Challenges of Bridge Design and Detailing in Revit

Jakub Bielski

SOFiSTiK AG

Dirk Münzner

Boll und Partner GmbH & Co KG

AUTODESK. UNIVERSITY

About the speakers

Jakub Bielski

Product Manager in SOFiSTiK AG, responsible for creating new solutions for bridge design and 3D reinforcement detailing in Autodesk Revit environment.

Dirk Münzner

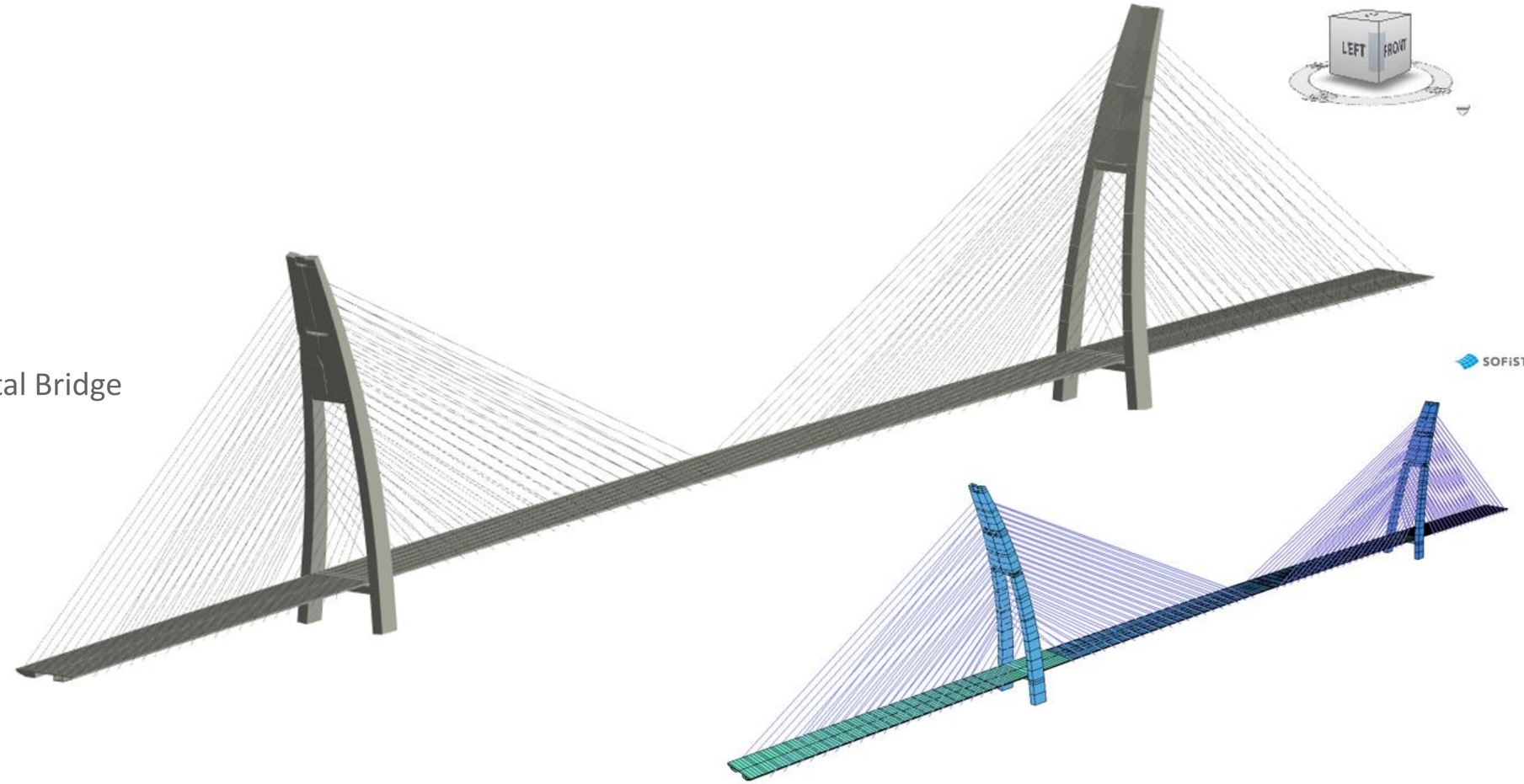
Managing Director in Boll und Partner GmbH & Co KG

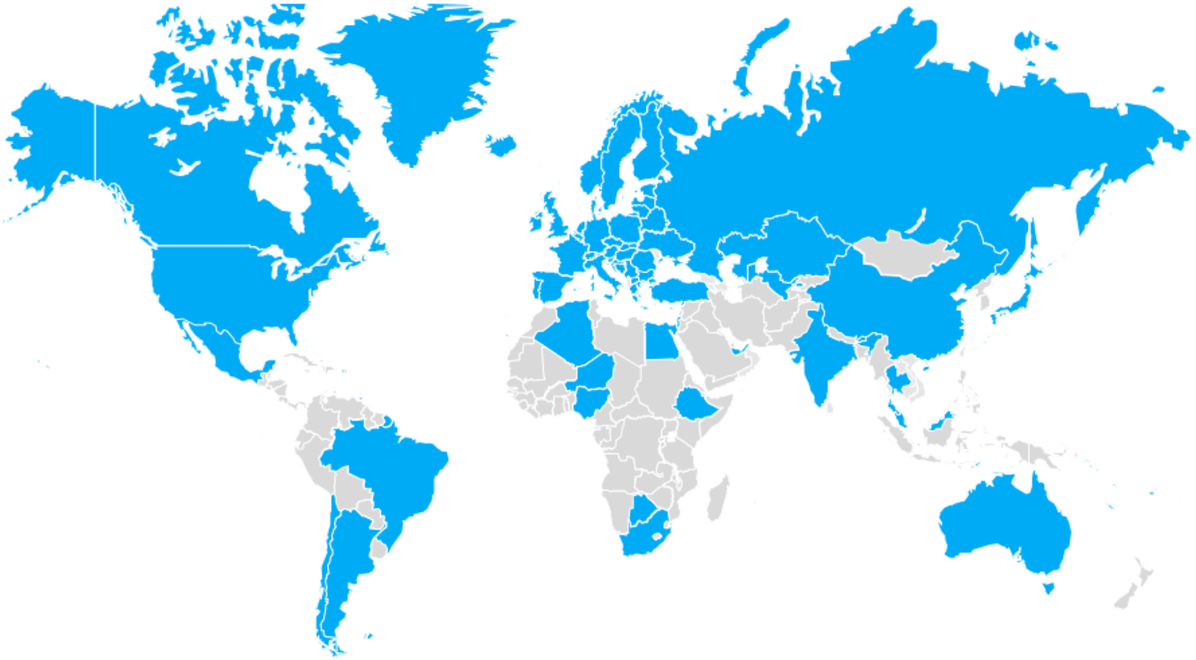
His main areas of expertise include the integration of collaborative BIM planning methods at large scale infrastructure projects. As a speaker and author, he is an acknowledged and eligible expert in the field of BIM implementation in national and international projects.

Introduction

Agenda

- Introduction
- Motivation
- SOFiSTiK Bridge Modeler
- Challenges - Modelling
- Challenges - Shop Drawings
- Project Example – 2nd Gauachtal Bridge
- What on the road?





SOFiSTiK AG

SOFiSTiK is Europe’s leading software developer for analysis, design and detailing of building and infrastructure projects worldwide.

AutoCAD as platform for analytical system input – SOFiPLUS - and creation of formwork and reinforcemnt drawings –SOFiCAD-

Boll und Partner GmbH & Co. KG

Motivation

Motivation

DIGITALIZATION OF CONSTRUCTION INDUSTRY

Positive experience gather by implementation BIM in Building Industry

Additional Value in Project Planning, Interoperability

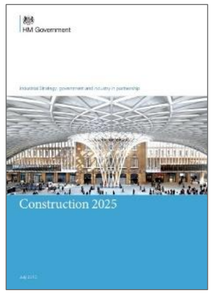
GOVERNMENTAL REQUIREMENTS

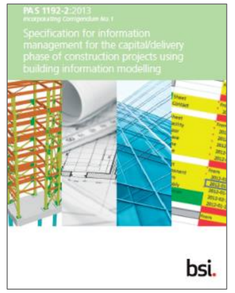
England [seit 2016]: Construction 2025, PAS 1992-2, BIM Level 2

Deutschland [ab 2020]: Stufenplan Digitales Bauen und Planen

„We will make it obligatory to plan and build infrastructure projects with BIM till 2020.“

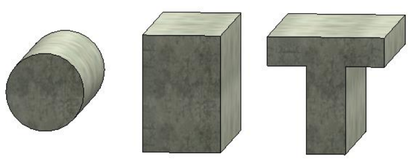
A. Dobrindt (former Minister of Transport and Digital Infrastructure, Dec 2015)

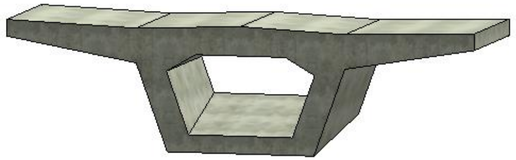




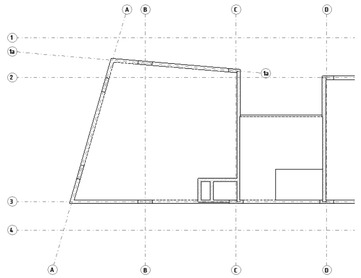
Differences between Buildings and Infrastructure

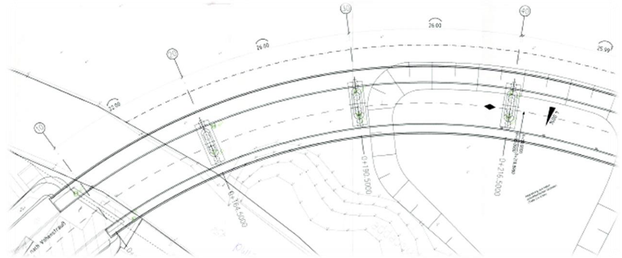
STANDARD VS. COMPLEX CROSS SECTION



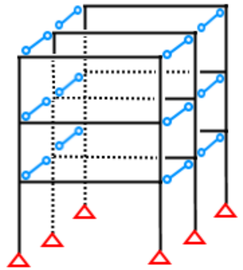


GRIDS LEVELS VS MAIN AXIS WITH GRADIENTS AND SLOPE

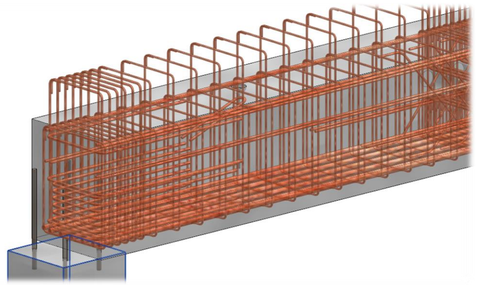




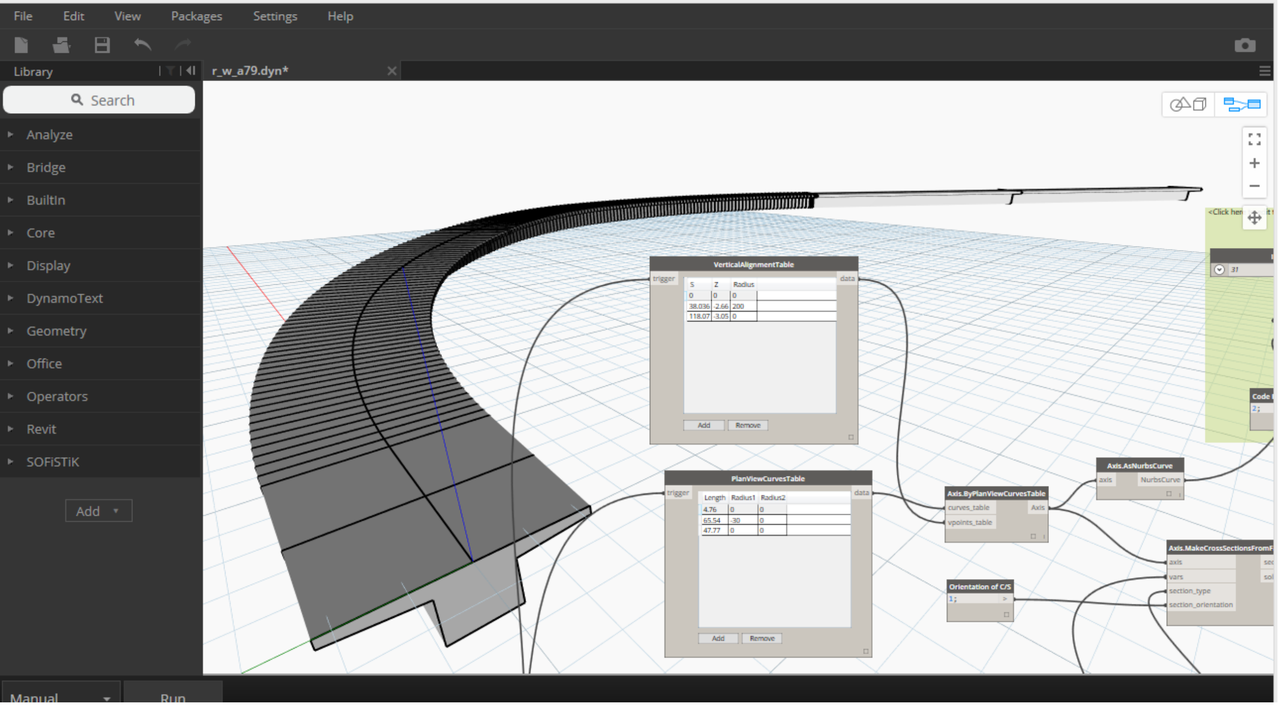
COMPLICATED 3D VS. BASIC STATIC SCHEMA

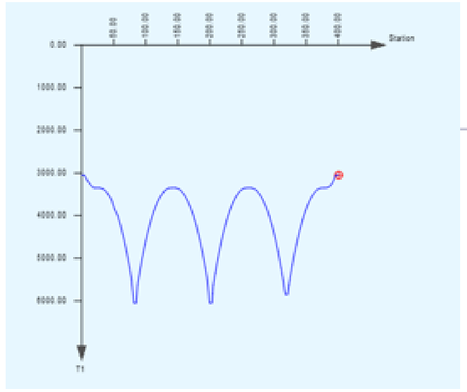


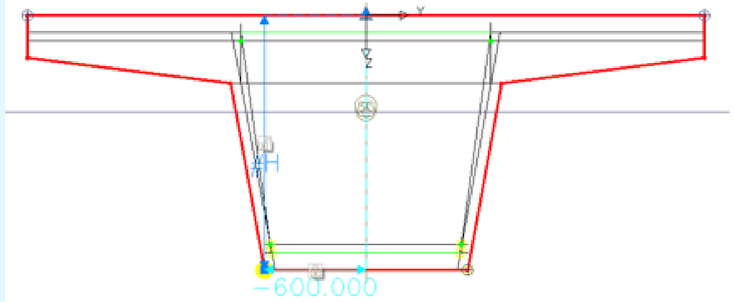
GRIDS AND LEVELS VS MAIN AXIS WITH GRADIENTS AND SLOPE

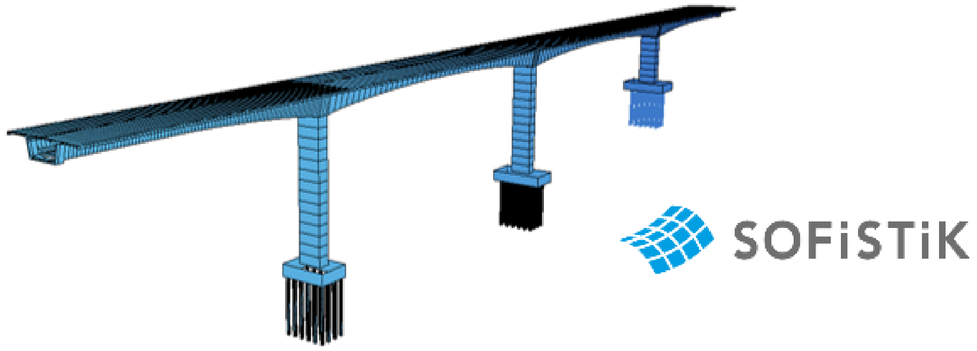


SOFiSTiK Bridge Modeler









General Concept

SOFiSTiK Bridge Modeler supports BIM in Bridge Design and Detailing. The application allows users to create parametrized 3D bridge models using alignment parameters and generic families in Autodesk® Revit® 2019.

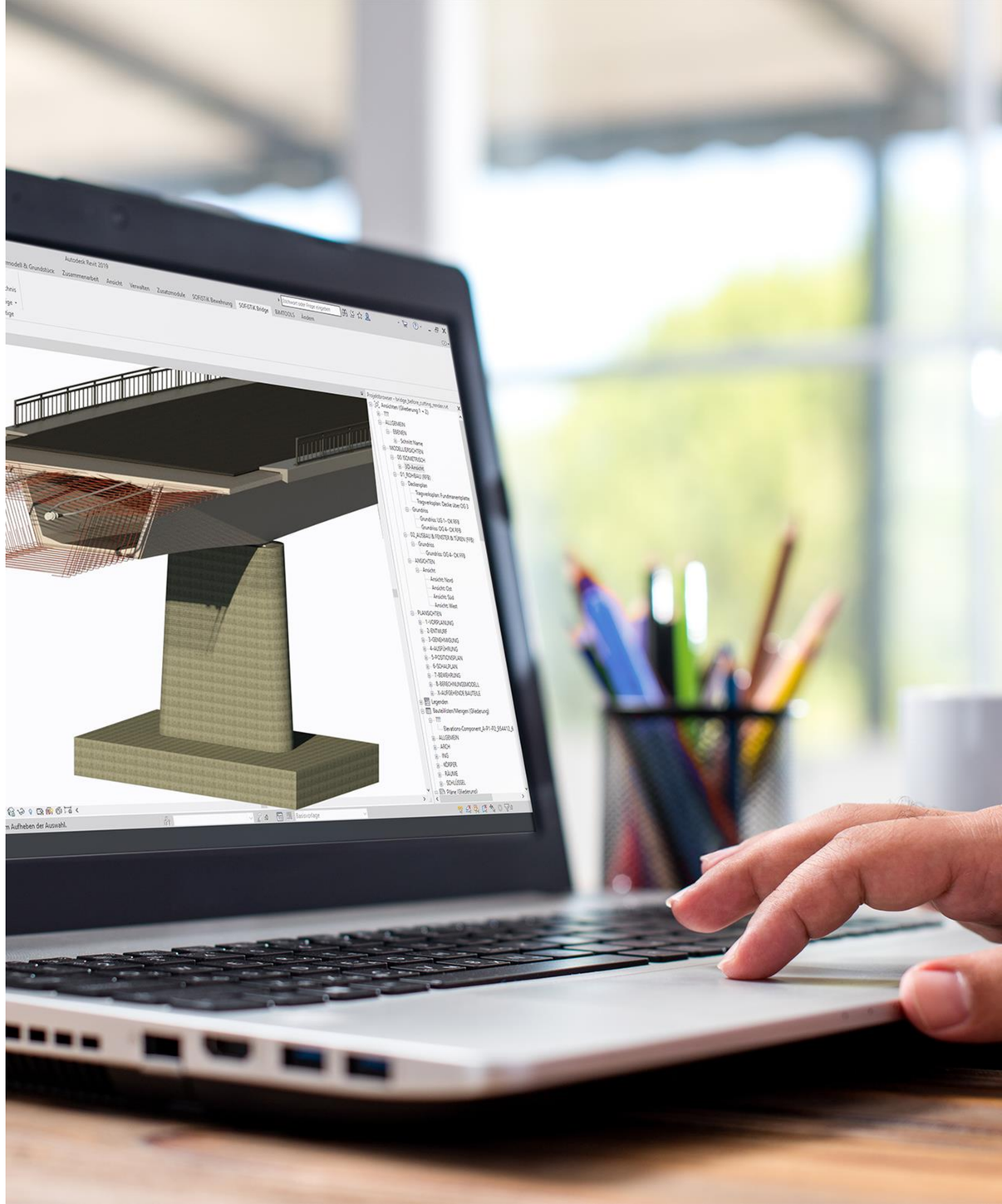
SOFiSTiK Bridge Modeler draws on experience from Computer Aided Bridge Design (CABD) concept implemented in SOFiSTiK FEA software.

