated-Beams
- Slender but still Robust Construction
- Elimination of Supporting Scaffolds and complex Formwork Constructions
- Parallel Dismantling/ New Construction Possible
- High Economic Effectiveness with a holistic view of Construction, usage and maintenance costs.

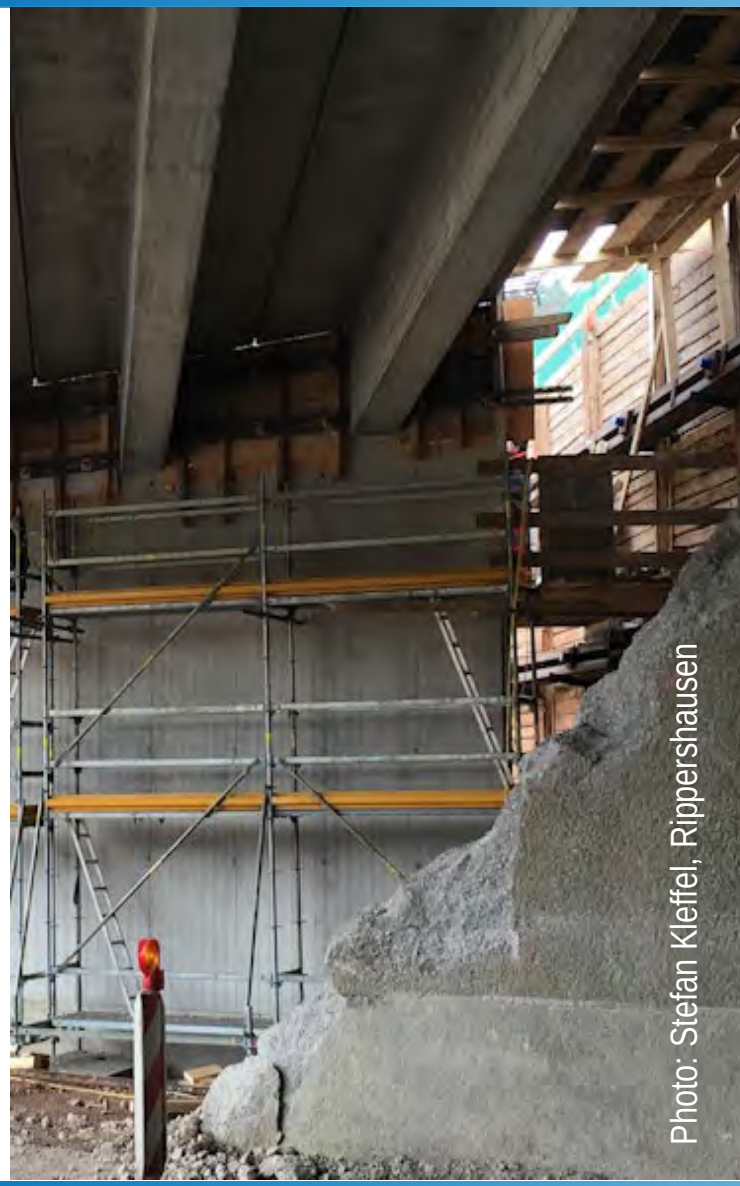
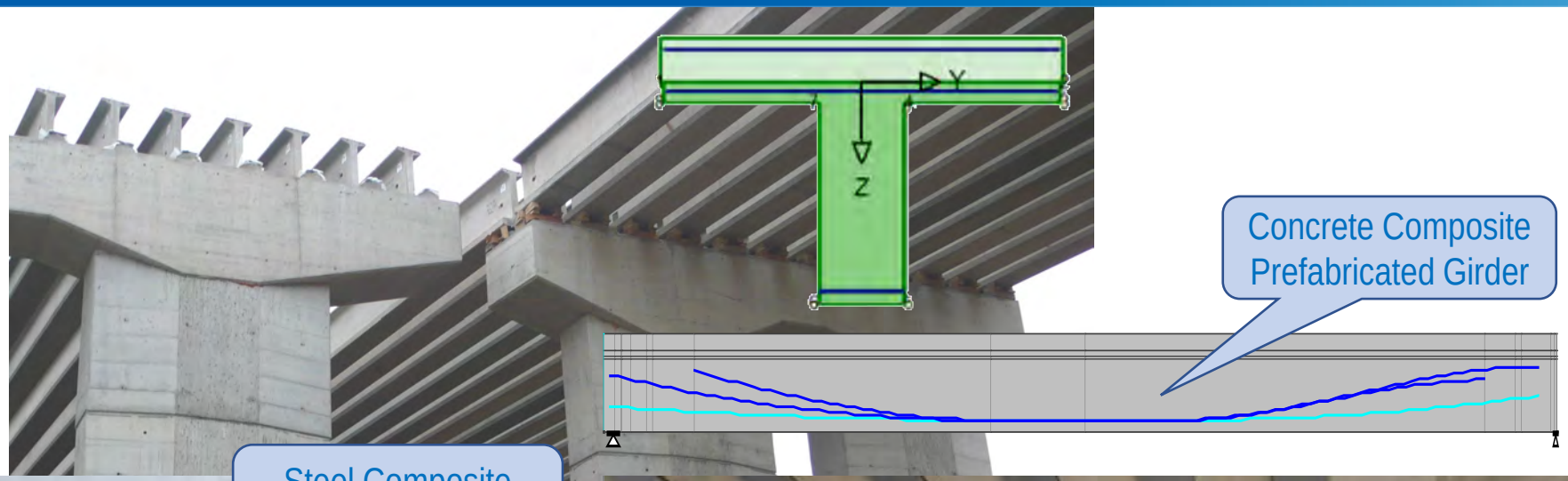
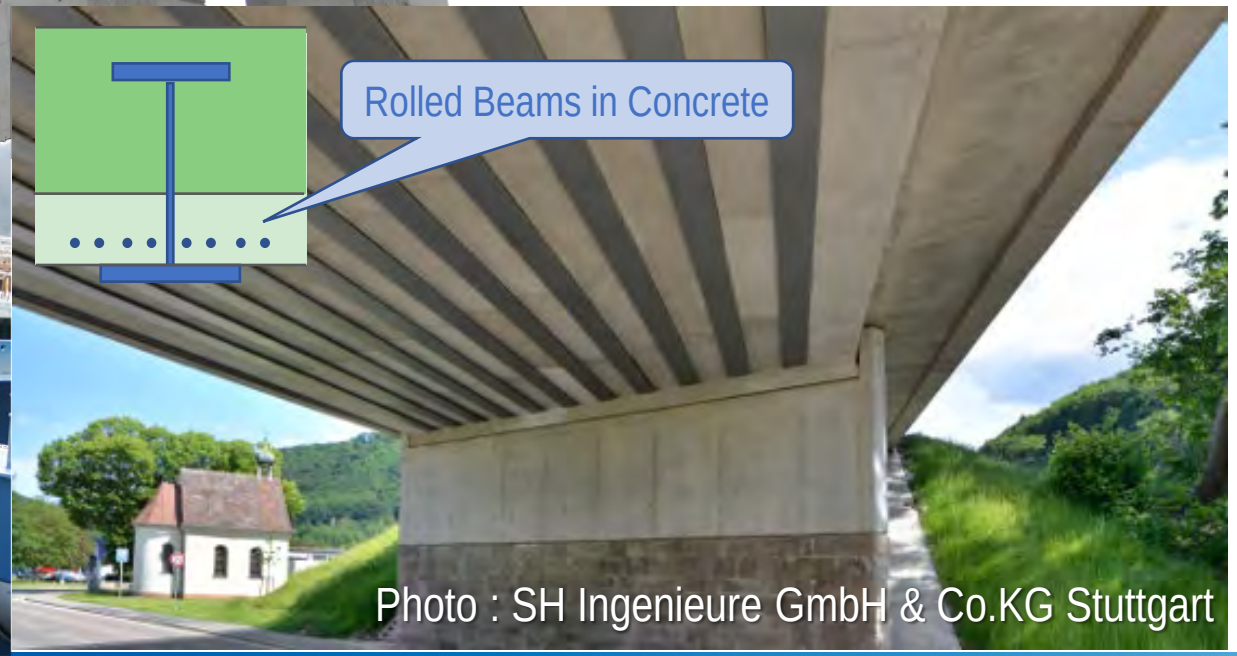


Photo: Stefan Kleffel, Rippershausen

# Different Types of Bridges in Modular Construction



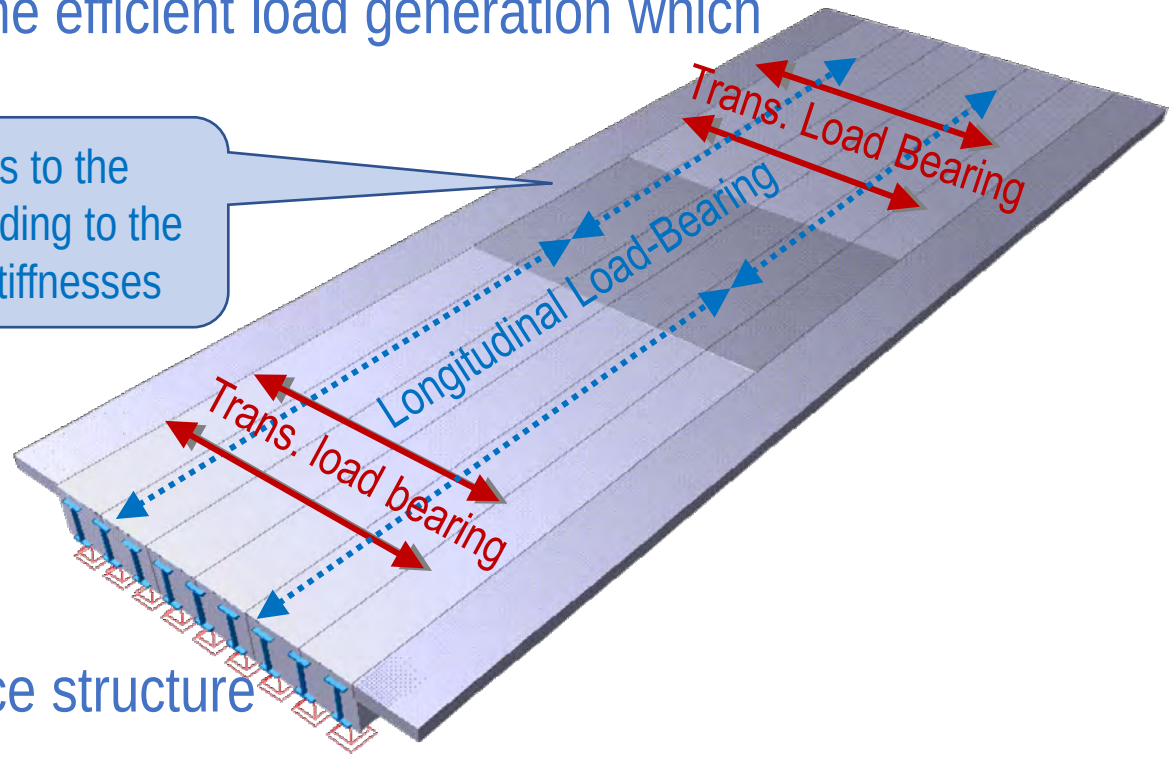


# Illustration of the Actual Bearing Behaviour

- <u>Always Processing on the Overall System</u>

  The use of combined models for beam and Folding Structure applications allows a type-specific bridge modeling and at the same time efficient load generation which supports a realistic load bearing behavior.

Transfer of the loads to the Precast- Girders according to the existing component stiffnesses

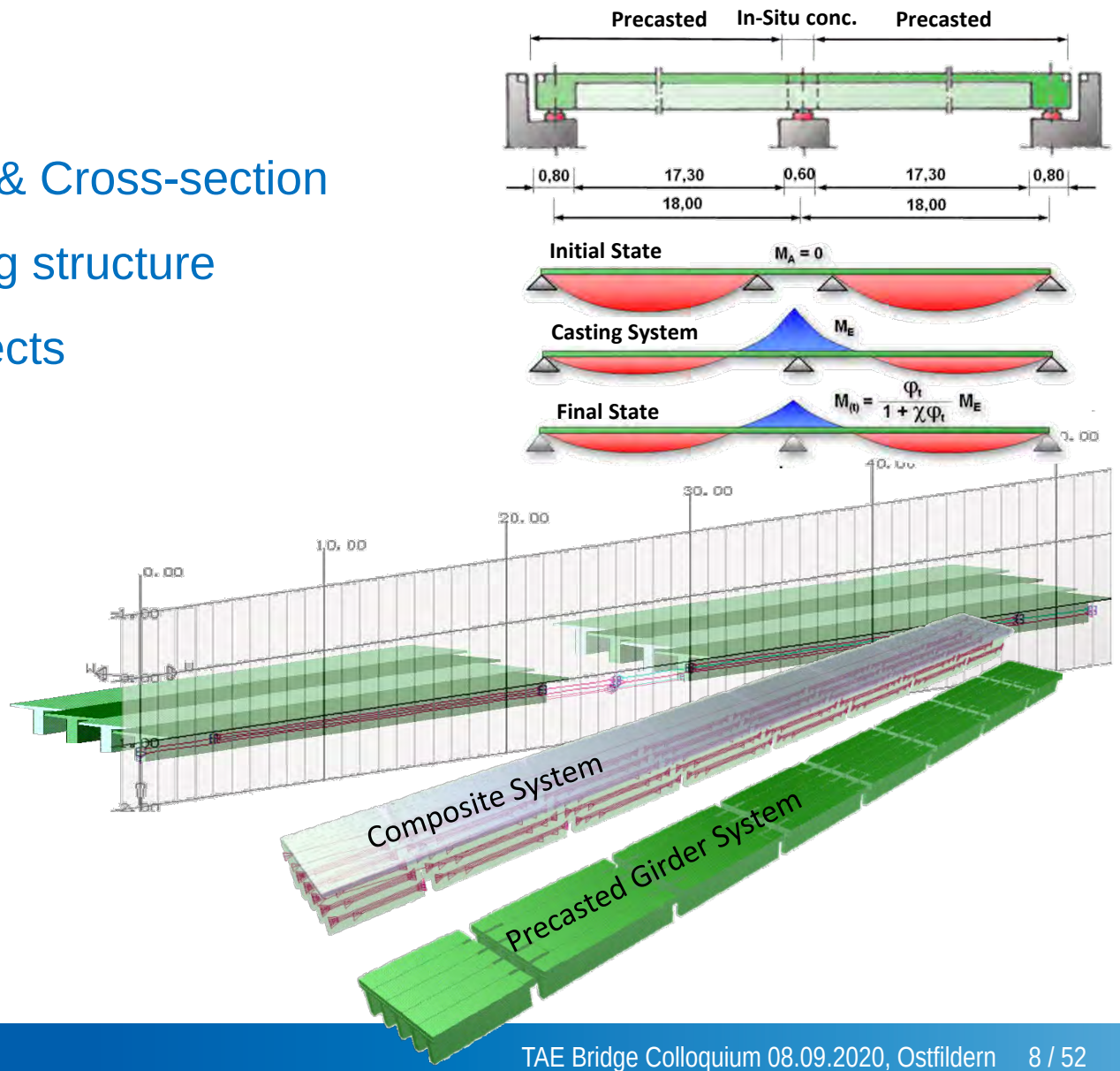



- Longitudinal Load-Bearing effect Beam structure

- Transverse Load-Bearing effect orthotropic surface structure

# Illustration of the Actual Bearing

- Consideration
  - of the history of Production, Load, & Cross-section
  - of the deconstruction of the existing structure
  - of time-dependent, secondary effects
  - of the involved Slab Widths
- use for different composite section types
- efficient Load generation by means of an orthotropic roadway(carriageway) Slab
- Complete and consistent designing of the carrier systems in ULS, SLS and FLS



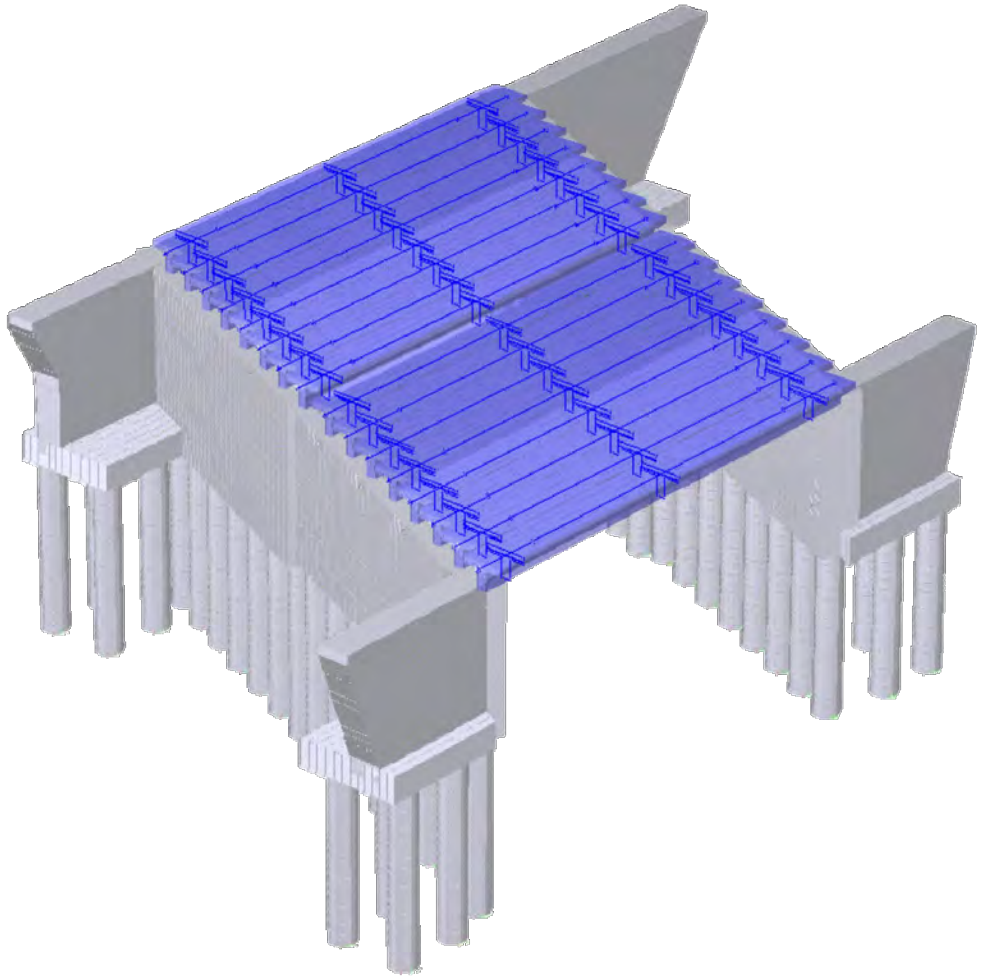
# Concrete Composite Bridge

Photo: IGS Ingenieure, Weimar

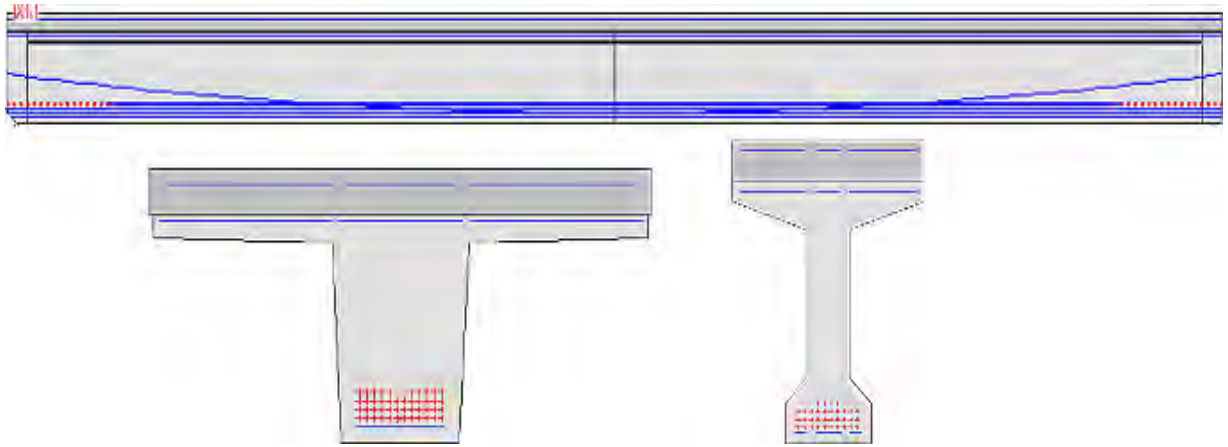
https://www.rib-software.com/loesungen/tragwerksplanung/brueckenbau/ponti-betonverbund-expert-fem-system-fuer-betonverbundbruecken

# Concrete Composite Bridge

Designed as an integral Entire Model



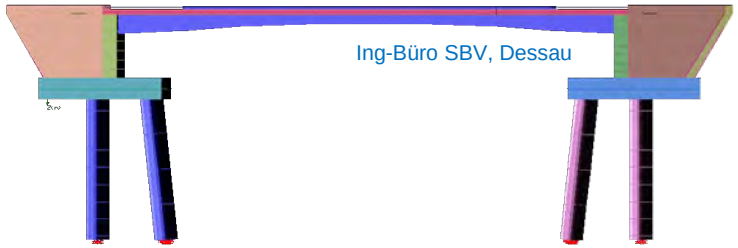
- Multi-layer T-Beams Bridge
- T- or I-Shaped semi-precast elements with In-situ concrete Filling
  - direct Bonding – one layer
  - additional Bonding – one layer
  - direct and additional Bonding – two layer
- Design as combined Model with Beams in longitudinal direction and orthotropic, load-distributing roadway slab in transverse direction.



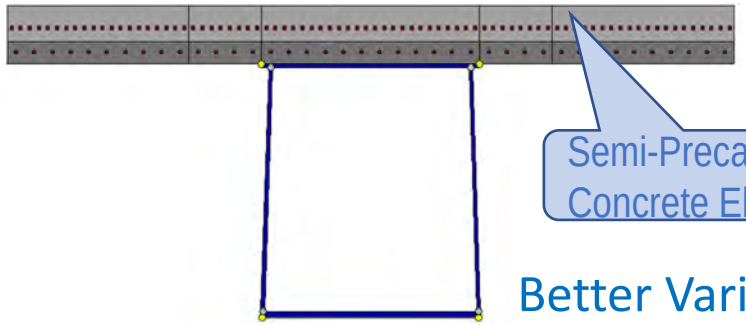
# Steel Composite Bridge in Composite-Precast-Girders Construction

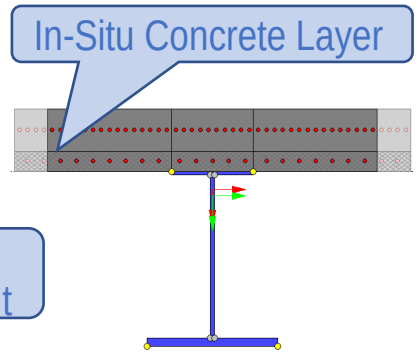
# Steel Composite Bridge in Composite-Precast-Girders Construction

## Frame Bridge with haunched Composite Girders Field widths 25 – 50 m



- Consideration of all system influences
  - Cross-Section history
  - Manufacturing and Load History
  - Influenced Slab Width
  - Crack Formation
  - Creep and shrinkage
  - secondary Effects
- Design as combined Model with Beams in longitudinal direction and orthotropic, load-distributing roadway slab in transverse direction.



