SOFiSTiK

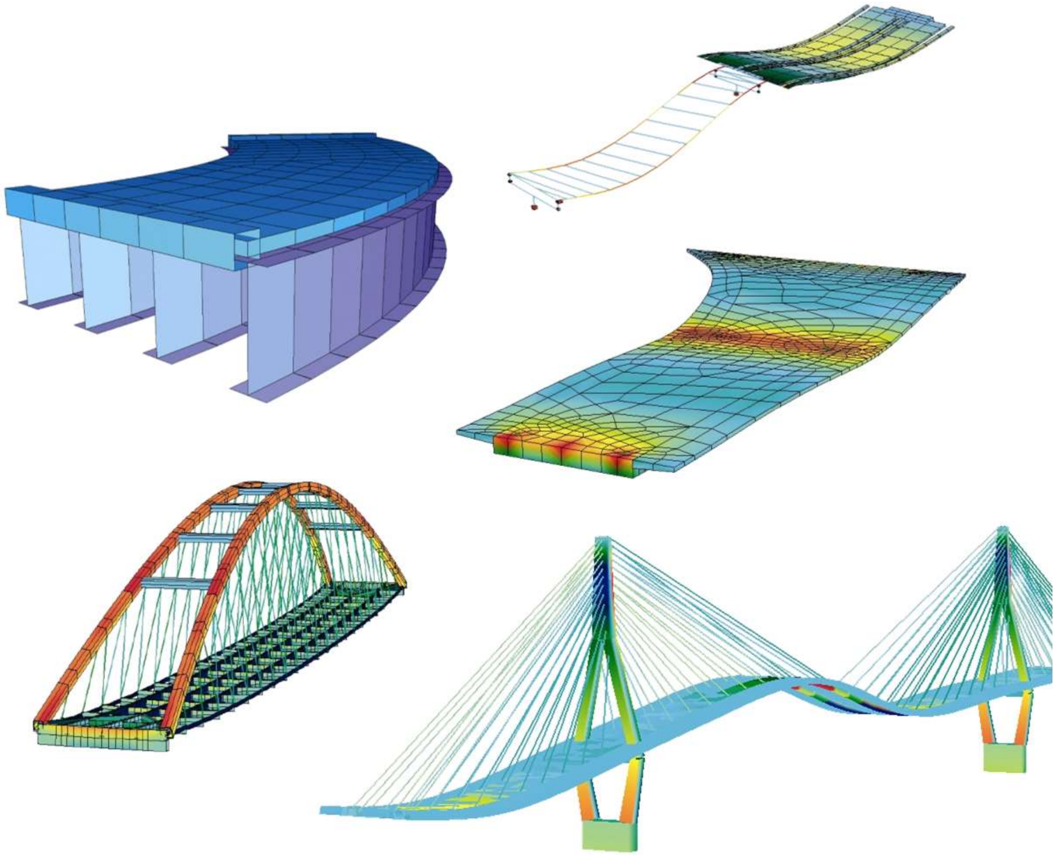
for BRIDGES

Georg Pircher Director Business Development

Bridge Types

Any structural bridge system is supported. Including:

- Box girder bridges.
- Slab bridges.
- Composite bridges.
- Slab/Beam decks.
- Plate girders.
- Arch bridges.
- Integral bridges.
- Cable-stayed bridges.
- Suspension bridges.
- FE, beam and hybrid systems.



Bridge Types

User Reference from KIEWIT; Shukre Despradel:

Great news! I hope they [Finley] buy the software. For us is very important you guys are very successful and we have more Consultants using Sofistik.

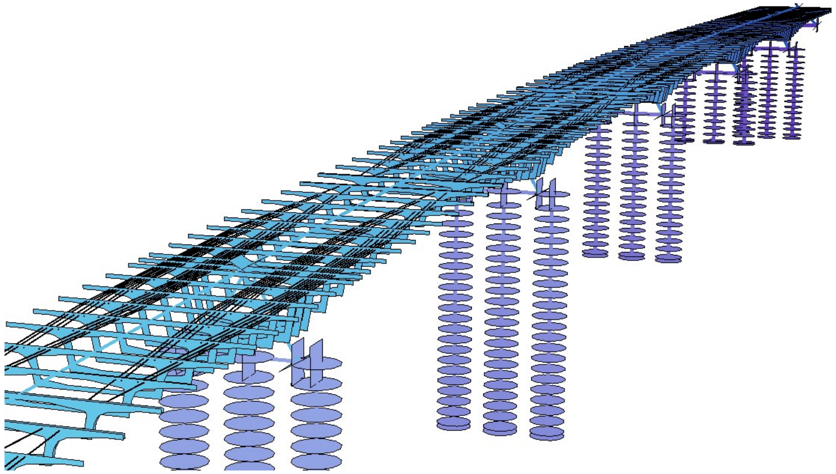
We have used them all, Larsa, LUSAS, Midas, CSI bridge, RM.

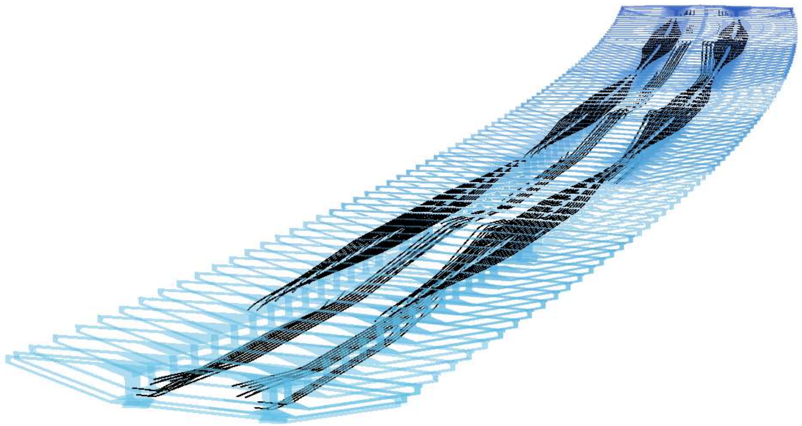
We think Sofistik is just the best software for bridges.

Bridge Geometry – parametric modelling since 1994

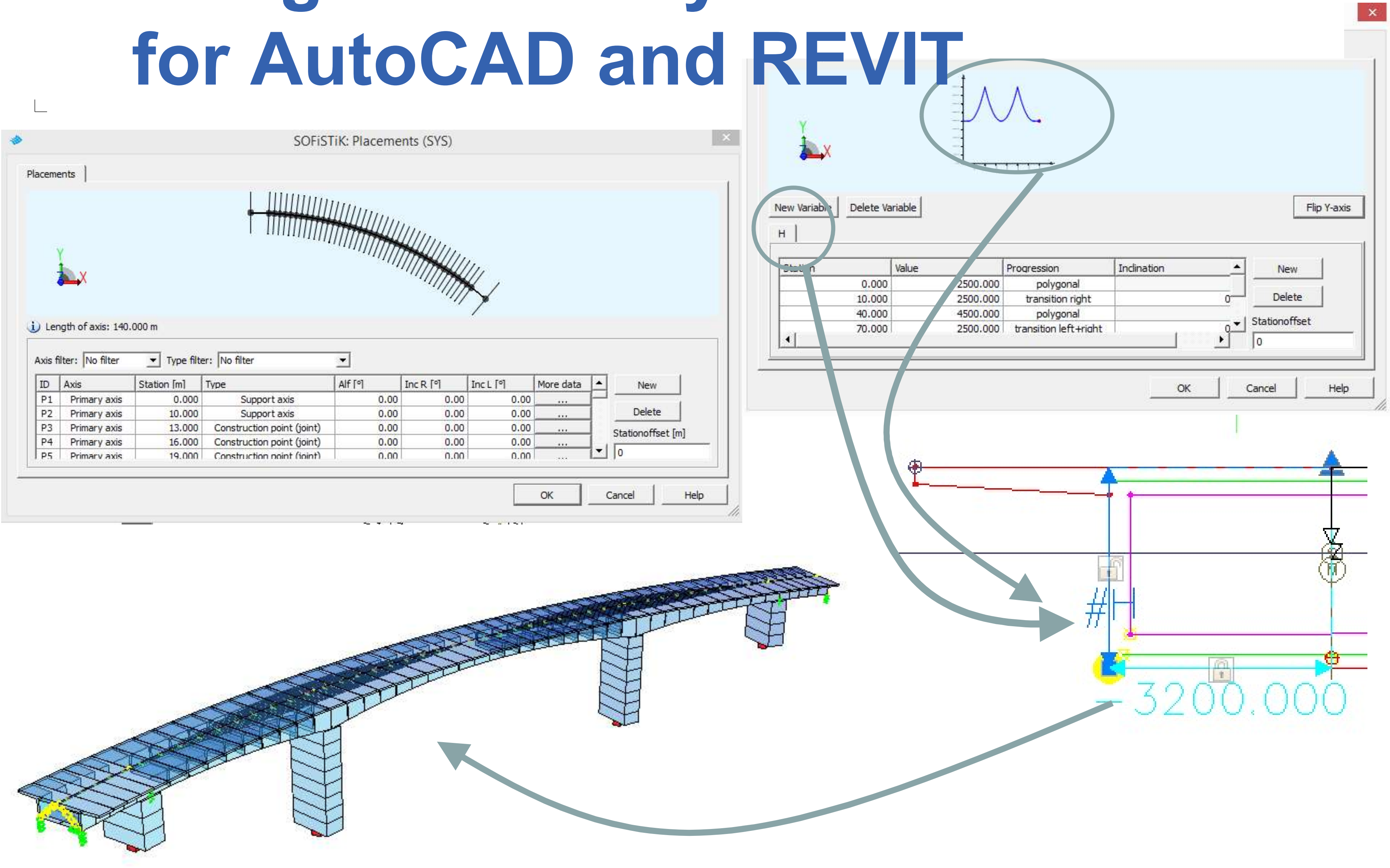
SOFiSTiK offers:
Computer **A**ided **B**ridge **D**esign -
CABD

- 3D Road/rail axes for any bridge type,
- Geometry of beams and shells depending on parametric input linking formulas and tables,
- Connecting sub-structures, pylons, cables, wing walls, foundations, piles … to superstructure,
- All parts hyperlinked and parametric.
- 3D axes also serve for traffic load and pre-stressing.





Bridge Geometry same workflow for AutoCAD and REVIT



SOFiSTiK

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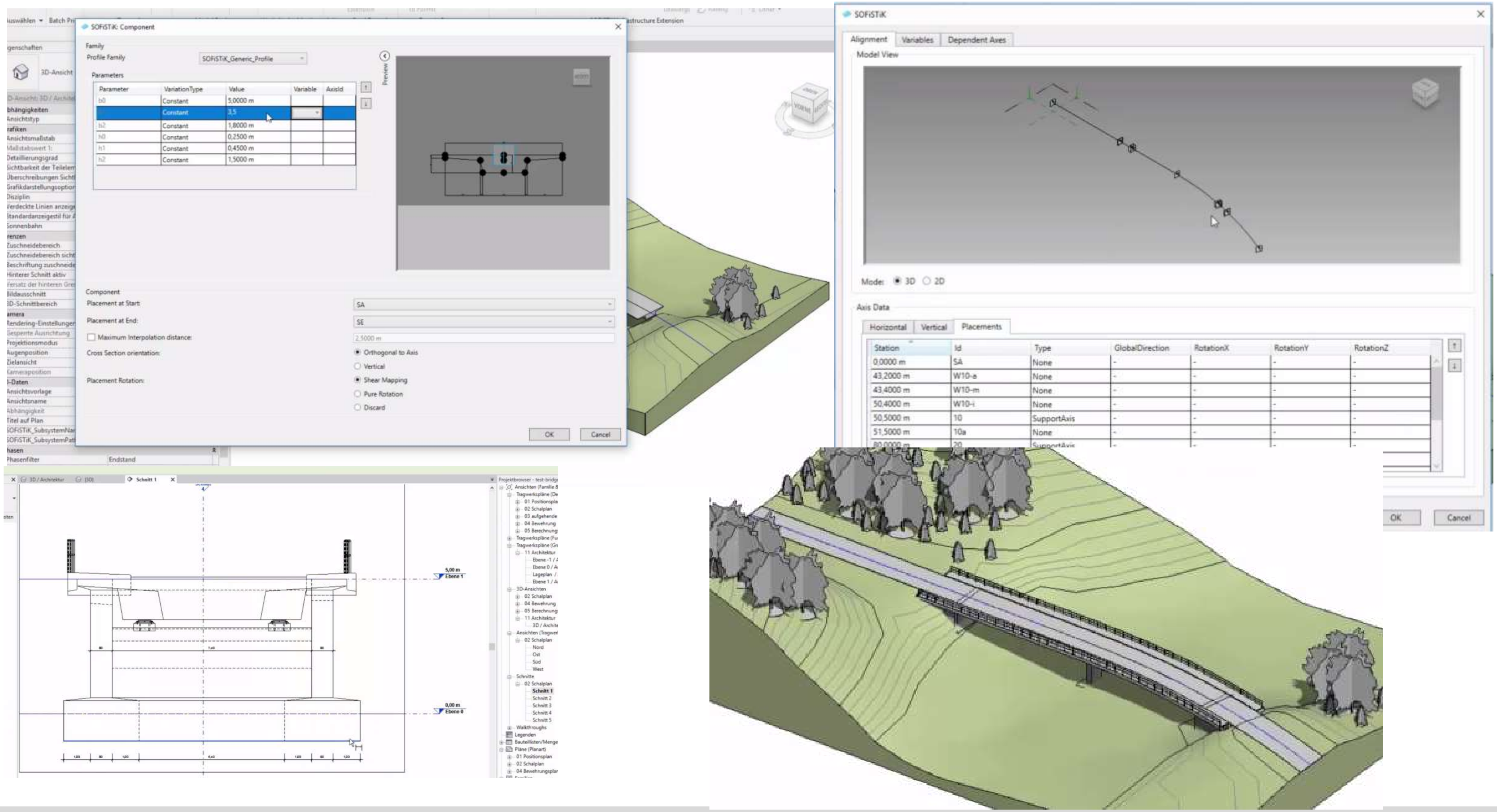


Bridge Geometry same workflow for AutoCAD and REVIT

Bridge Geometry same workflow for AutoCAD and REVIT

Bridge Geometry same workflow for AutoCAD and REVIT, but …

Bridge Modeler on AutoCAD:

- Focus is on analysis + design.
- Model is simplified (cross beams, sections, blisters, bridge equipment, etc).
- Stage definitions.
- PT definitions for both shells and beams.
- Load management.