Application integrates parametric bridge definition with generation of 3D solids in Autodesk Revit environment.

Design objectives

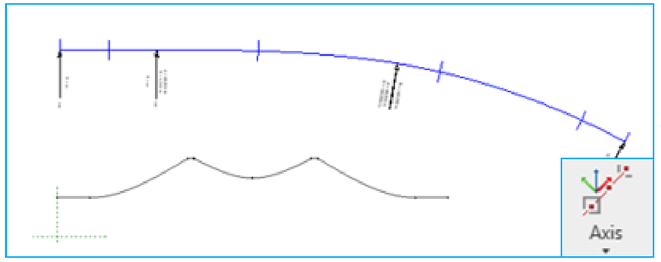
SOFiSTiK Development Team has set following aims to be fulfilled during the application design process and to be representative for Bridge Modeler

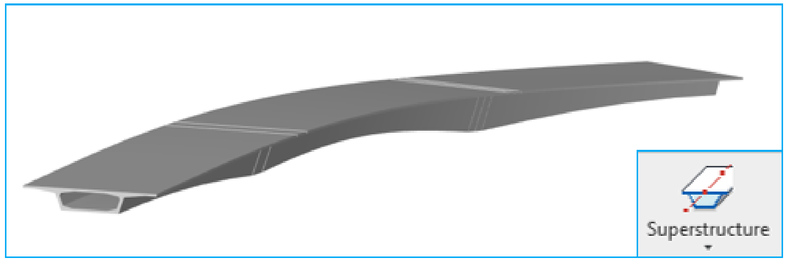
- Intuitive
  - Easy to use interface, logical steps
- Dynamic
  - Generation and modification in real time according to given data
- Generic
  - Engineer decides what and how he wants to model, not the software
- Fit in to current workflows
  - Help change the industry, not force it

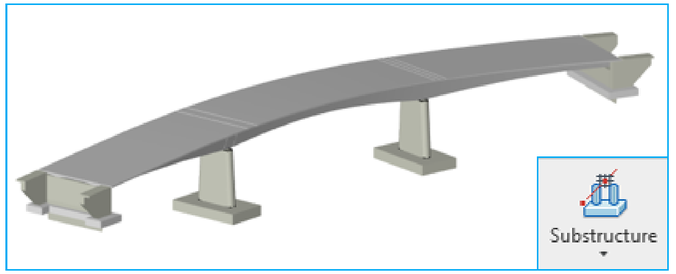


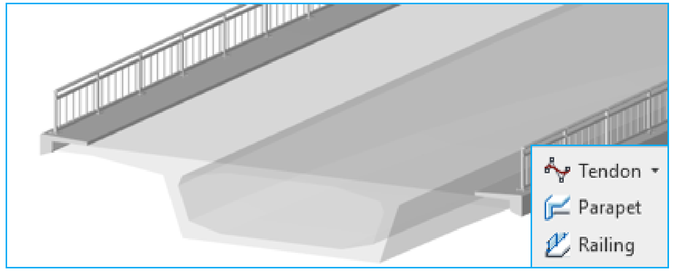
SOFiSTiK Bridge Modeler Workflow

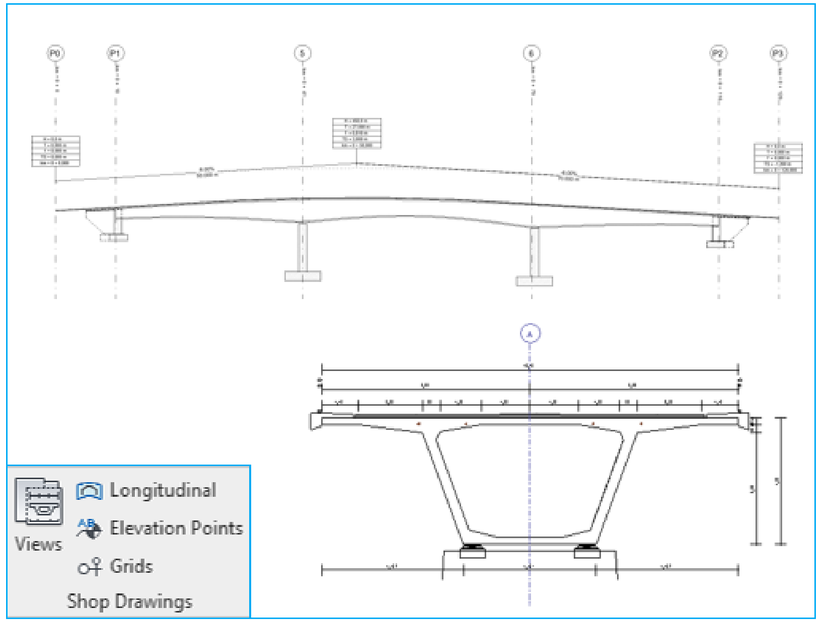
How can I go from Axis information through modeling into plan creation?











SOFiSTiK

Challenges - Modelling

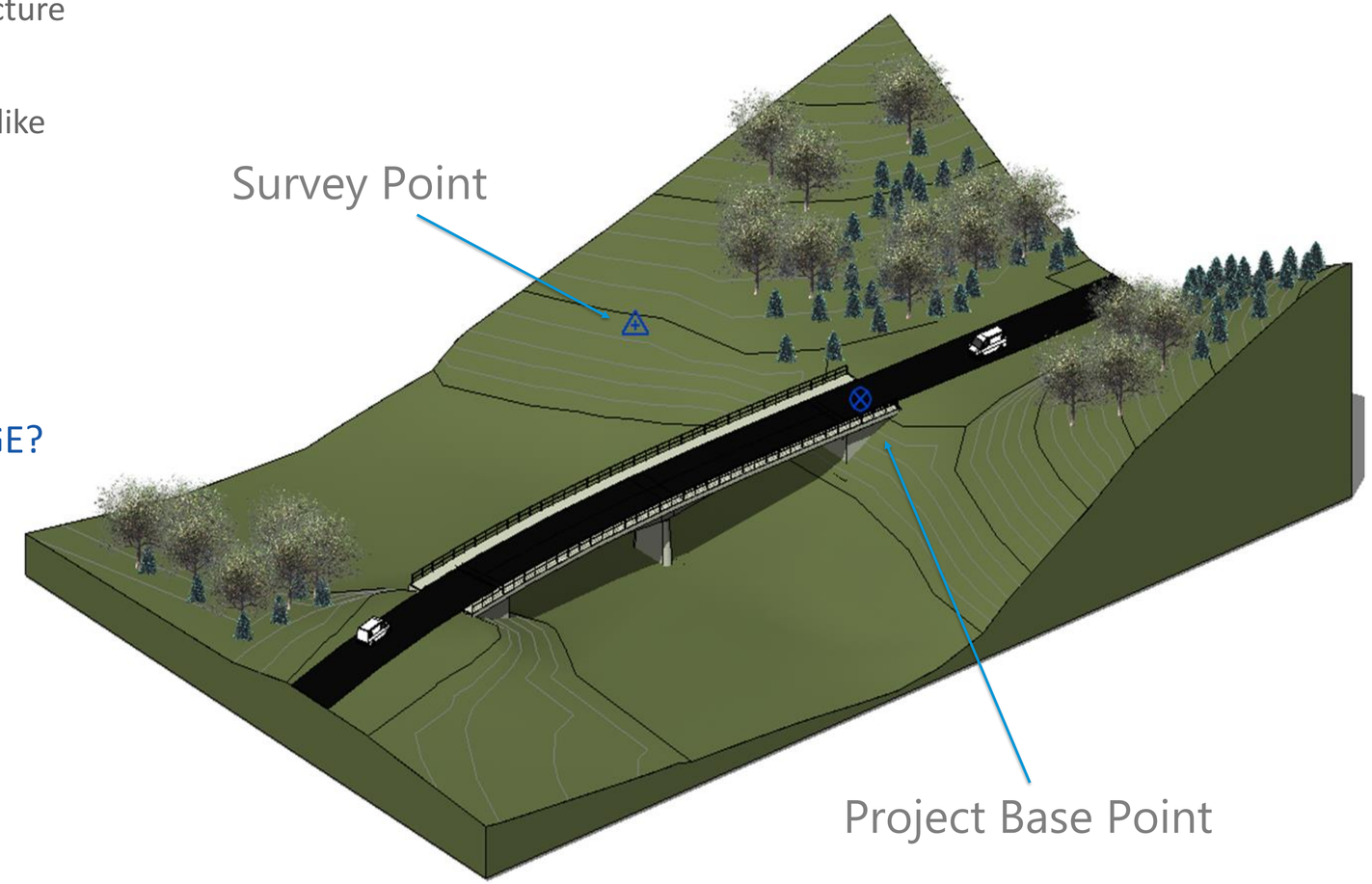
Coordinates

WHAT IS THE DIFFERENCE BETWEEN COORDINATE SYSTEMS? WHAT IS THE PURPOSE OF EACH OF THEM?

Project Base Point – is the know point of your bridge structure e.g. beginning of the superstructure or axis intersection

Survey Point – common known point that other elements like terrain model can relate to

Internal Origin – Defines the origin of Revit Design limit perimeter



HOW TO MANAGE THE COORDINATE OF MY BRIDGE?

Make sure that survey point is correctly defined

Find a known point of your bridge e.g. beginning of your superstructure

Place there Project Base Point

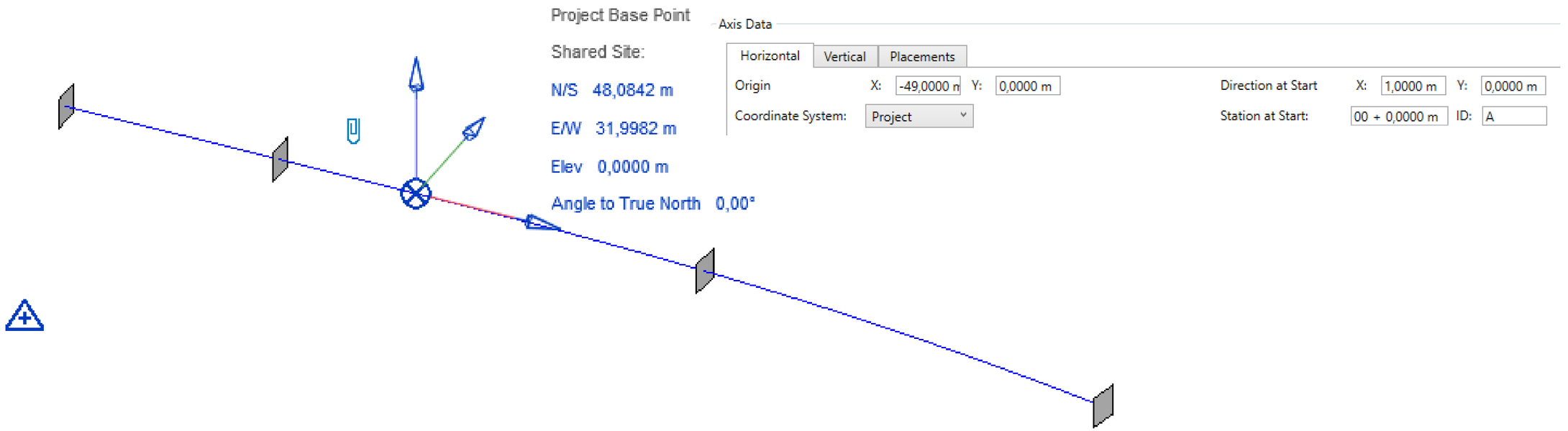
Define Axis according to this point – it will be easier to model your structure

Coordinates

HOW CAN I BE SURE, THAT MY BRIDGE IS IN THE CORRECT PLACE?

It can happen, that we don’t know exact coordinates of the beginning of the axis, but one of the stations.

We can simply move an axis using Revit functionalities in our project. Axis coordinates will be adjusted automatically.

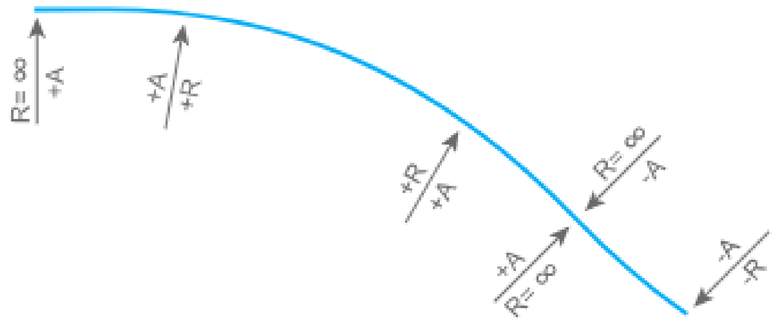


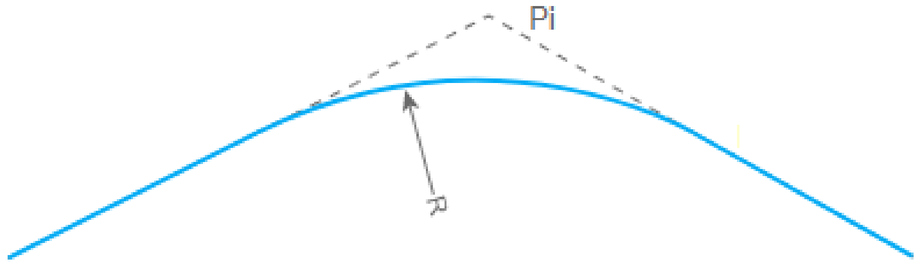
Axis

HOW CAN I DEFINE MY AXIS?

Horizontal + Vertical Alignment – curve type + parameters

Points with XYZ coordinates – connecting points to create 3D curve





Horizontal | Vertical | Placements

Origin X: 0,0000 m Y: 0,0000 m

Direction at Start X: 1,0000 m Y: 0,0000 m

Coordinate System: Project

Station at Start: 00 + 0,0000 m ID: A

Curve Type	Length	Start Radius	End Radius	Station
Line	20,0000 m	-	-	20,0000 m
Clothoid	30,0000 m	0,0000 m	150,0000 m	50,0000 m
Arc	50,0000 m	150,0000 m	-	100,0000 m

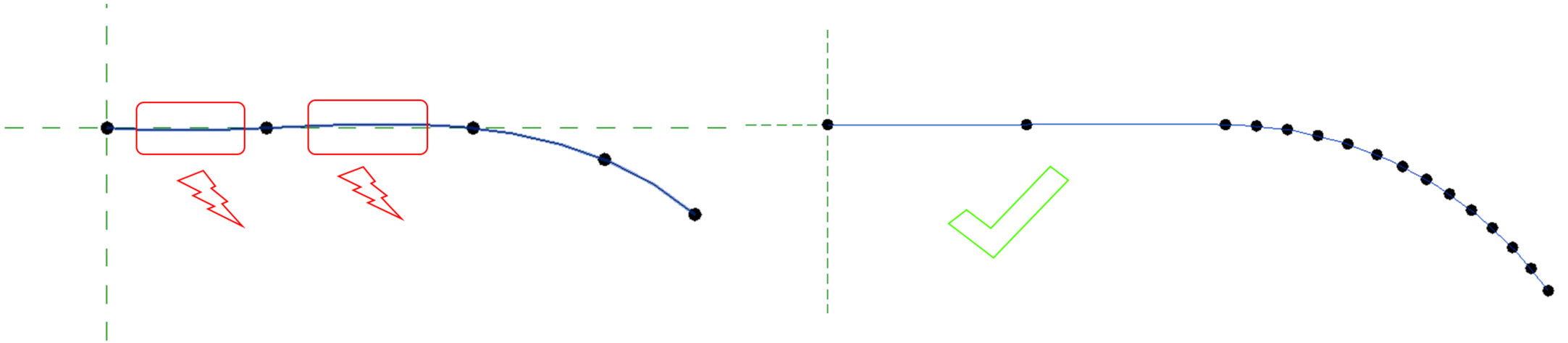
Horizontal | Vertical | Placements

Station	Height	Radius
0,0000 m	0,0000 m	-
50,0000 m	5,0000 m	200,0000 m
100,0000 m	0,0000 m	-

Axis

HOW CAN I CONTROL ACCURACY

Adjust number of points according to the curvature and neighboring curve’s geometry

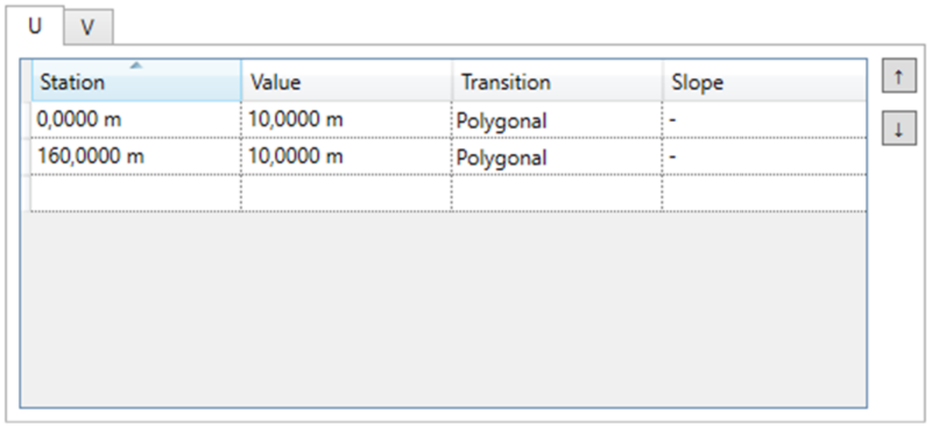


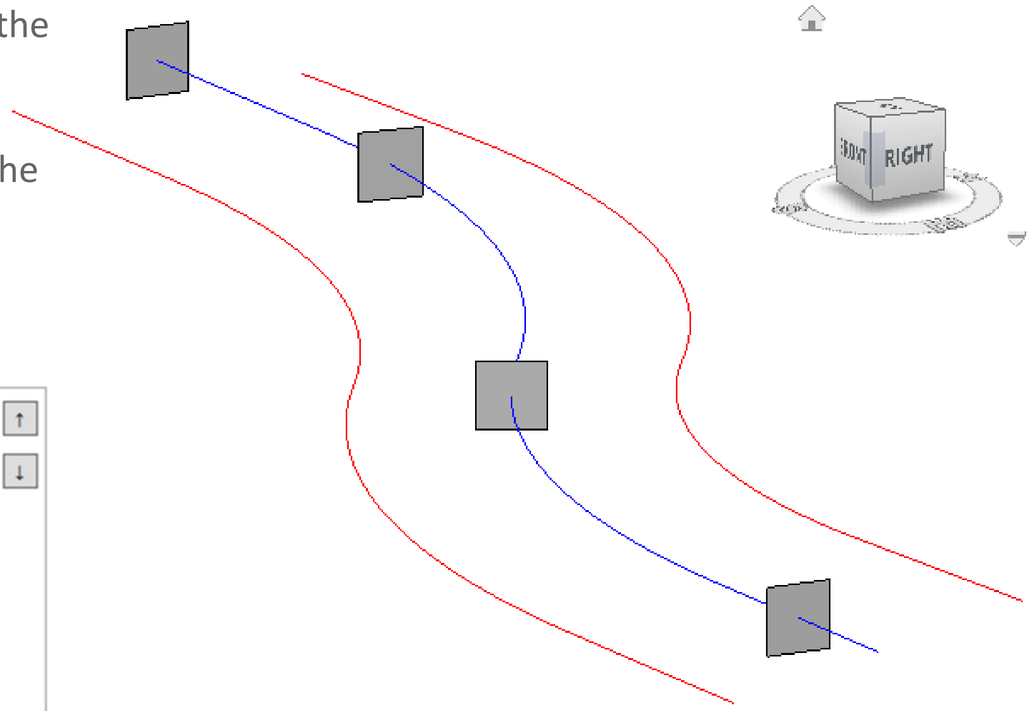
Axis c.d.

HOW CONNECT MORE AXIS AND MAKE THEM DEPENDENT FROM EACH OTHER?