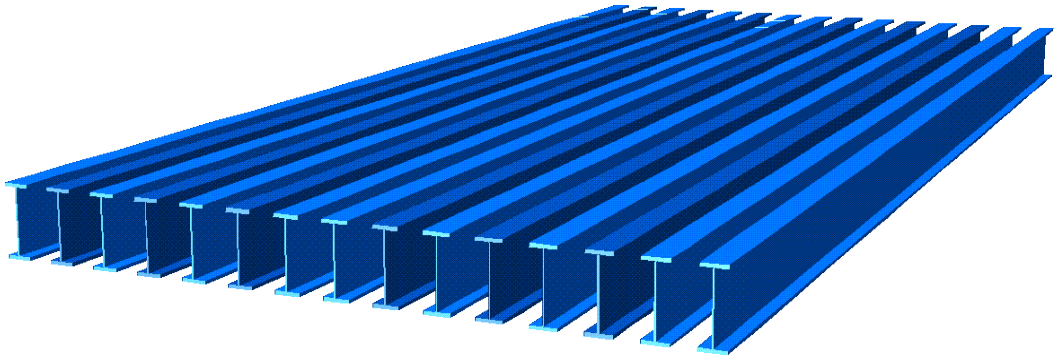

Better Variations!

# Steel Composite Bridge in Composite-Precast-Girders Construction

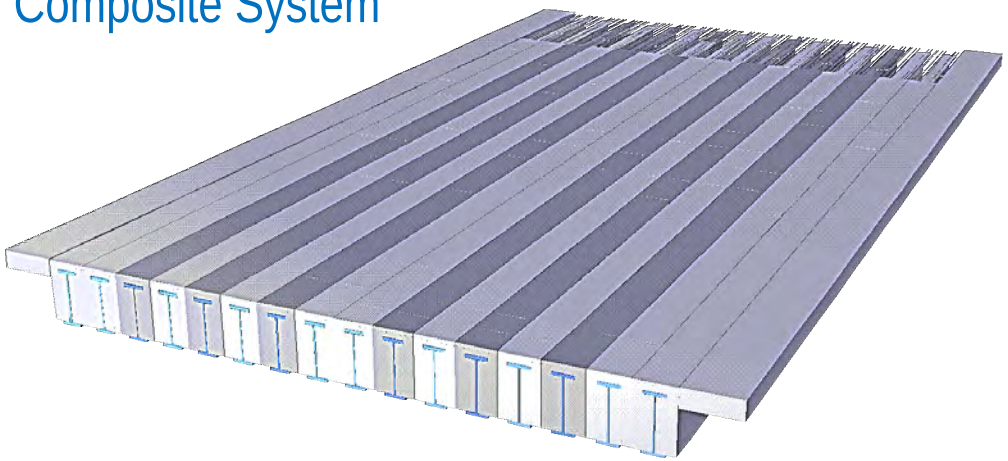
https://www.rib-software.com/loesungen/tragwerksplanung/brueckenbau/ponti-stahlverbund-wib-walztraeger-in-beton

# Rolled Beam-in-Concrete Bridge

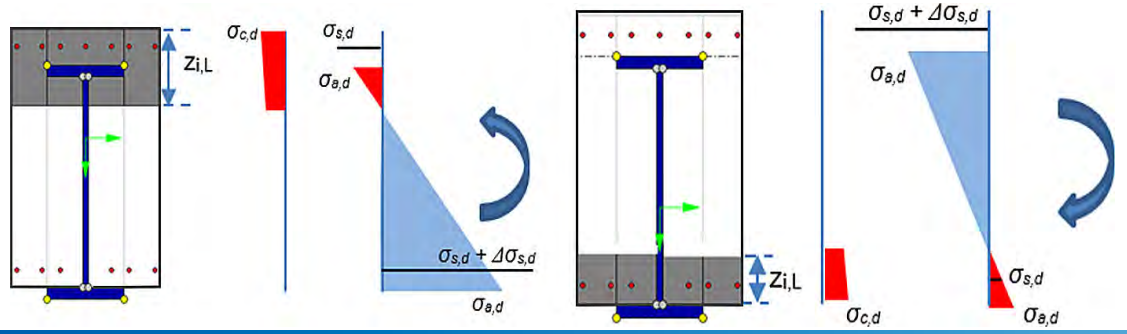
## Steel Girder System



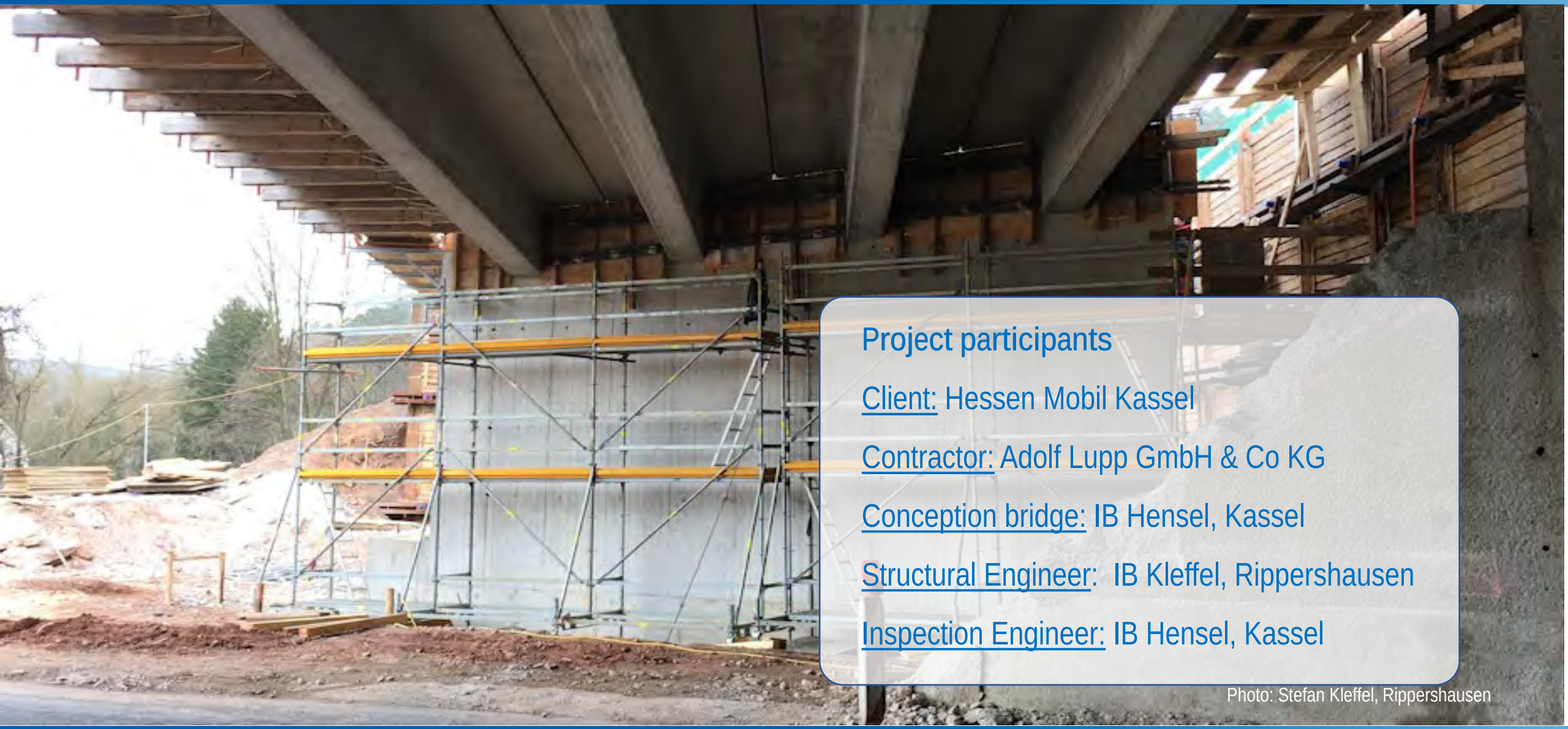
## Composite System



- Steel Girder set in Concrete
- Small spans from 10 – 20 m
- Very slender $L/h$= 25 to 30 and still relatively high stiffness
- Easy and fast assembly
- Design as combined Model with Beams in longitudinal direction and orthotropic, load-distributing roadway slab in transverse direction.
- Crack Formation
- Creep and shrinkage
- secondary Effects



# Case Study Integral Concrete Composite Bridge A7 Flensburg – Fuessen



## Project participants

Client: Hessen Mobil Kassel

Contractor: Adolf Lupp GmbH & Co KG

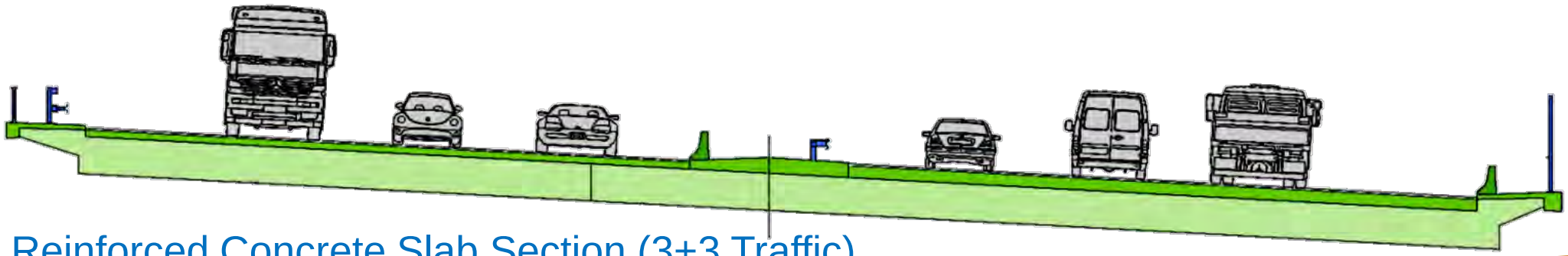
Conception bridge: IB Hensel, Kassel

Structural Engineer: IB Kleffel, Rippershausen

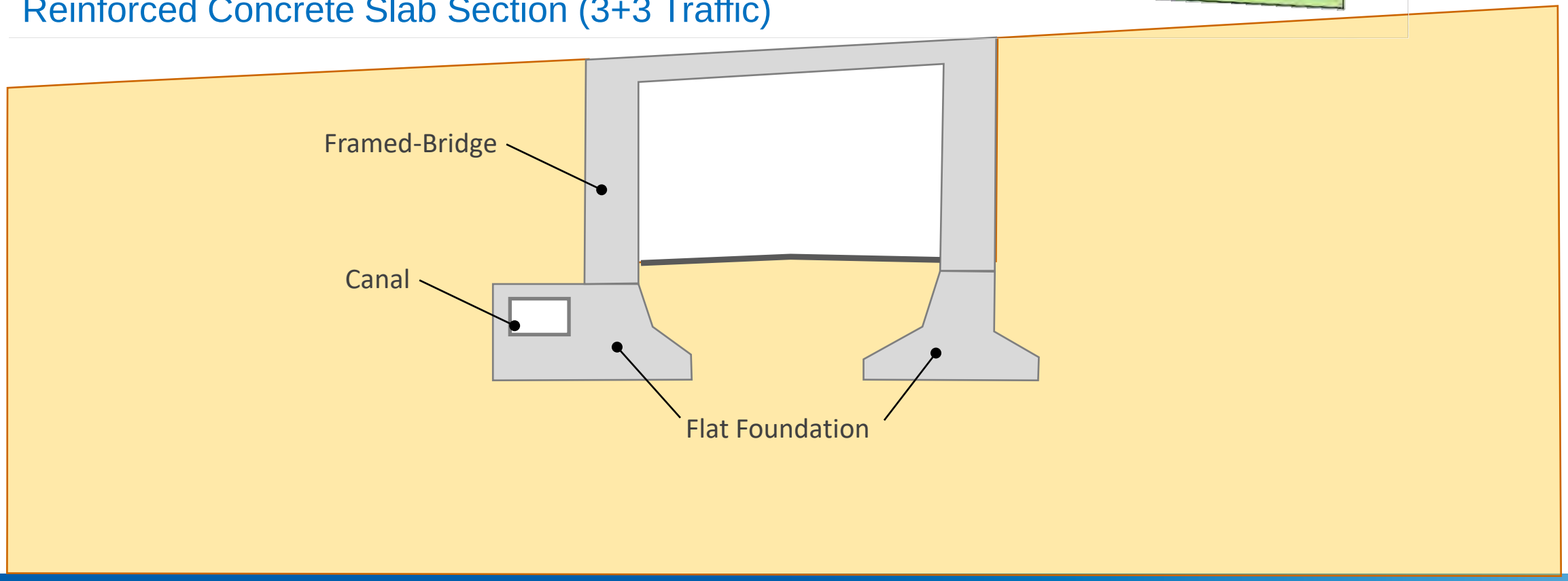
Inspection Engineer: IB Hensel, Kassel

Photo: Stefan Kleffel, Rippershausen

# Existing Structure

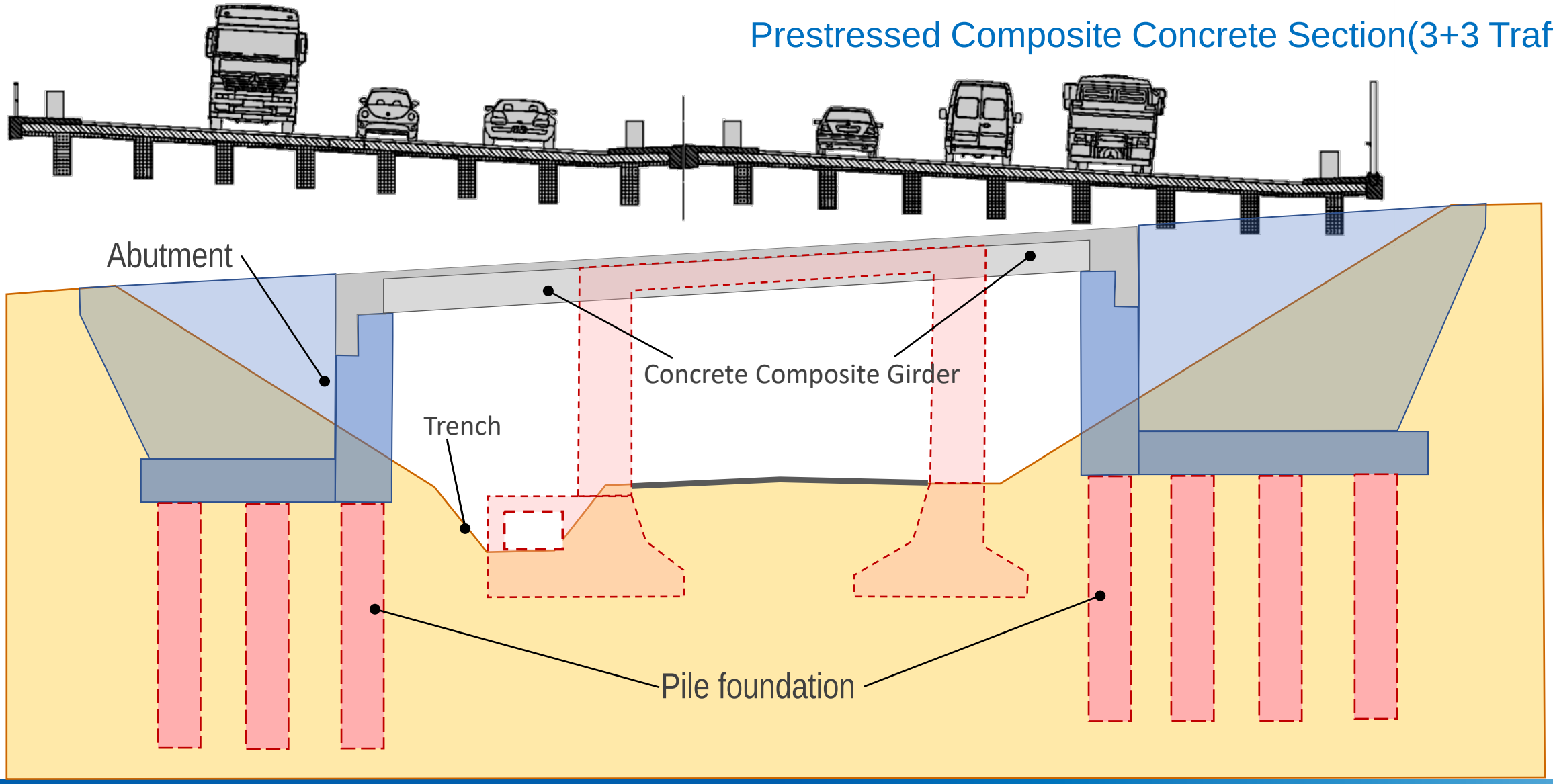


Reinforced Concrete Slab Section (3+3 Traffic)



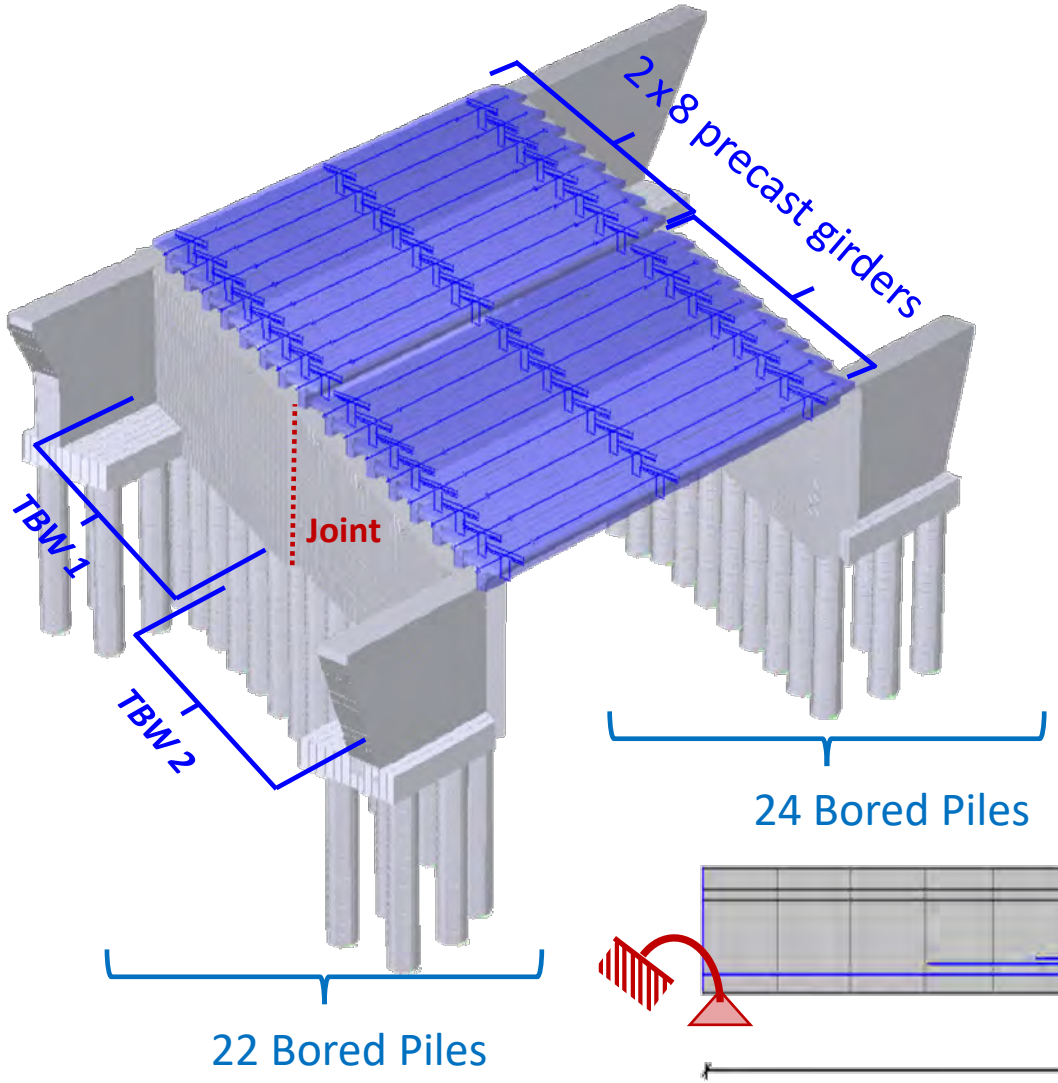
# New Construction of a Replacement Bridge

## Prestressed Composite Concrete Section(3+3 Traffic)

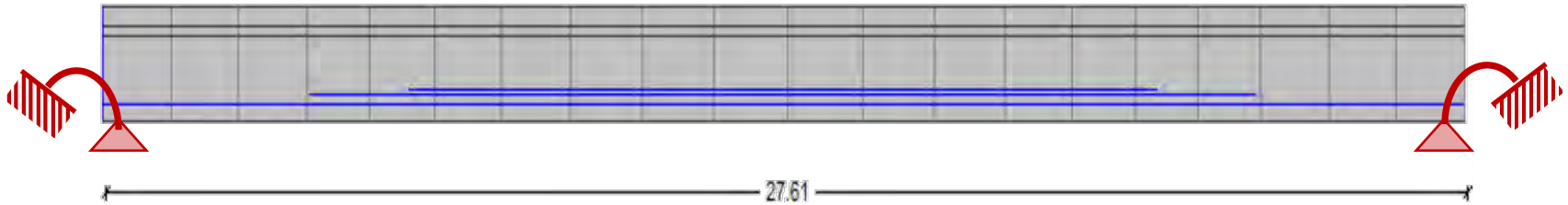


# Bridge Model

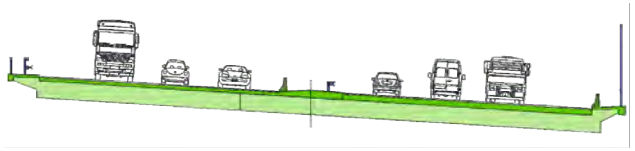
## Structure



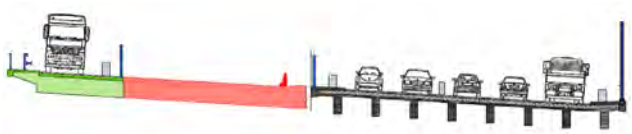

- Inclined Frame Structure TBW 1 + TBW 2 on Pile Foundation
- Assymmetric and inclined at an angle < 80 gon
  ⇨ Design as an integrated complete Model
- 2 x 8 Precast-Girder Prestressed with Prestressing Bed
- Designed as a combined Model with Beams in the Longitudinal direction and orthotropic to load-distributing carriageway Slab in the Transverse Direction.
- Precast-Girder elastically Fixed in Support Wall
- Support span of the Precast Beams are L= 27,61 m
- Sectional Dismantling and New Construction while operation continues
- Replacement new construction in 4 Phases with a total of 13 static construction stages in each direction