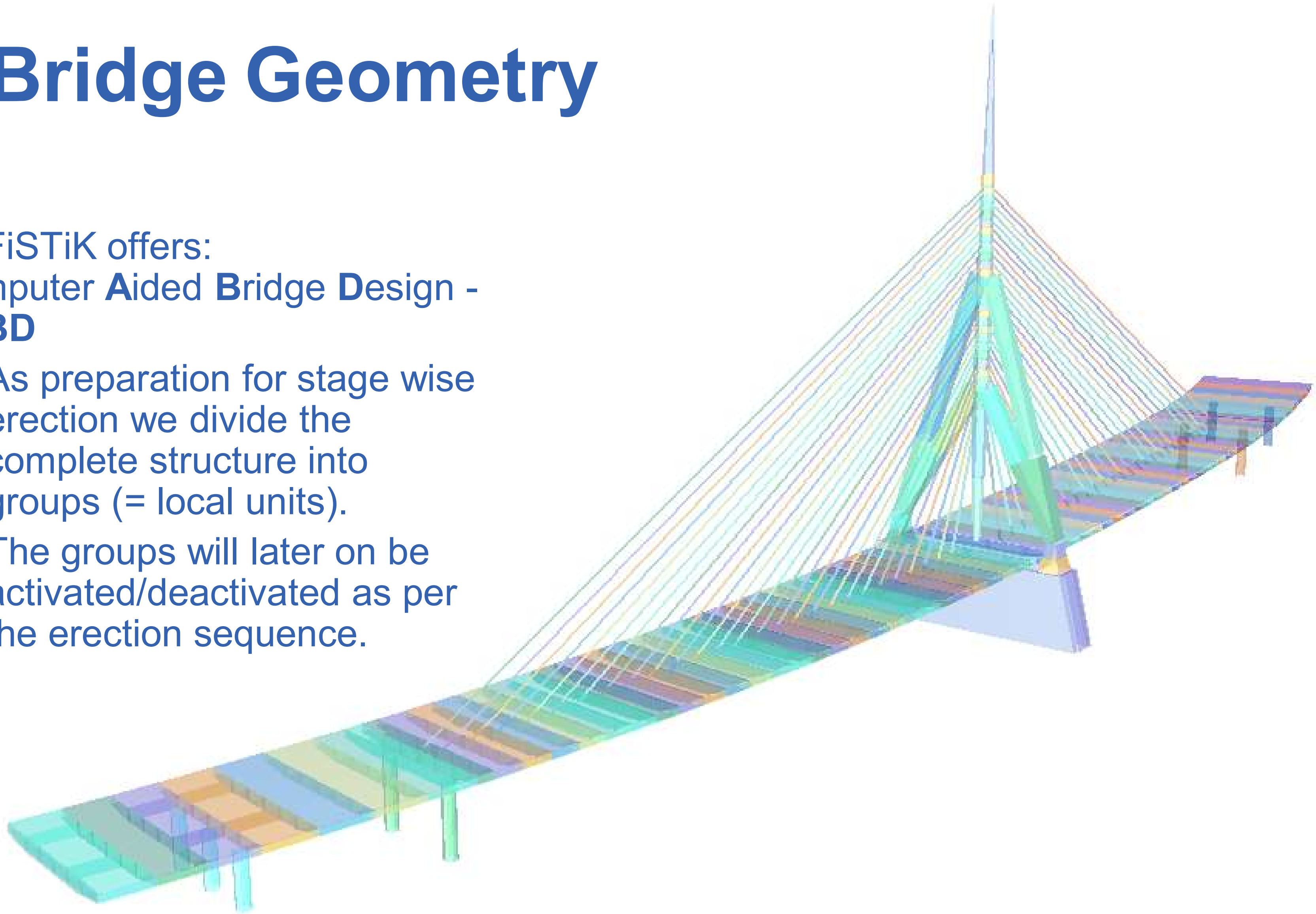
Bridge Modeler on Revit:

- Focus is on 3D modelling.
- Model is fully detailed, all masses and quantities.
- Deck has all parts and objects like handrail, kerbs, lightening, …
- Longitudinal cuts, unfolded view.
- PT modelling for CAD presentation.
- Substructures completely included.
- Detailing for anchorages, bearings, abutment walls, …

Bridge Geometry

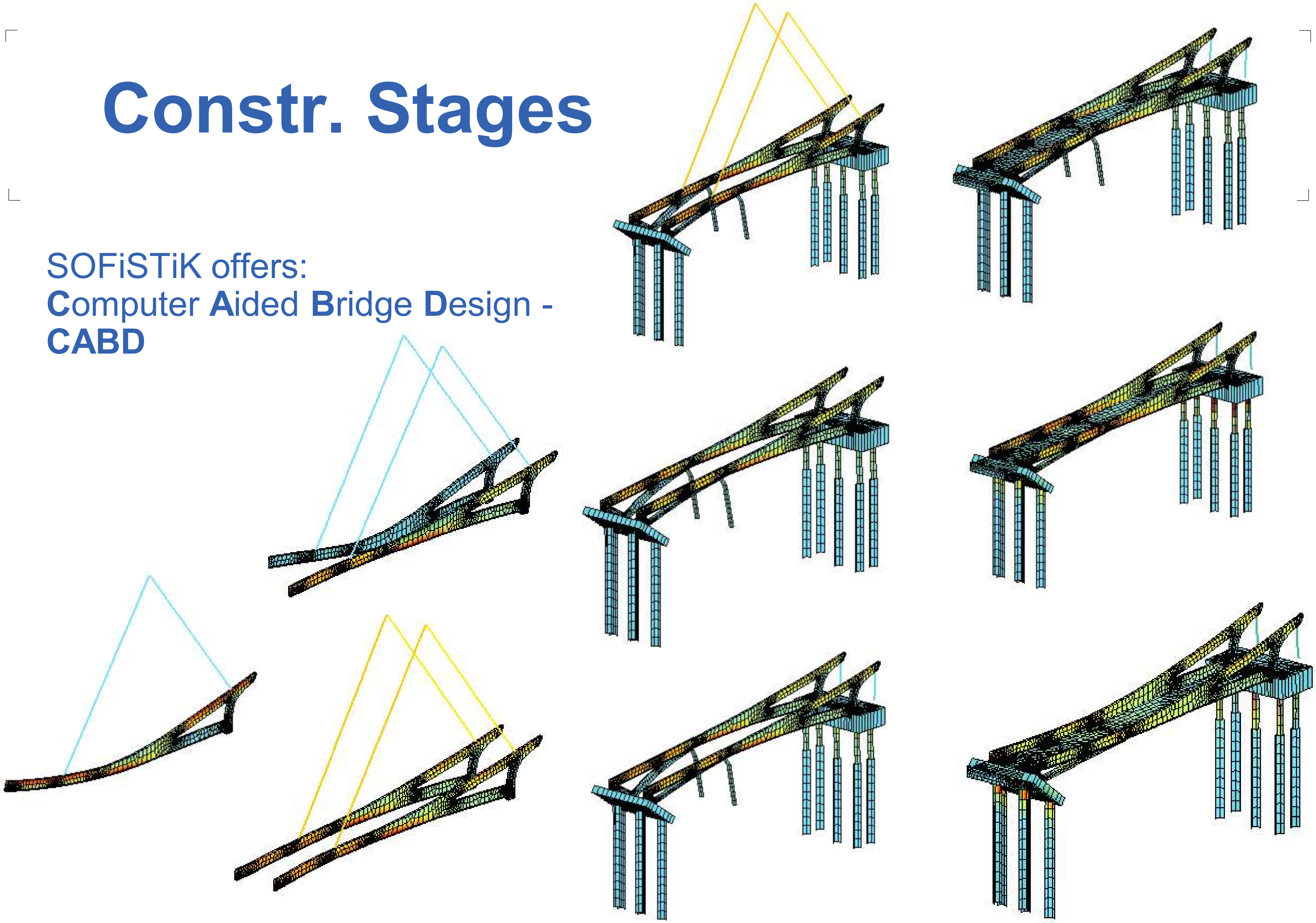
SOFiSTiK offers:
Computer **A**ided **B**ridge **D**esign -
CABD

- As preparation for stage wise erection we divide the complete structure into groups (= local units).
- The groups will later on be activated/deactivated as per the erection sequence.



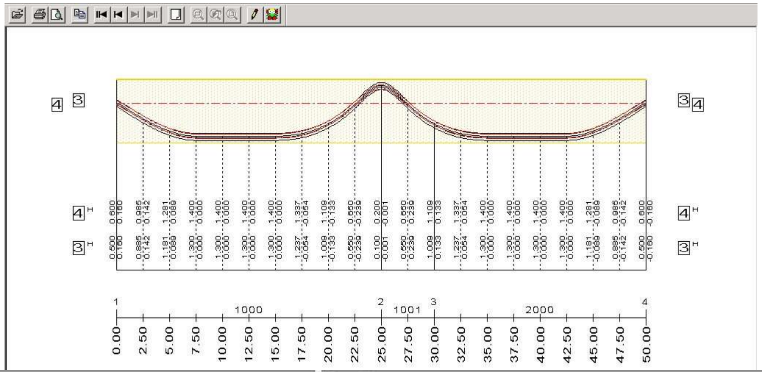
Constr. Stages

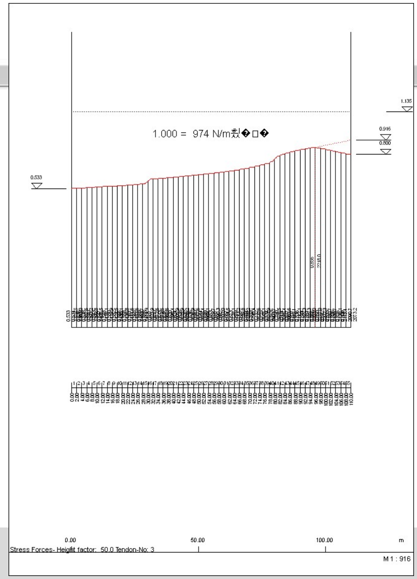
SOFiSTiK offers:
Computer **A**ided **B**ridge **D**esign -
CABD

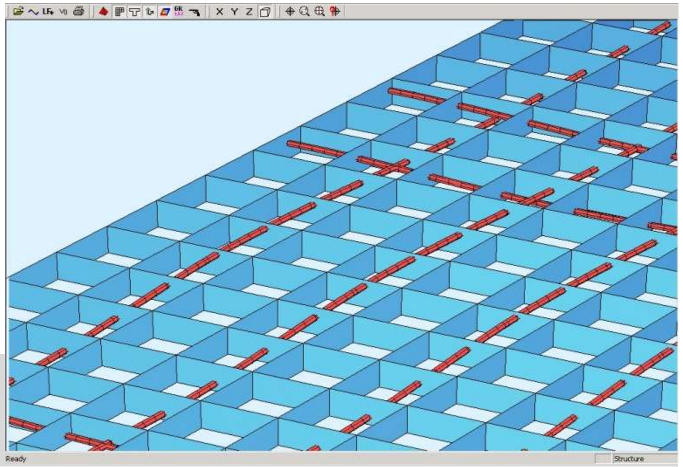


Pre-Stressed Concrete Bridges

- Internal and external tendons.
- Pre- and post-tensioning.
- Tendons in beam and shell-elements.
- 3D tendon profiles.
- Detailed loss calculation, including friction, wedge slip, time-dependent effects etc.
- Eccentric duct position.
- Hunched beams or plates.
- AutoCAD Pre-Processing.
- … more details later…

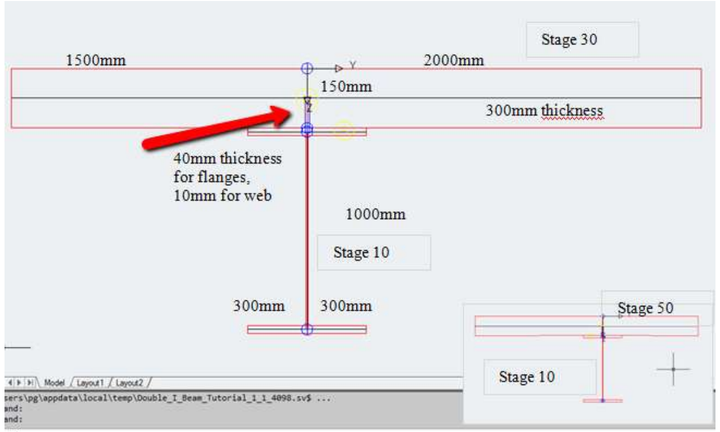


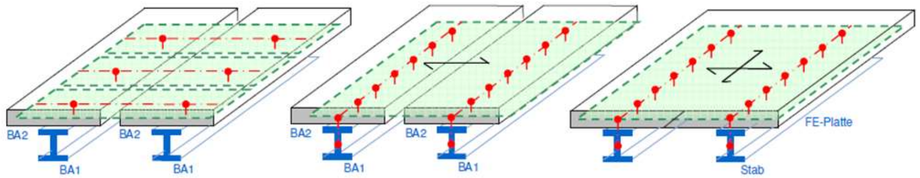


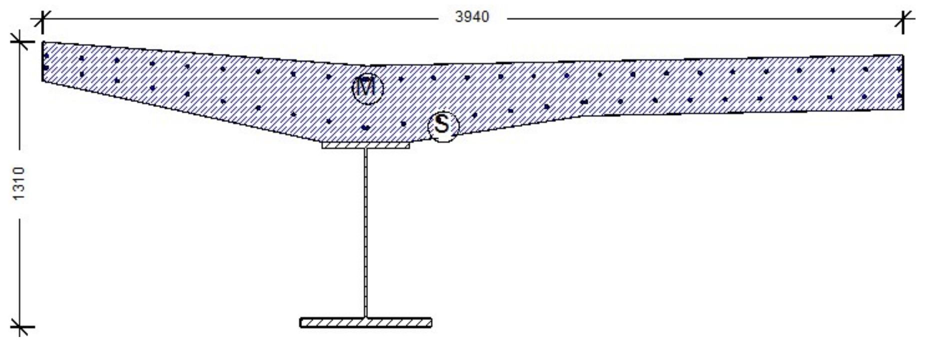


Composite Bridges

- Steel+concrete, concrete+concrete.
- Precast elements + insitu parts
- Thin- and thick-walled sections.
- Shear studs.
- Combination of beam and shell.
- Time-dependent effects, creep shrinkage etc.
- Stages within the section.
- Design for EC incl. class4 sections.
- Cracking of concrete over supports.
- AutoCAD Pre-Processing.
- … more details later…