Create Secondary Axes with geometry dependent on the main axis and additional offset parameters.

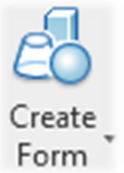
Modifications of the main axis will directly influence the secondary axis.





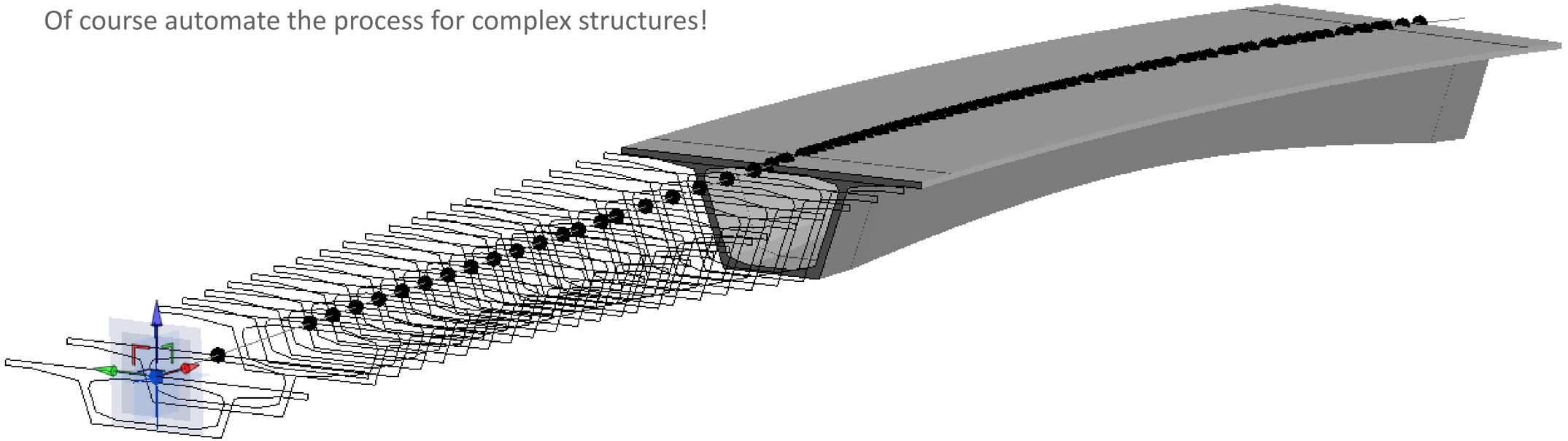
Superstructure

HOW CAN I CREATE A COMPLEX SUPERSTRUCTURE ELEMENT



Use 3D forming tools in Revit Family. Place a section on your axis and generate a form with loft tool.

Of course automate the process for complex structures!

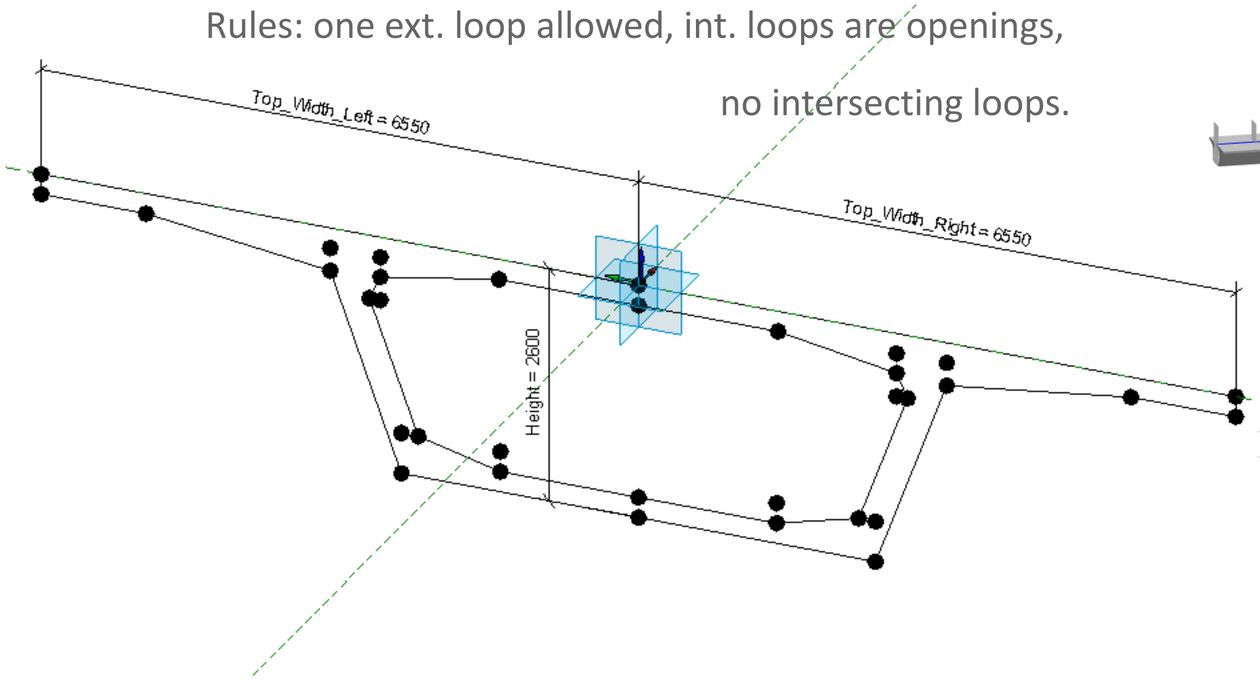


Superstructure

HOW TO DEFINE MY CROSS SECTION?

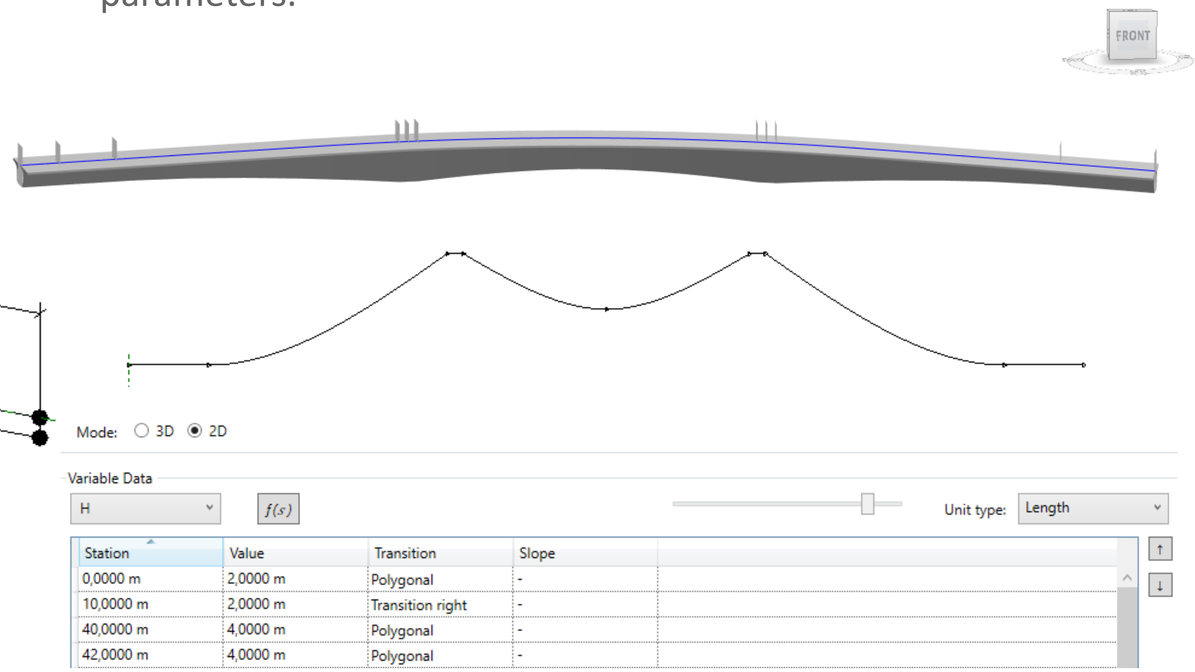
You can define bridge cross section using Adaptive Generic Family. Sketch lines on one plane forming a closed loop.

Rules: one ext. loop allowed, int. loops are openings, no intersecting loops.



HOW CAN I DEFINE THE VARIABILITY OF THE SUPERSTRUCTURE?

Define the Variables with accordance to your axis using tables or formulas and connect them with Cross Section parameters.

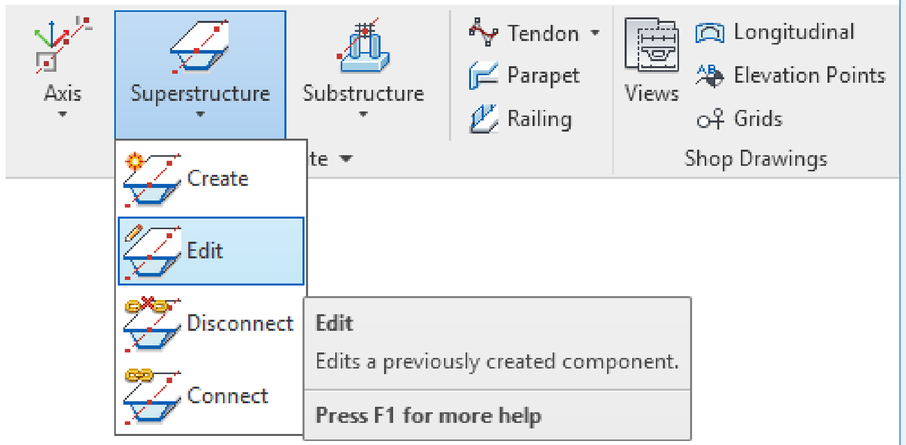


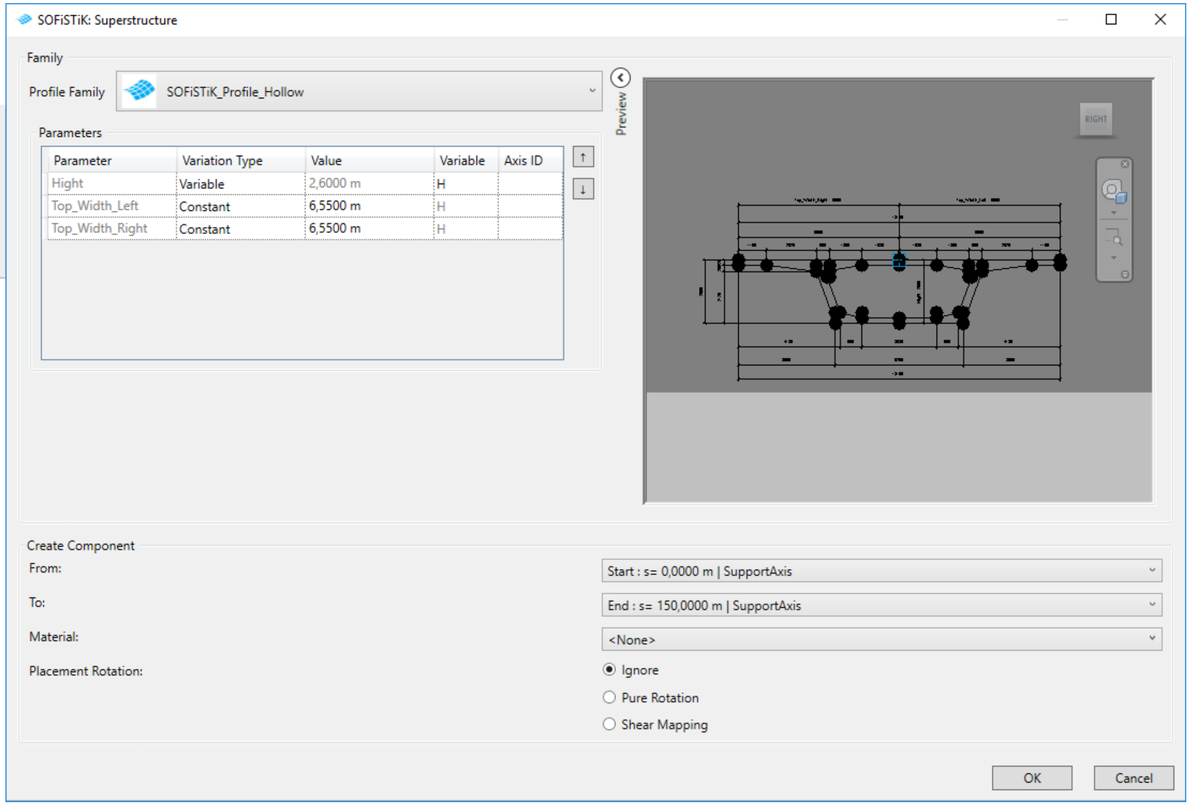
Superstructure

HOW CAN I MODIFY MY BRIDGE?

You can access model data at every stage of your project and modify it.

Decide if the modifications are on the superstructure or axis level.



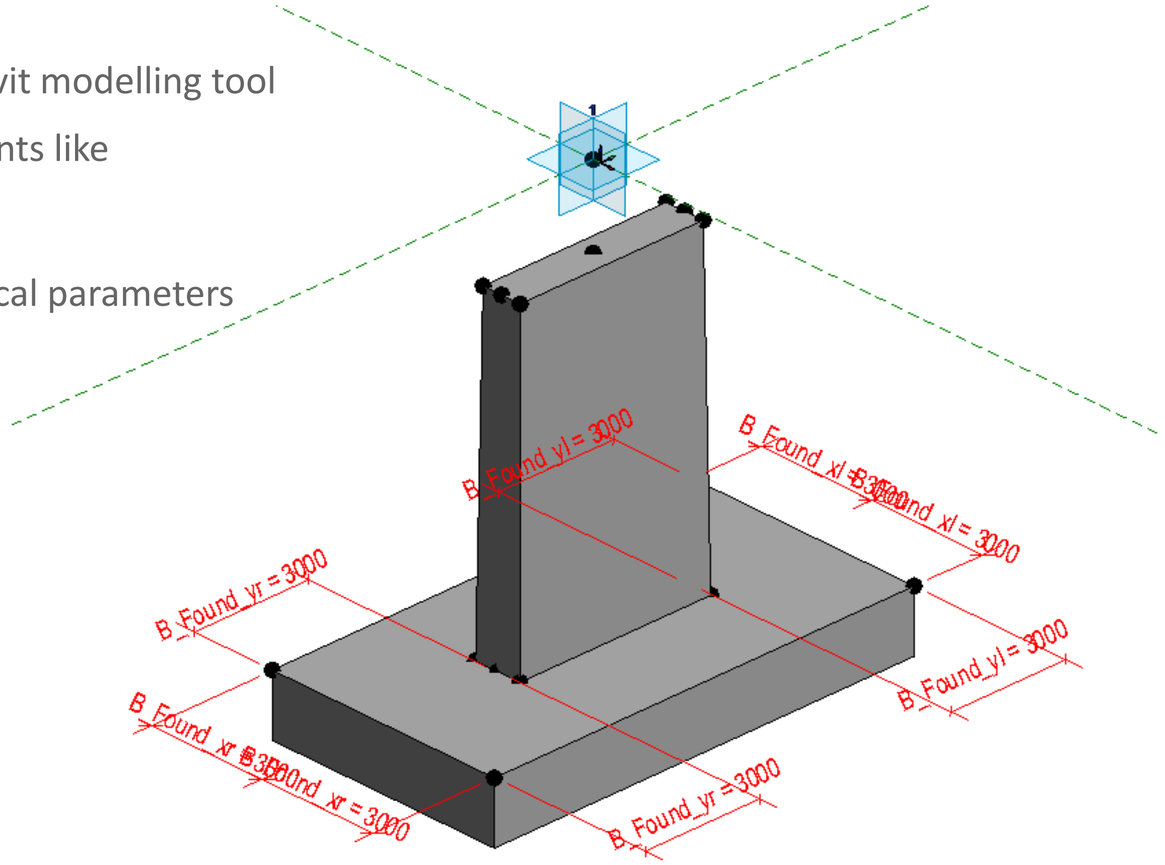


Substructure

HOW CAN I DEFINE MY SUBSTRUCTURE AND PARAMETRIZE IT?

Simply! Use Revit Families. This basic Revit modelling tool is perfect for modelling geometry elements like substructures, abutments, piers etc.

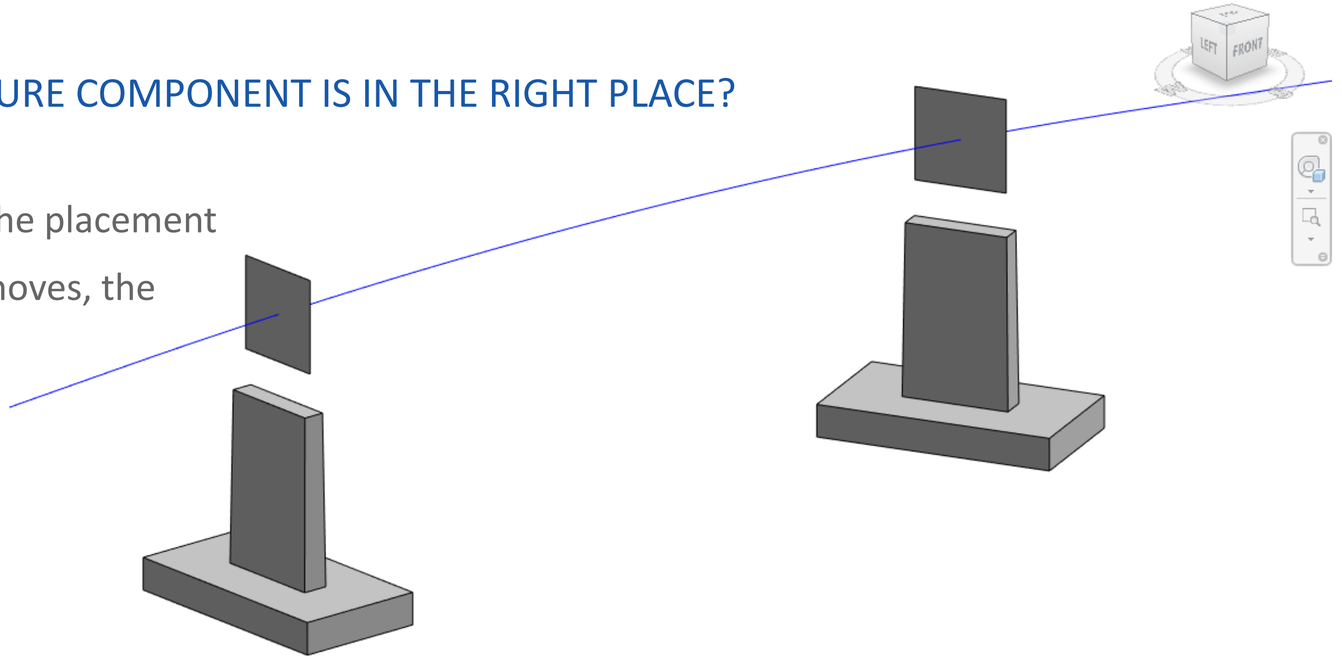
Decide the Level of Detail, add geometrical parameters and other attributes



Substructure

HOW CAN I BE SURE, THAT SUBSTRUCTURE COMPONENT IS IN THE RIGHT PLACE?

Substructure components are created at the placement and tightly connected to it. If placement moves, the substructure will move accordingly.