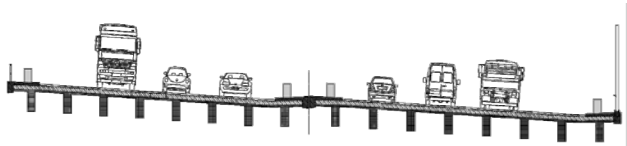
# Bridge Model for Existing and Replacement Construction



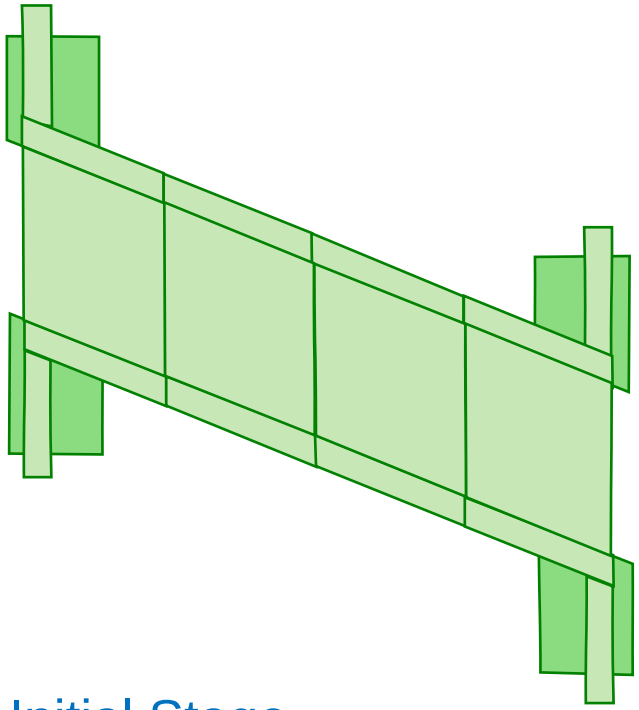
Frame Bridge



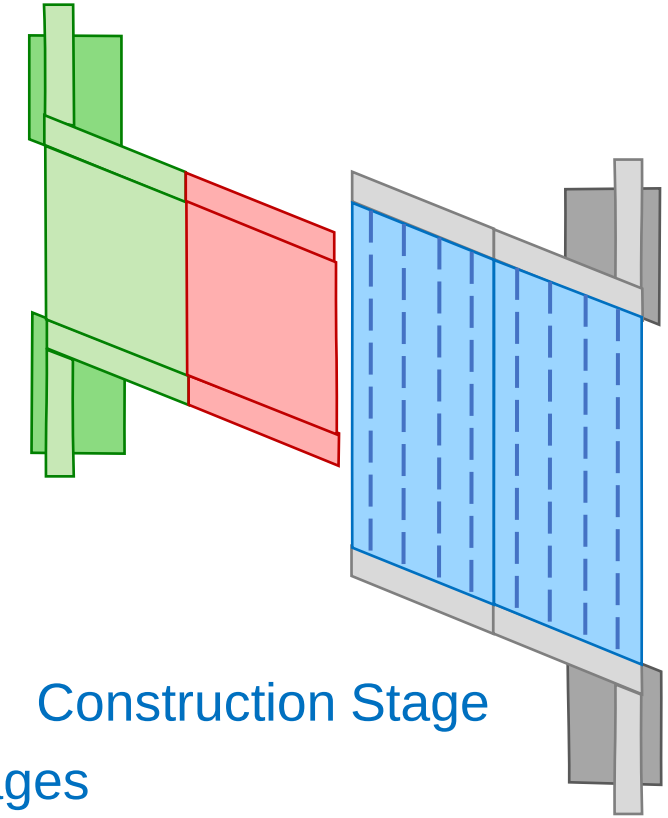
Demolition



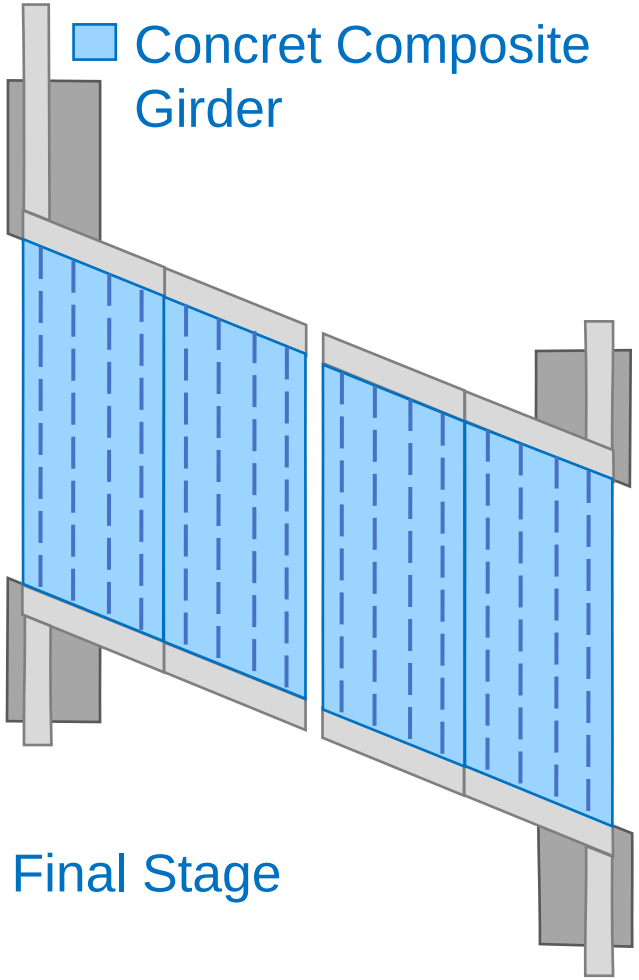
Concret Composite Girder



Initial Stage



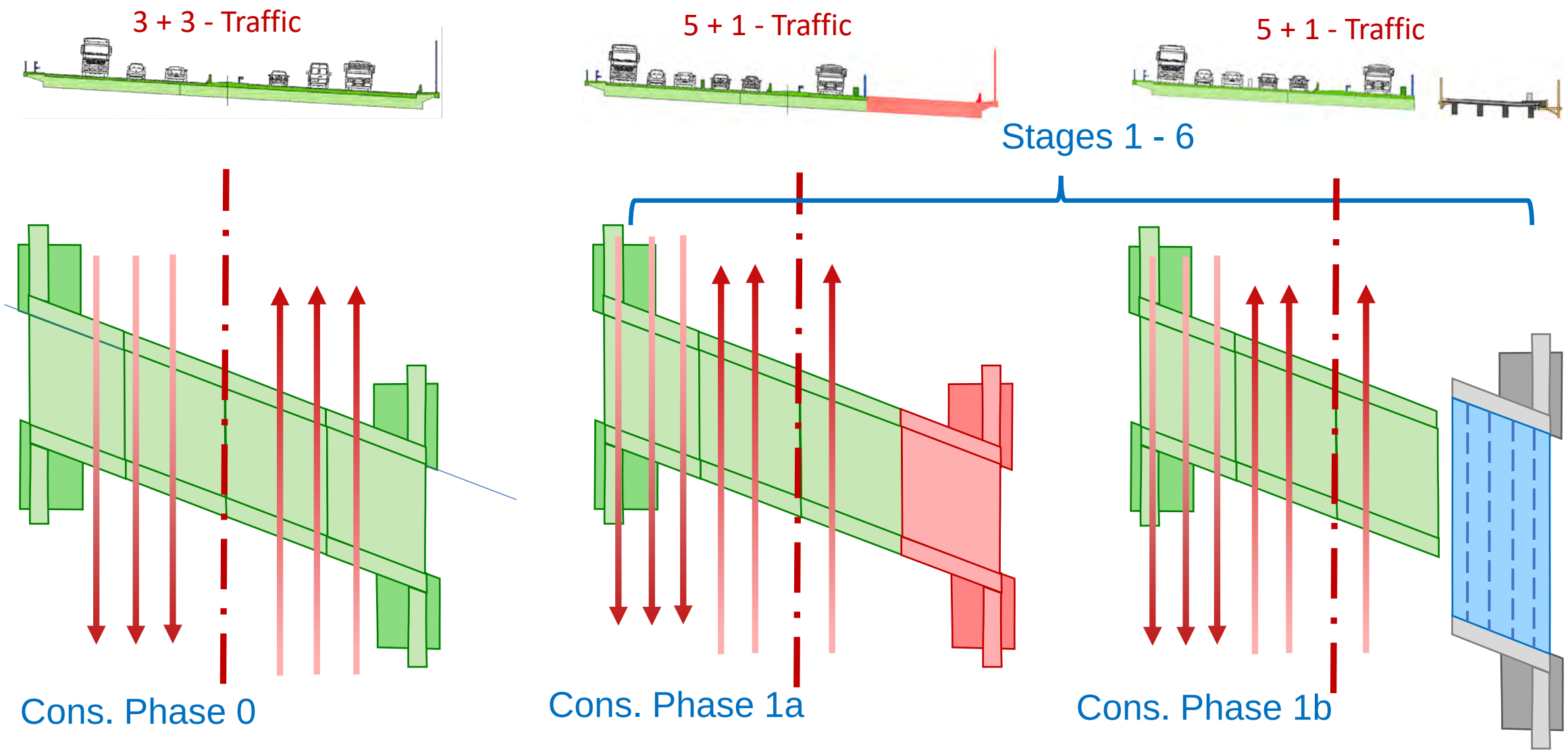
Construction Stage



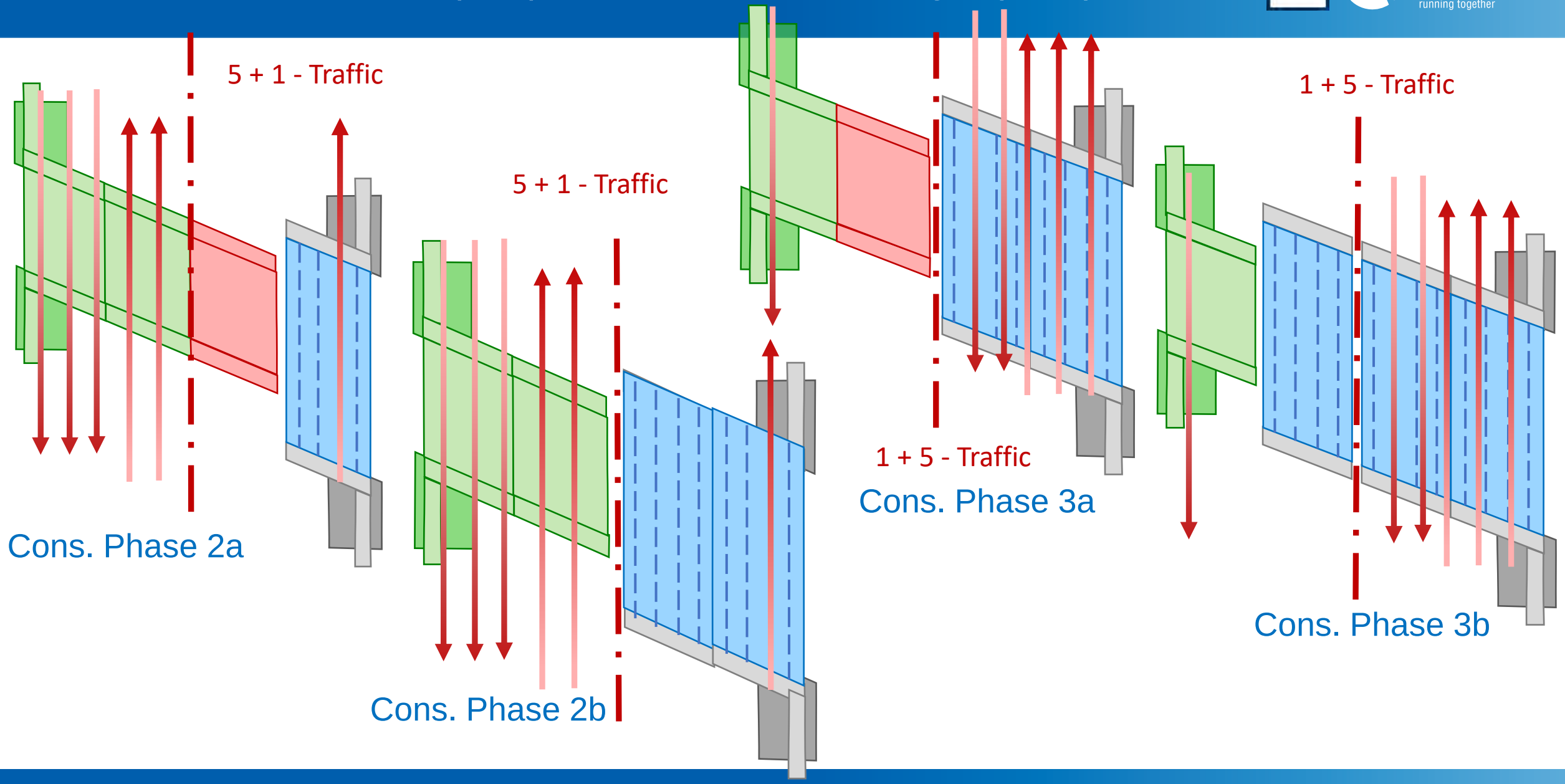
Final Stage

5 Cons. Phases and 13 Cons. Stages

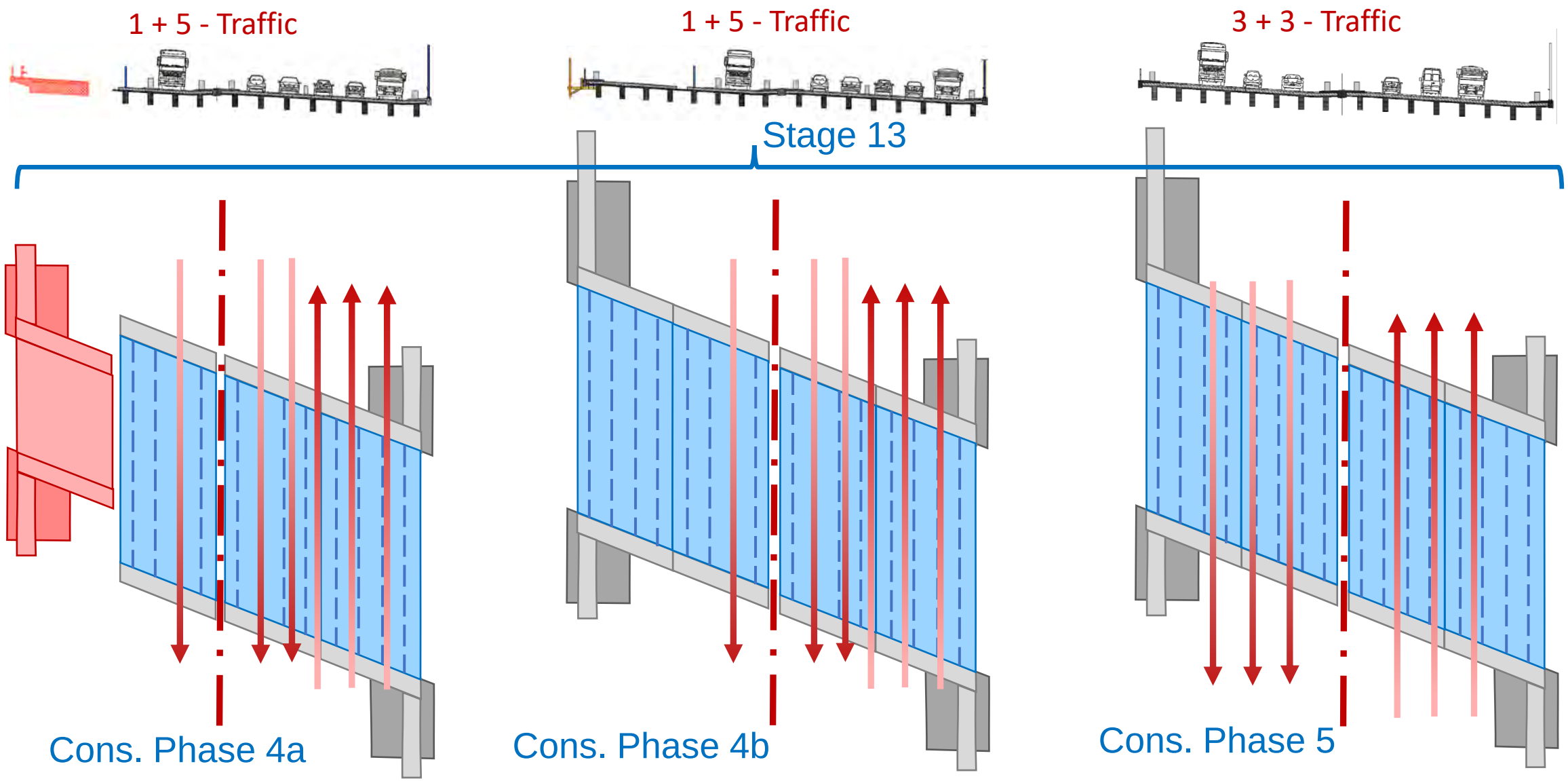
# Construction Phases (0+1) and Construction Stages (1-6)



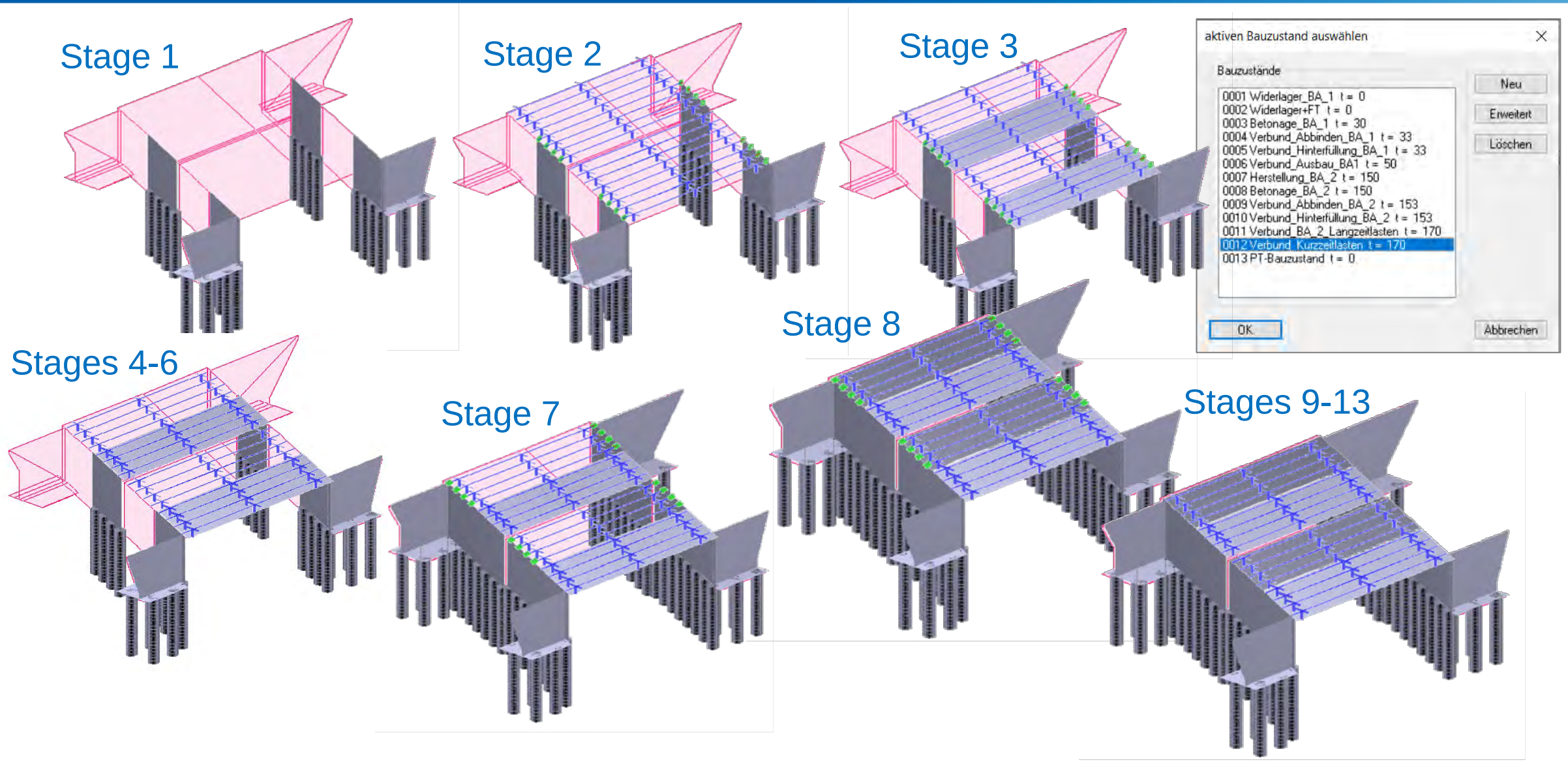
# Construction Phases (2+3) and Construction Stages(7-12)



