Computer Aided Bridge Design

A graphical workflow concept streamlines the FE-analysis based bridge design process of the SOFiSTiK software

The modular concept of the SOFiSTiK FE software has enabled many users to carry out different analysis and design tasks associated with bridge design in the past. Especially demanding and complex analyses like construction stage calculation, force optimization, hybrid beam-shell element models and integrated analysis of 3D soil-structure interaction make SOFiSTiK a reliable tool for the bridge engineer and designer. However, the input was mainly controlled by a parametric input language, making the software powerful but also sometimes daunting for the unexperienced user. To combine the power of a parametric background with an end-to-end graphical workflow inside the SOFiSTiK structural desktop SSD, the Computer Aided Bridge Design Concept (CABD) brings several improvements to the upcoming release of the SOFiSTiK 2010 version.

To realize this concept a software product consisting of several dedicated tasks has been developed which supports the design process of bridge structures starting from the first conceptual draft all the way to the appropriate design of all structural members. The different tasks control the high-end solver and design capabilities of the SOFiSTiK software package.

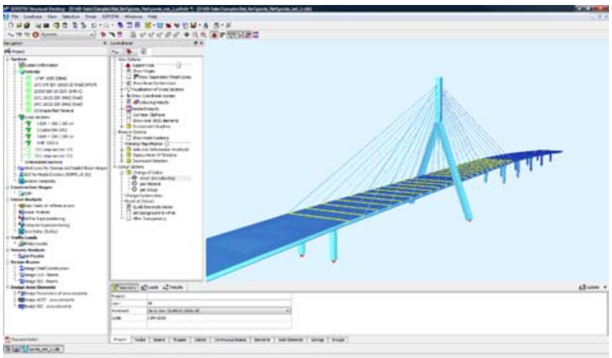

Figure 1: Cable-stayed Bridge

Reference Axis as Basis

The axis-based geometry concept allows a comprehensive definition of the structural model for any bridge structure. Complicated route layouts can be based on a reference-axis, described in the plan view by straight, circular or spiral segments and in the elevation as straight or quadratic parabola elements. These are the commonly used alignment elements in the field of traffic route engineering. The assignment of one or multiple secondary axes relative to the reference axis enables the modeling of grillages, multi-web beam and even hybrid systems (e.g. beam and orthotropic shell deck) as well.

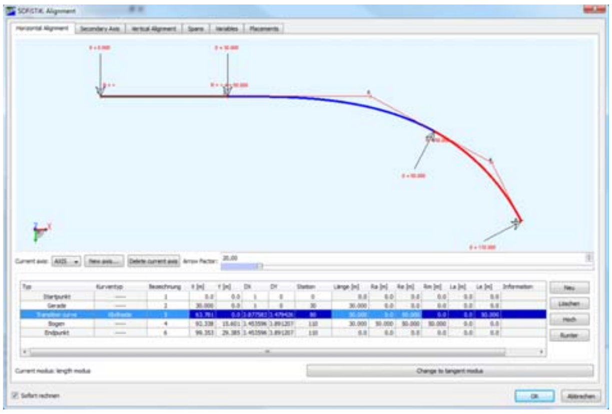

Figure 2: Horizontal Alignment

The structural members of the superstructure are then modeled and discretized with structural elements, which inherit their geometry from the underlying axis definition. Complex geometries can be modeled easily, by placing different cross-sections, variables and dependencies (e.g. for support conditions or construction stages) along these axes. If the geometry is changed, the structural system will be updated automatically as references are managed automatically.

Moreover, it is possible to define any special parameter along the axis e.g. for the generation of cross sections with varying depth, non effective parts and the developing of a secondary axis. For the values of these variables it is possible to assign formulas. Depending on the type and number of data points, linear, quadratic or cubic functions will be evaluated.