Axis Data

Horizontal | Vertical | Placements

Placements Orientation: ○ Orthogonal to Axis ◉ Vertical ☑ Create Placements represetation

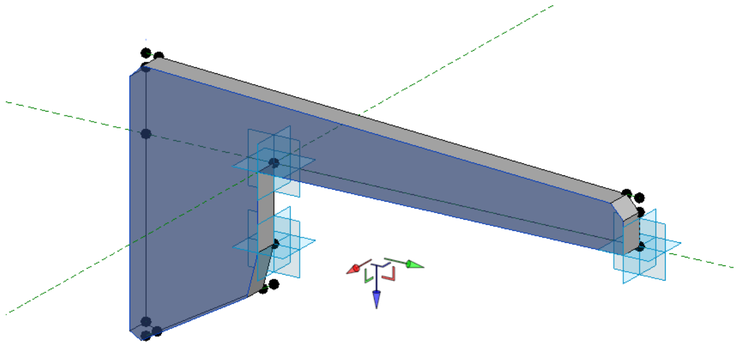
Station	ID	Type	Global Direction	Rotation X	Rotation Y	Rotation Z
0,0000 m	Start	Support Axis	-	-	-	-
41,0000 m	P1	Support Axis	-	-	-	-
79,0000 m	P2	Support Axis	-	-	-	30,00°
150,0000 m	End	Support Axis	-	-	-	-

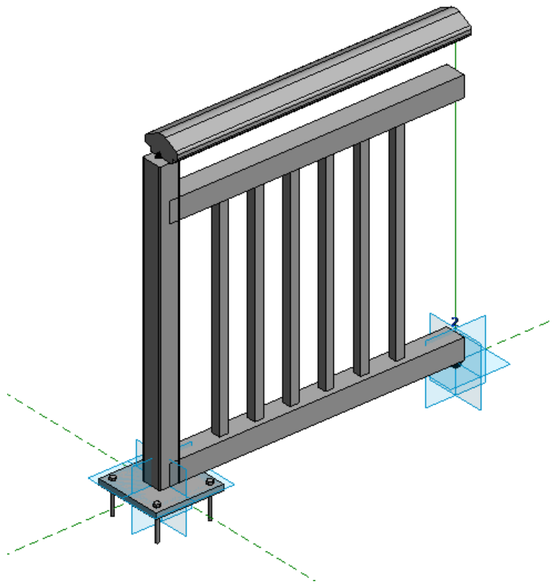
Bridge Equipment

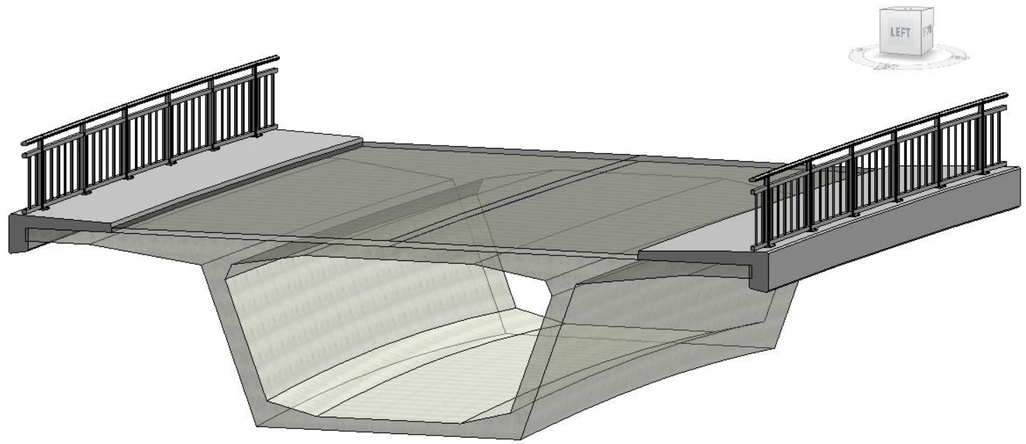
How to create the additional equipment of the bridge with proper alignment?

Parapets, railings etc..

As these elements are defined according to the bridge (in most cases deck) geometry, and cross slope, it makes more sense to define such elements with respect to these conditions. You can create continuous or repeated elements along the chosen edge of the bridge. These elements are responsive to the faces, that are creating chosen edge.







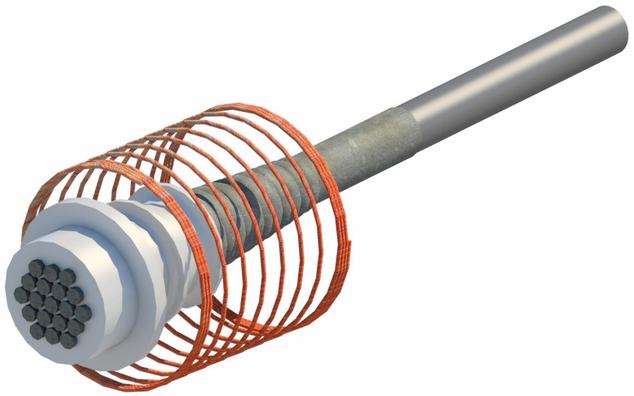
Prestressing

THERE IS NO PRESTRESSING OBJECTS IN REVIT. WHAT CAN I DO?

Be creative!

SOFiSTiK concept for prestressing in Revit

Use Free Form Rebar objects as prestressing cables and rebar couplers as anchorages.

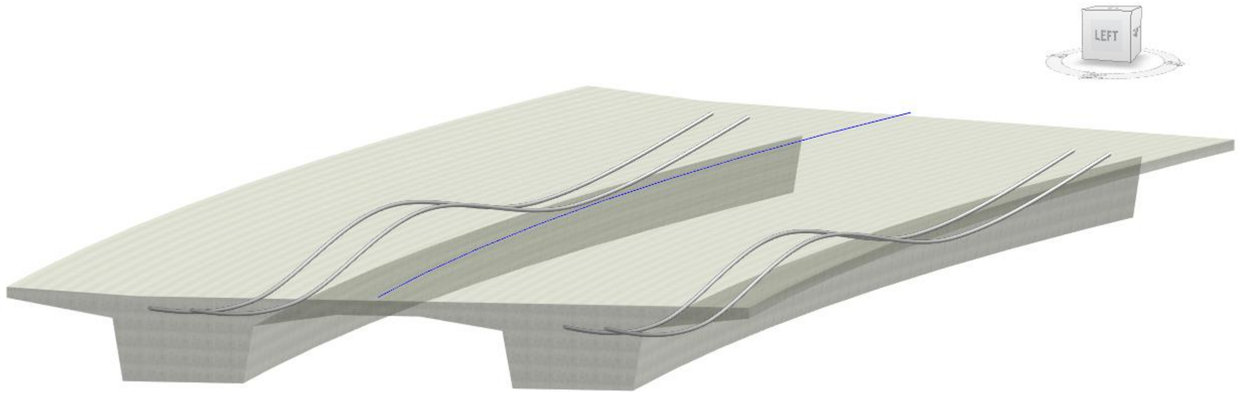


Prestressing

HOW CAN I DEFINE GEOMETRY OF PRESTRESSING CABLES?

You can create prestressing cables using the geometry of any 3D curve.

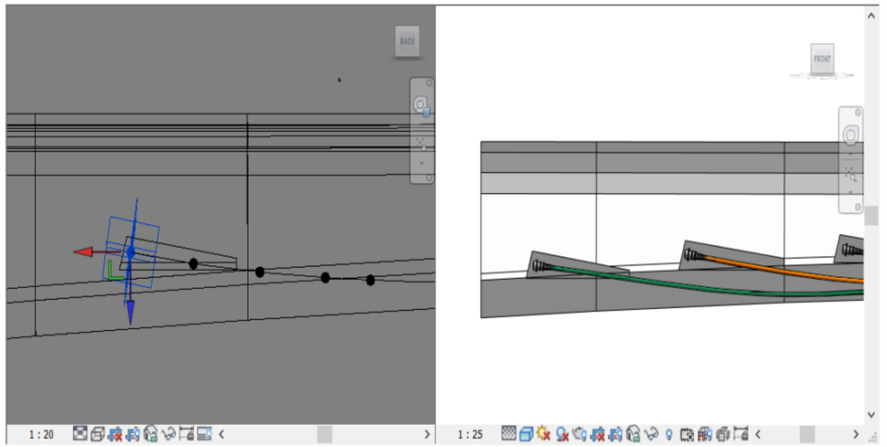
Bridge Modeler reads the geometry data of the curve.



HOW TO MODIFY IT?

Globally – modify the 3D curves

Locally – use Tendon Edit tool and modify the spline using points



Reinforcement

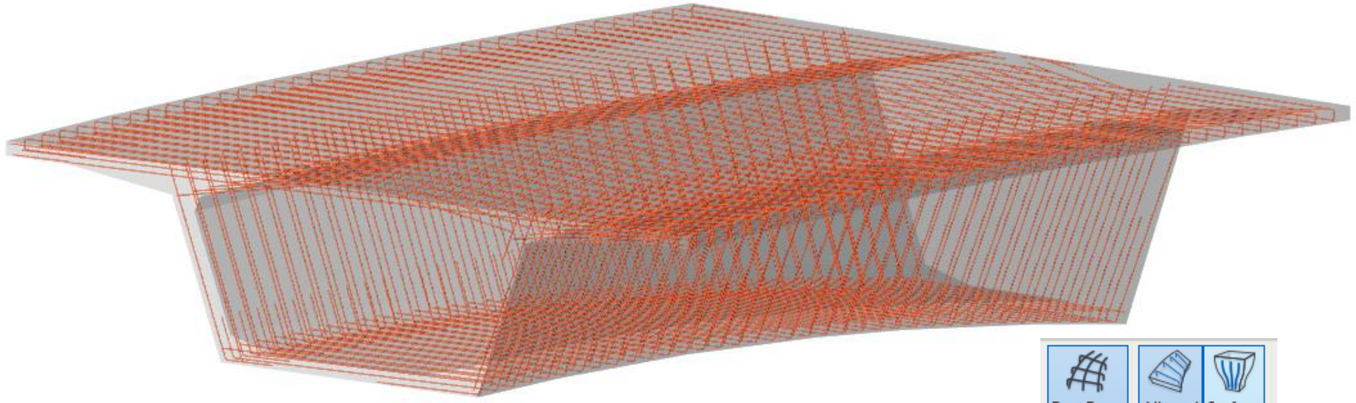
HOW CAN I CREATE REBARS IN COMPLEX STRUCTURES?

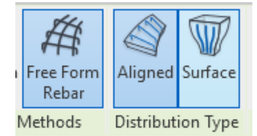
Use Free Form Rebar elements!

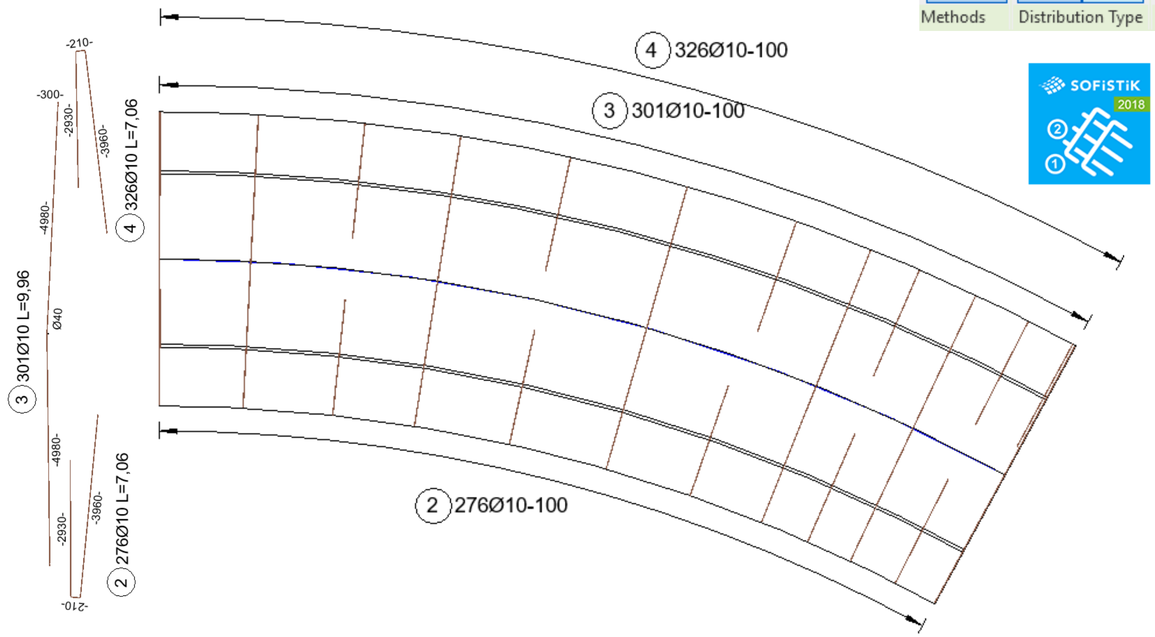
They are getting better with each Revit Version

New functionality enables you to define Rebar Set according to the host's faces and given path.

You can also align Rebar Set to the chosen face.







HOW CAN I ANNOTATE IT?

You can use SOFiSTiK Reinforcement Detailing

Wide range of tool for annotation and rebar detailing will accelerate creation of Rebar Drawings

Challenges – Shop Drawings

Section views

HOW CAN I DEFINE MY CROSS SECTION? SNAP TOOL DOESN’T WORK WITH COMPLEX CURVES

Bridge Modeler is using its own data structure. Access to this data is useful not only for modelling purposes, but also for detailing.

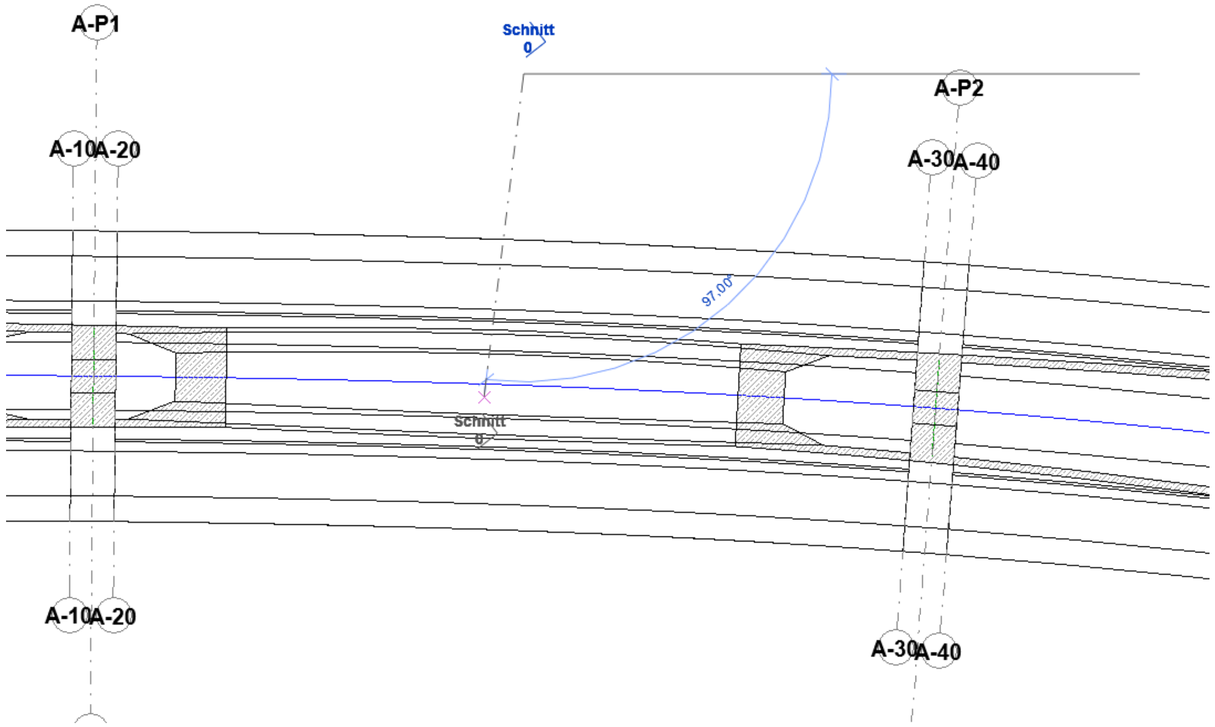
I DON’T KNOW WHERE EXACTLY MY SECTION VIEW IS. I CANNOT USE DIMENSIONS ANYMORE.

Cross sections are created according to the defined stationing. We know exactly where our cross section is!

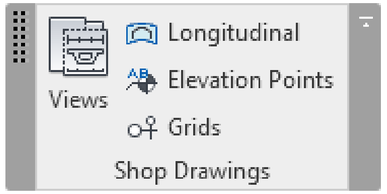
HOW CAN I CREATE MULTIPLE SECTION VIEWS? COPY OR ARRAY TOOLS DON’T WORK FOR BRIDGES.

Boost this process by creating multiple cross sections using well-known Revit layout definition.