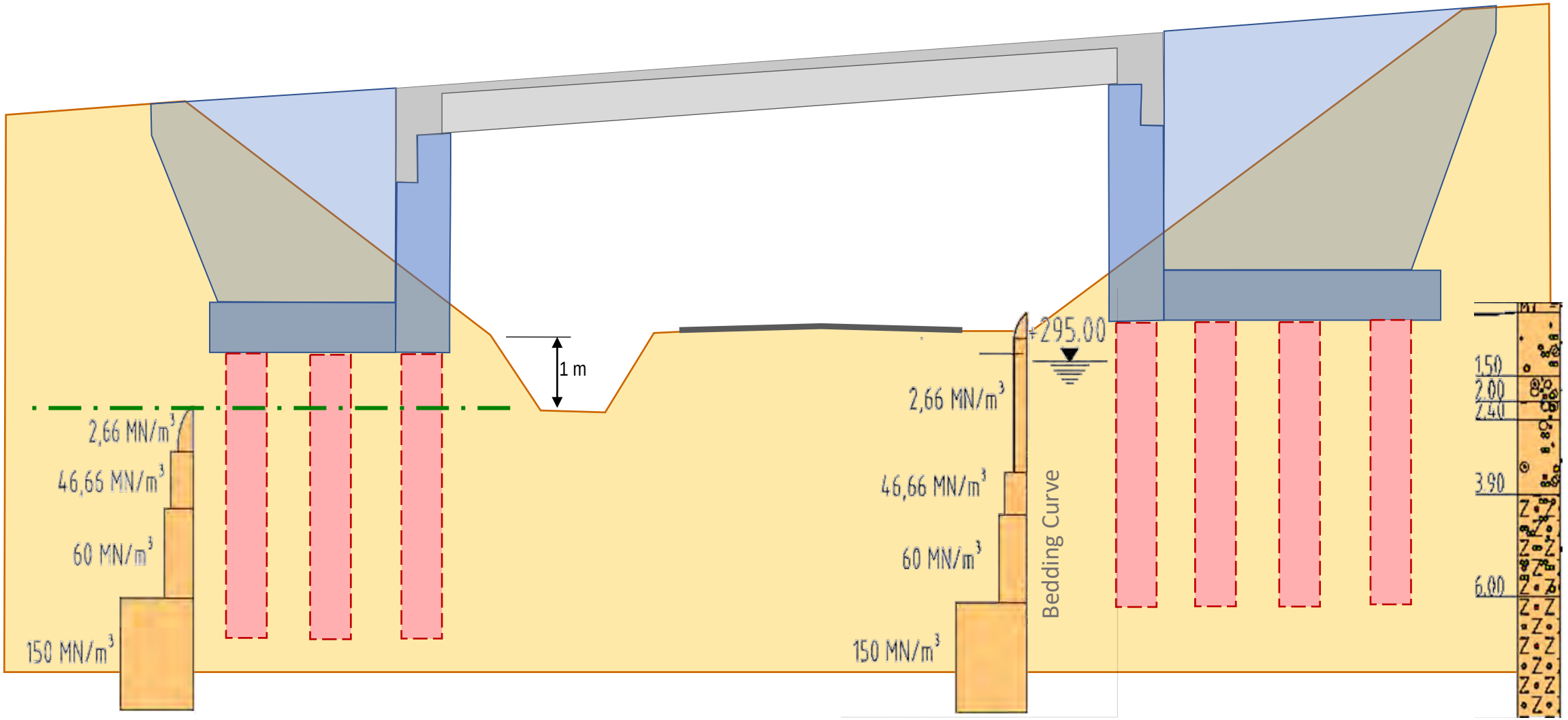
# Construction Phases (4+5) and Construction Stage (13)



# Definition of Construction Stages in FE-Model



# Pile Foundation

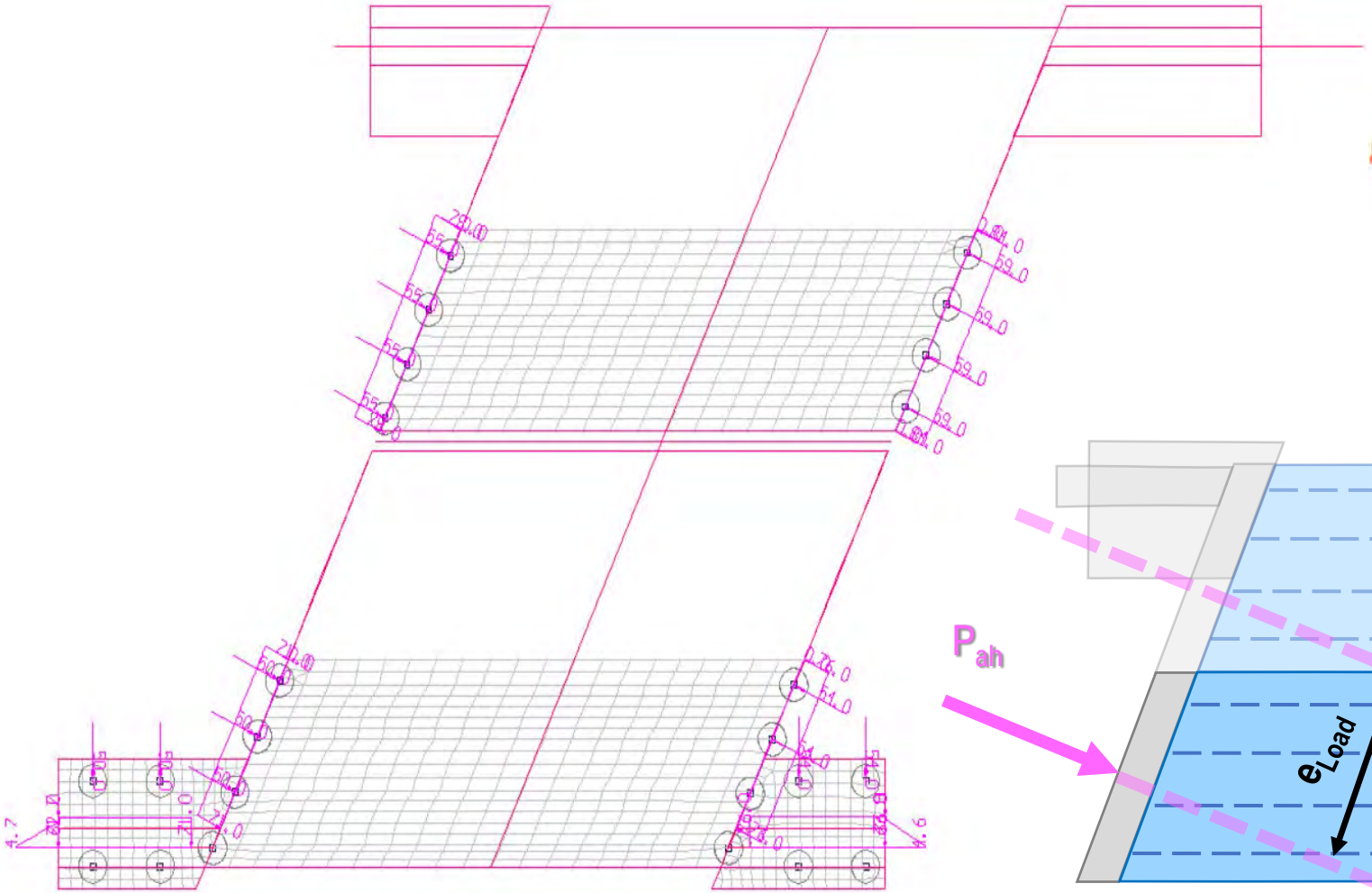



Pile Bedding Left

Pile Bedding Right

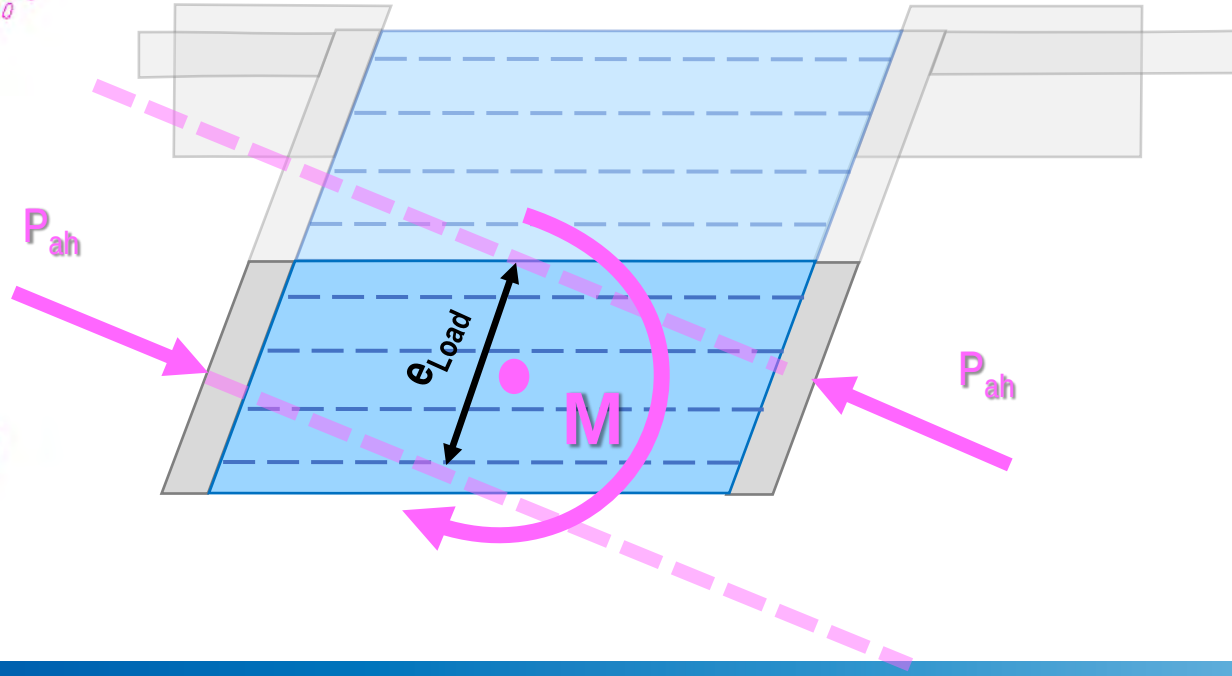
Soil Profile

# Pile Loading



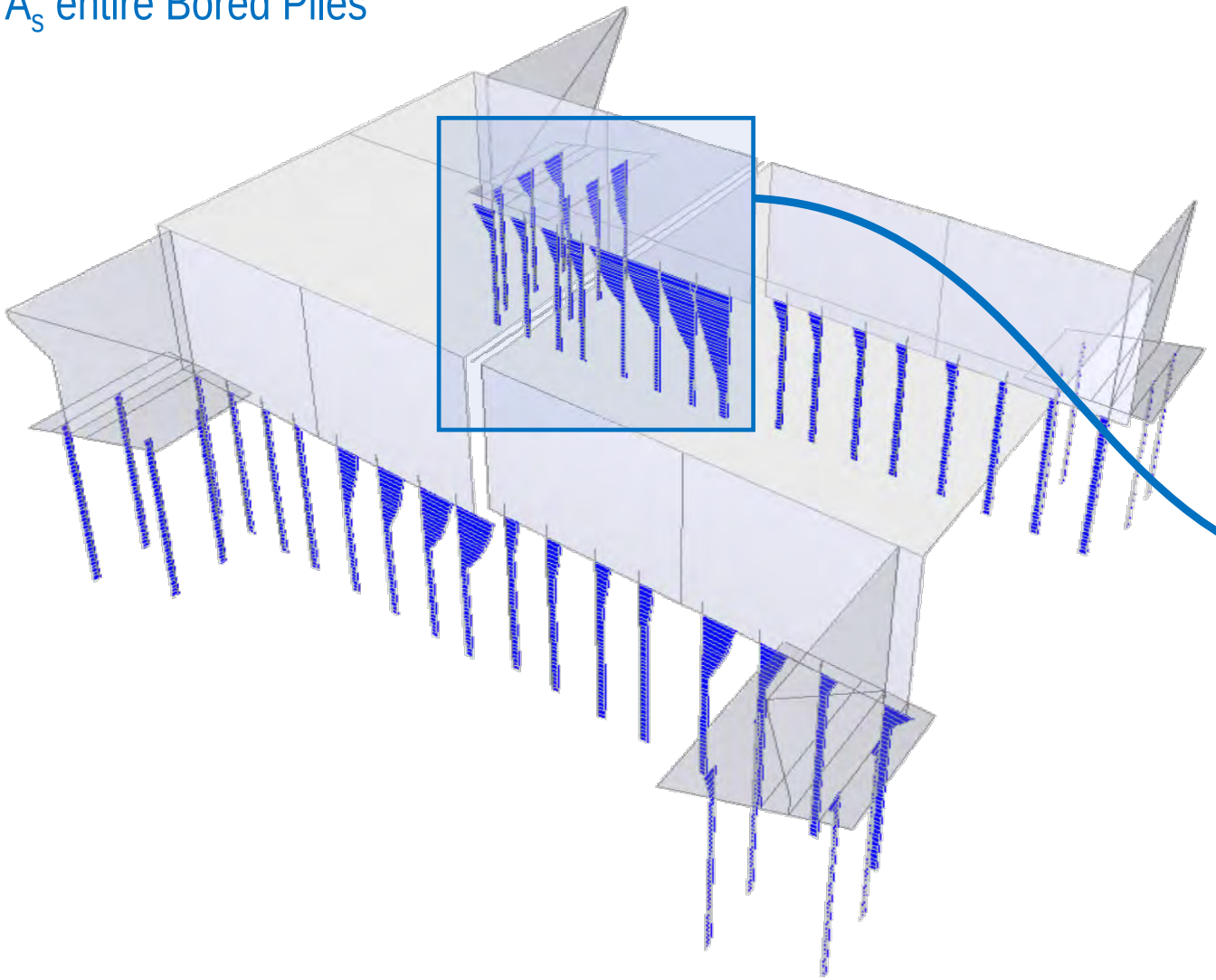
## Cons. Phase 4a

$M = e_{Load} * P_{ah}$

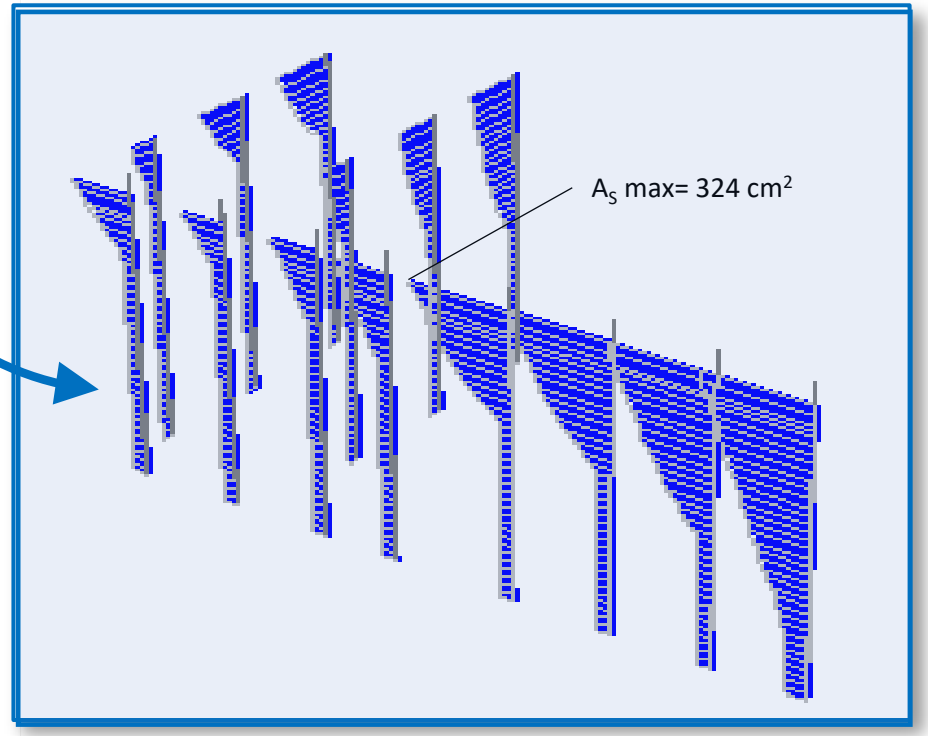


# Pile Design

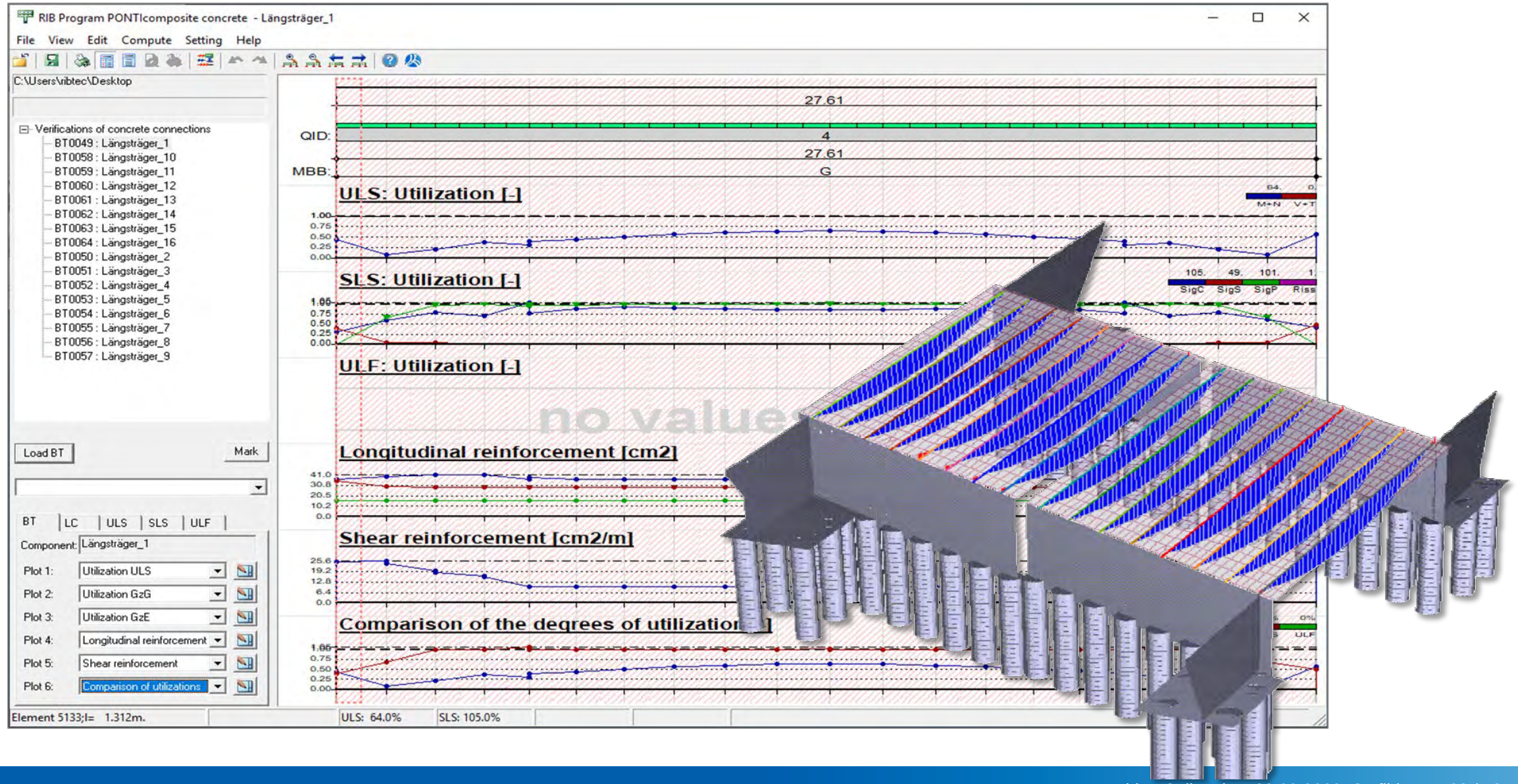
## $A_s$ entire Bored Piles



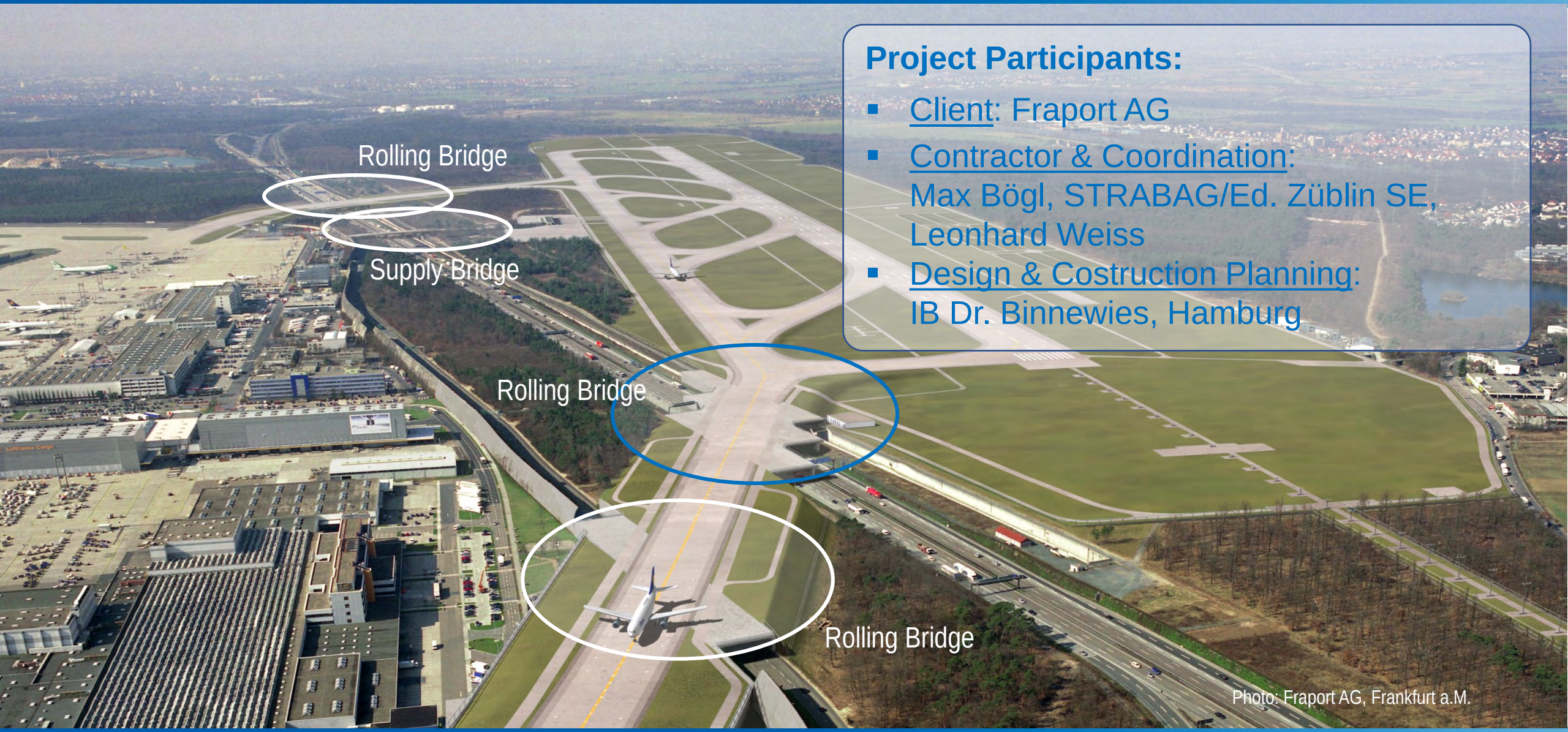
## Superimposed $A_s$- Results form Bending Bearing Capacity (ULS) and final Cracking (SLS)



