Working with SOFiSTiK
A User Report

One bridge – many static models

No matter how challenging the task, KMP ZT-GmbH (Linz) finds a solution using SOFiSTiK FEA tools.

Extraordinary structures require extraordinary features from the structural analysis software. The architect-designed bridge over the Danube with unusual load-bearing behaviour presented challenges for the structural design.

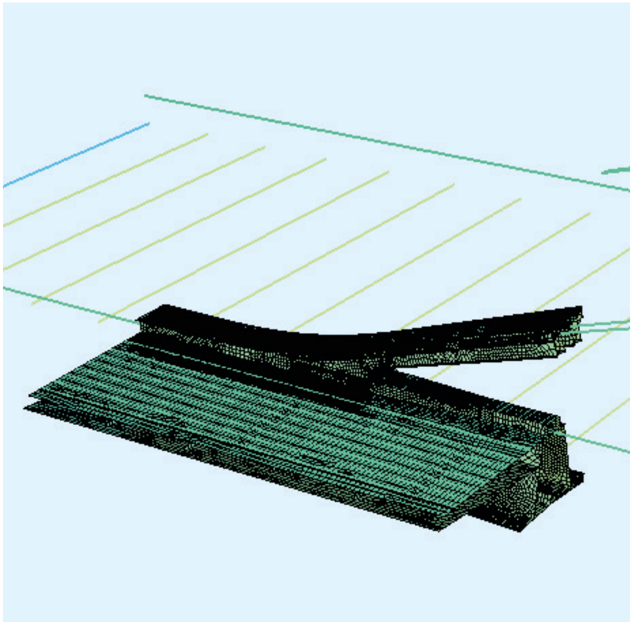
"For extraordinary projects, we also need structural analysis software that offers special features that go far beyond the everyday scope", says Günther Mayrhofer, project manager for structural analysis at KMP ZT-GmbH. The company has relied on SOFiSTiK FEA for bridge construction for more than 10 years. "It's even better to have software that covers both: everyday life and special applications."
After winning the competition for the replacement of the Linz railway bridge in the team of architects and engineers, they were tasked with the detailed design for such a project. A four-span tension chord bridge with arched, dissolved tension members is not your everyday load-bearing structure. Together with variable, very slender cross-sections and the combined loads of road, railway and pedestrian traffic, this project challenged the KMP ZT-GmbH team as much as SOFiSTiK's structural analysis software.

The bridge

The location in the inner-city area of Linz places various demands on the Danube crossing in terms of traffic. A more than 30 m wide bridge cross-section covers the space requirements for pedestrians, cyclists as well as for road traffic and local rail traffic.
Strikingly visible are the arch-shaped support elements above the carriageway with their dissolved cross-sections. Their height, width and cross-sectional shape change continuously to emphasise the lightness of the architectural appearance. Cle-

arly visible are V-shaped supports that dissipate the forces to the bearings.
The main supporting structure in the longitudinal direction consists of two multi-cell steel box girders, supported by arch-shaped flanges. The cross-sections of the longitudinal beams are variable along their length. The 5 m wide footpath and cycle track are firmly connected to the longitudinal beams and contribute to the bearing capacity of the construction. The composite slab made of steel cross girders and a concrete slab provides load bearing in the transverse direction but also increases the capacity in the longitudinal direction.

Team input
During the detailed dimensioning of such a complex load-bearing model, refinements and changes are inevitably made to the static model. As parallel processing by several people was necessary due to the size of the project, we were looking for a practicable way to make the necessary changes traceable, while being able to incorporate them in all the detailed models.



Local model of a steel junction

We decided to use the text-based input in SOFiSTiK. The creation of the basic model requires a little more thought with this input, but also allows for a clear and comprehensible input structure, which can also be supplemented with annotations. Repetitions, such as for the identical 132 cross beams, can be easily handled with loops. This allows input for one beam to be transferred to all the others with little effort. The text-based input also makes it possible to swop changes effortlessly between the project participants.

Detail model management
When analysing a bridge of this size, several analysis models are necessary. It is practically impossible to investigate all global and local effects together in a single model. For the global analysis, we investigated two models. A pure beam model for the effects on the steel components and a combined beam and area model for the joint effects of the deck plate with steel girders.
The designed construction causes most of the loads to be transferred across the entire structure. It was therefore necessary to carry out the local investigations on global models. Eight different node models were to be investigated. The advantage here was that the structure was planned completely symmetrically from the beginning. The big question, however, was how to ensure that any changes that occur are reproduced in all models.