‘Layout > Rule > Justification > Spacing ‘

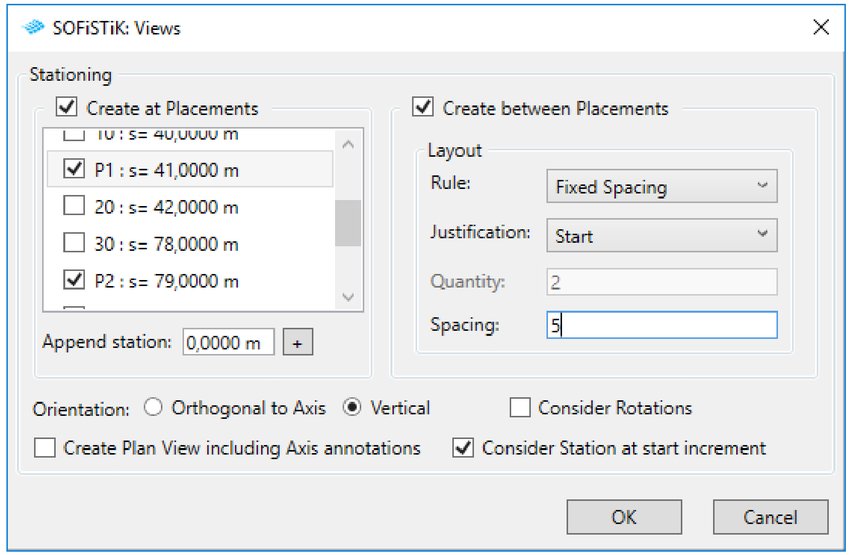


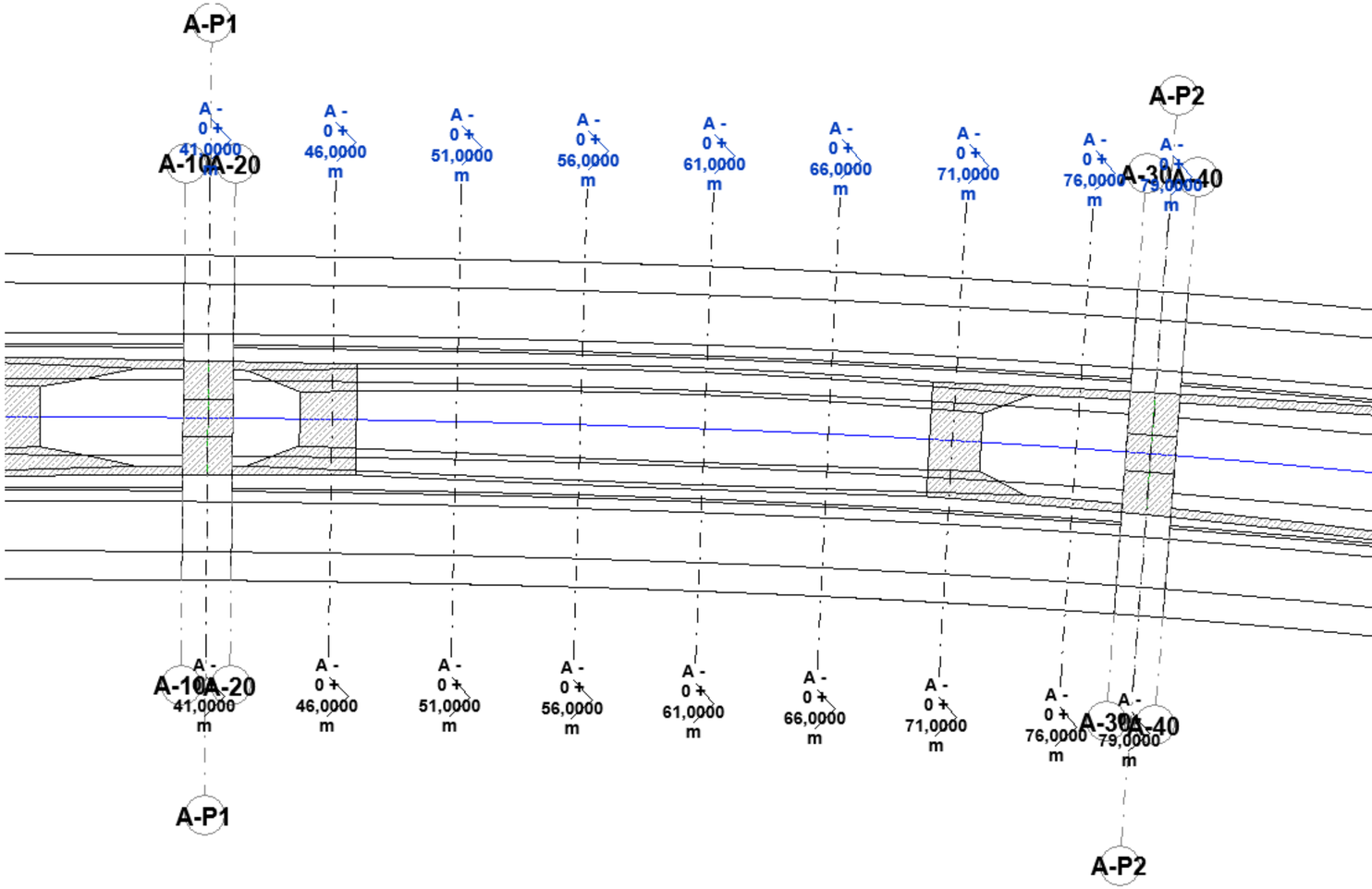
Section views



3 Problems – 1 Solution

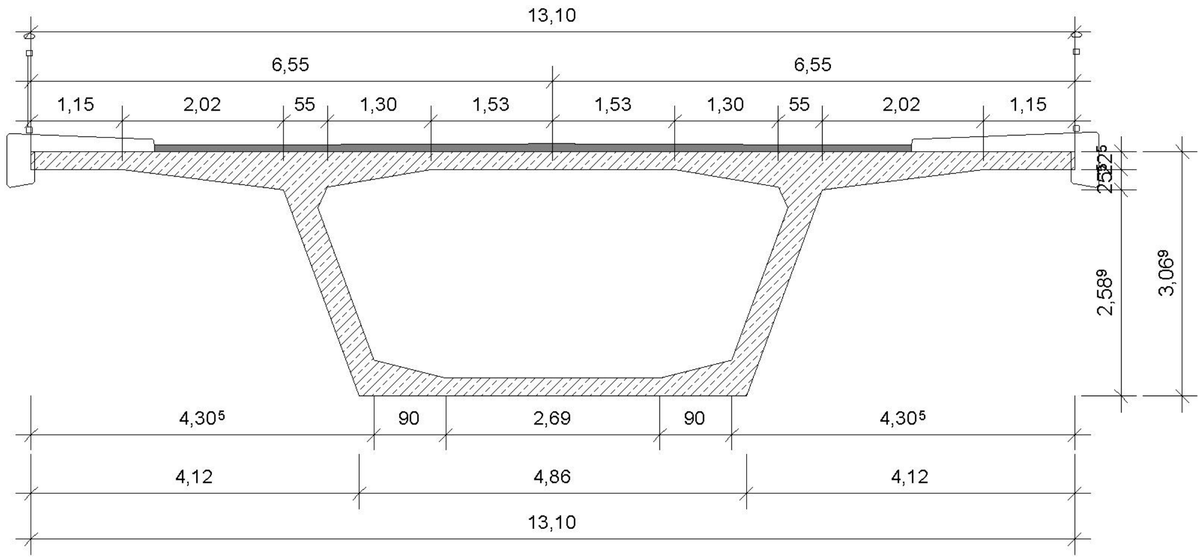
- Use axis as the position reference
- Define position of sections according to the stations
- Create multiple sections with layout rule definition

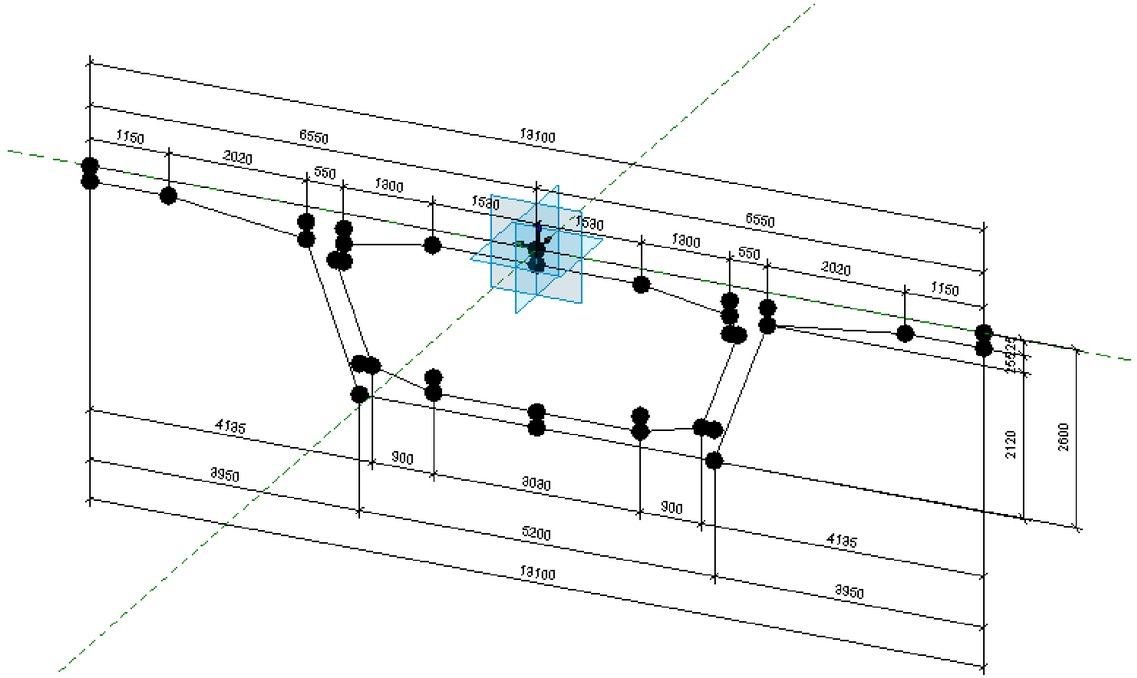


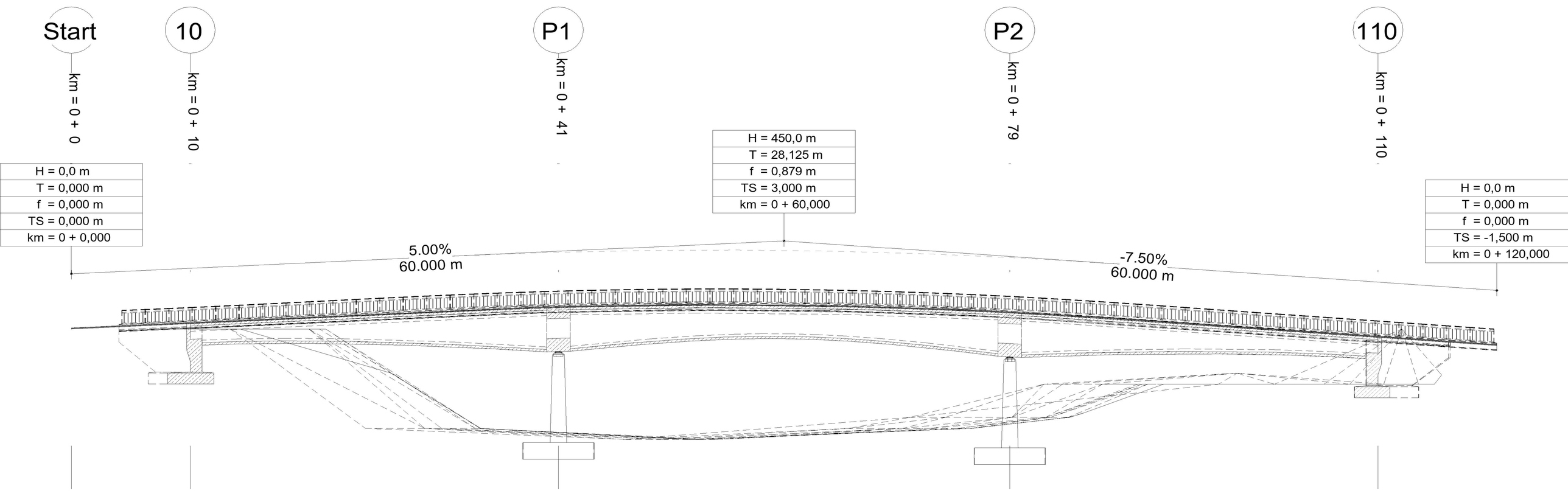


Section views – Bonus!

Dimensions defined in in Cross Section Family are automatically placed in the generated Section Views.





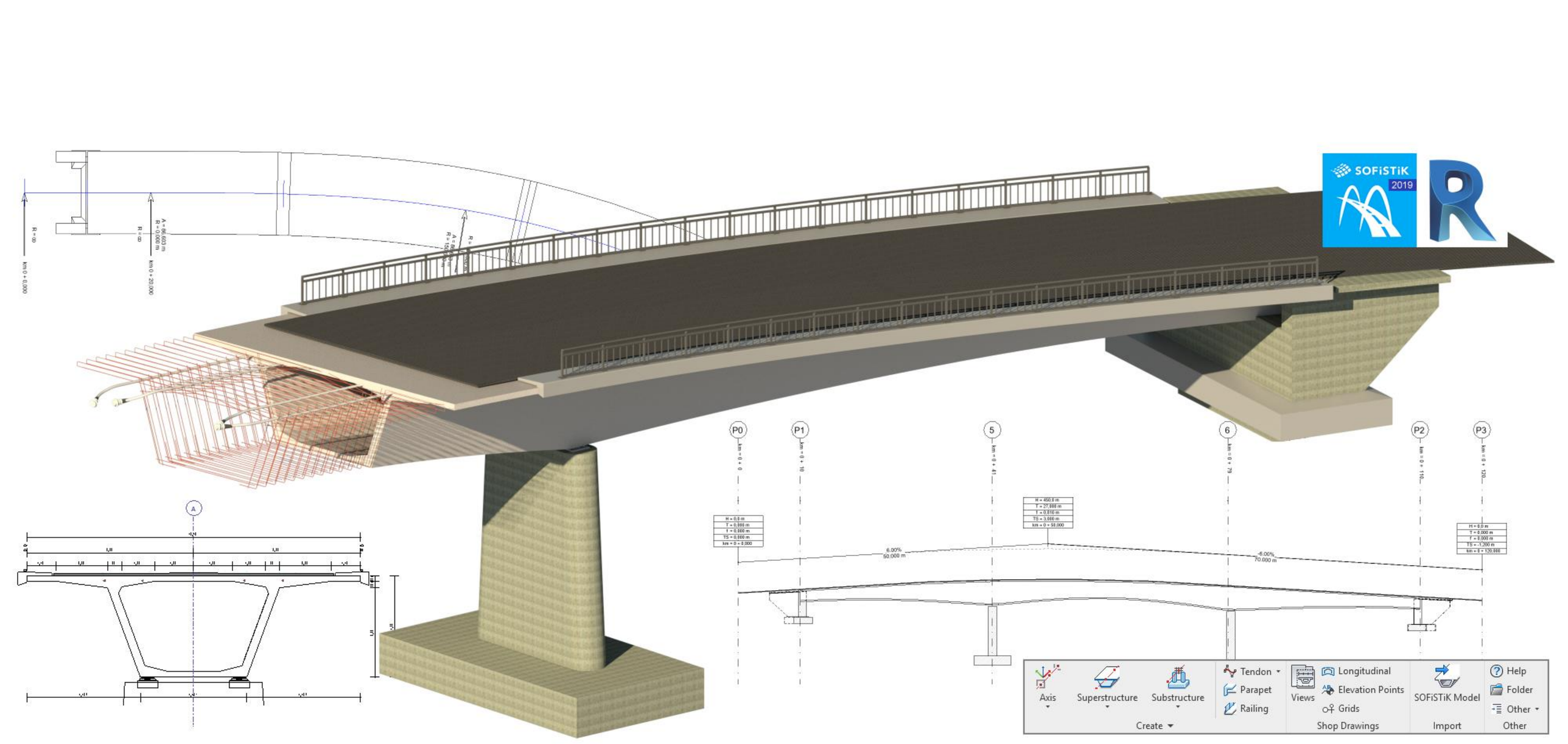


Longitudinal Unfolded Section

HOW CAN I CREATE UNFOLDED VIEW IN REVIT?

It is quite simple, you cannot. At least not now and not the one, that you are used to see. Till now, Revit provides no unfolded view.

Bridge Modeler offers another solution. We can cut the geometry with vertical surface defined by the axis or other curve. Intersection of the surface and cut element defines a line which is being unfolded and sketched in the detail element.


SOFiSTiK
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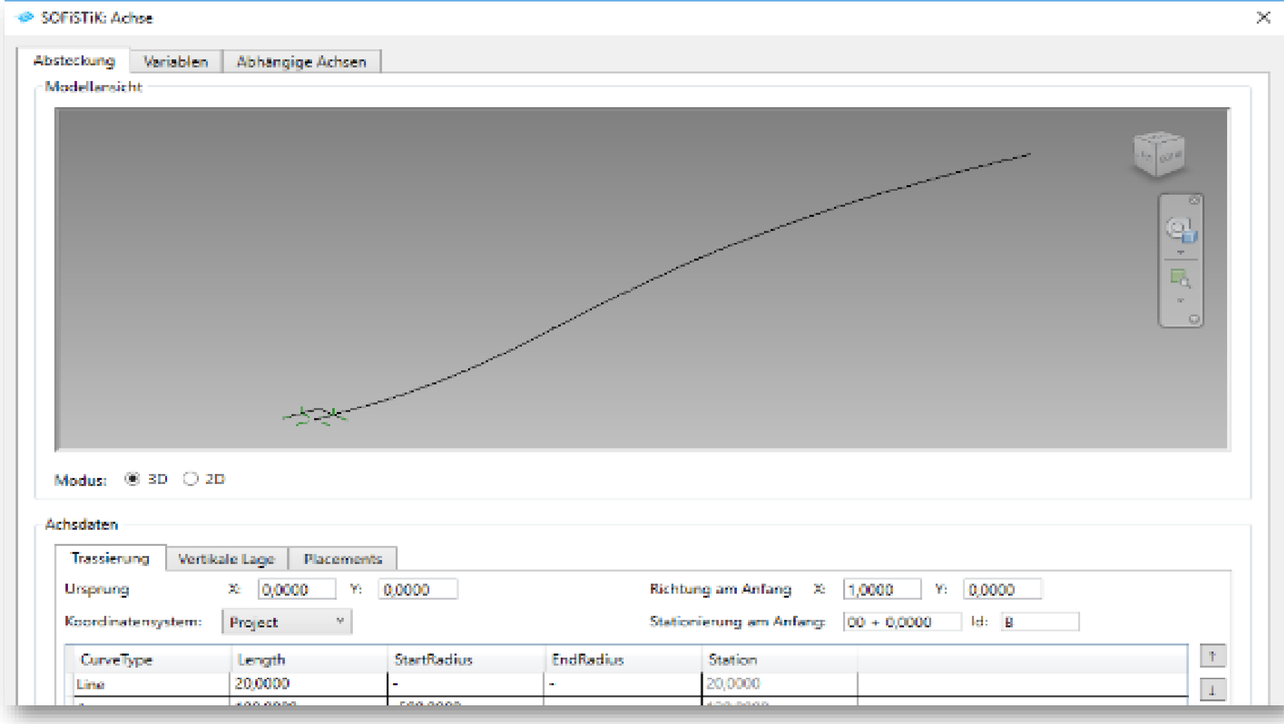
P0
P1
5
6
P2
P3
Axis
Superstructure
Substructure
Tendon
Parapet
Railing
Create
Views
Longitudinal
Elevation Points
Grids
Shop Drawings
SOFiSTiK Model
Import
Help
Folder
Other
Other

Example Project - 2nd Gauchachtal Bridge

The project

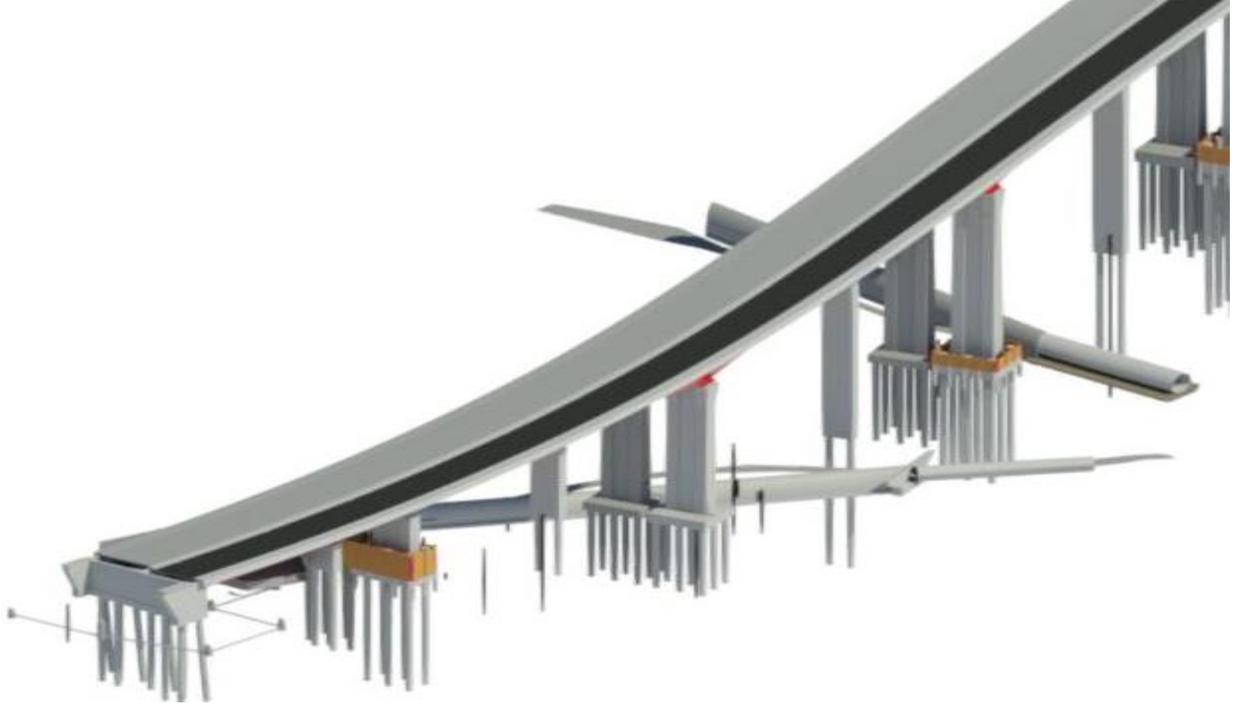
The German government has chosen several outstanding projects to be planned with the BIM- Method as lighthouse projects – the tallest of those Pilot- Projects is the 2nd Gauchachtalbrücke in the very south of Germany. Its crosses a side valley of the Wutachschlucht, one of the most rugged landscapes in Middle Europe, also know as the “Grand Canyon of Swabia”.