# Overview of Precast-Beam Designing



# Case Study integral Concrete Composite Bridges in Frankfurt a.M. Airport

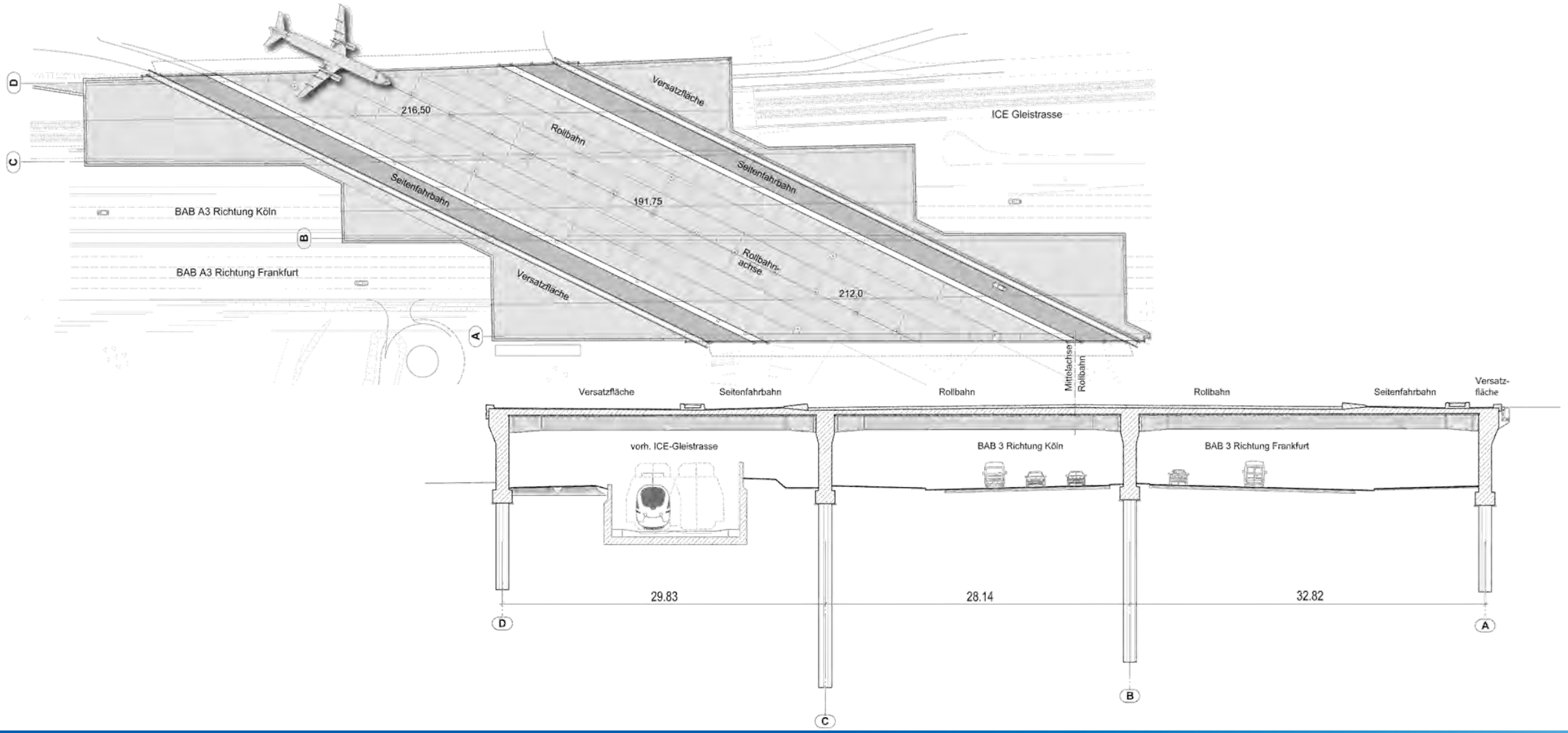



**Project Participants:**

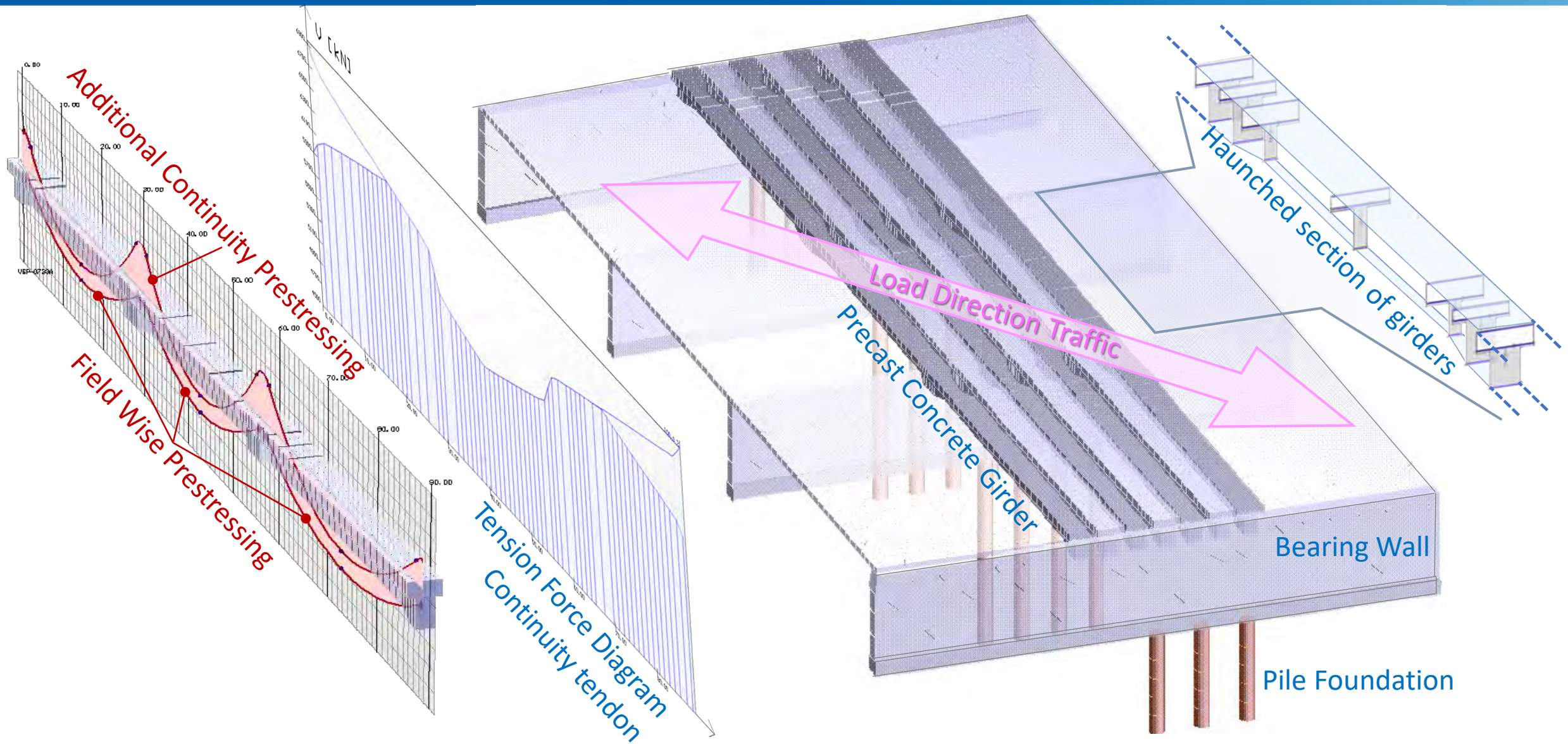
- Client: Fraport AG
- Contractor & Coordination: Max Bögl, STRABAG/Ed. Züblin SE, Leonhard Weiss
- Design & Costruction Planning: IB Dr. Binnewies, Hamburg

Photo: Fraport AG, Frankfurt a.M.

# Bridge Model



# FE-Model and Prestressing



# Building while Traffic is Running

Photo: IB Binnewies, Hamburg

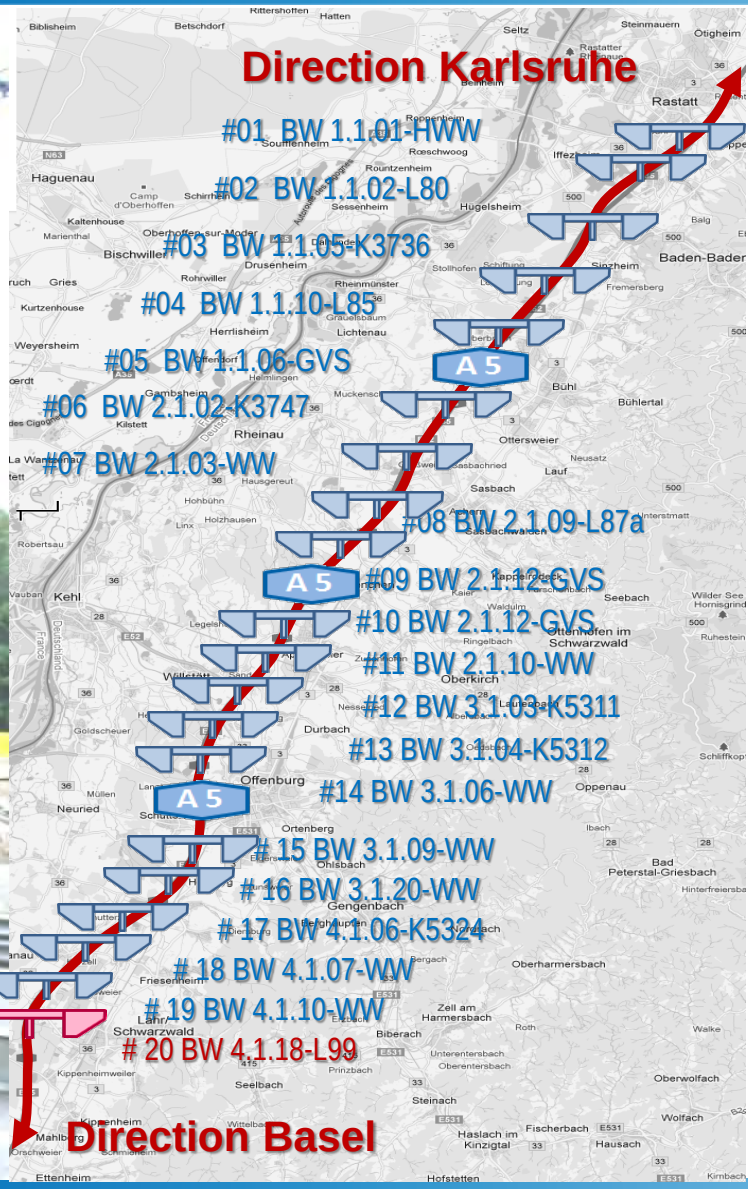
# Case Study: Road Bridges for the A5 Federal Highway

**Project Participants**

- Client: Regional Council KA
- Planning, maintenance and Operation: Via Solutions Südwest
- Construction: EUROVIA, Kirchhoff and construction Company Reif
- Design & Implementation Planning: IGS Ingenieure GmbH & Co. KG, Weimar

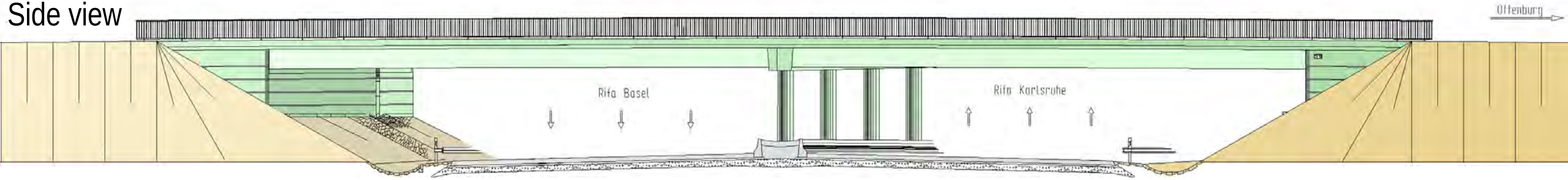
Photo: IGS Ingenieure, Weimar

# Planning & Construction of 20 2-field Fly-Over Bridges

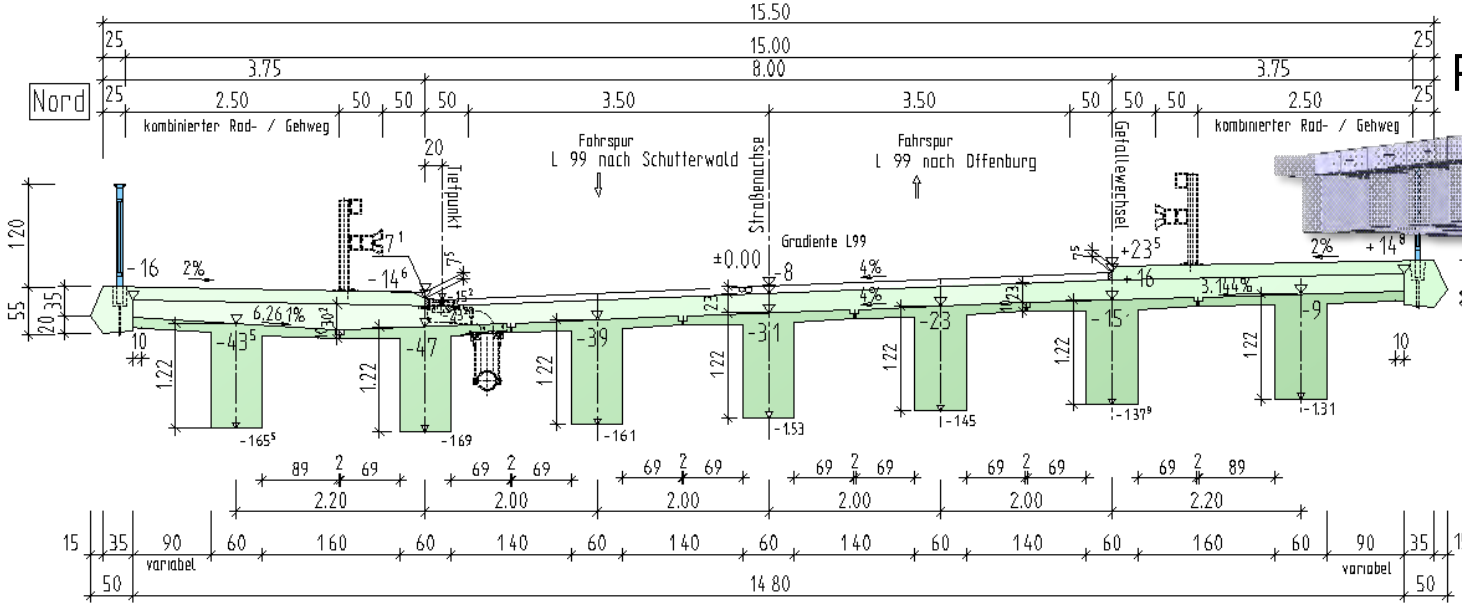


# Bridge Model BW 4.1.18-L99 and FE-System

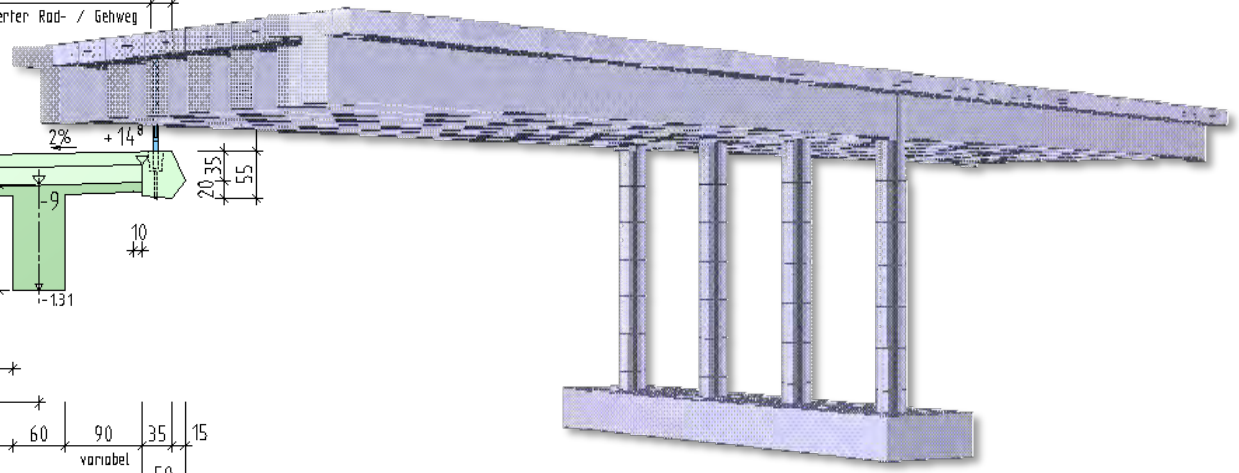
Side view




Standard cross section

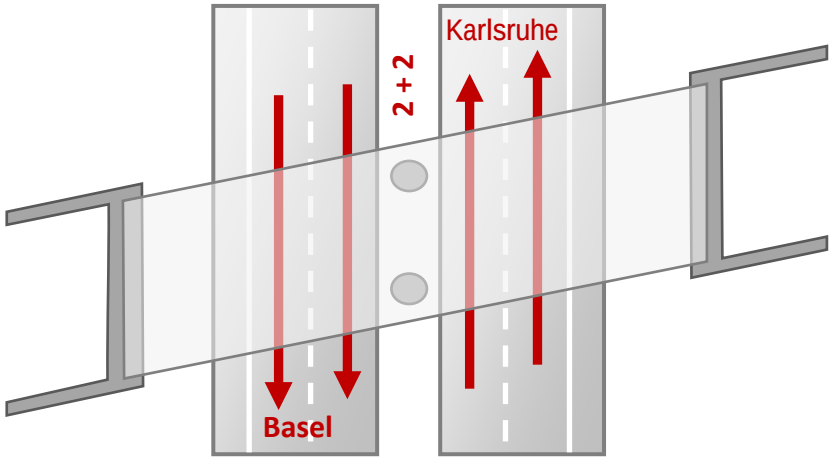



FE-model 2-field prefabricated girder

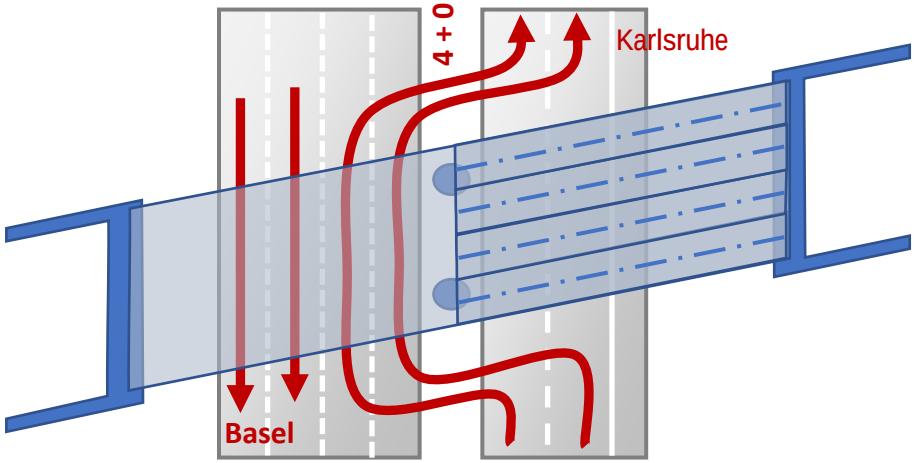


# Illustration of the Traffic Situation in terms of Construction stages

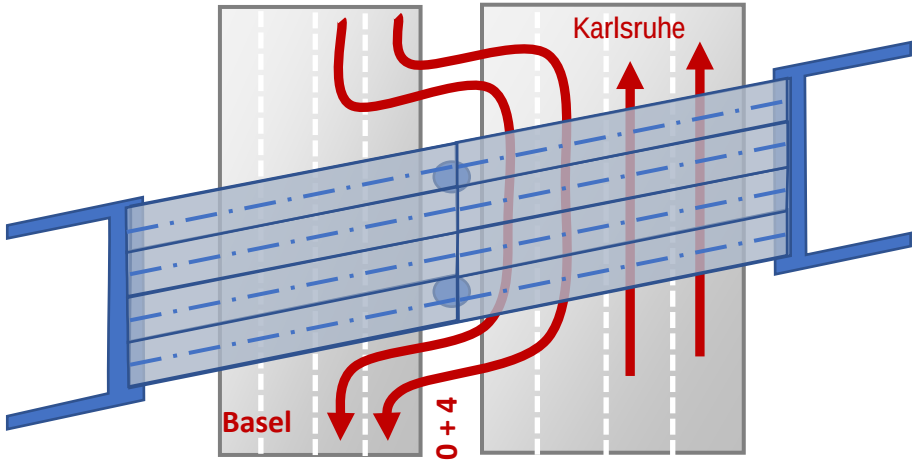
## Initial situation (4-Lanes)