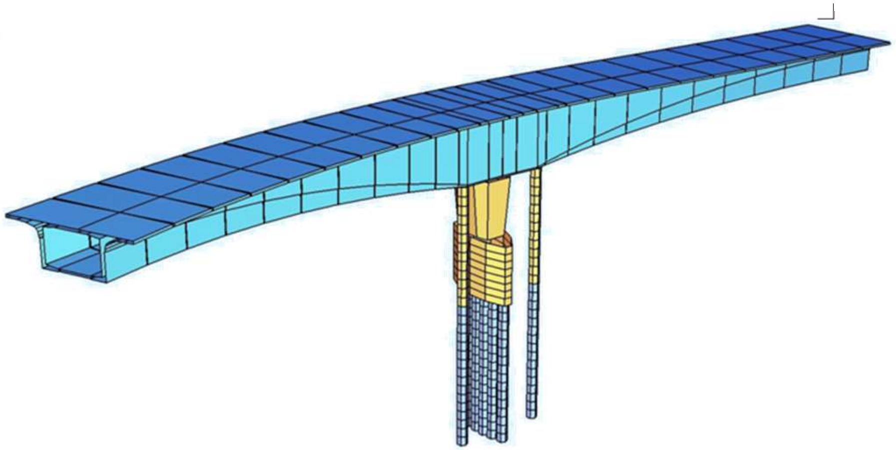


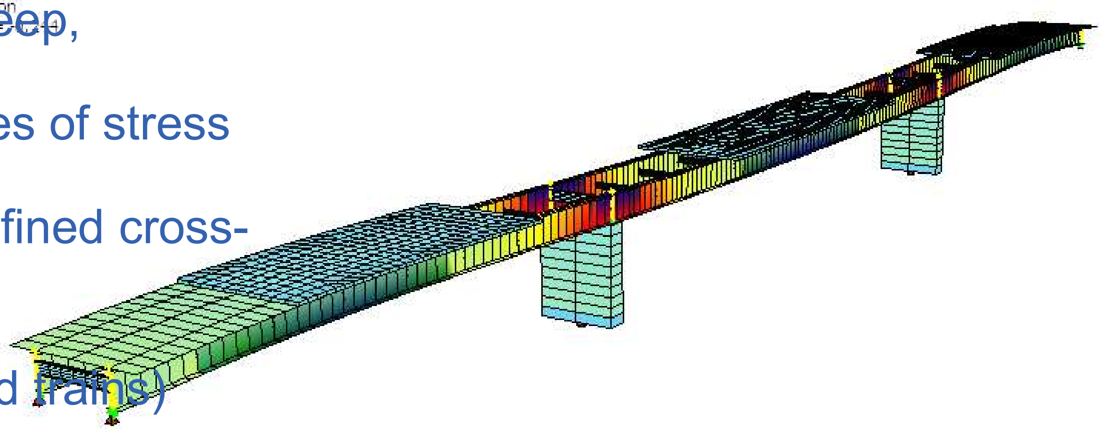
SOFiSTiK

Bridge Construction Simulation

CSM: **c**onstruction **s**tage **m**anager for detailed simulation of any erection method including:

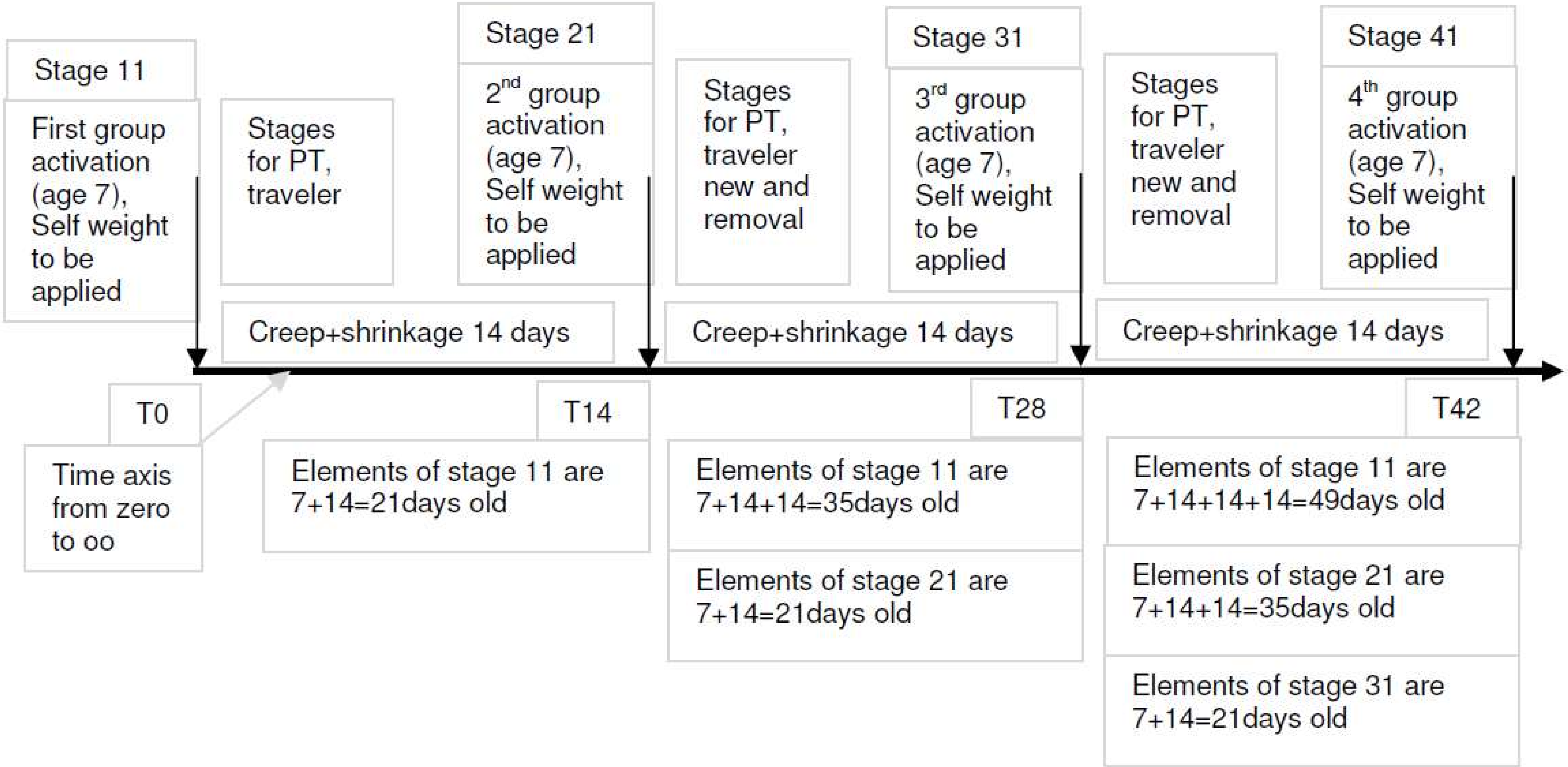
- Span-by-span.
- Cantilevering.
- Incremental launching.
- Moveable scaffolding system.
- Repair works, deconstruction of components.
- Time-dependent effects- creep, shrinkage, relaxation.
- Primary and secondary states of stress and displacements.
- Thin- or thick walled user defined cross-sections.
- Automatic bridge loader.
- Dynamic loading (high speed trains)
- Bridge / Vehicle Interaction
- Influence lines and surfaces





Bridge Construction Simulation

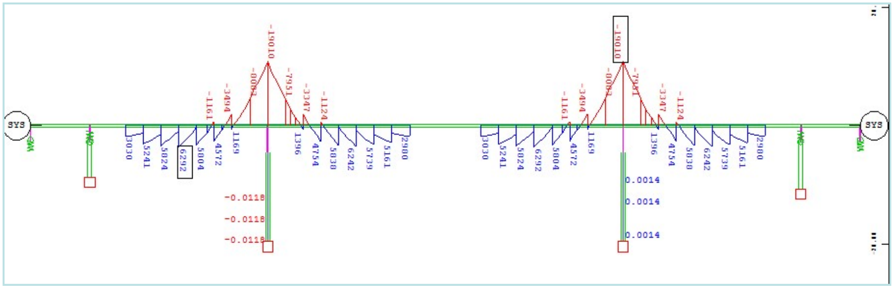
Schematic construction sequence:

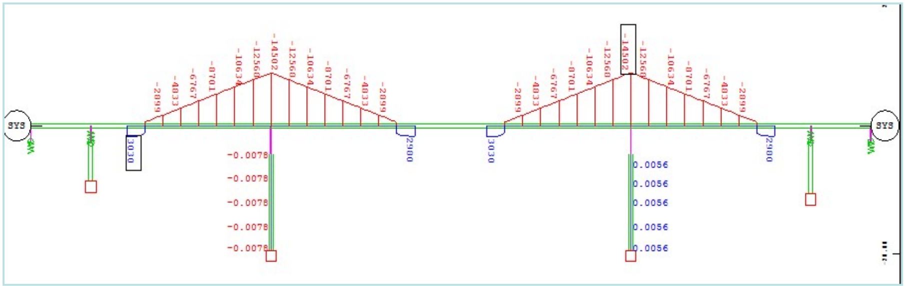


Bridge Construction Simulation

SOFiSTiK offers a unique method for saving the stage analysis results. This method is fundamentally different to what other packages do.

- The “current situation” (= forces + stresses + displacements) at the end of each stage is frozen and saved as “primary state” for the next stage.
- The new stage is added to the previous one and again frozen for the next stage.



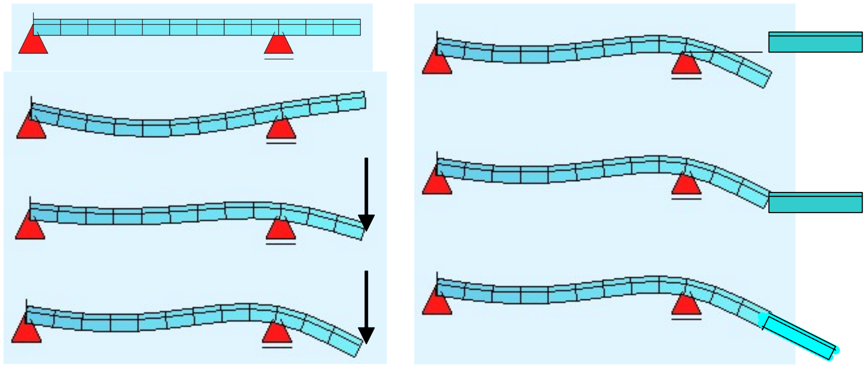


- SOFiSTiK saves the accumulated results (= forces + stresses + displacements) per stage.
- SOFiSTiK saves the individual stage results. These results are going to be used for the design code combinations: “G”, “P”, “C” etc.

Bridge Construction Simulation

A Precamber is available automatically when using CSM. We have three options:

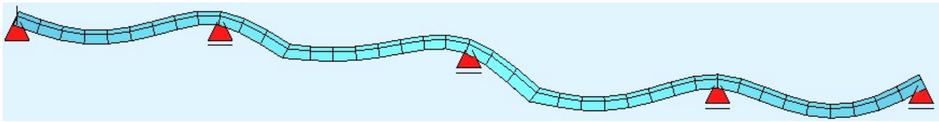
- Placing next formwork as in the original drawing level
- Placing next formwork at the actual connection point with its initial geometry,
- Placing next formwork at the actual connection point tangentially to the previous stage:



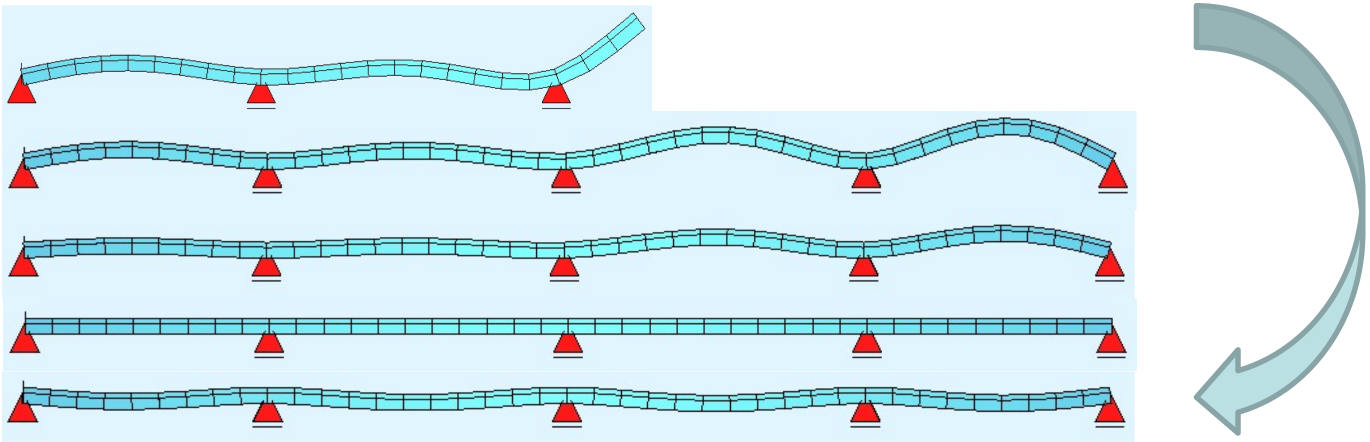
- For all options we have to define a “target stage” for which the geometry should be “perfect”. SOFiSTiK gives you the necessary precamber to achieve this stage.