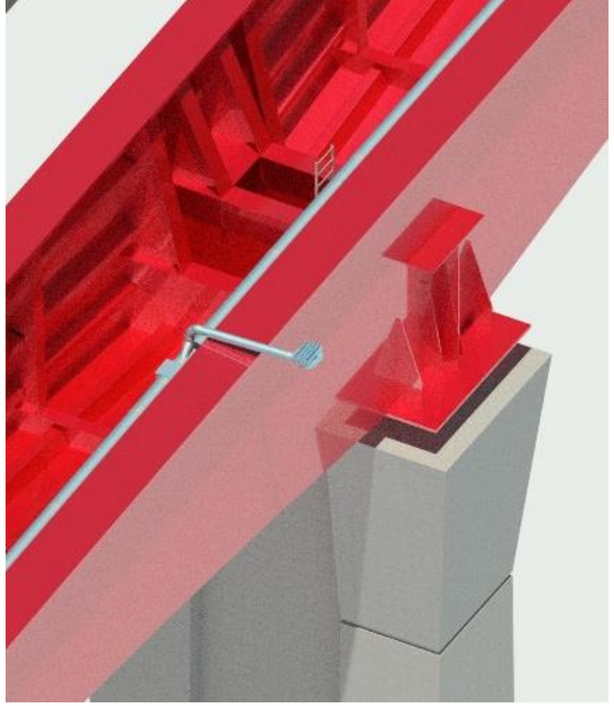


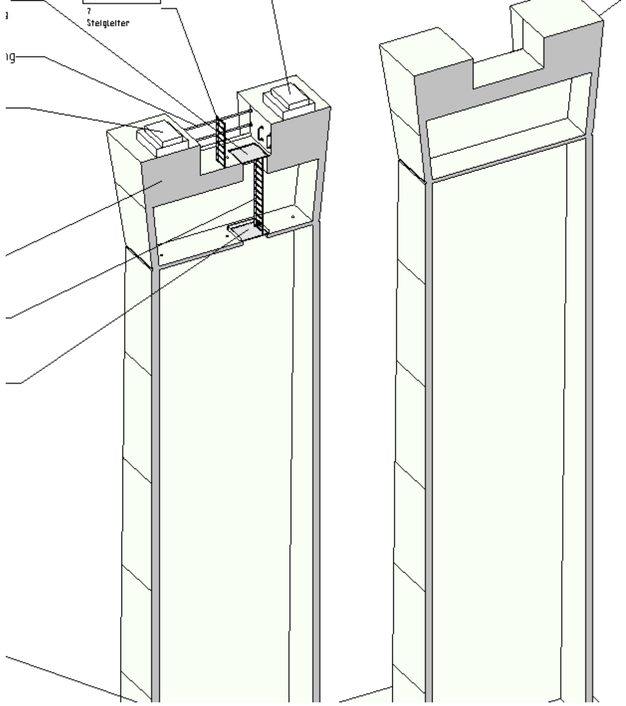
BIM = 3D model?

The Sofistik Bridge Modeler brings an extraordinary simplification to the modelling process, as there is no further need to use additional programs like C3D or to intensively use Dynamo to get a bridge “into” an BIM-environment.

But a BIM process is more than modelling



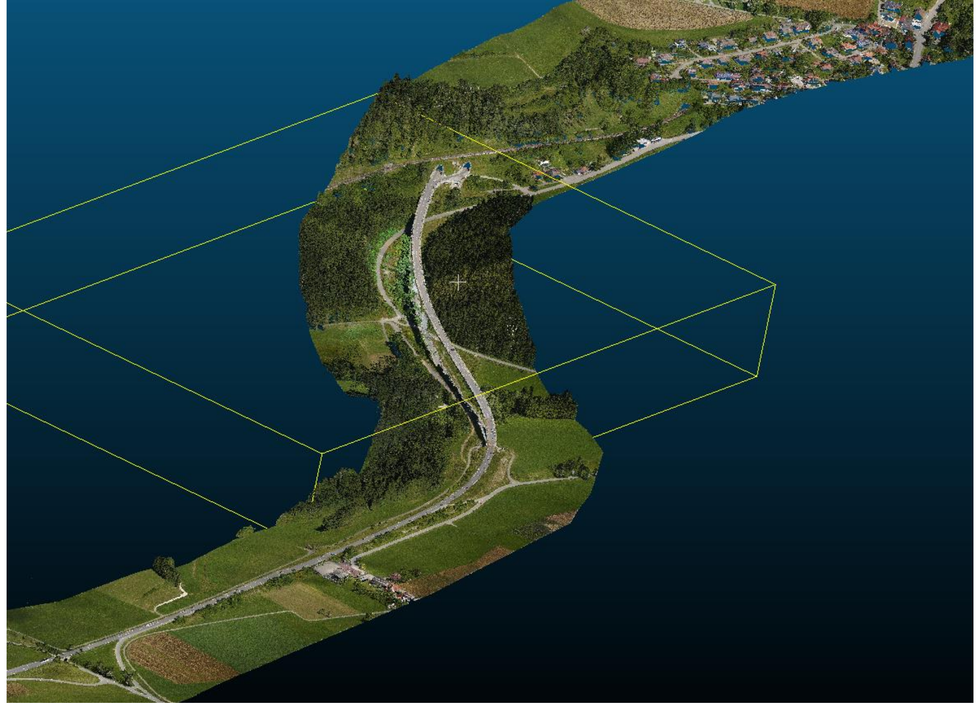




BIM = 3D model with many details?

The Sofistik Bridge Modeler brings an extraordinary simplification to the modelling process, as there is no further need to use additional programs like C3D or to intensively use Dynamo to get a bridge “into” an BIM-environment.

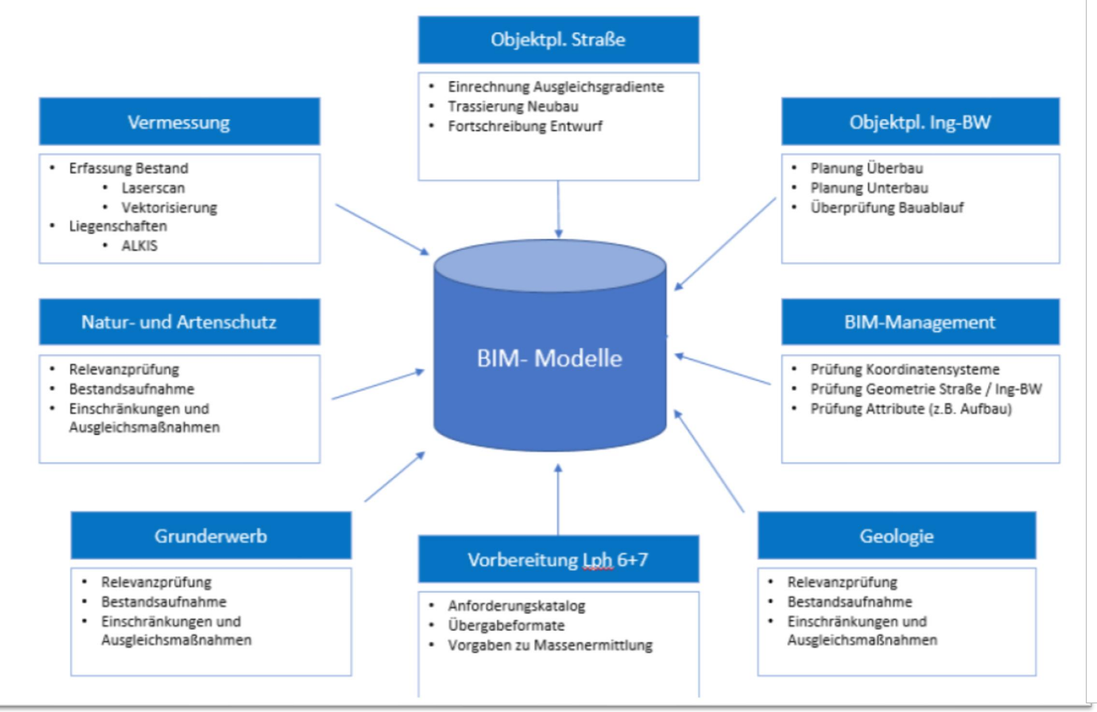
But a BIM process is more than modelling

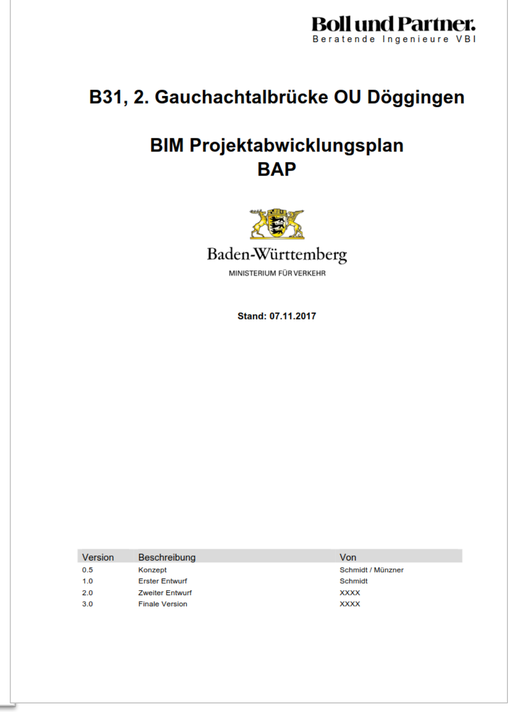


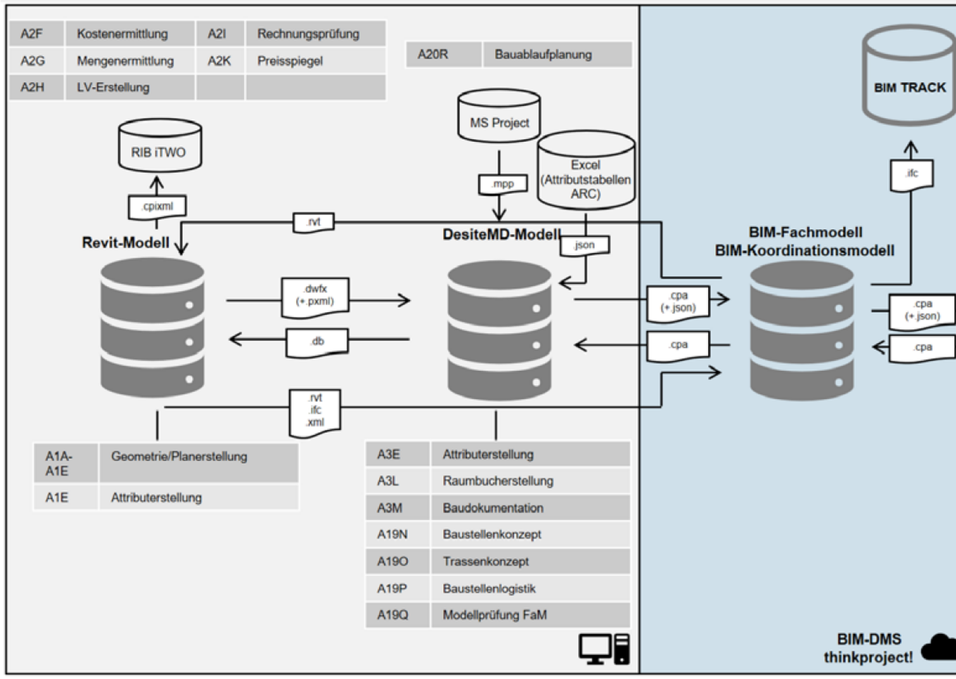
BIM = 3D model with a pointcloud?

A common issue regarding infrastructure projects (compared to highrised uildings) is that a bridge or tunnel always must be planned into an existing terrain, other infrastructure and regarding the environment protection.

One of the first steps at the Gauchachtal Bridge was to take several large scale laserscans via Gyrocopter, drones, terrestrial and by car. The result could be loaded into Revit und was a great support while modelling retaining walls, logistics and the structure itself.







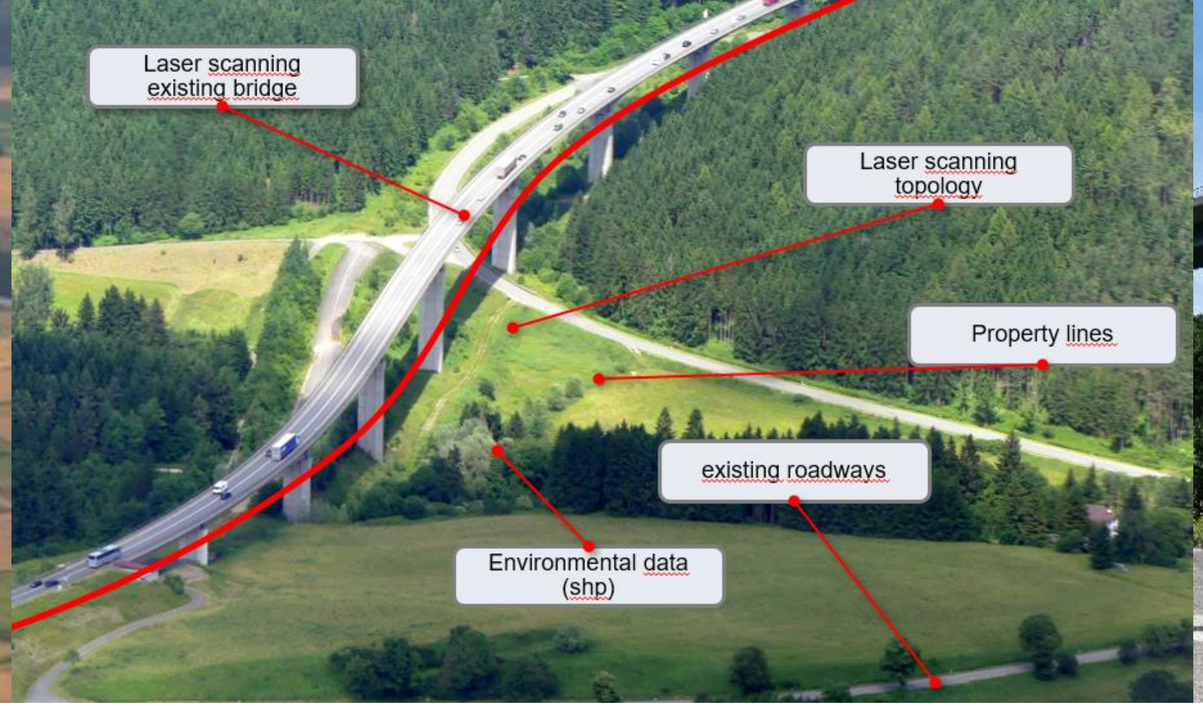
BIM is a method and not only a geometric model

BIM = defining use- cases

The use- cases and the needed level of development of the model are defined within the BIM- Project Execution Plan. it's necessary to first read that paper, develop processes etc before starting to setup an model.

Common use-cases are:

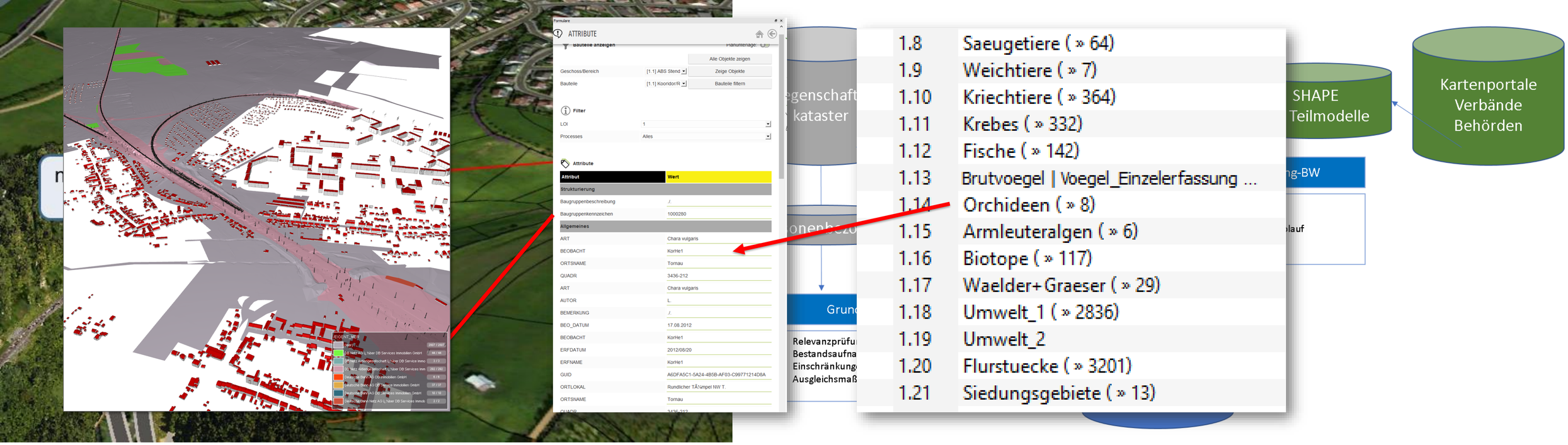
- Automatic 2D Plan generation
- Control of cost and schedules
- Clash detection
- - …



First step = survey and GIS

The first step was to create an initial model, representing the terrain, existing road- and waterways, environmental issues and property lines.

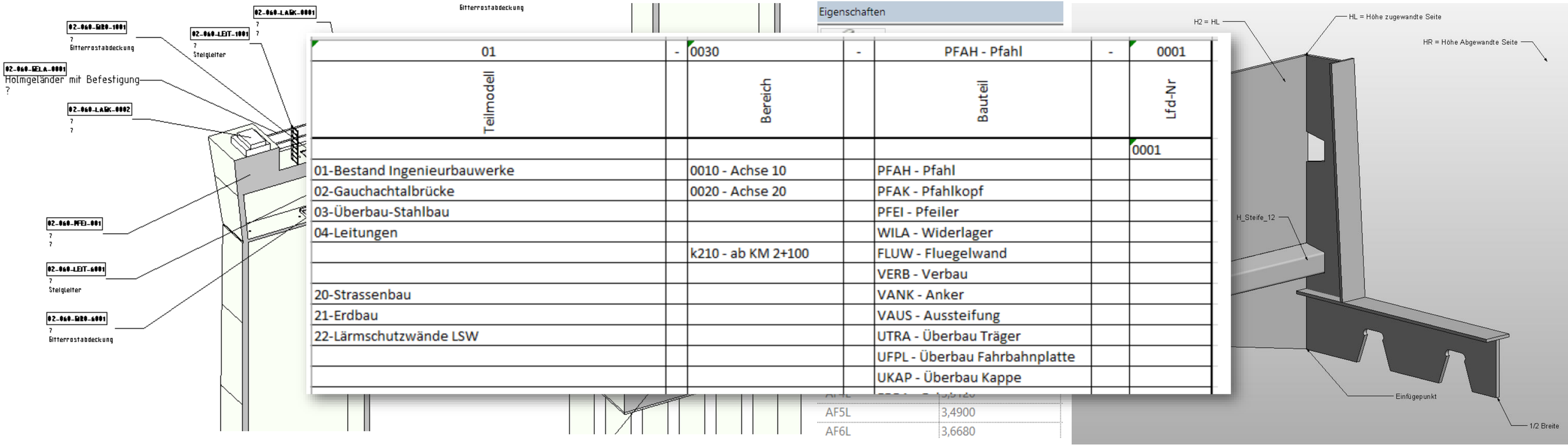
A really demanding problem for the roadway planner was to find a axis which lies parallel to the existing bridge and includes the as-build geometry of the existing bridge and which also was according to the normative rules.



First step = survey and GIS

The GIS an environmental data was transformed to be loaded into Infraworks and Revit.

As GIS databases are pretty comparable to BIM databases its easy to include that information into the BIM- proesses. So the engineer can be pretty sure find an solution regarding all aspects – no only a solution which means *optimal* from the civil engineers point of view.