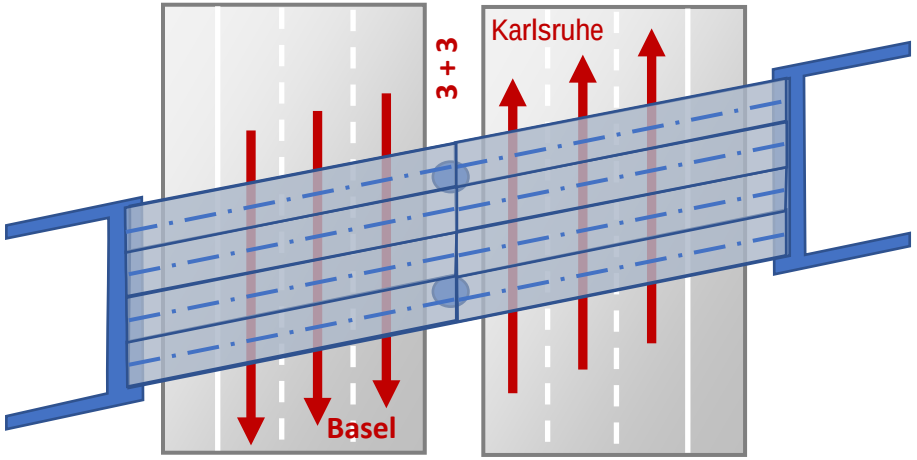

## Extension towards Karlsruhe



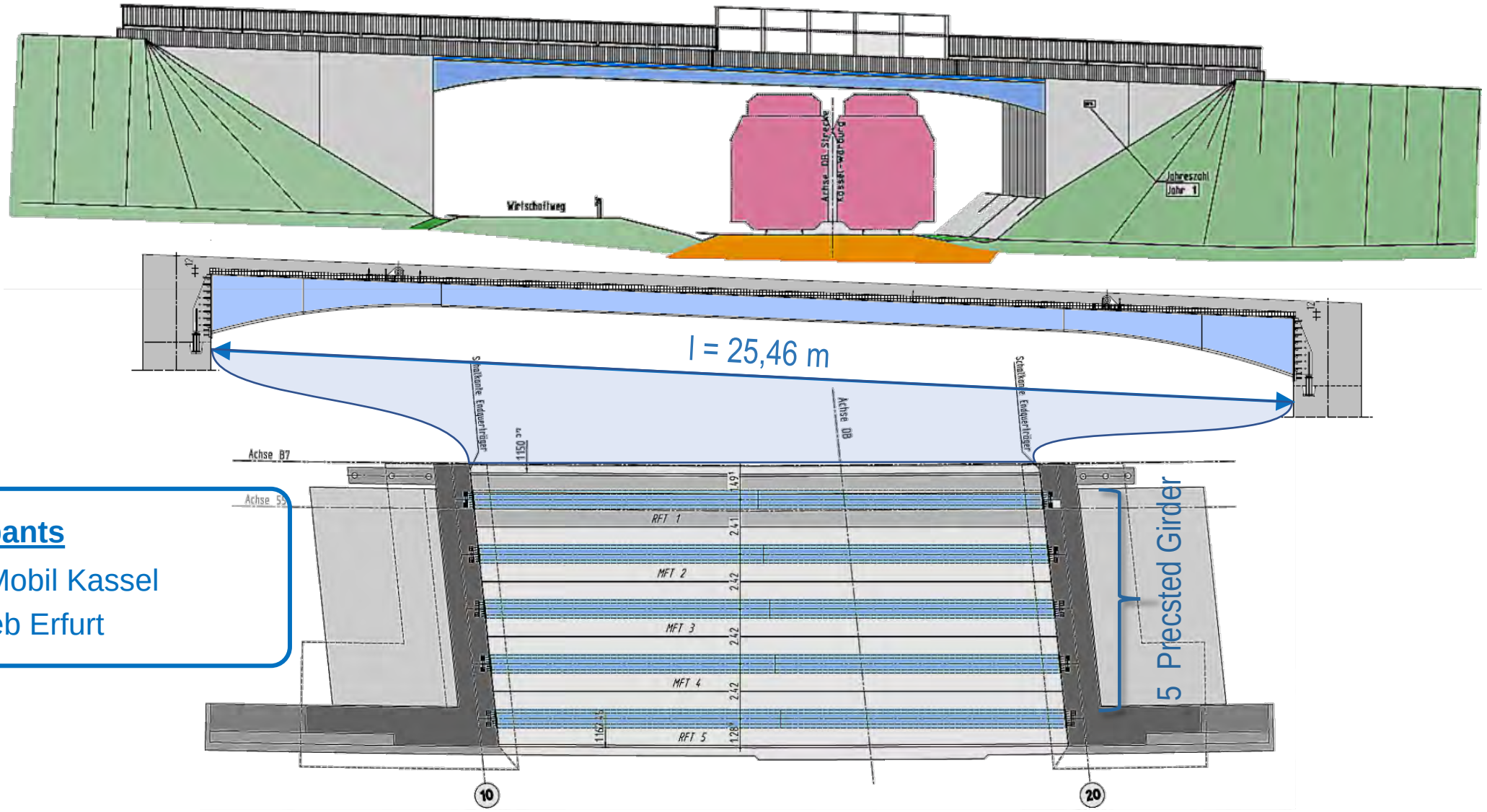

## Extension towards Basel




## Final Situation (6- Lanes)



# Case Study Steel Composite Precast Bridges

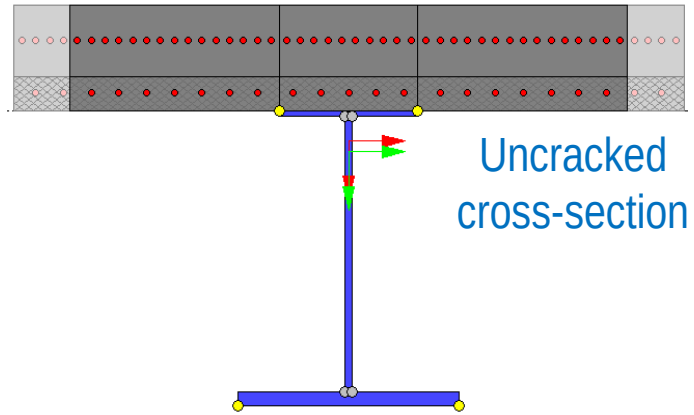


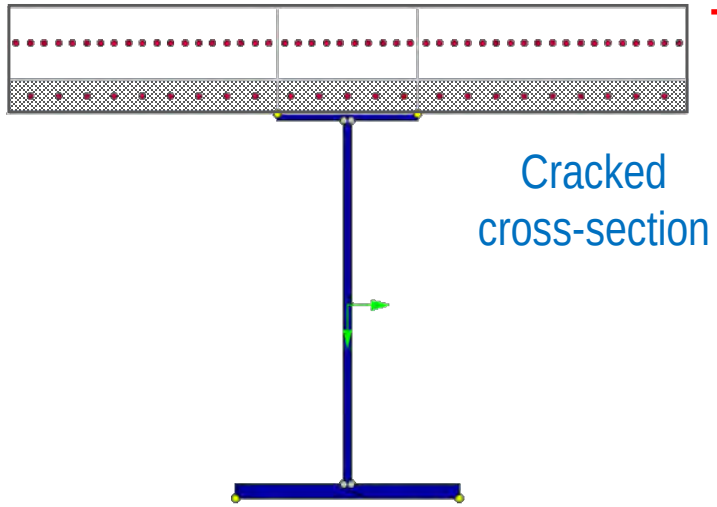

**Project Participants**

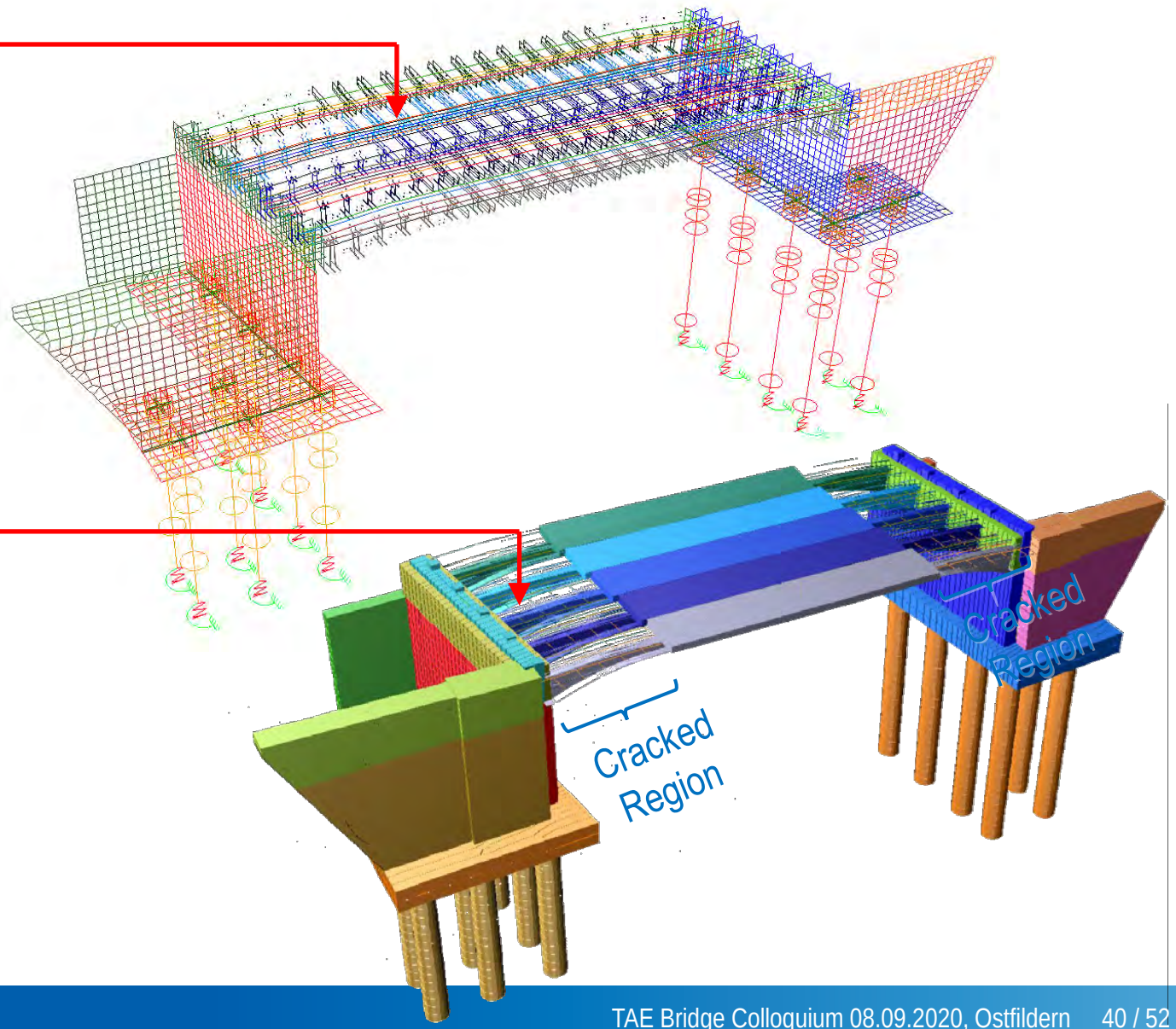
Client: Hessen Mobil Kassel

Aufsteller: IB Kleb Erfurt

# Cracked cross-sectional areas in Steel Composite Bridges

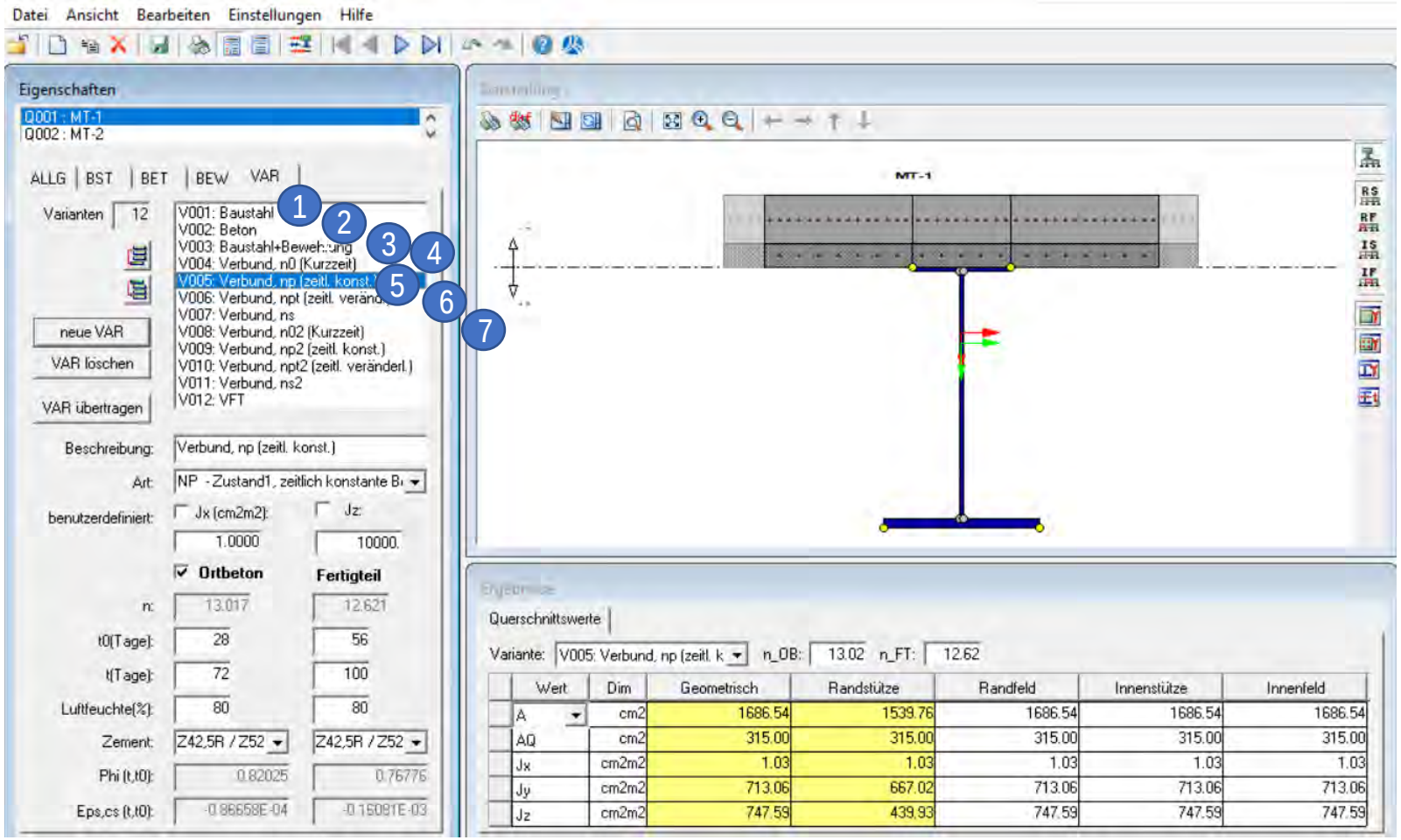


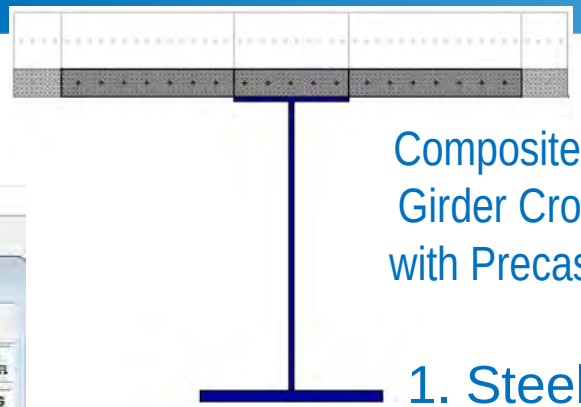



# Cross-Section Editing for Steel Composite Bridges

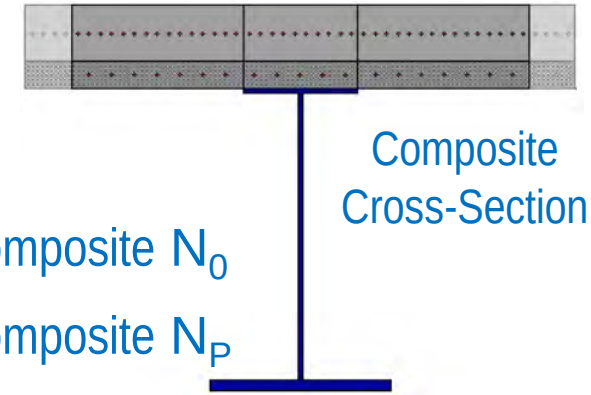
## Fast and efficient Cross-Section Editing



Composite Precasted Girder Cross-Section with Precast Concrete

1. Steel
2. Concrete Slab
3. Steel + Reinforcement

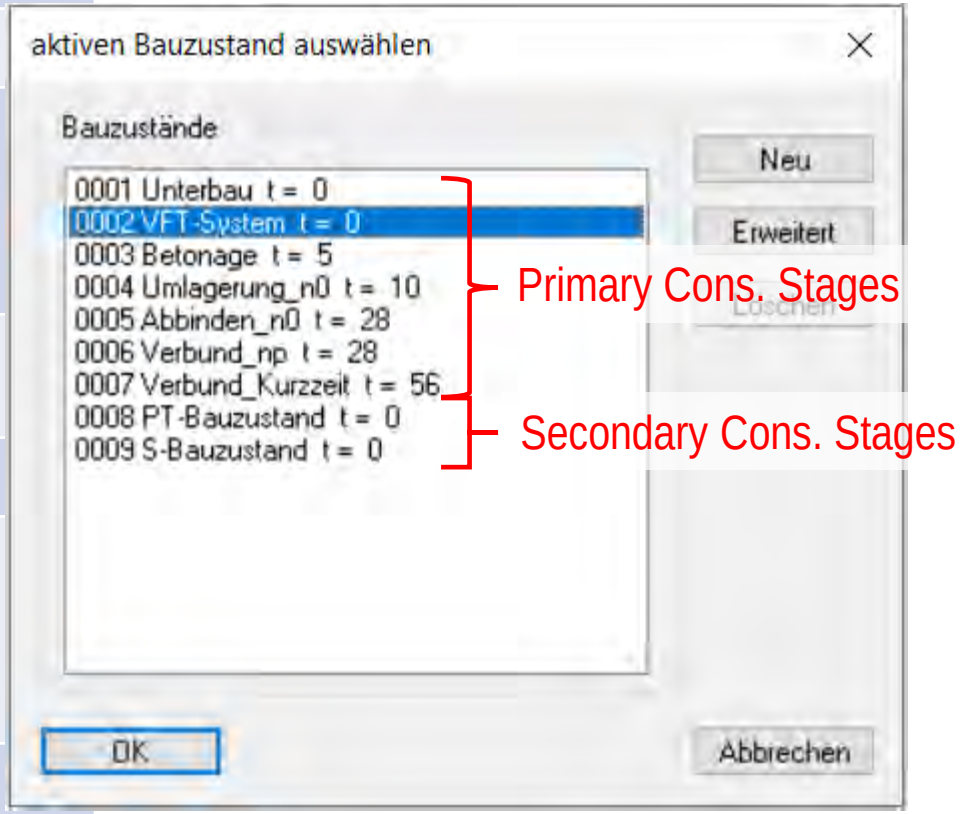


Composite Cross-Section

4. Composite $N_0$
5. Composite $N_P$
6. Composite $N_{PT}$
7. Composite $N_s$

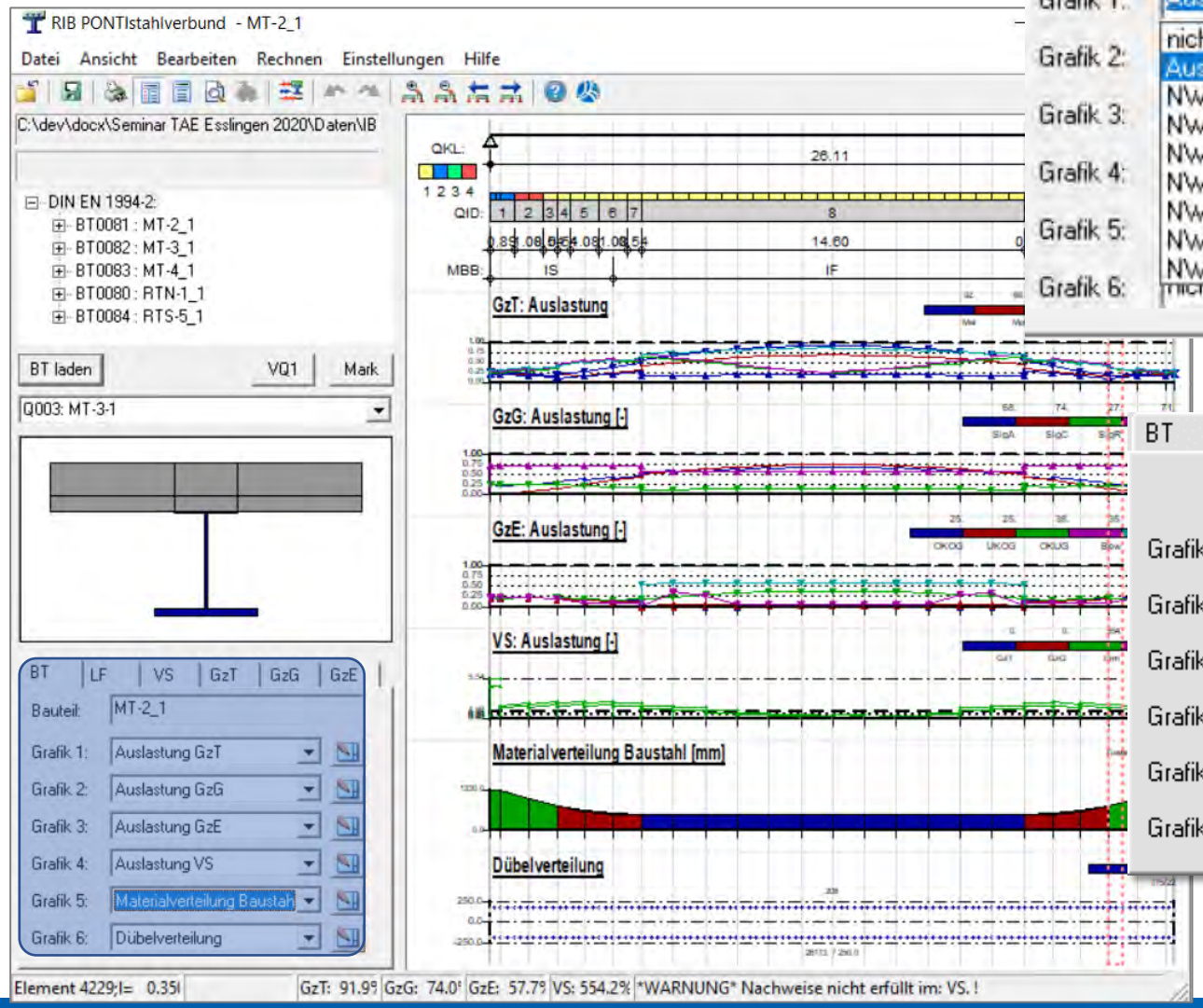
# Cross-Section variants for Steel Composite Bridges