Bridge Construction Simulation

- This are the displacements at a say stage 35 (before creep+shrinkage to oo) when running the stages without a precamber:

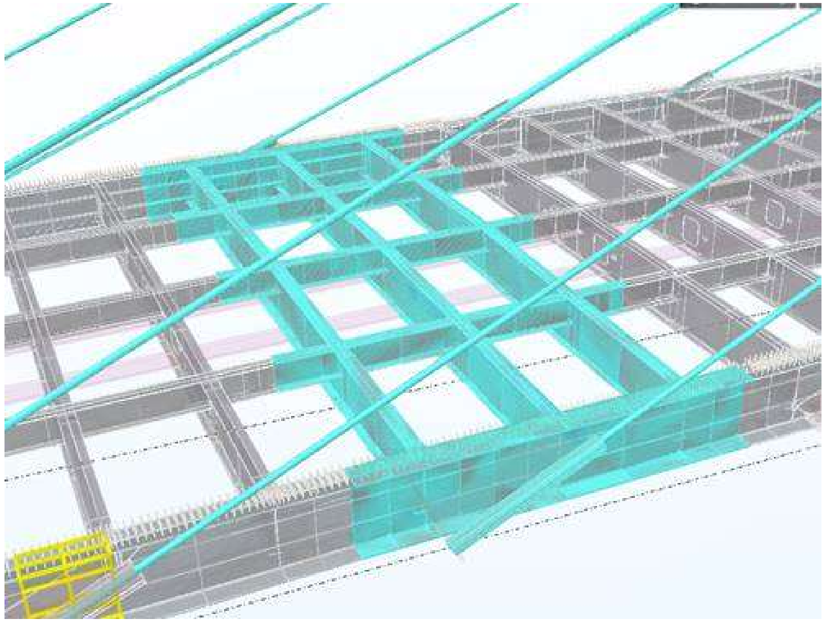


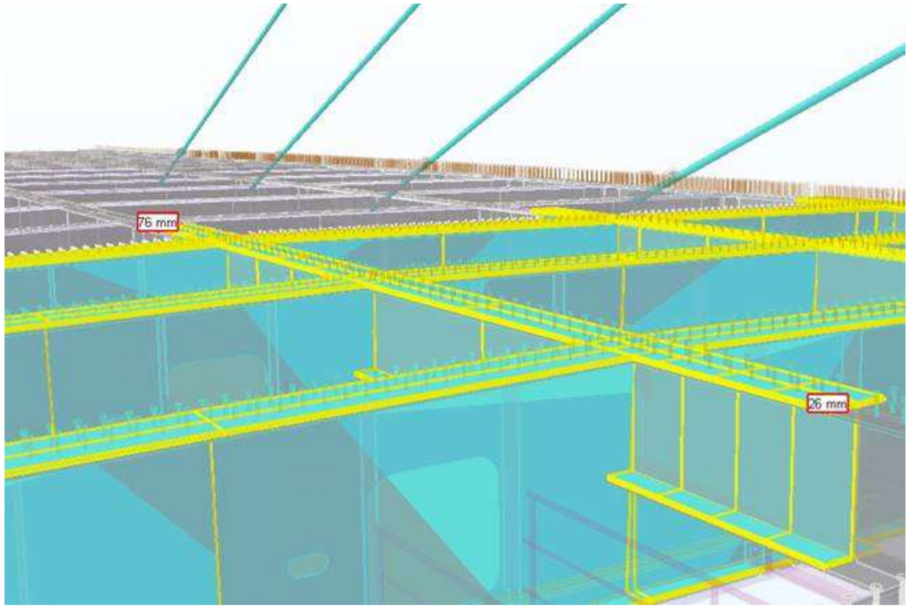
- The inversed shape is the actual precamber
- The target geometry ("perfect" at stage 35) will be reached when using the precamber as initial starting geometry:



Bridge Construction Simulation

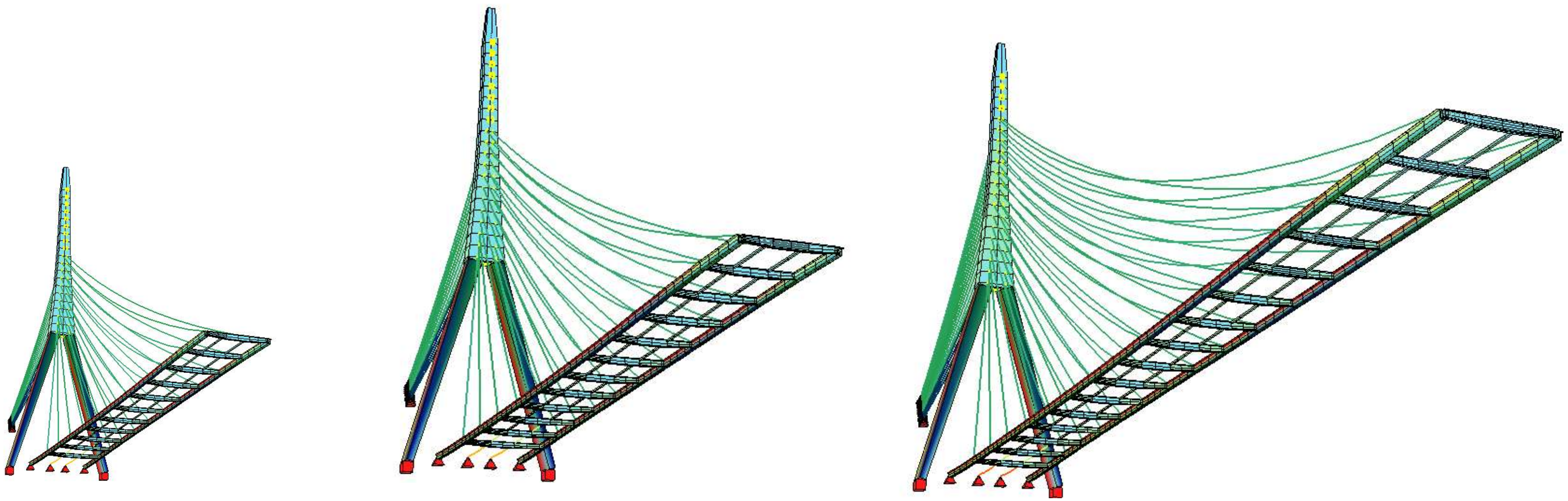
- In addition to the precamber we also provide what we call “fabrication shape”. The detailed “as to build” shape is the SOFiSTiK result that can be e/imported through IFC etc.





SOFiSTiK and cable elements

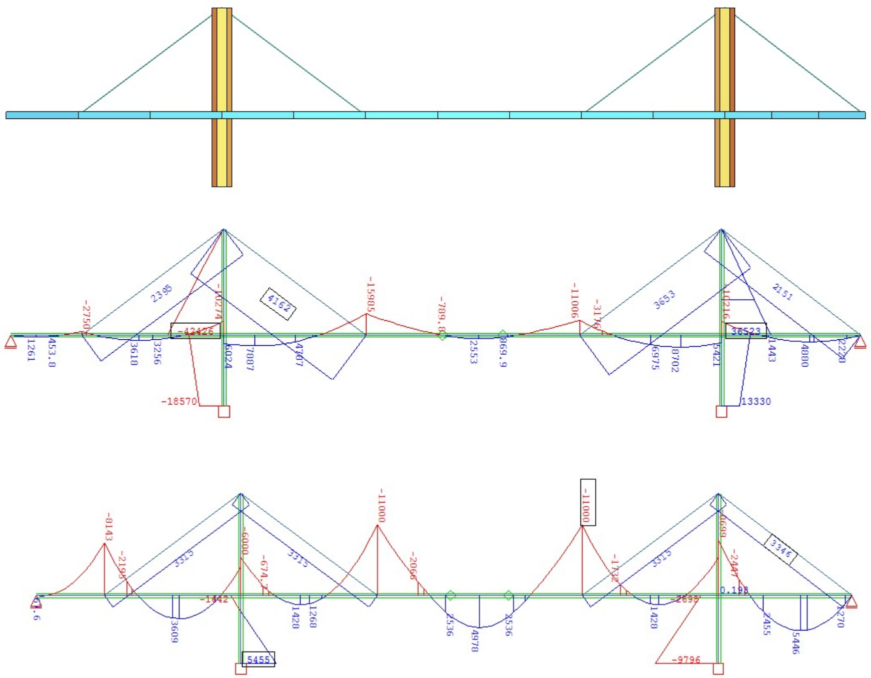
- Cable elements need to be defined as such.
- One can chose between “linear” or “non-linear” calculation.
- The explained CSM procedure (“frozen situation”) allows to also use cable elements for non-linear-stage-analysis.
  See below: cable sagging for cantilever erection (scale 1:5):



SOFiSTiK and cable elements

Force optimization for cable elements:

- A target case needs to be defined +
- A unit load = cable stressing force needs to be defined.
- We have to distinguish between “constant” and “variable load”.
  Variable load can be: creep + shrinkage, cable sagging, etc. constant: self weight, traveler, pavement, …
- After a first run of CSM the unit loads are factorized in order to achieve the target. CSM is repeated until convergence is achieved (convergence).



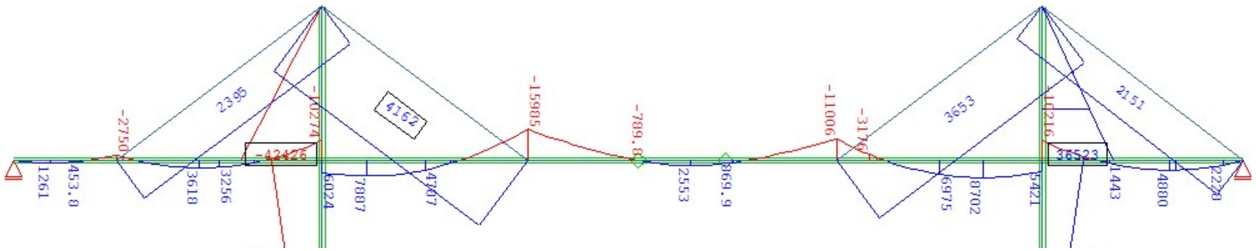
SOFiSTiK and cable elements

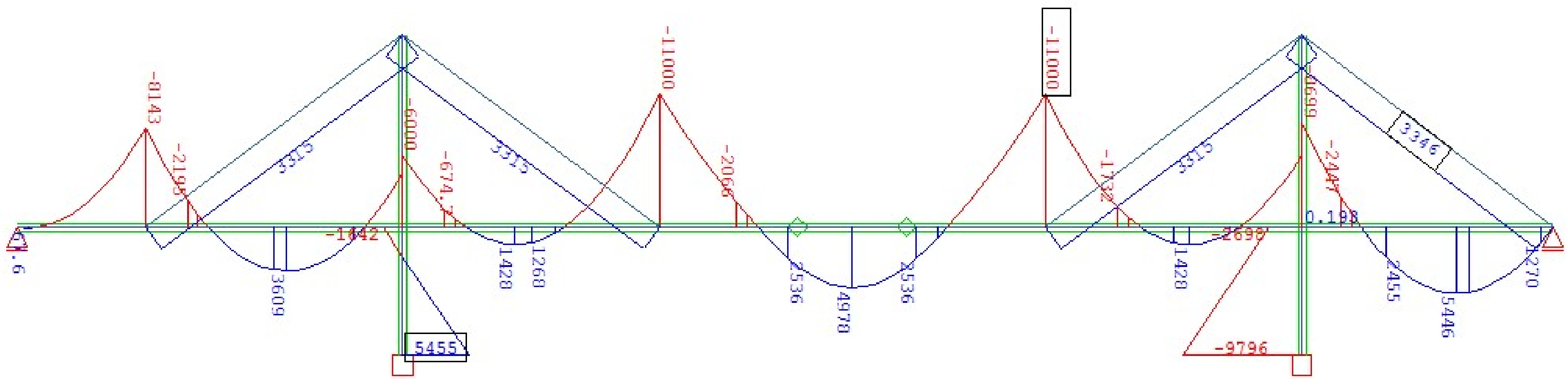
Target and actual values of the desired restrictions
CSM EQUATION ITERATION 1

Restriction	type		number	x	CS	target	act.value	tolerance		fulfilled?
1	beam	MY	10304	0.000	92	0.000	-42425.69	>	1.000	no
2	beam	MY	10311	0.000	92	0.000	36523.062	>	1.000	no
3	beam	MY	20104	0.000	92	-6000.000	6024.339	>	600.00	no
4	beam	MY	20110	20.000	92	-6000.000	5420.642	>	600.00	no
5	beam	MY	50106	0.000	92	-11000.00	-15985.40	>	1100.0	no
6	beam	MY	20109	0.000	92	-11000.00	-11006.49	<	1100.0	OK

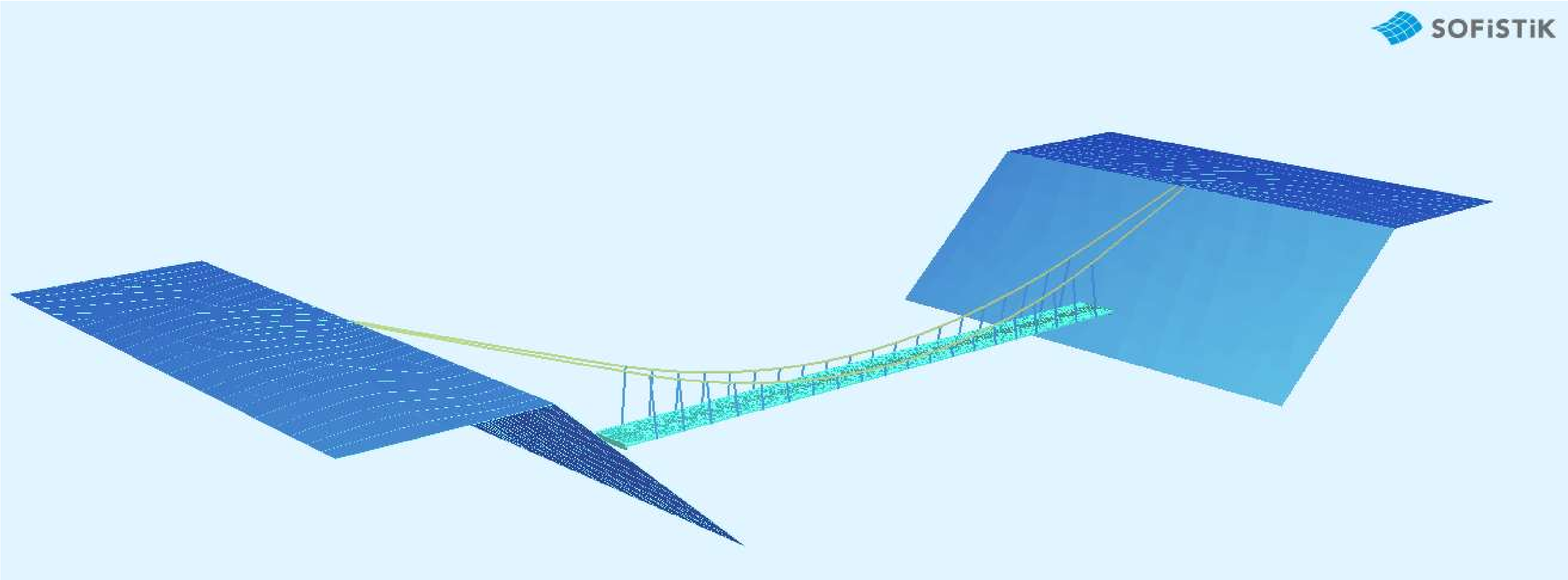
Factors of loadcases to be calibrated
CSM EQUATION ITERATION 1

loadcase	last factor	new factor
5031	1.000000	2.063367
5032	1.000000	0.876473
5041	1.000000	2.203351
5042	1.000000	0.671847
5071	1.000000	-0.361850
5072	1.000000	0.478390