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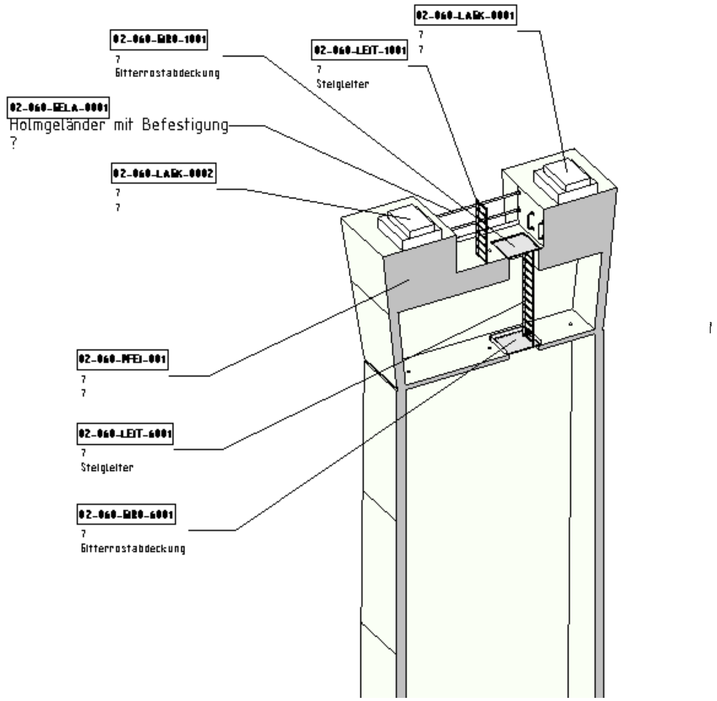
02-Gauchachtalbrücke		0020 - Achse 20		PFAK - Pfahlkopf		
03-Überbau-Stahlbau				PFEI - Pfeiler		
04-Leitungen				WILA - Widerlager		
		k210 - ab KM 2+100		FLUW - Fluegelwand		
				VERB - Verbau		
20-Strassenbau				VANK - Anker		
21-Erdbau				VAUS - Aussteifung		
22-Lärmschutzwände LSW				UTRA - Überbau Träger		
				UFPL - Überbau Fahrbahnplatte		
				UKAP - Überbau Kappe		

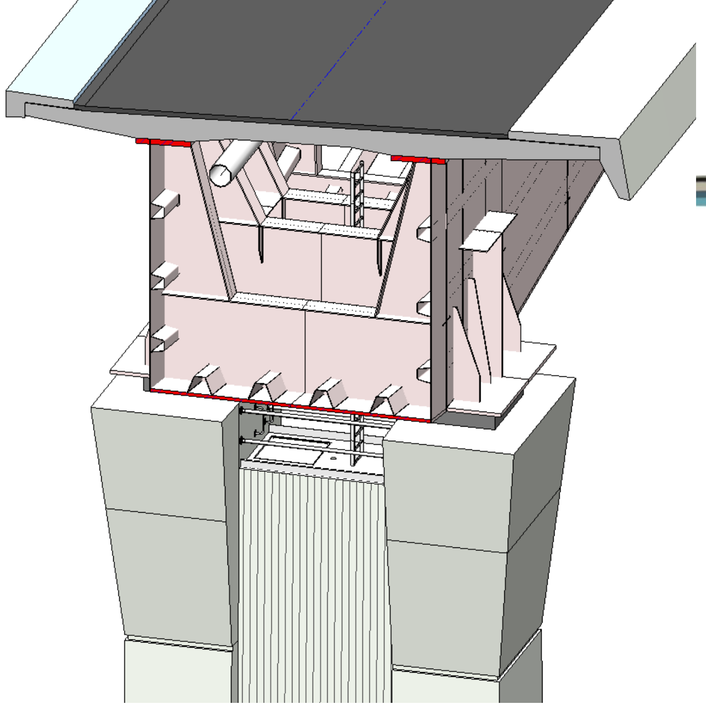
Second step = define Revit families and attributes

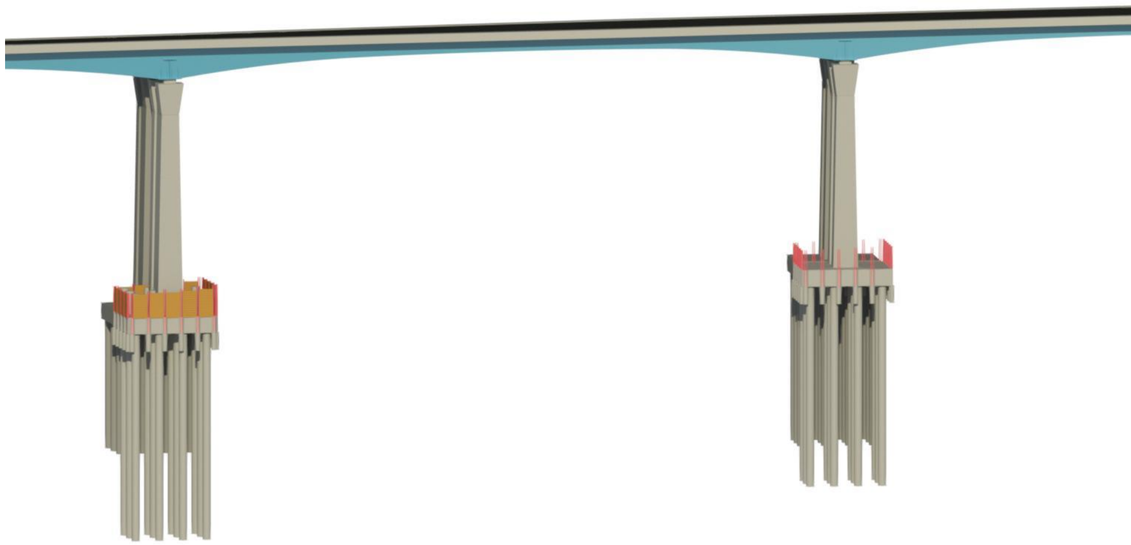
The Sofistik bridge modeler is highly depending on the families used as placements or parts of the model.

Setting up those families to meet all the requirements of the PEP is a very demanding job, as those parts are used for all the use- Cases but should be overloaded and too complex to handle.

Its also interesting to define different familys for different LOD, because you will need different informations during the different design phases.

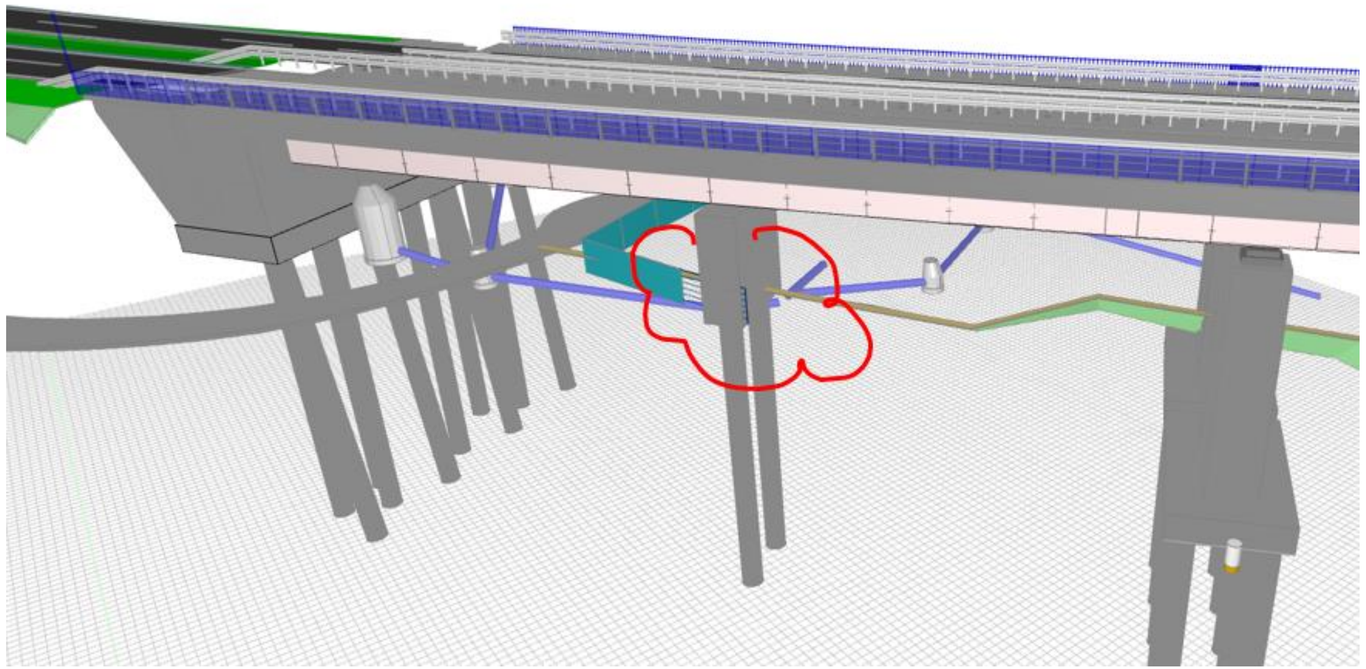






Third step = bring it together

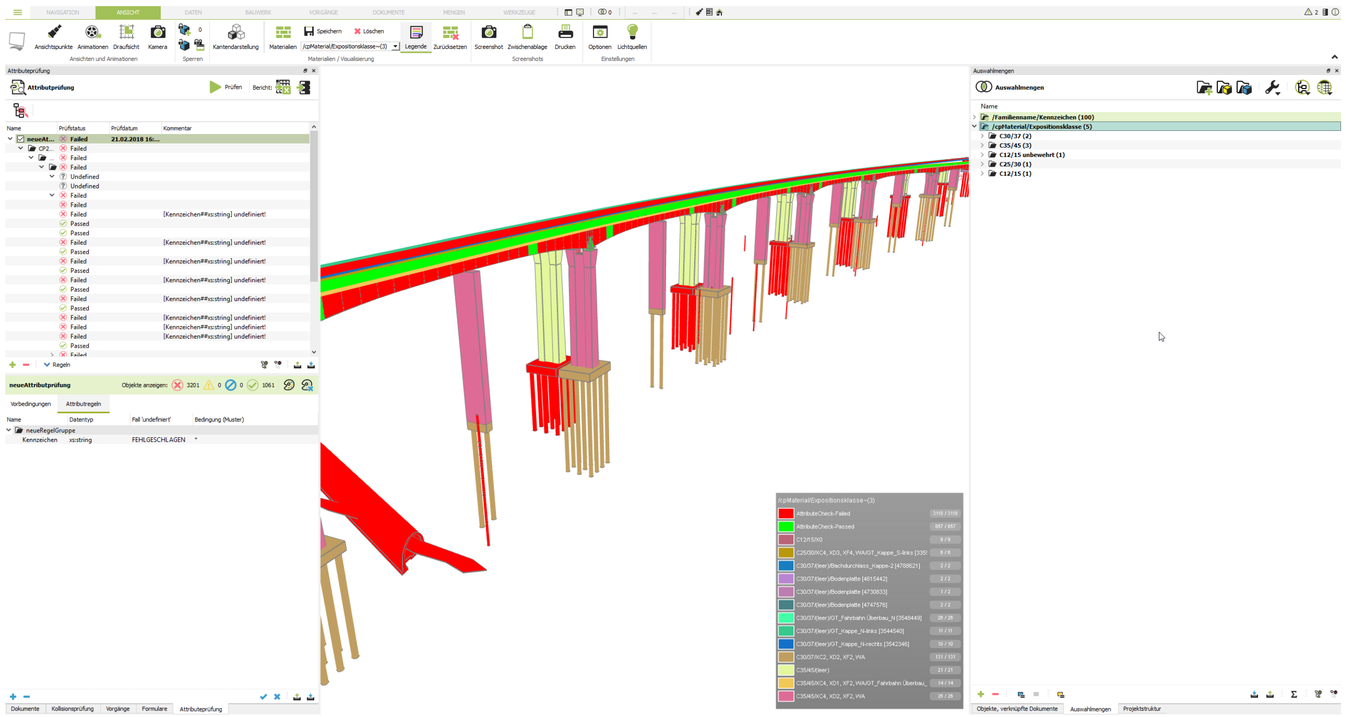
Using the Sofistik bridgemodeler it’s possible to dynamically place piers, griders, parapets, railings and all the bits and parts needed to model an bridge. Dynamically in this case means: if you change an axis or the angle of an placement, the whole geometry will change too. Having invested a lot of time in step 2 in order to implement all the attributes and WBS into the families, the result is a BIM model – and not only a 3D model.



Forth step = checking the BIM model for clashes

A BIM model is a database representing a bridge. Every parameter and attribute can be checked by automated runs and rules generated by the database itself.

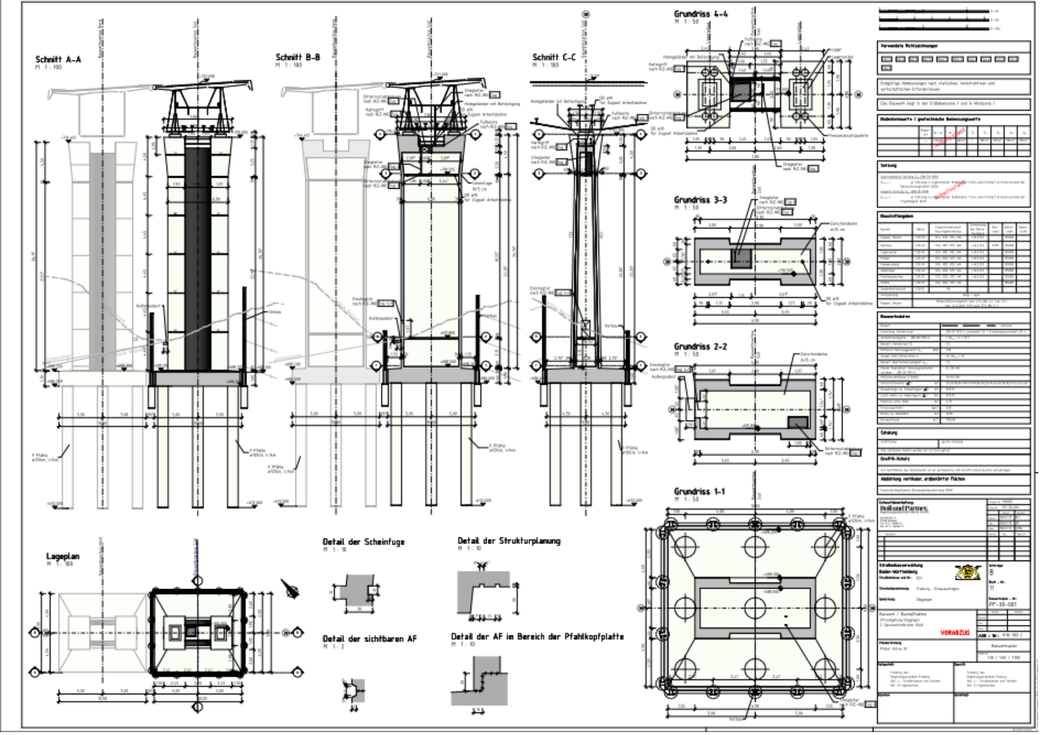
Before handing over the model to the CDE for further use-cases it has to be checked.

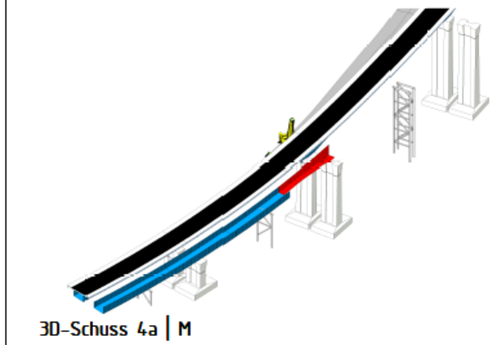


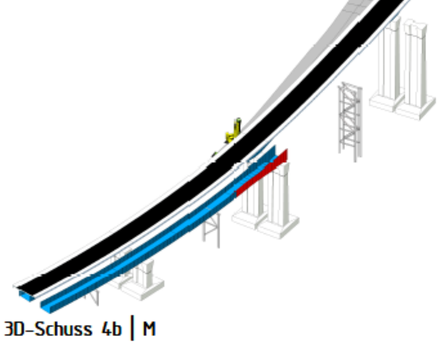
Forth step = checking the BIM model for attributes

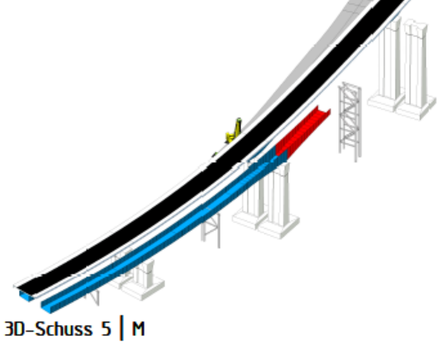
Regarding the possibilities of automated model checking compared to the classic 2D drawing brings a massiv advantage to the planning process.

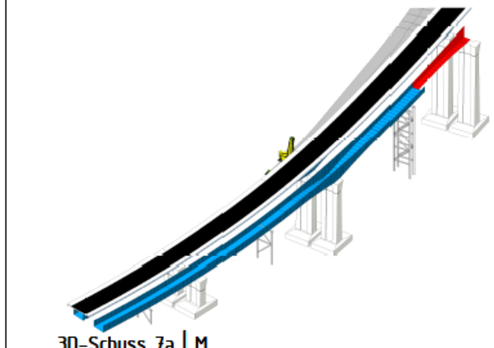
Its amazing how projects have been planned without it until now…

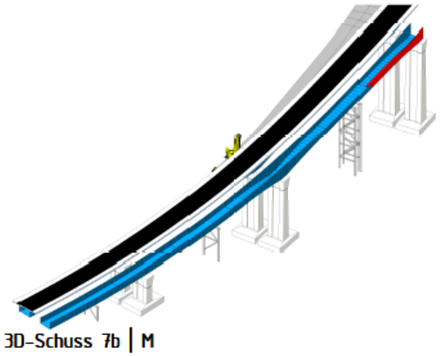


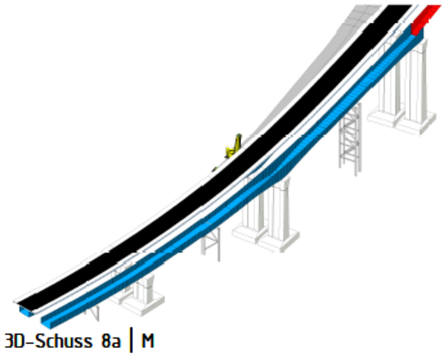








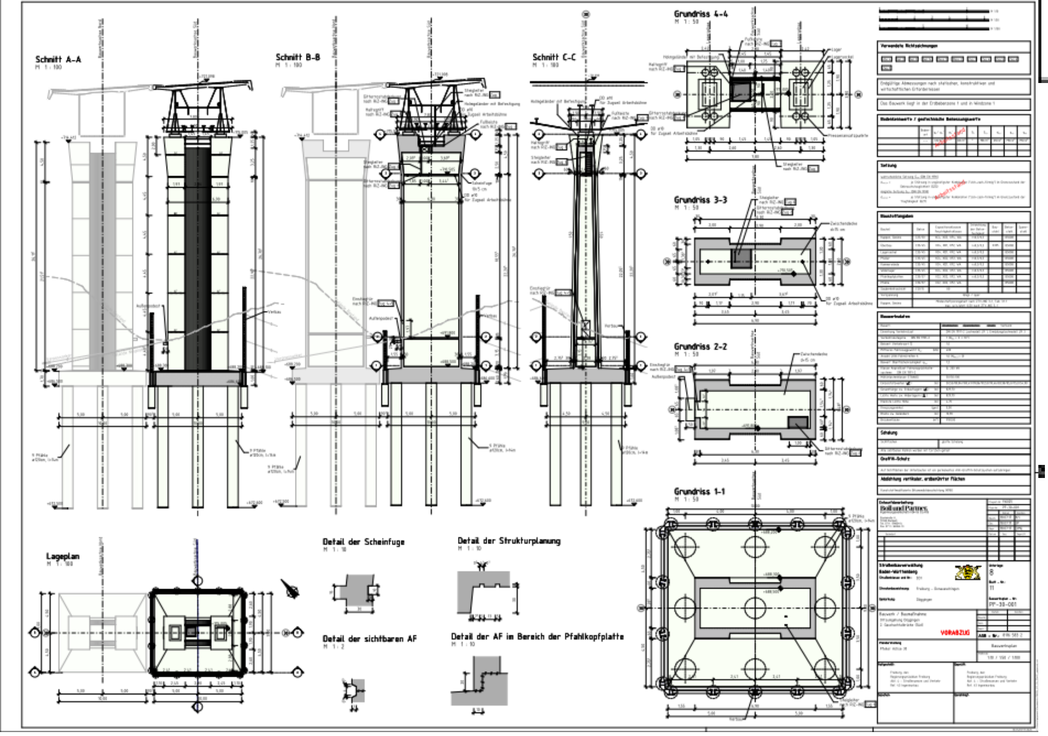


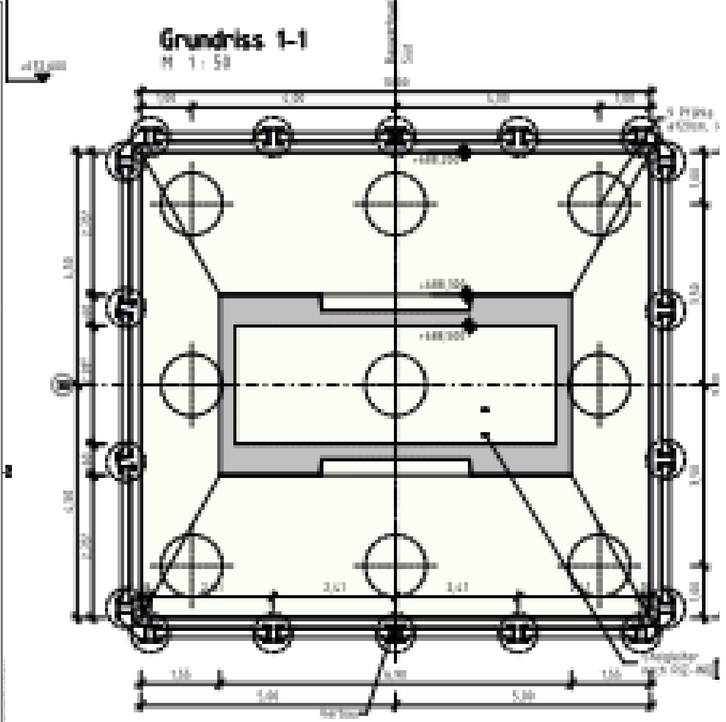


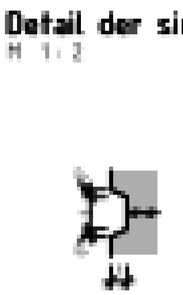
Fifth step = using the BIM model

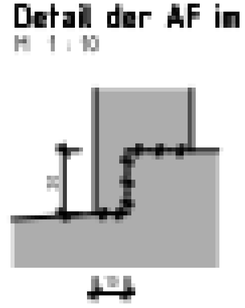
After the BIM- model was handed over into the CDE as an approved model, all the planes in the BIM- project can start using it for their purposes and use- Cases.