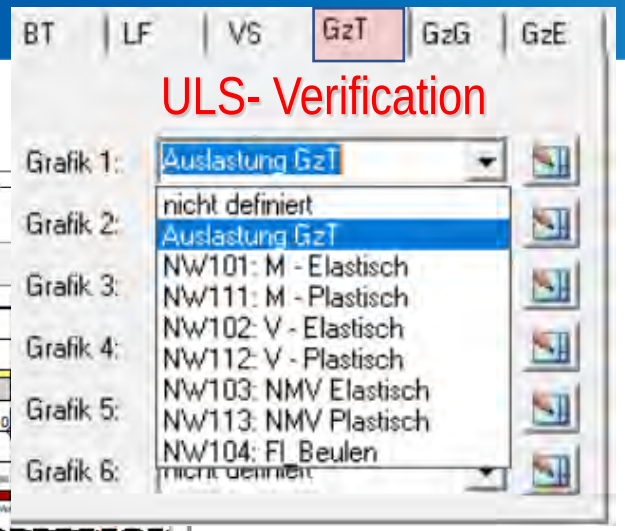
| Variant | Description | Effect in Struc. Condition / loads |
|---|---|---|
| 1 | CP-System | Composite Precast - Girder System |
| 2 | Betonplatte | Secondary Stages |
| 3 | Costruction Steel and Reinforcement | NP- Structure Condition<br>Composite-Short time<br>NPT- Structure Condition<br>NS- Structure Condition |
| 4 | Composite $N_0$ | Composite Cons. Loads Condition<br>Short-term Composite Loads |
| 5 | Composite $N_P$ | Long-term Composite Loads |
| 6 | Composite $N_{PT}$ | Secondry loads due to:<br>- Concreting Loads<br>- Finishing Loads<br>- Support sinking |
| 7 | Composite $N_S$ | Secondary load due to:<br>- Shrinkage |
| 8 | Composite $N_{PT2}$ | Steel+Reinforcement in NPT |
| 9 | Composite $N_{S2}$ | Steel+Reinforcement in NS |

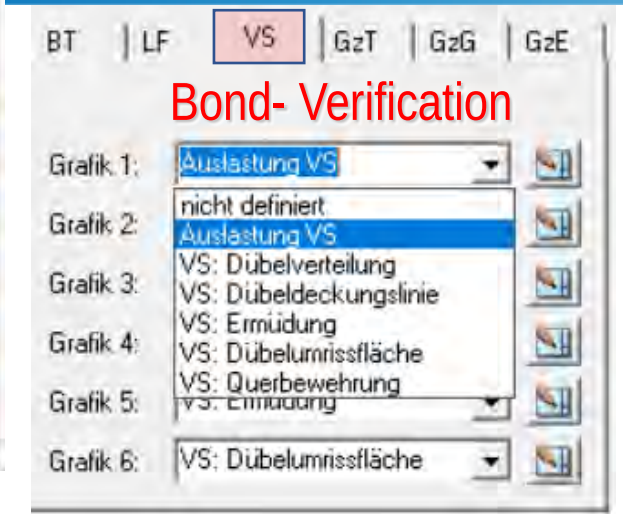


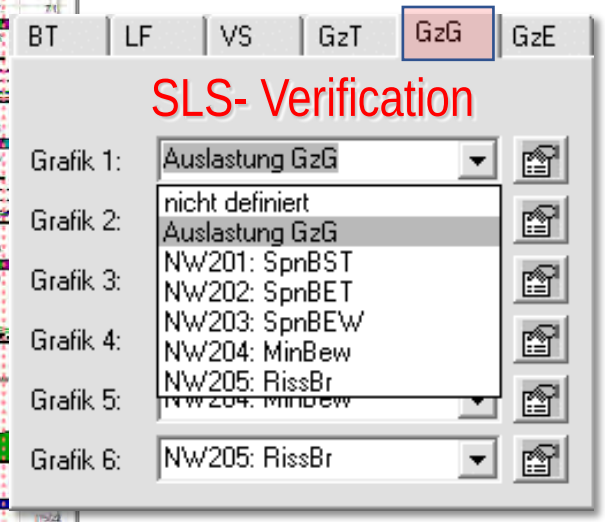
# Versatile graphical output of Results

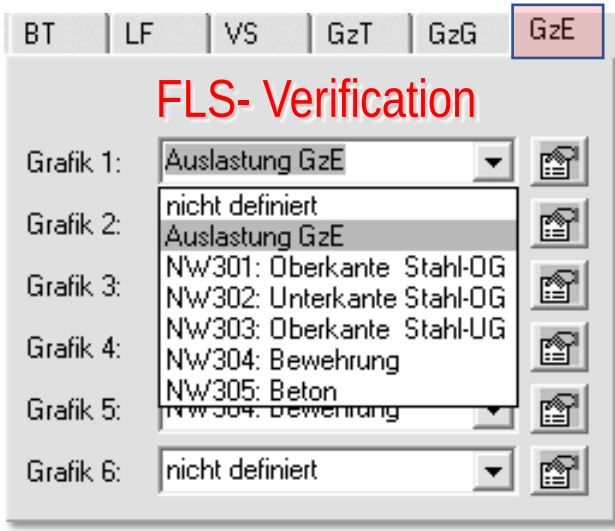
## Direct Verification Control



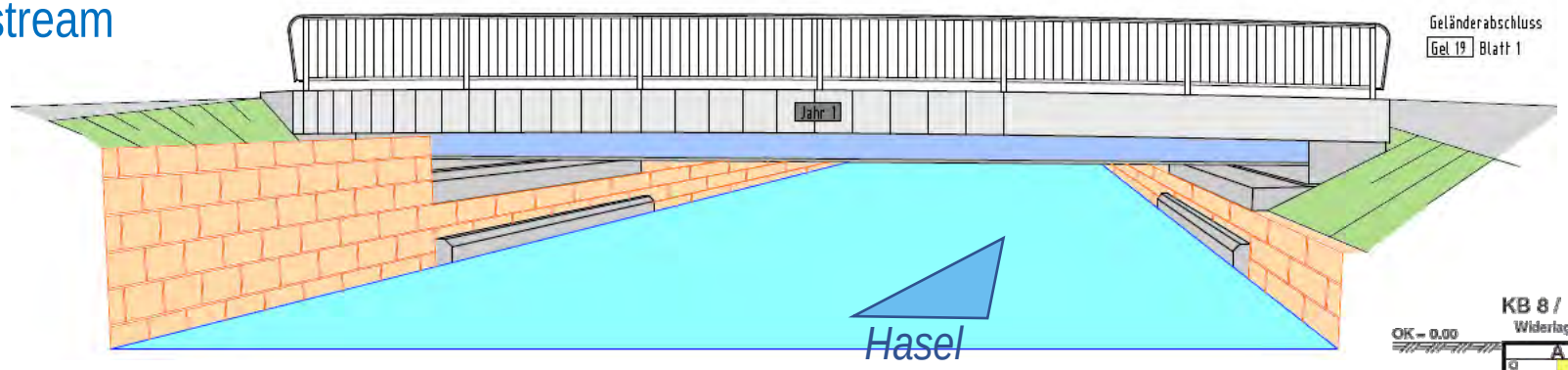



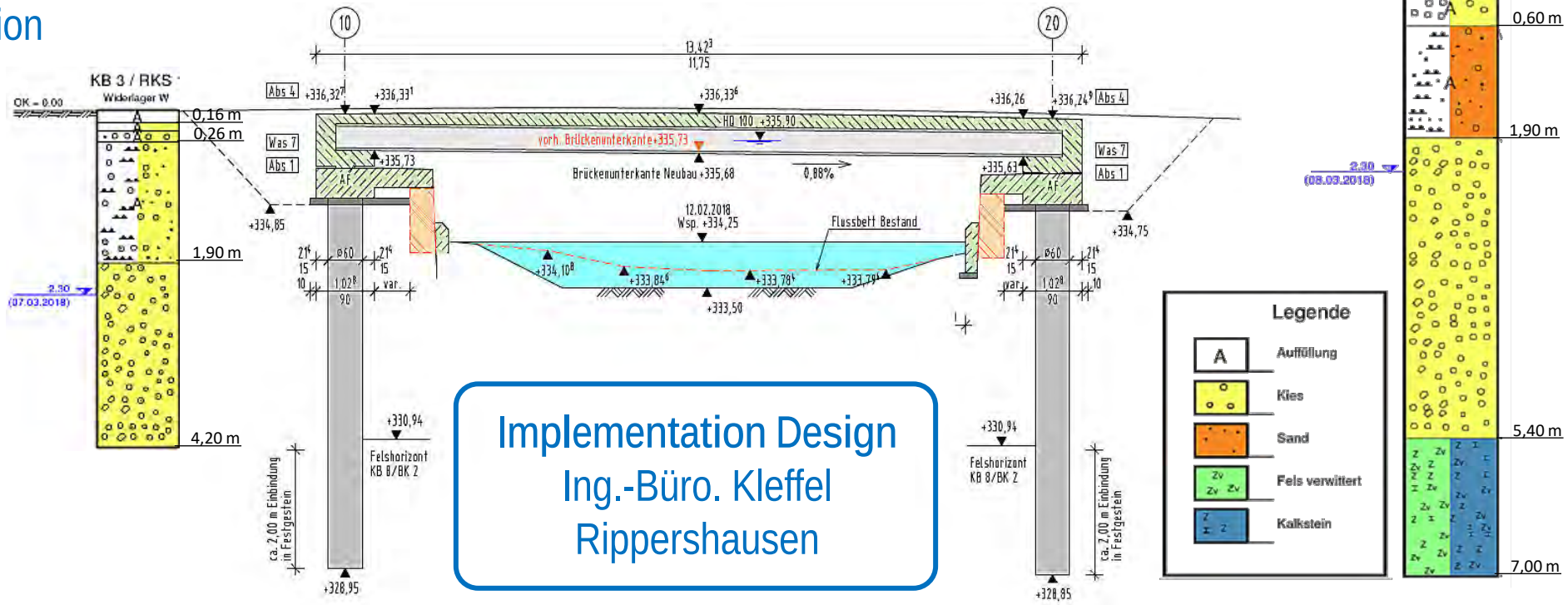



# Case Study: Rolled Beam In-Concrete as Replacement for a Bridge

## View Downstream




## Section




**Implementation Design**
Ing.-Büro. Kleffel
Rippershausen

# Rolled Beam In-Concrete Bridge as integral Structure

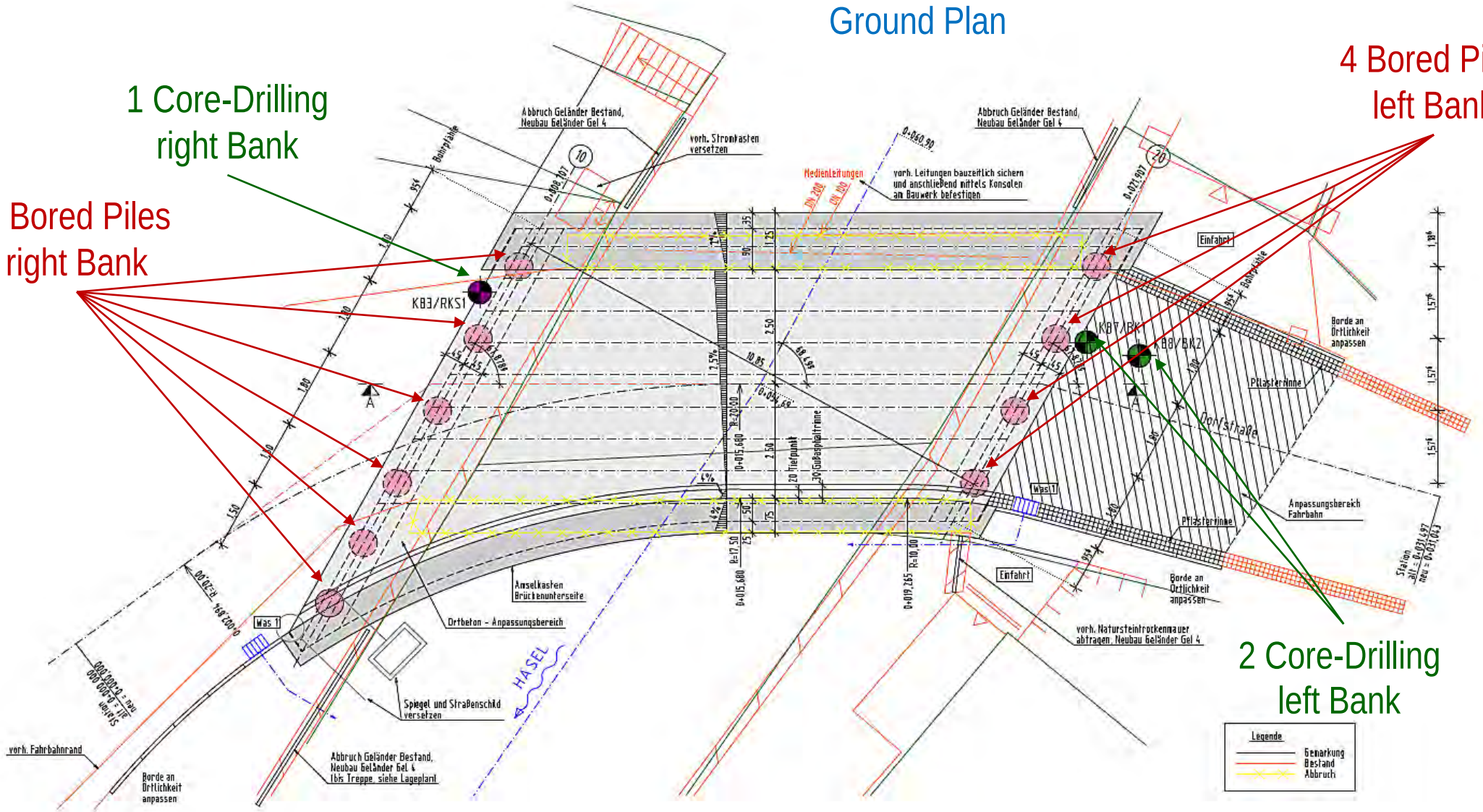
## Ground Plan

1 Core-Drilling right Bank

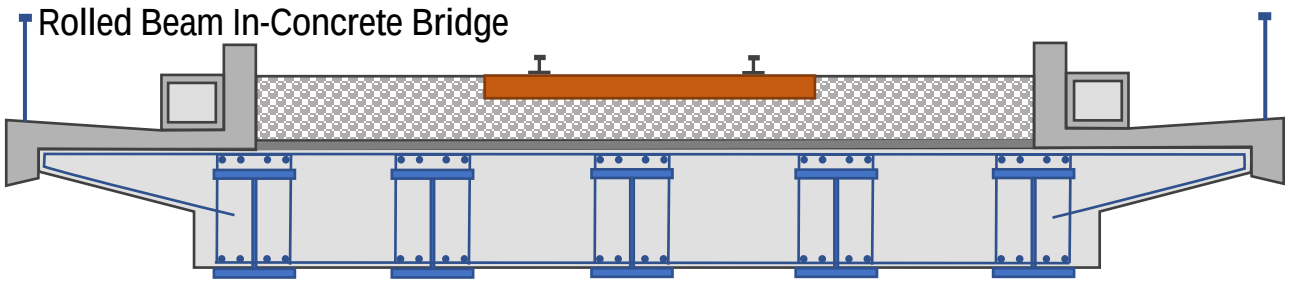
6 Bored Piles right Bank

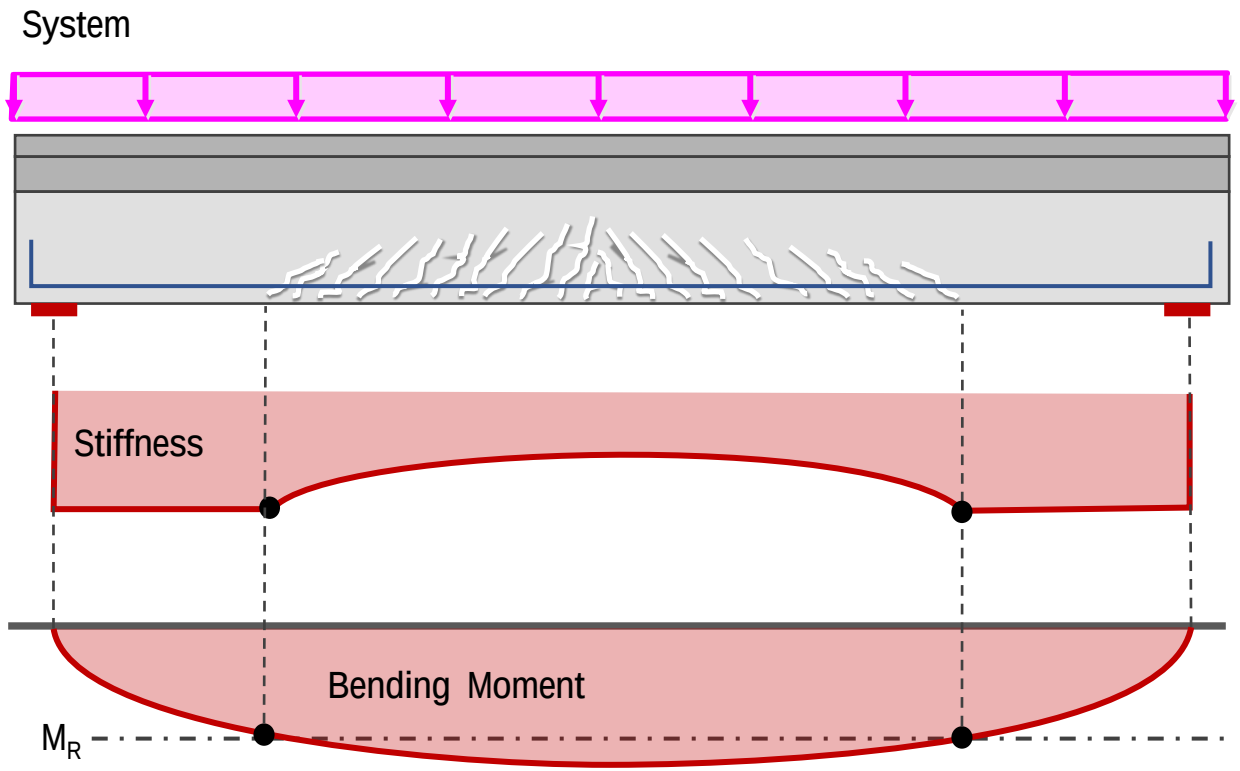
4 Bored Piles left Bank

2 Core-Drilling left Bank

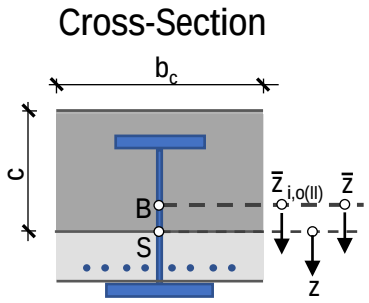


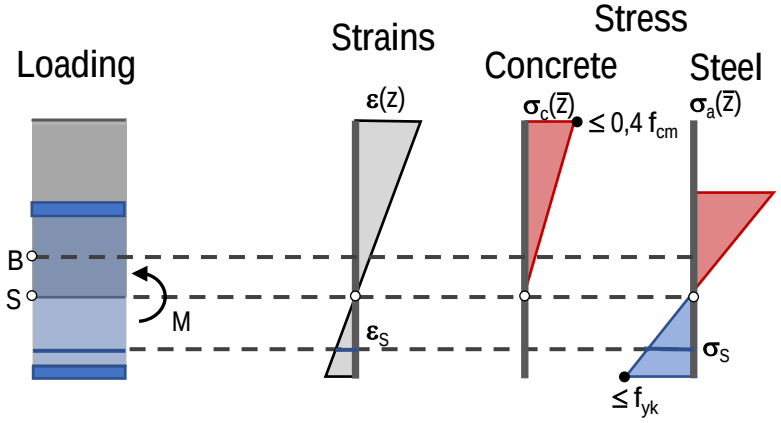
# Cracked cross-sectional areas for Rolled Beam In-Concrete Bridges



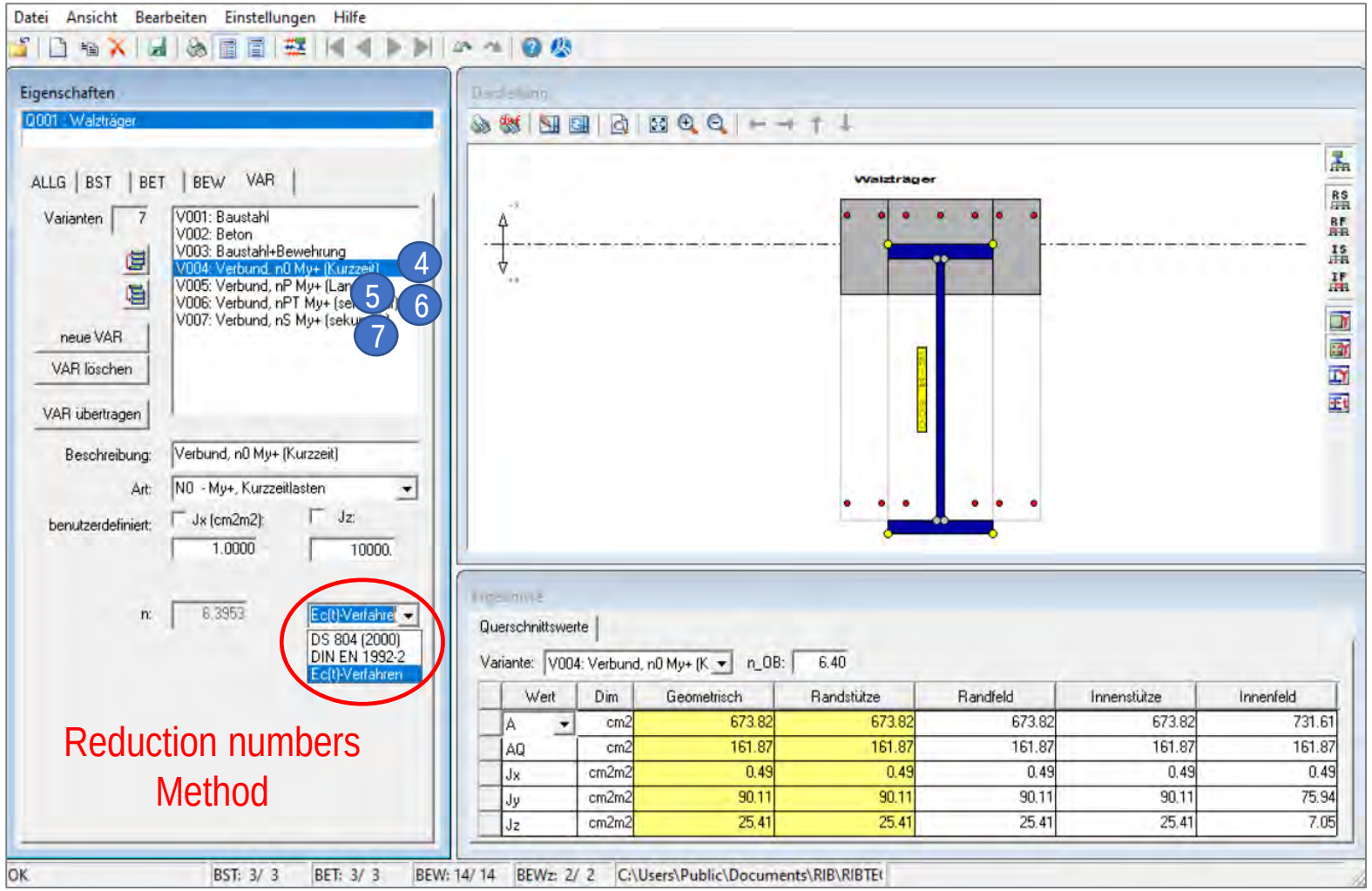

## Stress and Strain Distribution with positive Bending in State II



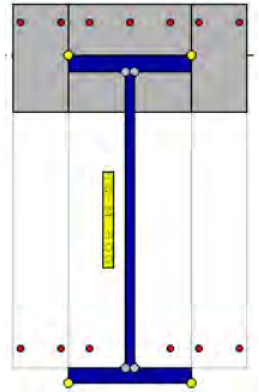



# Cross-Section Editing for Rolled Beam In-Concrete Bridges

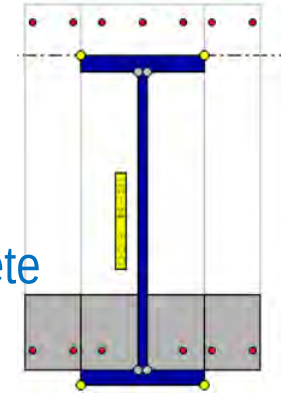
## Fast and efficient Cross-Section Editing