SOFiSTiK and suspended structures



SOFiSTiK and suspended structures

Cable elements for suspension bridges:

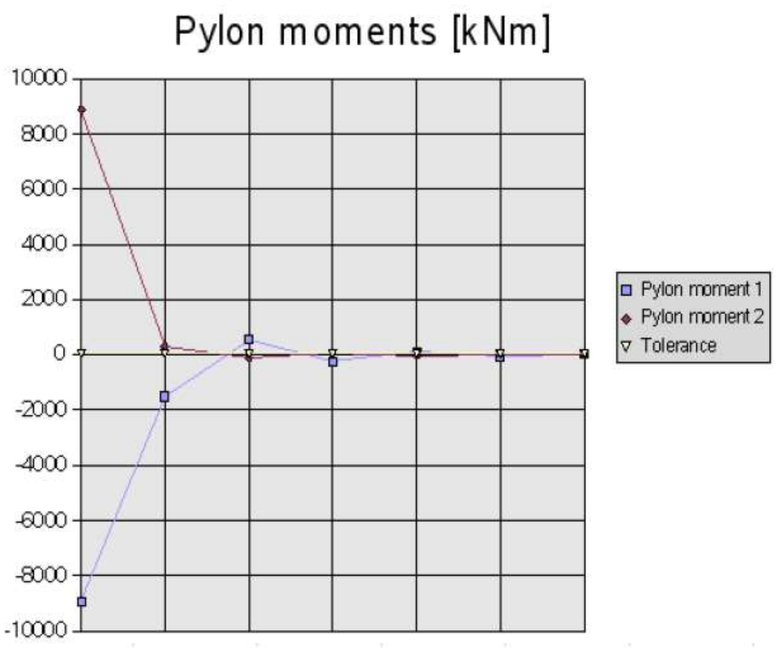
- Before going into force optimization and stage simulation the "form finding" has to be done.
- We define the wanted final deck geometry under permanent load and the program gives us the required stress free cable length.
- Using the now known basic geometry the optimization as before is done – now including IIIrd order theory (large displacement),

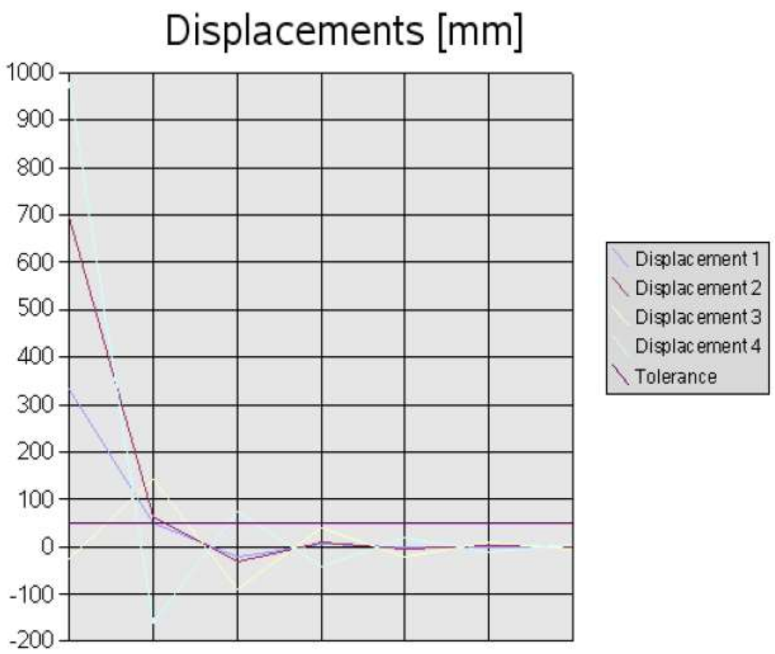
```
CSM EQUATION ITERATION    4
 Restriction type number    x      CS     target act.value tolerance fulfilled?
   1    beam    MY   1001   0.000    95      0.000  -247.868  >  50.000 no
   2    beam    MY   1002   0.000    95      0.000    68.067  >  50.000 no
   3   node     UZ    102              95      0.000     0.006  <   0.050 OK
   4   node     UZ    103              95      0.000     0.010  <   0.050 OK
   5   node     UZ    104              95      0.000     0.041  <   0.050 OK
   6   node     UZ    105              95      0.000    -0.042  <   0.050 OK
   loadcase      last factor      new factor
       5025         2.375179        2.433804
       5035        73.376015       72.064659
       5045        56.735054       65.950233
       5055       190.951141      181.488937
       5085         0.534482        0.514303
       5095         0.524737        0.518421
```

SOFiSTiK and suspended structures

Cable elements for suspension bridges:

- The following graphs show the convergence of the optimization during 7 optimization iterations.

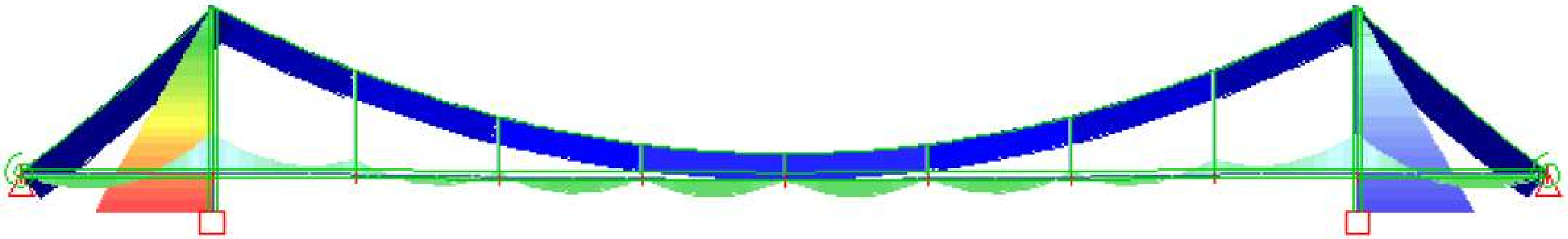




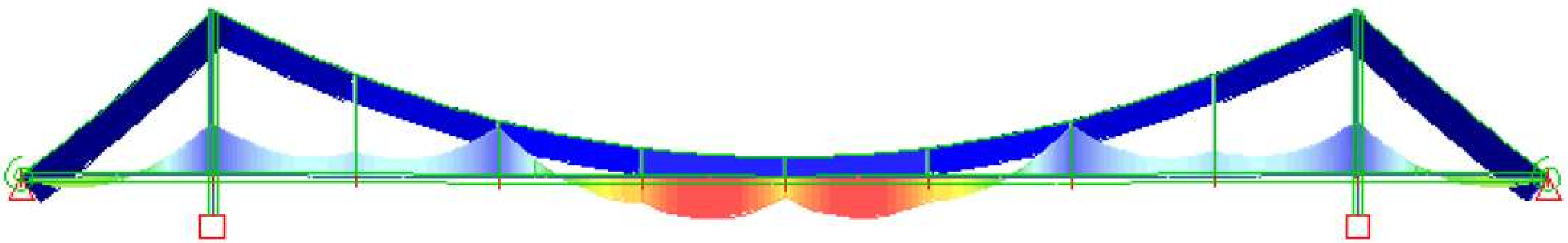
SOFiSTiK and suspended structures

Cable elements for suspension bridges:

- Beam and cable forces on built-in-one system



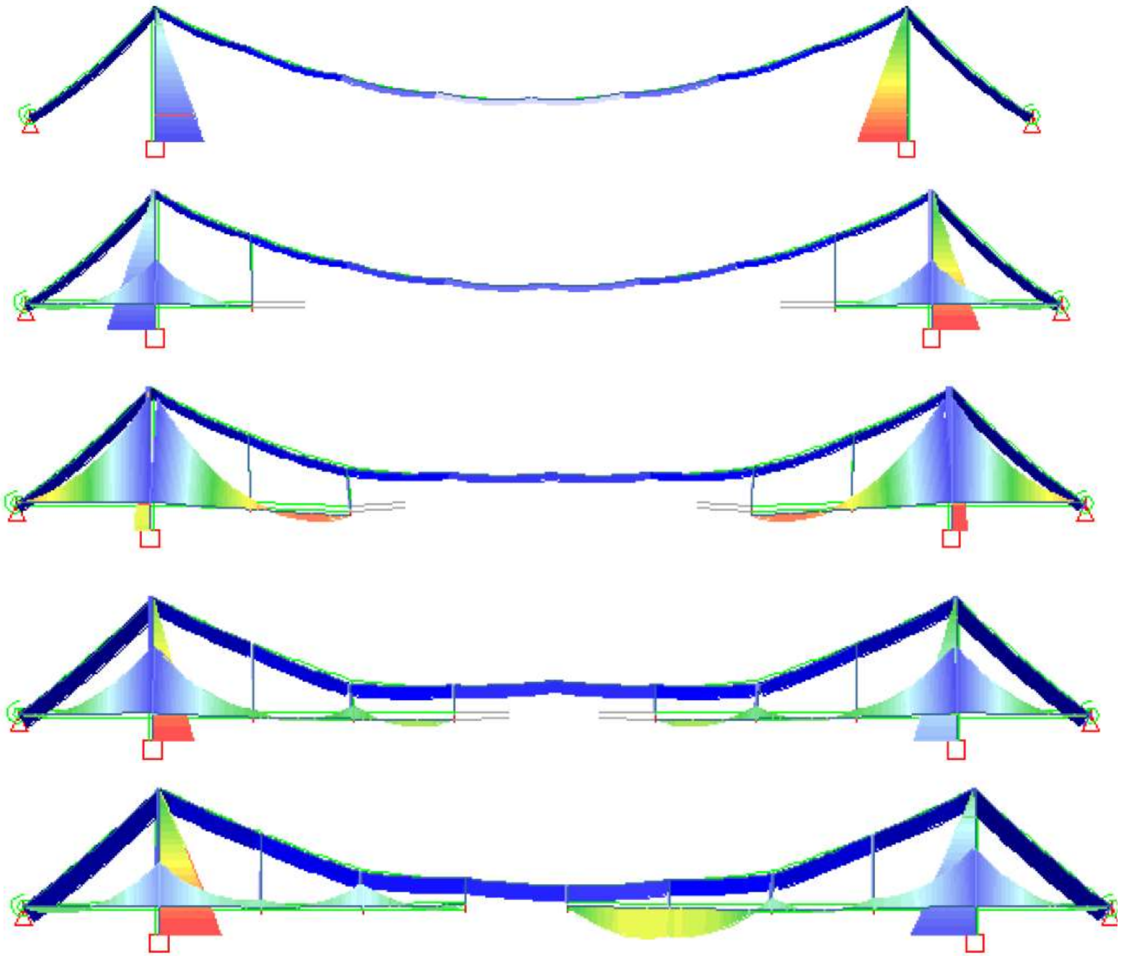
- Beam and cable forces after system optimization – pylon MY = 0



SOFiSTiK and suspended structures

Cable elements for suspension bridges:

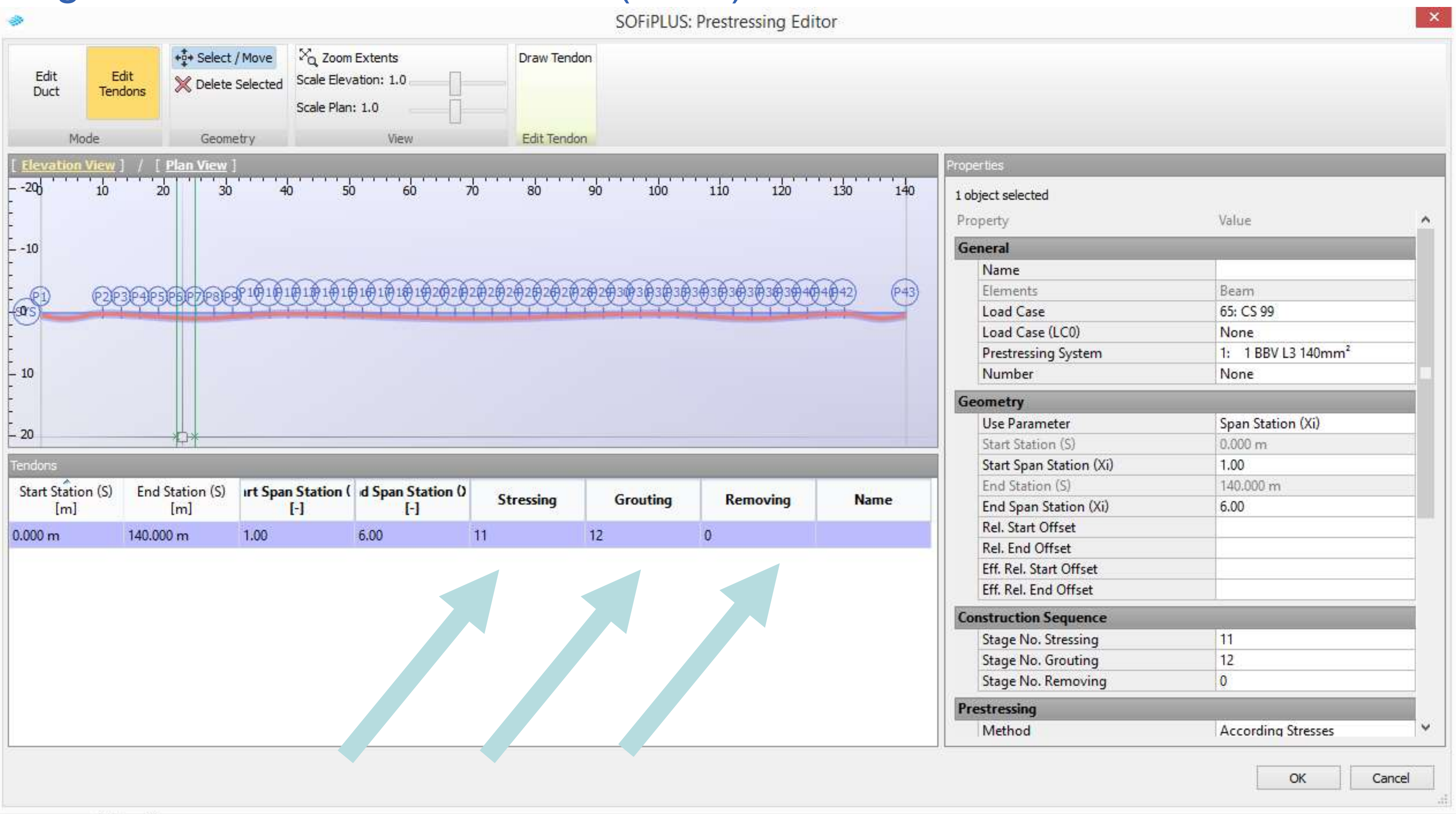
- Non-lin construction stages:



More about pre-stressing

In connection to the stage wise erection PT requires info for tendons like:

- When is the tendon jacked (ICS1)
- When is it grouted (ICS2) – or bonded,
- And if not grouted- when is it removed (ICS3)



More about pre-stressing

As for the geometry of a tendon along the structural part:

- Straight or as cubic spline, in any case independent from element numbers (!!)
- Positions either relative to station of one or several reference axes or relative to supports (so called "high points"),
- or following a parametric section reference point

Within the section:

- Either as global coordinates
- or by defining "u" and "v" relative to the section origin (beam elements),
- or relative to a reference axis (shells).

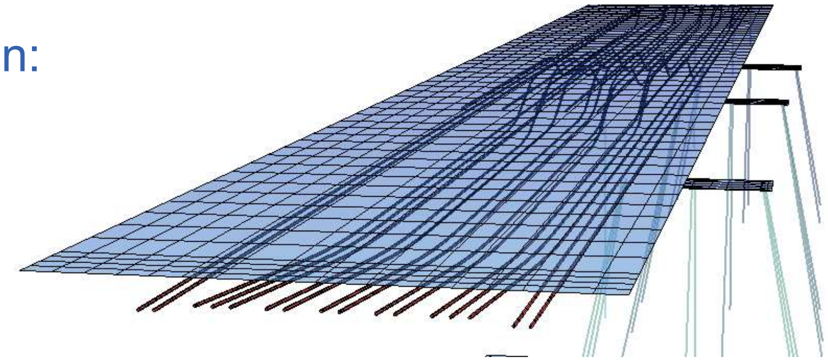
Duct Geometry: Points

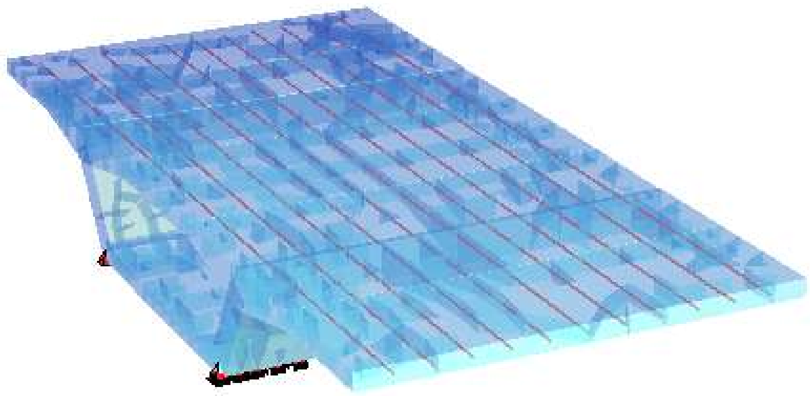
Station (S) [m]	Span Station (Xi) [-]	U [m]	V [m]	Horiz. Incl.	Vert. Incl.	Straight neg. [m]	Straight pos. [m]
0.000 m	1.00	0.000 m	0.400 m				
4.000 m	1.40	0.000 m	0.900 m		0.00		
10.000 m	2.00	0.000 m	0.150 m		0.00		
25.000 m	2.50	0.000 m	0.900 m		0.00		
40.000 m	3.00	0.000 m	0.150 m		0.00		
70.000 m	3.50	0.000 m	0.900 m		0.00		

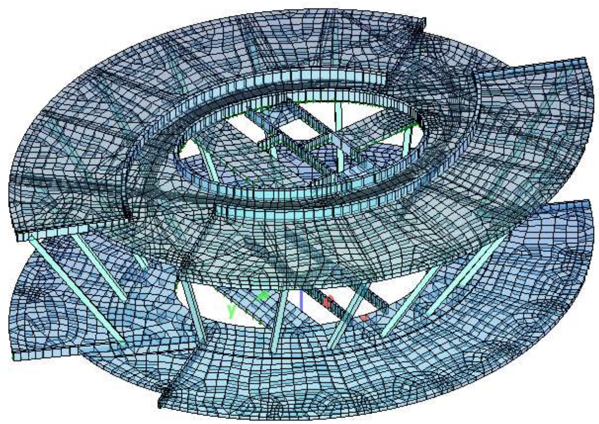
More about pre-stressing

No limitation for geometry and application:

- Local and global PT
- Longitudinal and transversal PT
- PT in shells and beams







More about pre-stressing

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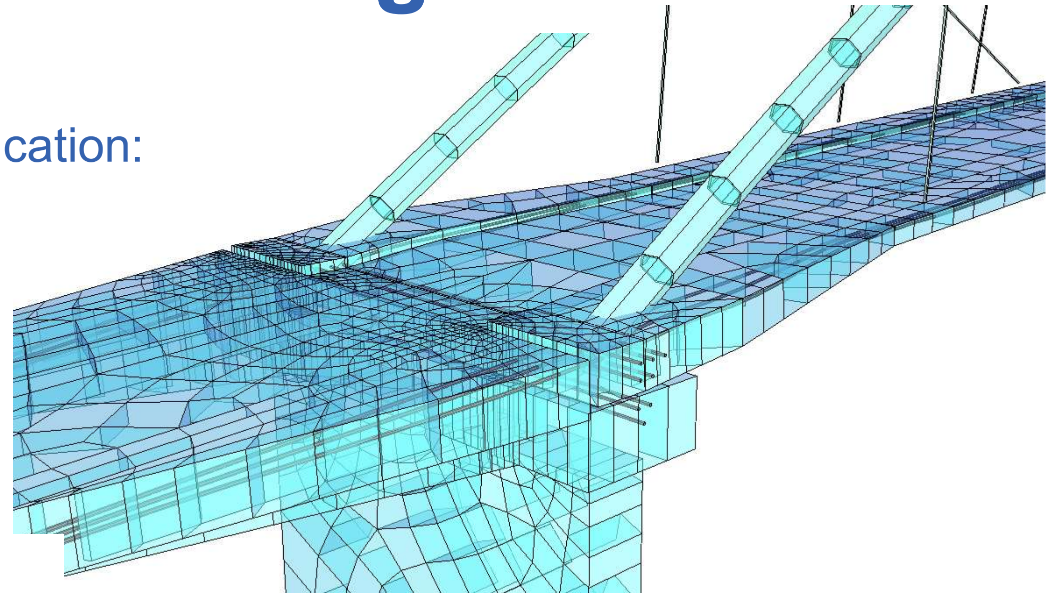
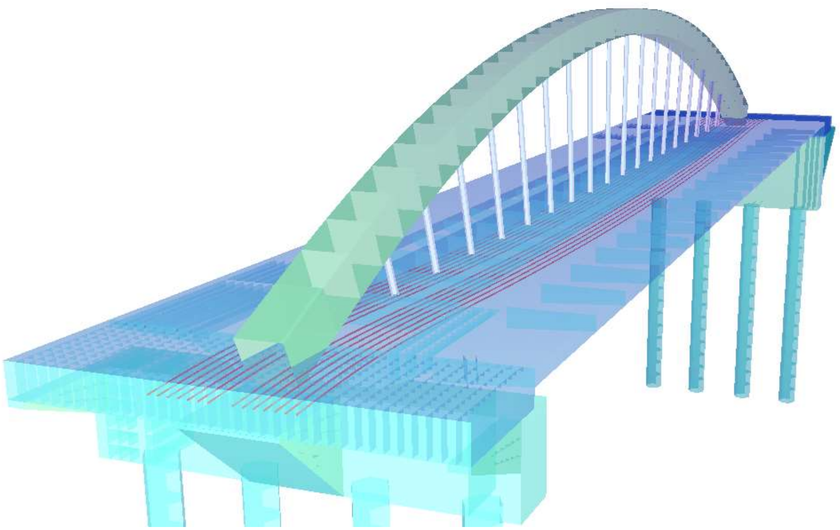
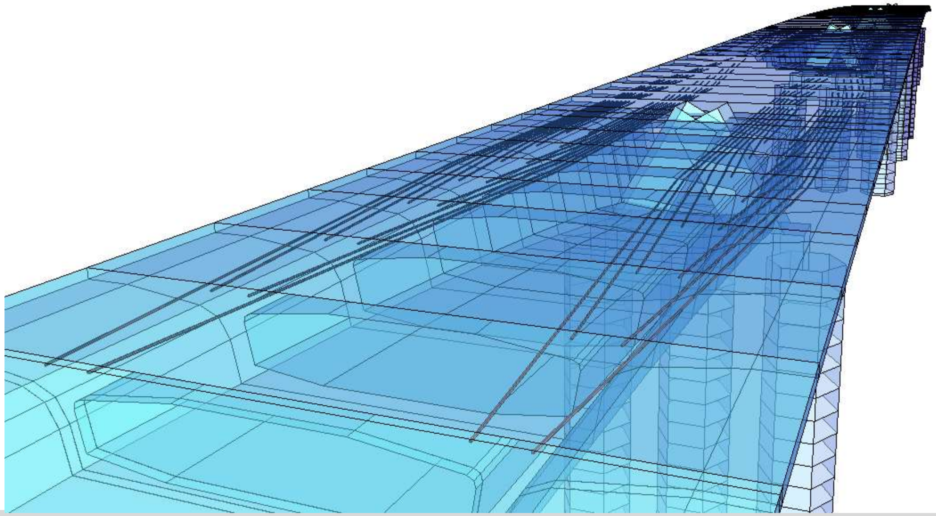


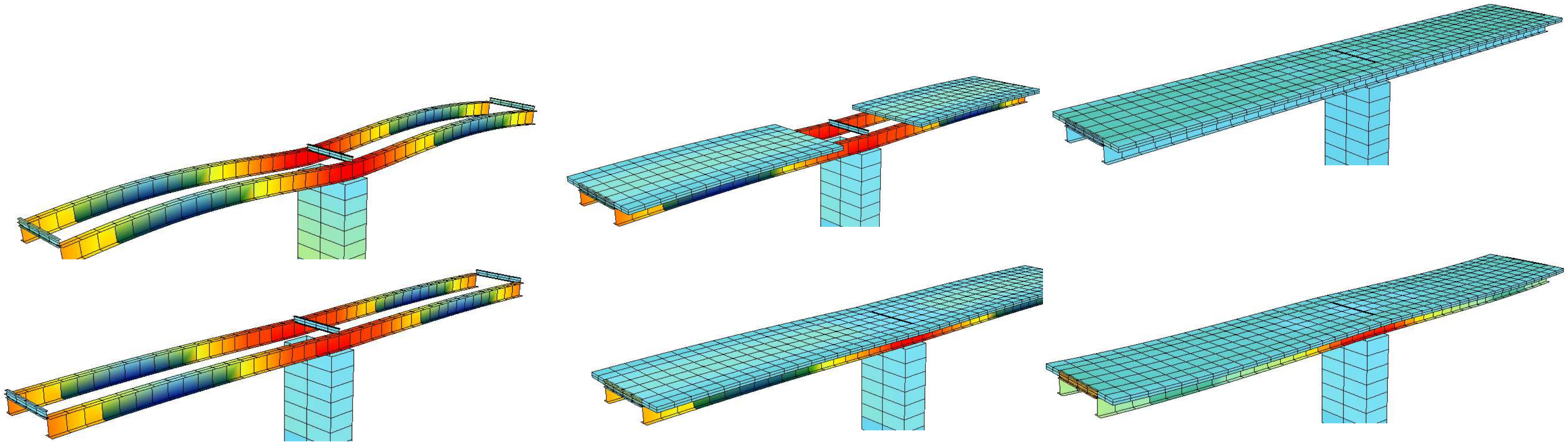




More about composite

When treating composite sections as beams we need to connect:
“section part activation” with “construction stage”.