The use of and *Common Data Environment* ensures every planner uses data from a single source of truth is not relying on a set of models sent by e-mail or USB- stick.







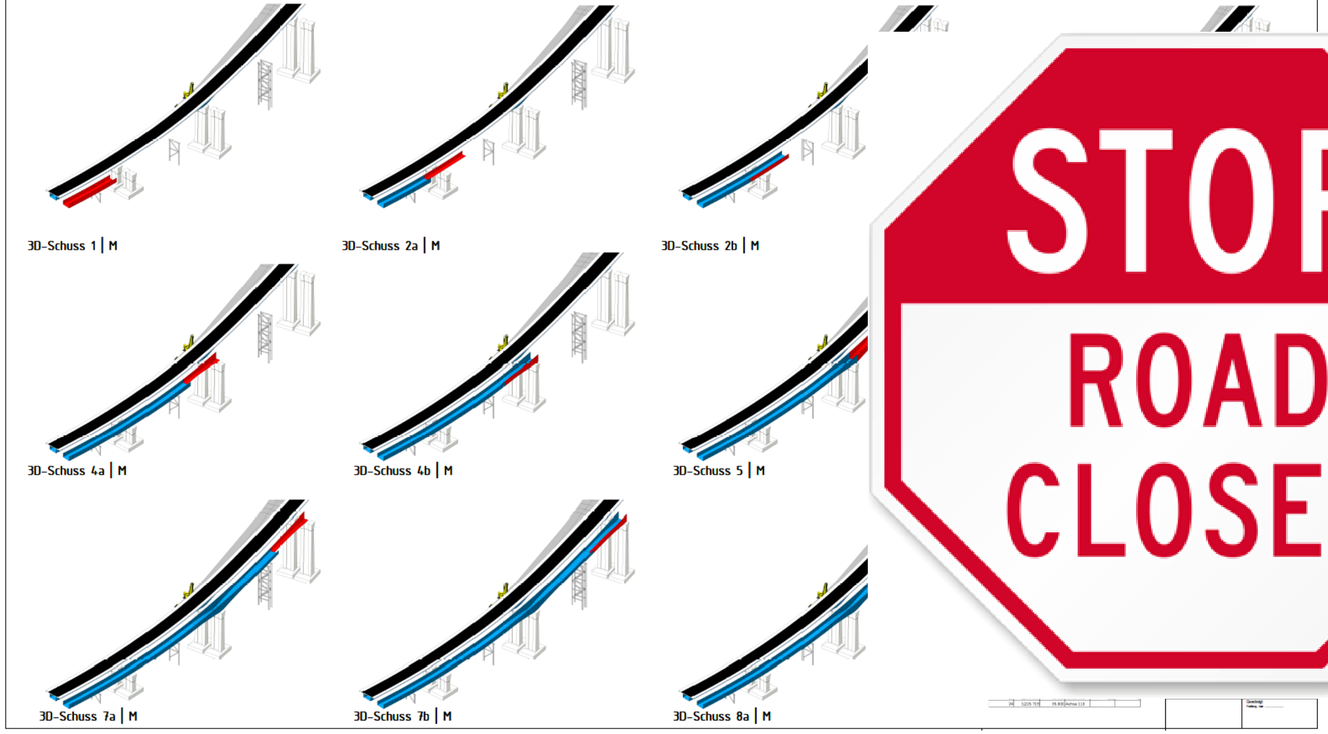


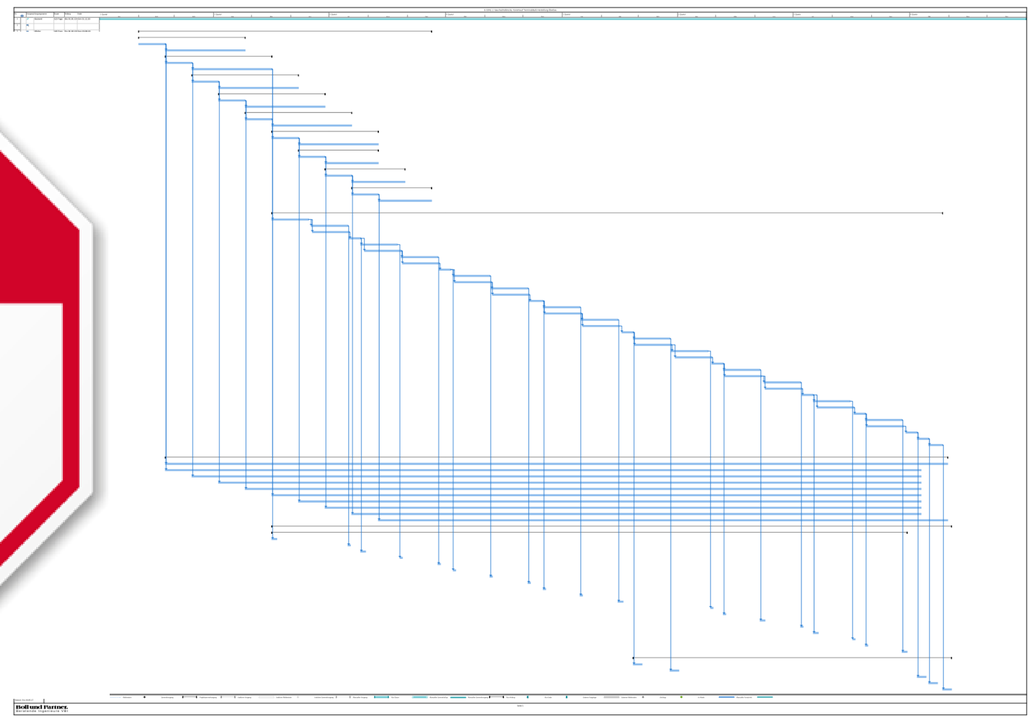
Fifth step = using the BIM model, 2D drawings

At least for the German market, 2D drawings will be essential for the next 10-20 years, regarding not only on site but also approval processes.

A further aspect is to provide access to the plan/ models for the next decades. Everybody can read a paper document, but who will be able to open a Revit 2018 file in 2038?

How to open an AutoCAD 13 file in 2018? .





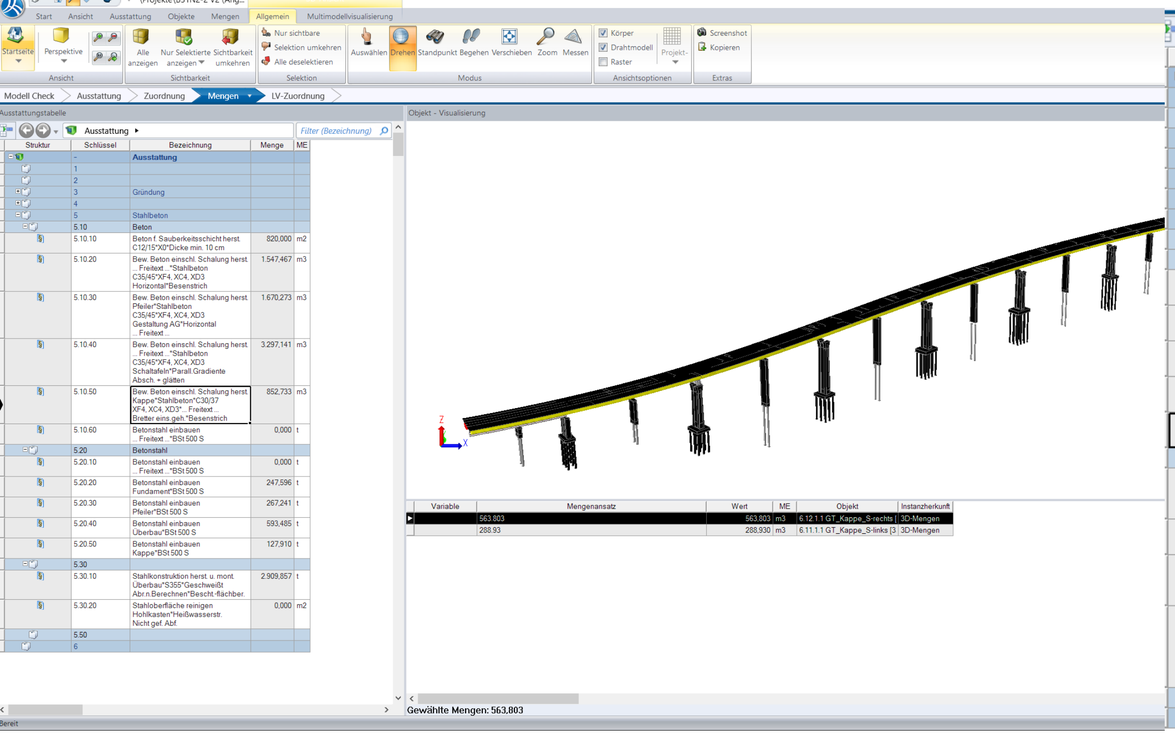
Fifth step = using the BIM model, timeline

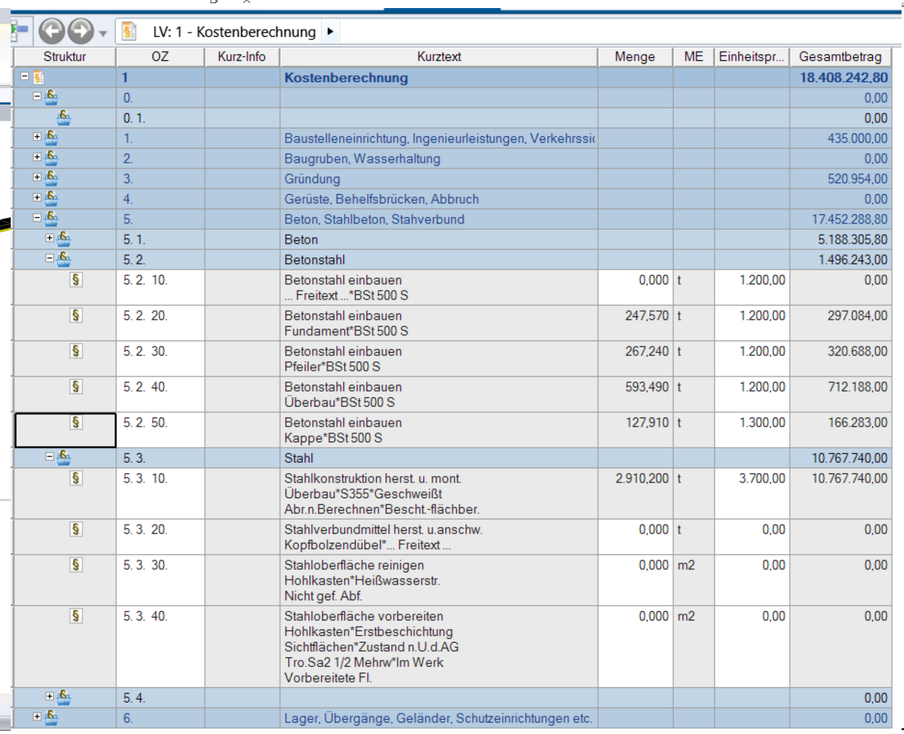
An engineer always has to consider the influence of the on site building processes to the construction itself. Sometimes an even more elegant solution has to be discarded because the building process is too complex.

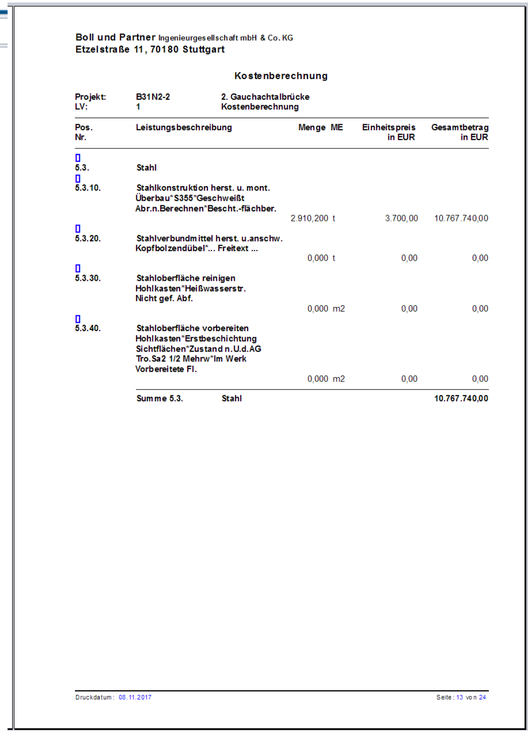
Also the approval processes by the authorities sometimes takes a bigger scope on the timeline and traffic issues than on the structure itself. .

Woche 4 - 25.01.2019

PSP	Name	Start	Finish	Duration	
1	Bestand	01.01.2019	31.12.2020	0 Tage	0 %



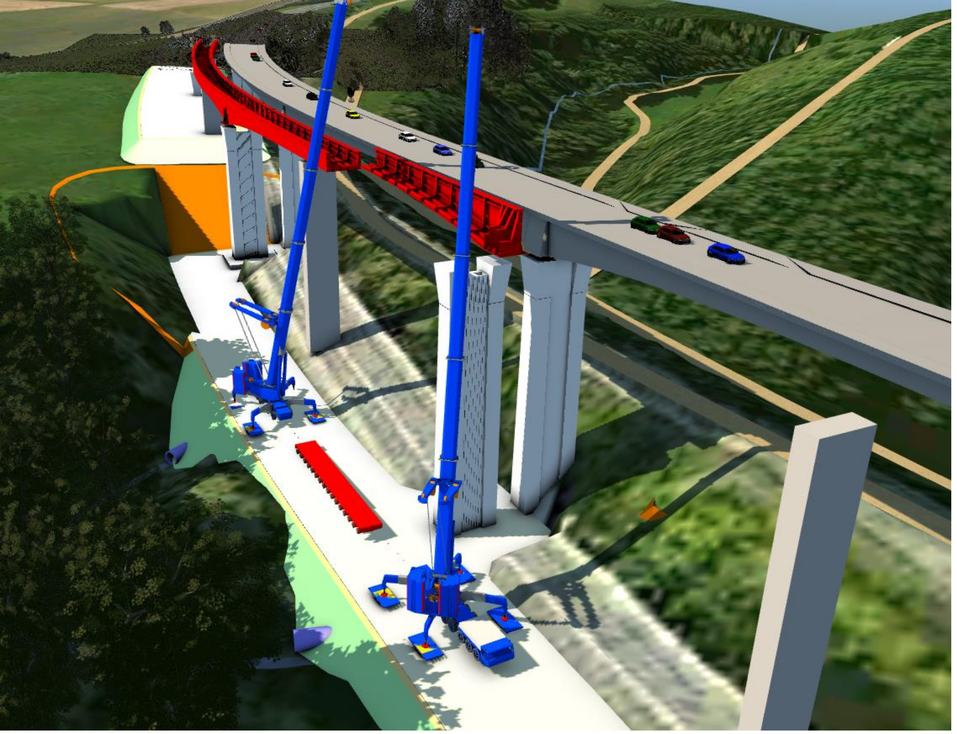




Fifth step = using the BIM model, masses and costs

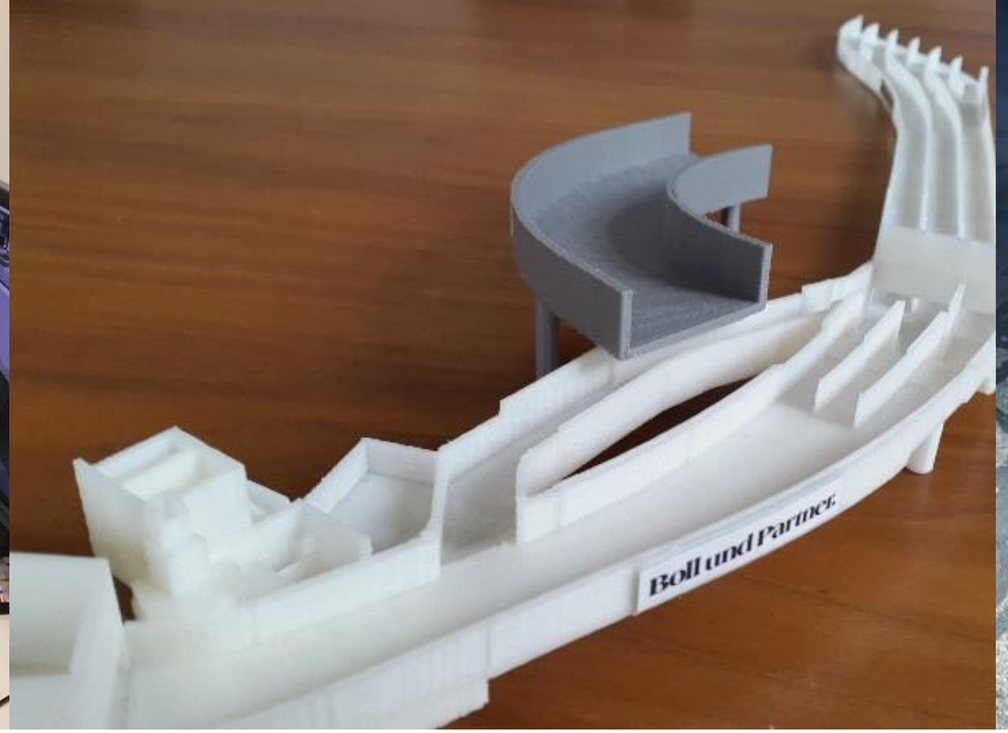
For the client, the most interesting part of the process are the costs. The main reason for the German government to enforce the BIM method for all large scale infrastructure projects starting from 2020 is the risc of exploding costs.

So using an BIM model linked with the tender documents gives the client the best security about the costs in the tender phase and also during the building process.



Fifth step = using the BIM model, logistic

Logistics often are less sought after issue within infrastructure projects – *on site solutions on the fly are often the best solutions.* During the building phase of the first Gauchachtal bridge, the constractor run into several massive problems – so this time there was a long list of topic to be considered. Especially the increased laws regarding environmental issues makes an fully develped condideration about on-site logistic crucial.



Sixth step = using the BIM model for something new

The digitalization process within infrastructure projects has just started. The usability of those digital models is not just restricted to the transformation of *traditional* workflows – we at Boll und Partner trying to thing about disruptive a new ways of planning, communicateing and managing projects in the future, including VR, rapid prototyping and robotics.

Thank you for your attention

Jakub Bielski
SOFiSTiK AG

Dirk Münzner
Boll und Partner

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Make anything™