Reduction numbers Method



Rolled Beam In-Concrete My+



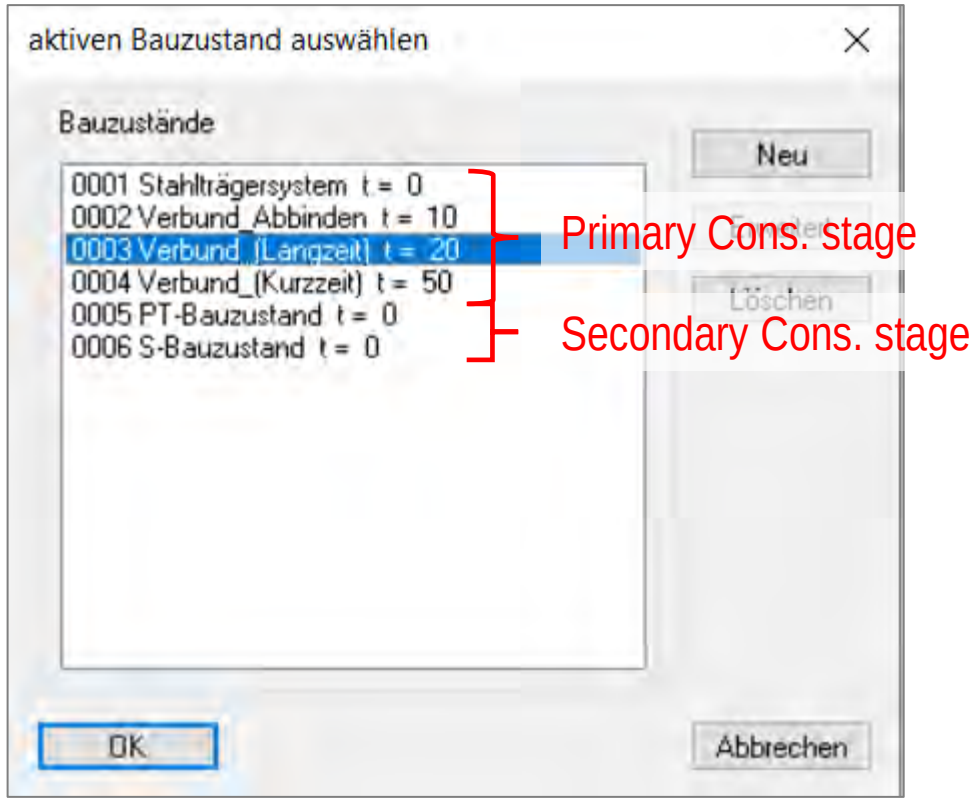
Rolled Beam In-Concrete Variante My-

always as State II Variants

4. Composite $N_0$
5. Composite $N_P$
6. Composite $N_{PT}$
7. Composite $N_s$

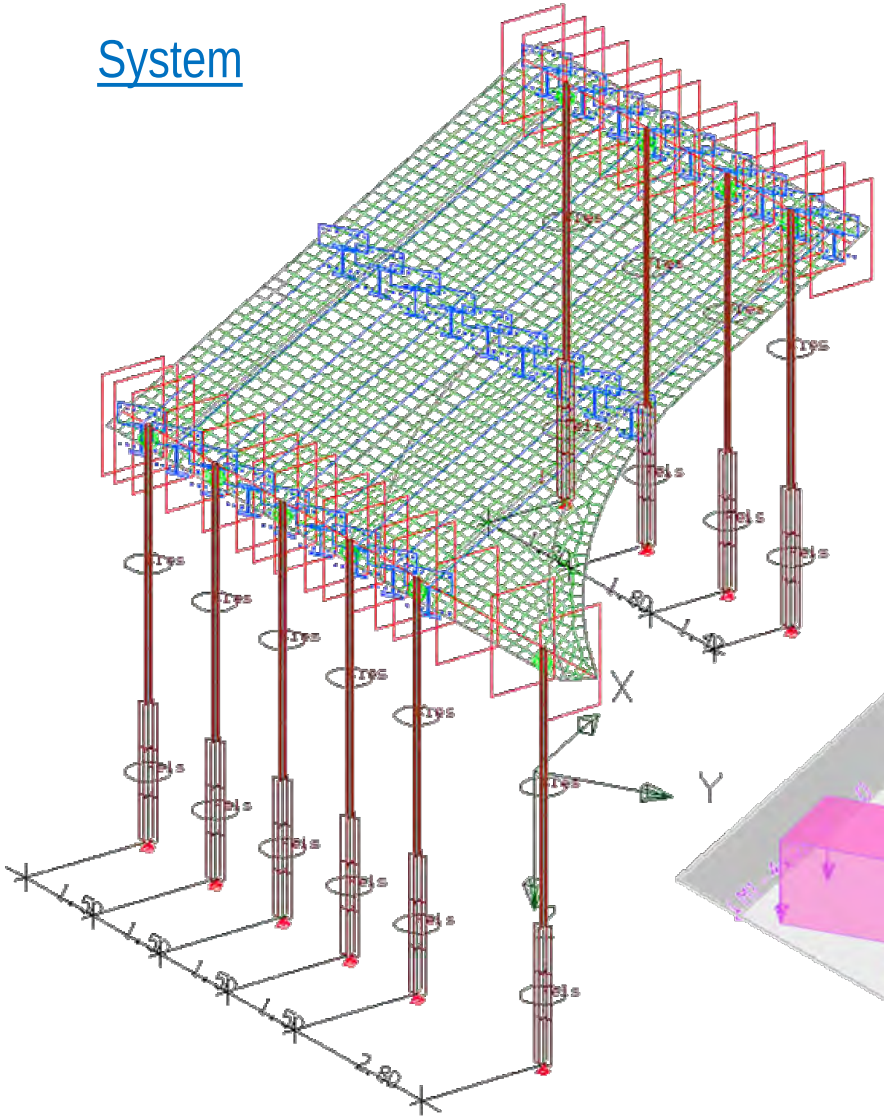
# Cross-Section variants for Rolled Beams In-Concrete Bridges

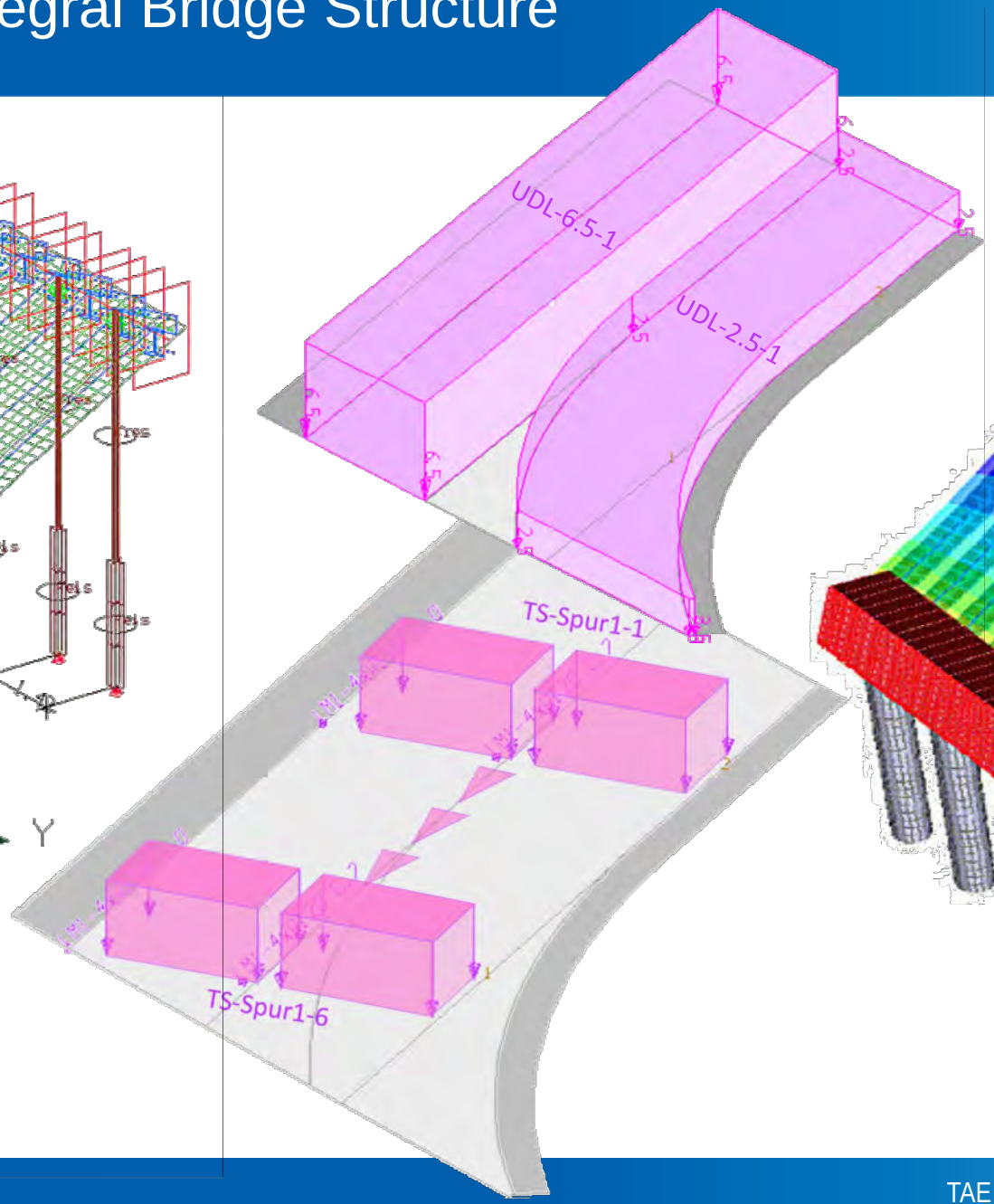
| Variants | Description | wirksam im Bauzustand / Lasten |
|---|---|---|
| 1 | Construction Steel | Construction Steel-Girder system |
| 2 | Concrete Slab | Secondary Stage |
| 3 | Composite $N_0$ $M_y$+ | Composite cons. Loads Condition<br>Short-term Composite Loads |
| 4 | Composite $N_P$ $M_y$+ | Long-term Composite Loads |
| 5 | Composite $N_{PT}$ $M_y$+ | Secondry loads due to<br>- Concreting Loads<br>- Finishing Loads<br>- Support sinking |
| 6 | Composite $N_S$ $M_y$+ | Secondary load due to:<br>- Shrinkage |

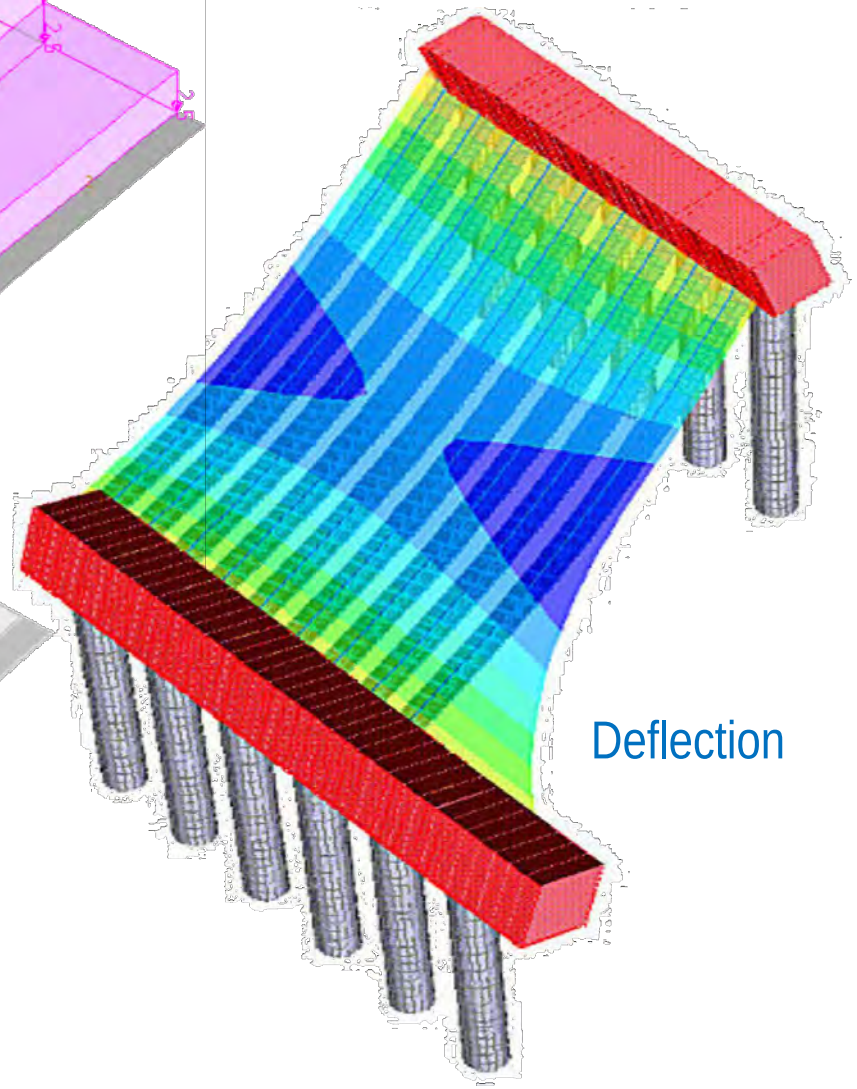


# FE-Model for the integral Bridge Structure

System

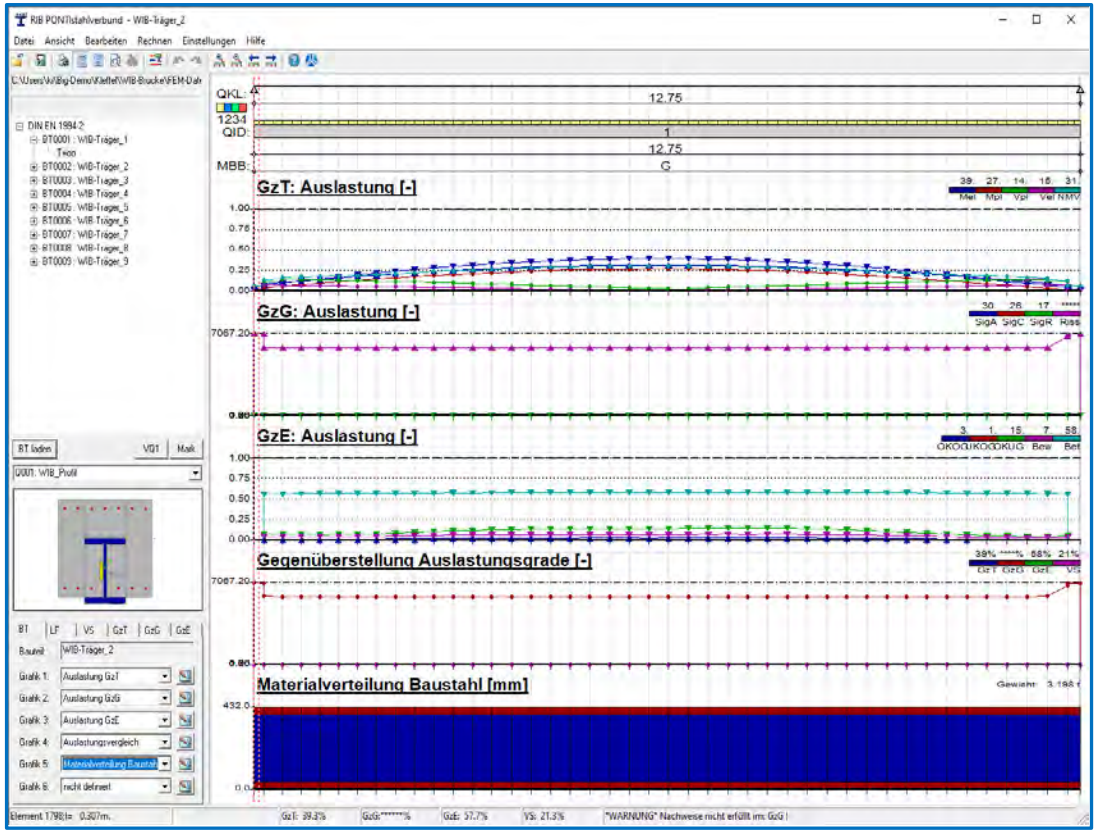


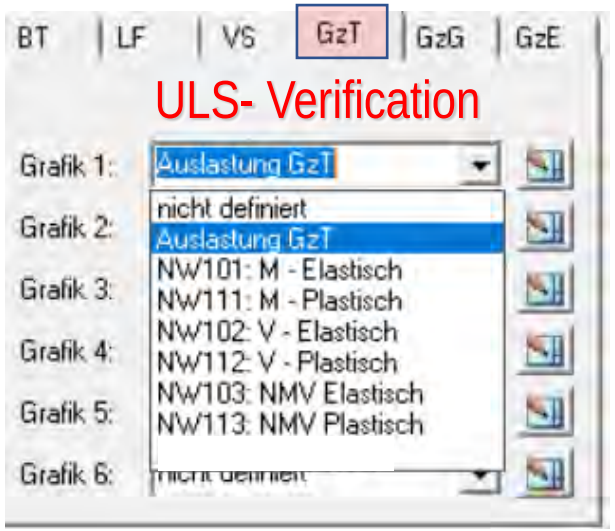



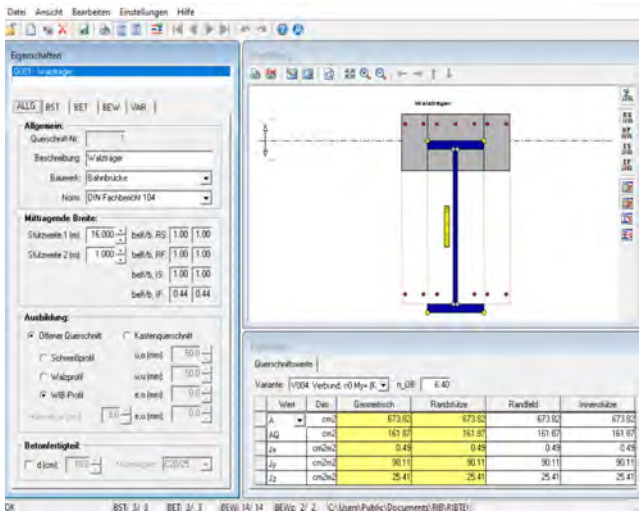



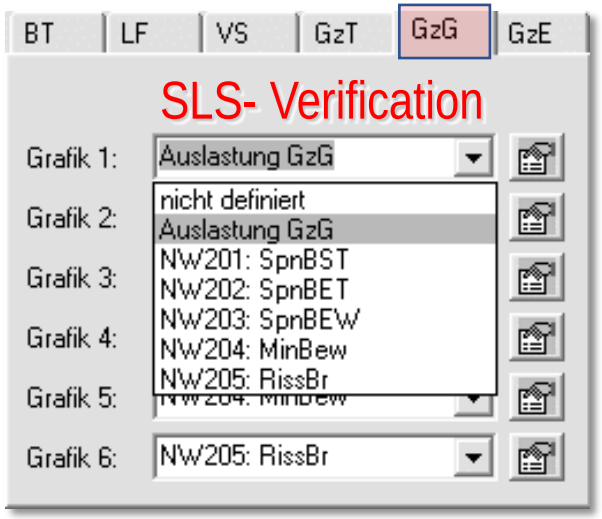
Deflection

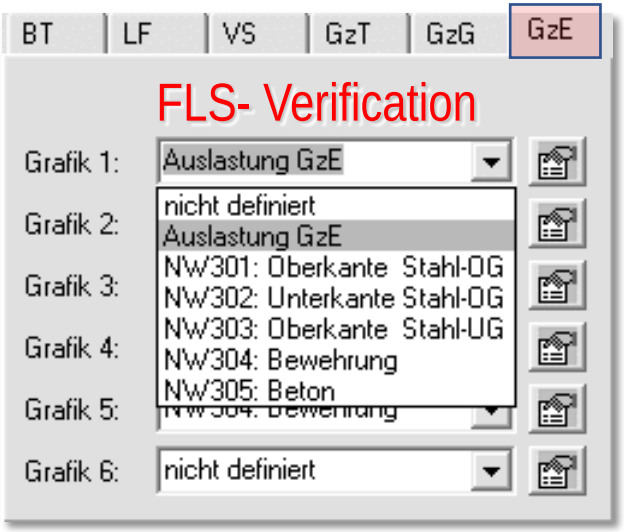
## Direct Verification Control





# Summary

- Modular Bridges are fast, **efficient** and **economical**
- High Performance **without** serious **mobility restrictions**
- Composite constructions with **high quality standard** by Prefabrication of the Precasted parts
- **Complex Construction measures** (demolition and new construction) and **sophisticated traffic situations** can be represented by overall static models
- Track individual Construction Phases via Construction Stages
- **Load distribution** can be implemented very efficiently by using **orthotropic Precast slab components**
- Modular Design is particularly suitable for frame constructions as **integral Structures** without central piles
- **Great Innovation potential** for bridge in Modular design

Thank you ขอบคุณ
ありがとう Grazie 謝謝 Merci
Terima Kasih Obrigado
Gratias agimus tibi شكرا Danke 谢谢
Շնորհակալություն
Hvala спасибо 감사합니다
Falemnderit Tack Gracias Дзякуй
Děkuji Dankon Salamat Takk
σας ευχαριστώ Kiitos धन्यवाद
Teşekkür ederim Go raibh maith agat
Mulțumesc cảm ơn bạn
Köszönöm dziękuję

TAE

RIB
running together