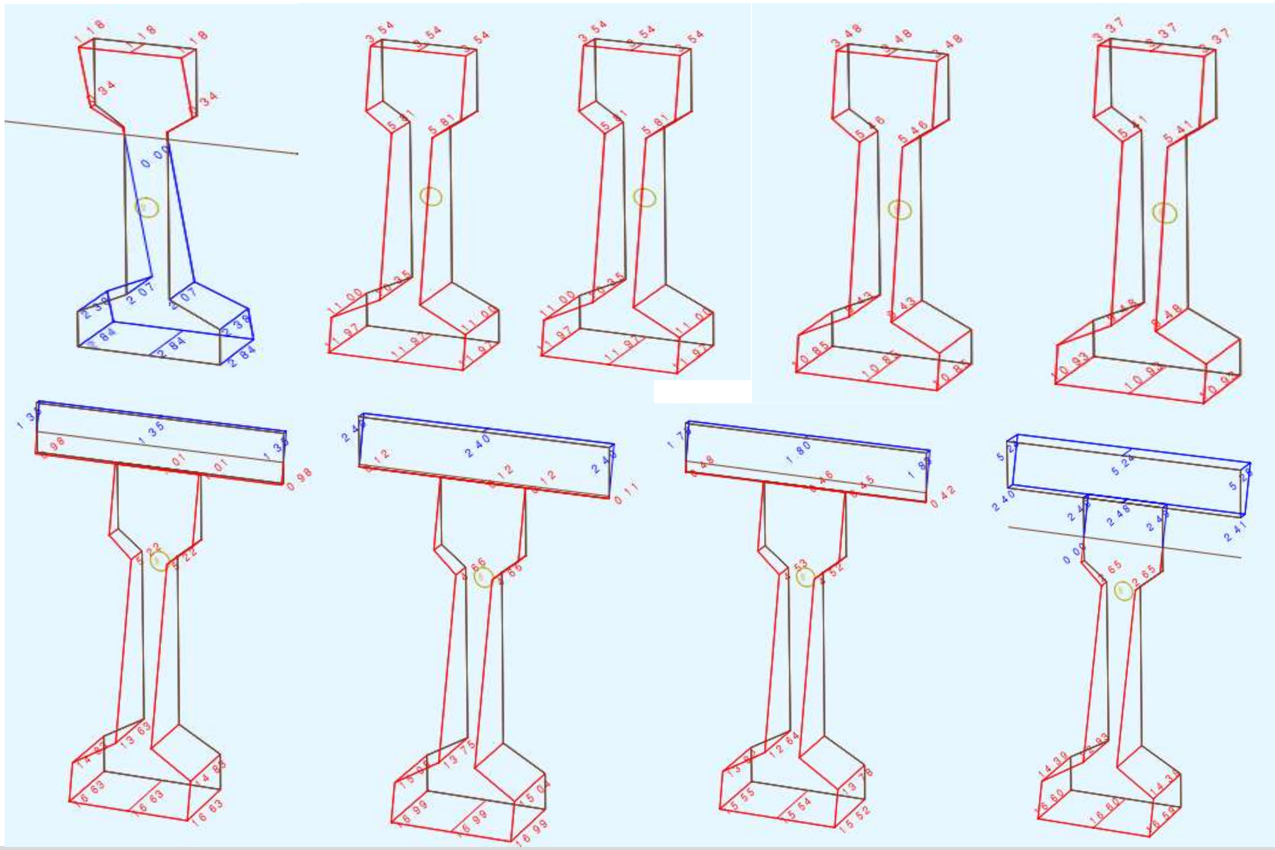
- There is one beam element, all stages are defined on section level:
  part 1 – steel – stage 10
  part 2 – concrete – stage 15 as wet concrete (only weight/load)
  part 2 – concrete – stage 30 as structurally active
- Possible combination with orthotropic slab or shell elements in general.
- Design forces for shear studs in interface between parts.



More about composite

Same procedure for precast and pre-tensioned beams;
Possibly in combination with an eventual post-tensioning.
Results on cross section level – here stresses

1- precast beam
2- pre-tensioning
3- creep+shrinkage
4- wet concrete as load
5- creep+shrinkage
6- composite beam
7- creep+shrinkage
8- add. Load
9- creep+shrinkage



More about composite

Results on cross section level, stresses

1- precast beam

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3- creep+shrinkage

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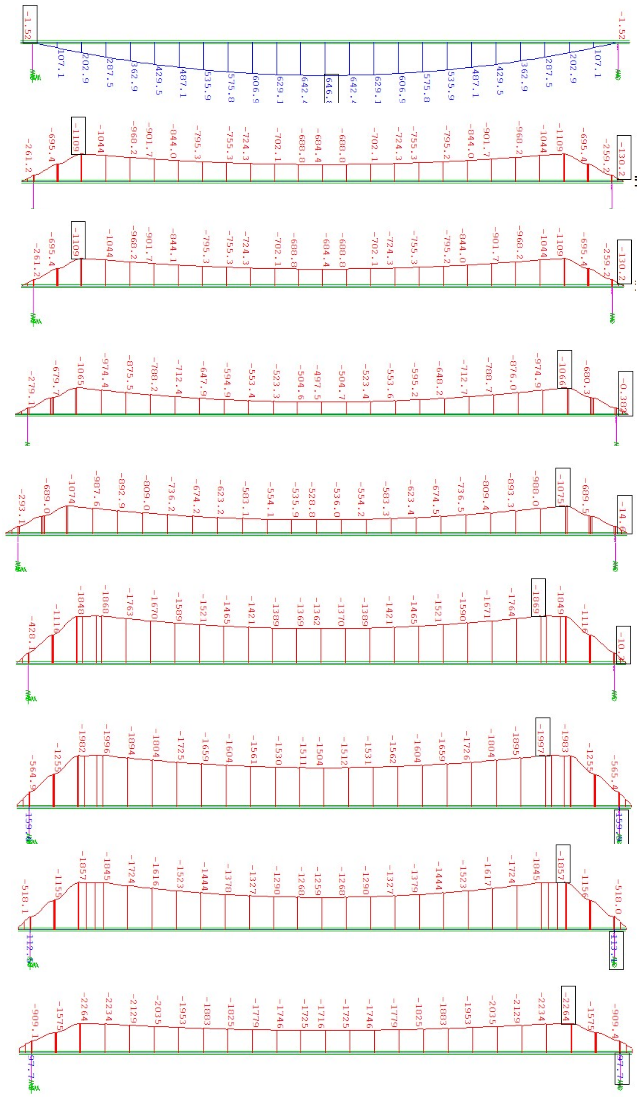
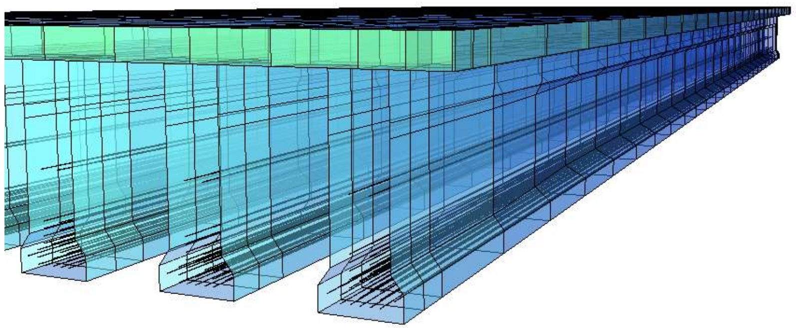
6- composite beam

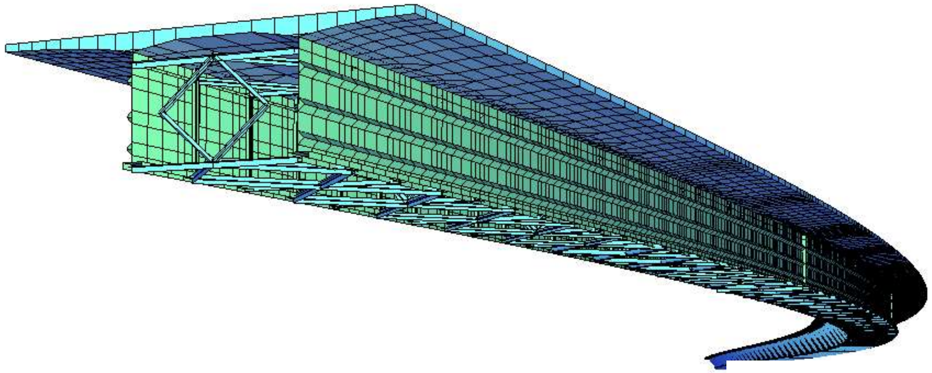
7- creep+shrinkage

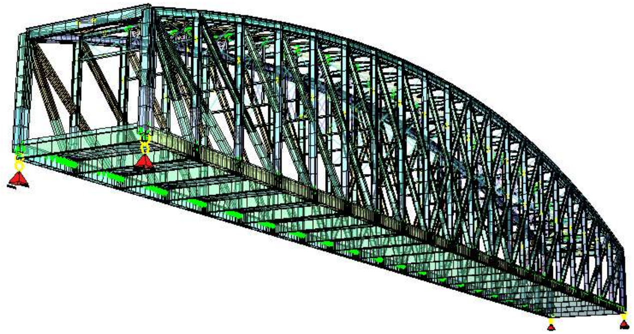
8- add. Load

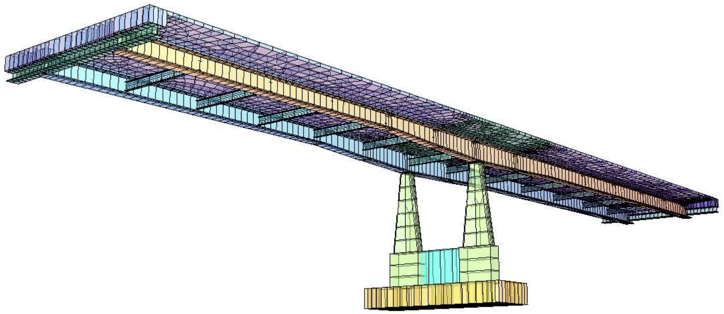


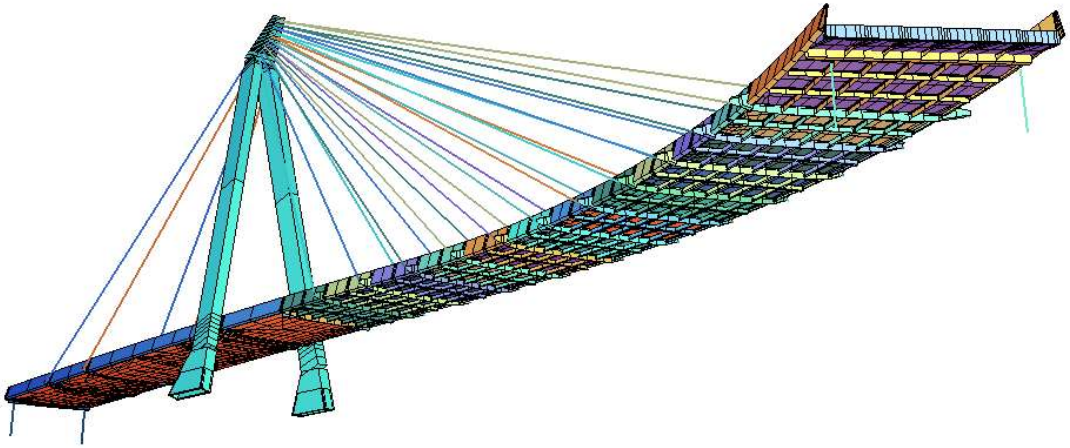


More about composite

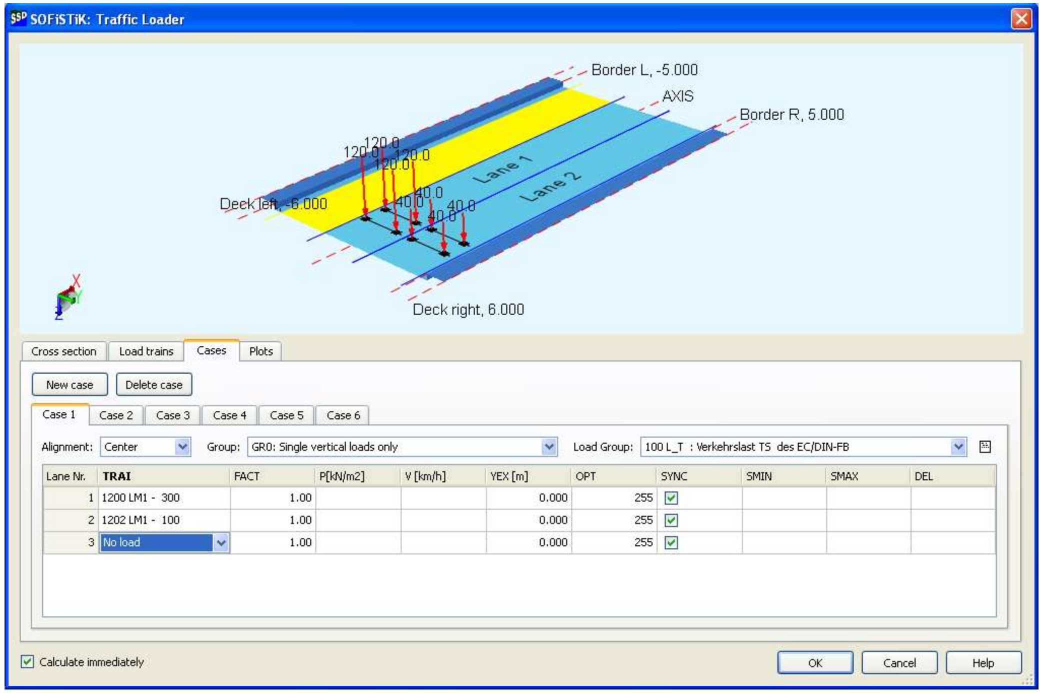




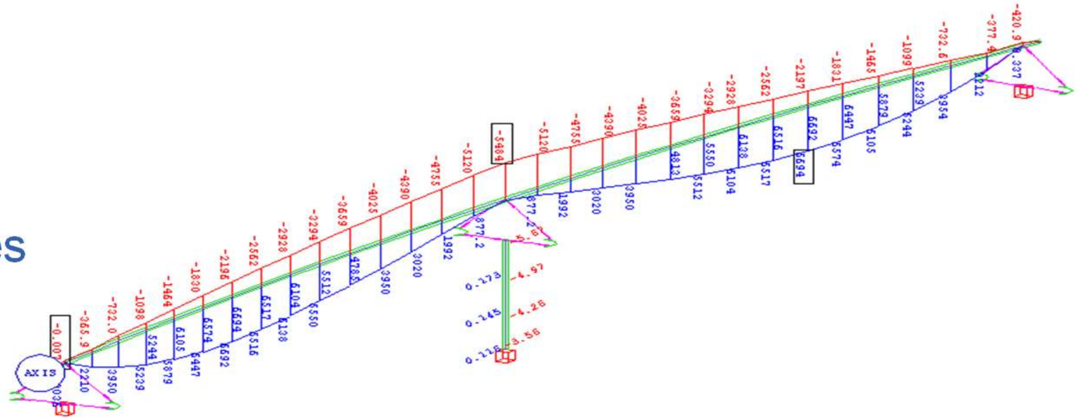




Bridge loads



- Self weight activated together with Stages
- Creep&Shrinkage based on time-axis
- Additional loads:
  - Additional dead load
  - Temperature gradient and global change.
  - Settlement
  - wind on loaded and unloaded deck
- Traffic – 2 approaches:
  1- Load blocks step over deck along a lane with a defined increment, combined to envelopes
  2- influence lines/surfaces are generated, load is applied accordingly.