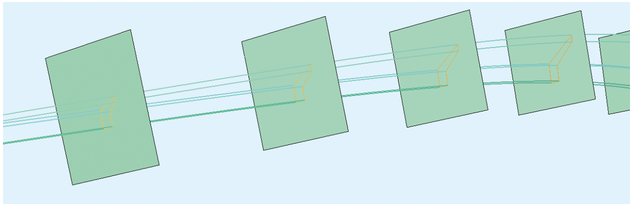
SOFiSTiK's powerful input language was a great help. This allowed us to manage all models in a single file and to control model generation and load applications with variables in such a way that the different models could be generated. More specifically, a combination of parameter substitutions using #define and logical queries with IF functions were used in a single SSD file.
For example, for the node model above the support in this area, no beam elements were generated for the steel girders, but instead surface elements were modelled for the individual plates. The traffic loads on the carriageway and the wind loads on the arched girders could be acquired unchanged from the basic model. If an adjustment had to be made to the loads or to the plate thicknesses of the beams outside the node area, these could be carried out in the global model and the node model could be regenerated accordingly.

Combination of graphic and text-based input
Creating area elements for the node models with text input is possible but would have been somewhat time-consuming. Therefore, we decided to do the modelling in SOFiPLUS. SOFiSTiK's modular structure allows us to combine different input methods. With the graphical, AutoCAD-based input in SOFiPLUS, even the sophisticated, three-dimensional geometry of the nodes could be modelled clearly. One of SOFiSTiK´s export functions was used to create a text file of the modelled 3D drawing, which was then inserted into the basic model's file. The fact that every input to SSD is divided into tasks contributed to the clarity here. A separate task was used for each node model, which could then be easily changed.

Geometric calculations with SOFiMSHC

The bridge was designed by a team of architects from MMA and MMI using freeform modelling in Rhino. The main girders' cross-sections are variable in height and width, and the curved flanges also have variable angles. For the detailed design planning, the component surfaces were described with the help of coordinates in numerous vertical sections. The challenge was to transfer this information to the analysis model. For this purpose, the cross-section values perpendicular to the axis had to be determined and entered along the respective member axis. The task could have been solved with the help of spatial sections in a 3D model in Autodesk® Revit®, AutoCAD® or Rhino, but this would have meant a lot of manual effort. It made sense to specify the cross-section values in the transverse bulkhead planes, but the exact layout had not yet been determined at that point.

We already had good experience with the SOFiMSHC meshing and geometry module. Curved axes, arbitrary planes and the intersection of elements are just some of the tools the module offers. This gave rise to the idea of having the cross-section values for the beam elements of the arched flanges calculated automatically with the SOFiMSHC module. The basic idea was to reproduce the surface edges with splines. This was done by using the GAX command to create geometry axes. The transverse bulkheads were divided along the defined beam axis. Perpendicular planes can be conveniently defined by automatically rotating structure points along the axes. The intersection of surfaces with axes is one of the basic functions offered by the module. The intersection points constructed in this way formed the beam's cross-section. The local Y and Z ordinates of the cross-section elements were determined with the help of structural lines, the length of which was read out. This allowed the cross-section values to be determined automatically from the geometry data. After changing the cross-section, the new cross-section values could be determined at the push of a button.



3-dimensional cuts in SOFiMSHC allow for complex generation of cross section dimensions

Checking the geometry

Using SIX, the predecessor of the SOFiSTiK Bridge + Infrastructure Modeler (SBIM), the generated geometry from the FEA model was exported back into a 3D geometry model. This was an easy way to check for consistency between the analysis and the architectural model.

Designing the roadway slab

The design of the carriageway required the latest features of SOFiSTiK FEA to meet the desired requirements. Due to the manufacturing process, a combination of precast elements and an in-situ concrete top was planned. Due to the low slab thickness, the designer had to split up the lower reinforcement between the precast elements and

The finished bridge

Rendered preliminary project

the in-situ concrete. This required an analysis with a total of six reinforcement layers. The BEMESS design module now offers the possibility to consider multiple – including parallel – reinforcement layers. With this layer design, an economical solution could be found for the highly reinforced slab, because the load-bearing effect of all reinforcement bars could be taken into account.
The carriageway slab mainly bears loads from the local traffic loading, but global loading also causes significant strain. Therefore, apart from the symmetry around the bridge centre, each section of the deck had to be analysed separately. This requirement brought the FEA model to its limits. A fine FEA mesh of the carriageway slab is required to consider the local effects, but an overall model is required to calculate the global effects. A sufficiently fine mesh over the entire bridge length of 400 m would have exceeded the capacities and computing times of the available hardware. Four separate models were therefore used for one half of the structure, in which only the area under consideration was refined. Nevertheless, each of the databases required more than 80 GB to store all the necessary load cases.

To speed up the evaluations, the dbMerge module was used. This made it possible to create a new results database that contained only the design-relevant load case and design results. Post-processing worked much faster because the database size was reduced to 5 GB.

Project Manager Structural Engineering KMP ZT GmbH, Linz
Civil engineer Günther Mayrhofer is pleased:

„There was a solution for every challenge.“

SOFiSTiK

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