Bridge loads

SOFiSTiK allows to organize loads into

- ACTIONs with all the safety factor and
- LOADING CASEs that belong to an ACTION.
- In addition to safety factors we define a combination rule (permanent, conditional, exclusive) allowing for max/min envelope creation per ACTION.
- The envelopes “T”, “L”, “S”, “E” can then be combined and factorized with the stage results being ACTION “G”, “P”, “C”, etc. ...
- .. in order to create SLS and ULS design envelopes.

SOFiSTiK: Loadcase Manager

Actions | Loadcases

Act	Description	Partition	Superposition	γ-u	γ-f	γ-a	ψ-0	ψ-1	ψ-2	ψ-1'
B	construction stage loading	Q (Variable)	EXCL exclusive	1.000	0.000	1.000	1.000	1.000	1.000	1.000
C	creep + shrinkage	P (Prestress)	PERM always	1.000	1.000	1.000	1.000	1.000	1.000	1.000
E	Earthquake	E (Earthquake)	USEX unfavourable exclusi...	1.000	0.000	1.000	1.000	1.000	1.000	1.000
F	settlement	Q (Variable)	EXCL exclusive	1.000	0.000	1.000	1.000	1.000	1.000	1.000
G_1	dead load g1	G (Permanent)	PERM always	1.350	1.000	1.000	1.000	1.000	1.000	1.000
G_2	dead load g2	G (Permanent)	PERM always	1.350	1.000	1.000	1.000	1.000	1.000	1.000
L_T	Traffic load TS	Q (Variable)	EXCL exclusive	1.350	0.000	1.000	0.750	0.750	0.000	0.800
L_U	Traffic load UDL	Q (Variable)	EXCL exclusive	1.350	0.000	1.000	0.400	0.400	0.000	0.800
P	prestressing	P (Prestress)	PERM always	1.000	1.000	1.000	1.000	1.000	1.000	1.000

New | Delete

EuroNorm EN 1992 (2004) Concrete Structures

OK | Cancel | Help

Bridge loads

SOFiSTiK allows to organize loads into

- ACTIONs with all the safety factor and
- LOADING CASEs that belong to an ACTION.

SOFiSTiK: Loadcase Manager

Actions | Loadcases

I	Title	Action	DLZ	γ-u	γ-f	γ-a	ψ-0	ψ-1	ψ-2	ψ-1'
1	sw	None	1.000	1.500	1.000	1.000	1.000	1.000	1.000	1.000
2	g2	G_2 dead load g2	0.000	1.350 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
51	Loadcase 51	F settlement	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
52	Loadcase 52	F settlement	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
53	Loadcase 53	F settlement	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
54	Loadcase 54	F settlement	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
55	Loadcase 55	F settlement	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
56	Loadcase 56	F settlement	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
57	CS 19	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
58	CS 29	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
59	CS 39	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
60	CS 49	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
61	CS 59	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
62	CS 69	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
63	CS 79	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
64	CS 89	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)
65	CS 99	B construction stag...	0.000	1.000 (Action)	0.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)	1.000 (Action)

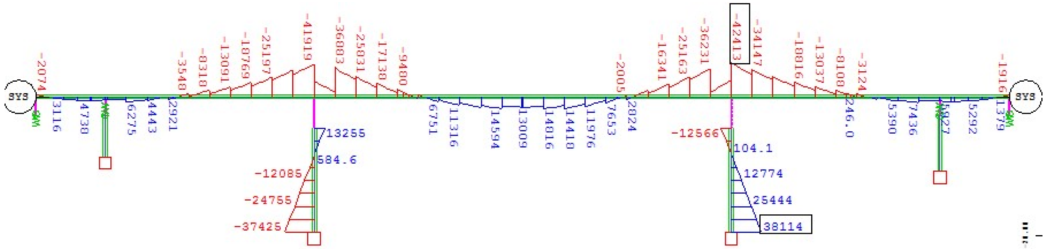
New | Delete

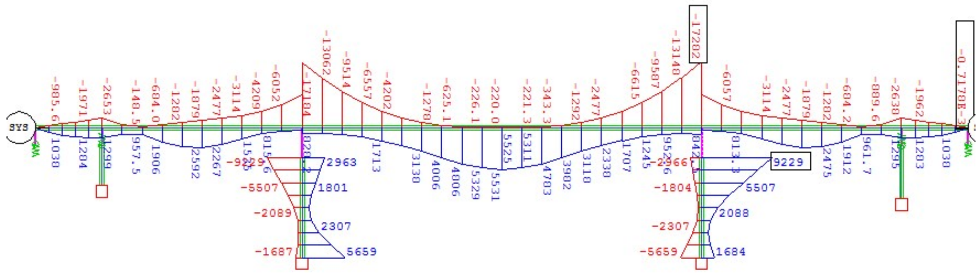
☐ Use global deadload directions ☑ Increment loadcases automatically from selected on

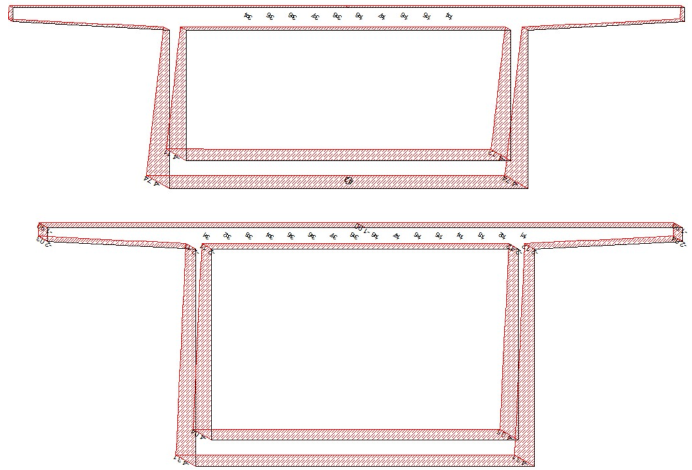
EuroNorm EN 1992 (2004) Concrete Structures

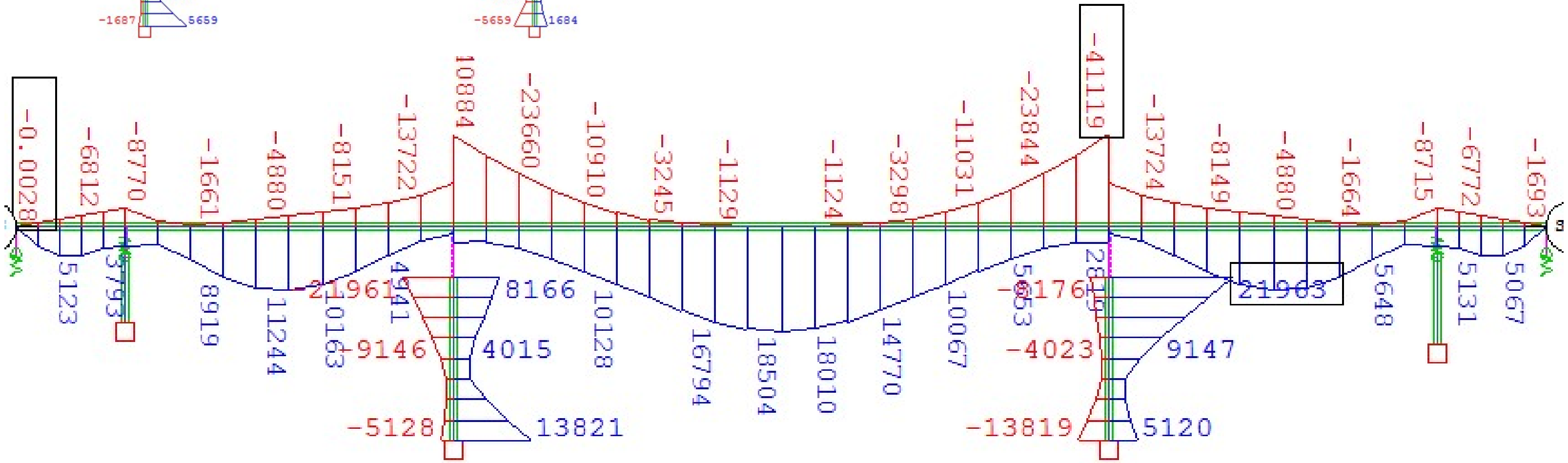
OK | Cancel | Help

Bridge SLS and ULS combinations



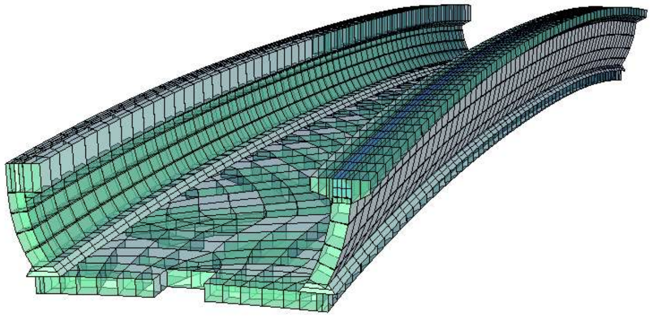


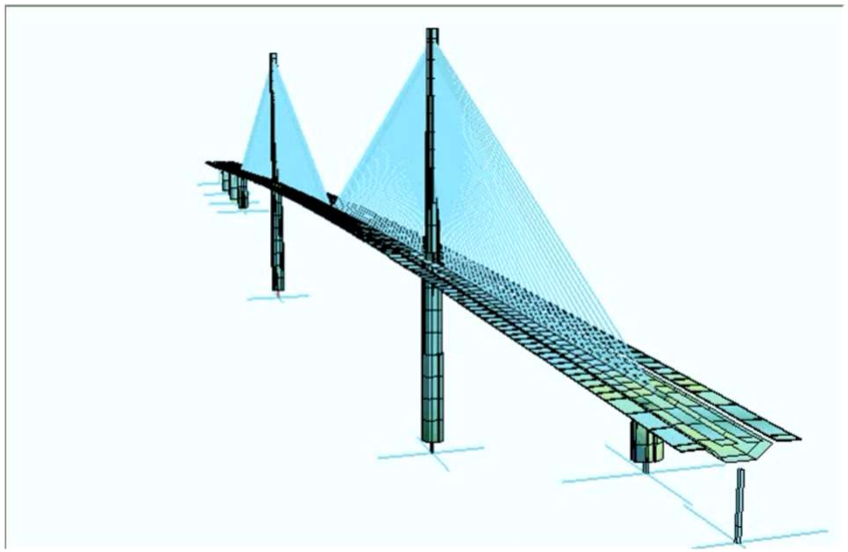




Bridge features

- Statics and Dynamics
- Rail bridges and road bridges
- Super- and substructure
- Analysis and design
- Many design codes available
- Special tools for non-linear material and geometry
- Seismic and Wind
- Piles, wells
- Wing walls and abutments
- Bearing design and capacity check





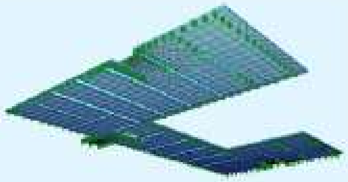
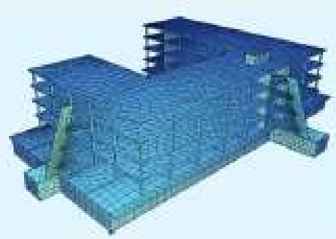
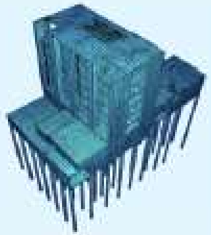
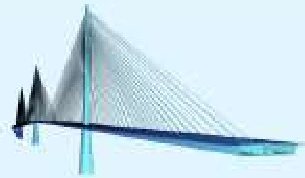
Bridge Types

User Reference from KIEWIT; Shukre Despradel:

Great news! I hope they [Finley] buy the software. For us is very important you guys are very successful and we have more Consultants using Sofistik.

We have used them all, Larsa, LUSAS, Midas, CSI bridge, RM.

We think Sofistik is just the best software for bridges.

	2D FEM professional	3D FEM professional	3D FEM premium	3D FEM ultimate
				
Fields of application	2D FE Static analysis incl reinf. concrete design.	3D Building / BIM incl. reinf. concrete design.	3D structural analysis and design.	3D structural analysis and design incl. Bridges.
Feature list	2D FE slabs and shear wall analysis. Up- and down-stand beams as FE elements. 2D reinforcement design for SLS and ULS (e.g. DIN EN 1992-1-1/NA:2011, OEN B 1992-1-1:2011, SIA 262). Non-linear slab analysis acc. to Eurocode for realistic deflection and economical design. Tension cut-off for elastic slab bedding. Graphic interactive Plot-creation.	(in addition to "2D FEM professional"). 3D FE Beam-, Slab-, Shell elements. Pre- and user defined graphic cross section creation. Automatic calculation of elastic support conditions for 2D analysis when exporting from a BIM Modell[1]. 3D reinf. concrete design for SLS and ULS (e.g. DIN EN 1992-1-1/NA:2011, OEN B 1992-1-1:2011, SIA 262). Steel design acc. to Eurocode (EE,EP with autom. section classification cl.1-3).	(in addition to "3D FEM professional"): Construction stage simulation and time dependent effects. Pile elements. Eigenvalues. Non linear spring and user defined working laws. Non linear beams for concrete and steel section design. Lateral torsional buckling. Automatic consideration of effective widths for class 4 steel sections. Integration of shell results into beam equivalent forces.	(in addition to "3D FEM premium"): Parametric graphic modelling of beam and/or shell structures (CABD). Design checks for pre- and post tensioned beam and/or shell and/or composite elements. Cable elements. Consistent geometrical non linear calculation (cable sagging, shell buckling, formfinding, etc.). Influence lines and traffic load template (road and rail).

Thank you