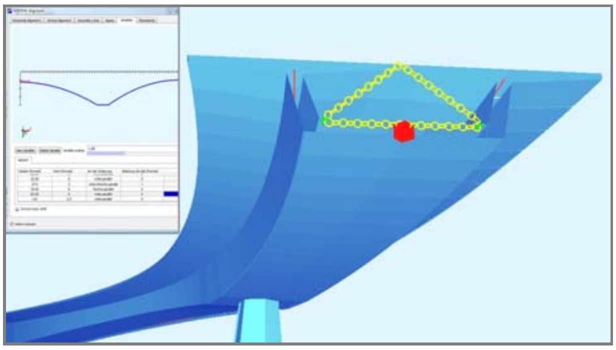

Figure 3: Definition of Variables – e.g.: Depth

Graphical Cross-Section Input

Another extensive innovation in the CABD-concept are the graphical input facilities for a much easier and more efficient definition of even unconventional cross sections shapes within the AutoCAD based tool 'CrossMAX'. This has been fully integrated in SOFiSTiK's standard pre-processor SOFiPLUS. The program takes full advantage of the modeling capabilities of AutoCAD, enabling the engineer to generate any type of cross section (solid-, thin–walled and FE–sections). Additional components allow for the selection of standard cross-section types (e.g. Super-T, I-Beam, Box-Girder) using a template library. This part of the product is contributed by the SOFiSTiK development and technology partner ABES.

Where variable sections exist, section properties are automatically interpolated and calculated by defining a master cross-section and assigning the variability within CrossMAX. The aforementioned formulas will be saved with the section and may be reevaluated for any section with different values along an axis. In this way, longitudinal and transverse variable sections can be specified easily.

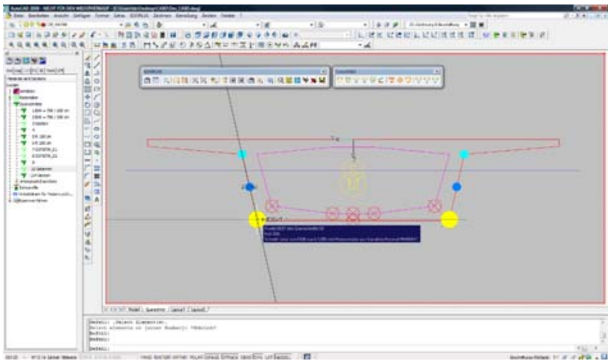

Figure 4: CrossMAX, Assignment of Variables

Tendon Layout

As an integral part of the CABD-concept, SOFiSTiK delivers a graphical-interactive Task for the placement and design of the pre- and post-tensioning as well. The tendons may be freely placed, irrespective of nodes or other structural constraints. SOFiSTiK enables a full 3D geometry definition in plan-, elevation and cross-sectional views. In this task, as in previous tasks, the tendon layout and loss calculation will be automatically updated once the geometry is changed. The analysis offers the well-established features of the SOFiSTiK core technology:

- Prestressing effects for pre-/post-tensioning and internal or external tendons
- Cubic 3D spline tendon geometry
- Calculation of losses for tendons with 3D profile and curvature
- Jacking and construction sequences
- Prestress for beam and shell structures
- Immediate bond with additional strain in ULS
- Unbonded tendons
- Library of prestressing systems
- Tendon stress diagram
- Jacking protocol (numerical and graphical)

Traffic-Loader

Furthermore, SOFiSTiK offers within the framework of the CABD-concept the 'Traffic-Loader' as another very helpful tool in the design process of a bridge structure, as the analysis and evaluation of imposed traffic loads is one of the key issues in bridge engineering. The task offers simple data entry, automatic subdivision of the deck into traffic-lanes according to different design codes, establishment of influence lines and surfaces and the evaluation of load trains according to different design codes. Standard load models for road and railway can be selected from an extensive library; user defined load trains are possible as well.

Following the general concept, the moving load process is based on the bridge axis as well. Traffic loading for bridges is governed by the fact that the most unfavorable position of the loading is different for every single element and reaction, and is not known in advance. The evaluation of influence lines or surfaces becomes necessary for an accurate analysis of larger bridge systems with complex multi-lane traffic loading schemes. Further enhancements to this task will offer an explicit load stepping method for all kinds of systems as well. The calculation of all other load cases like self-weight, settlement, wind and temperature effects can be carried out with graphical input using the state-of-the-art SOFiSTiK FE solvers.

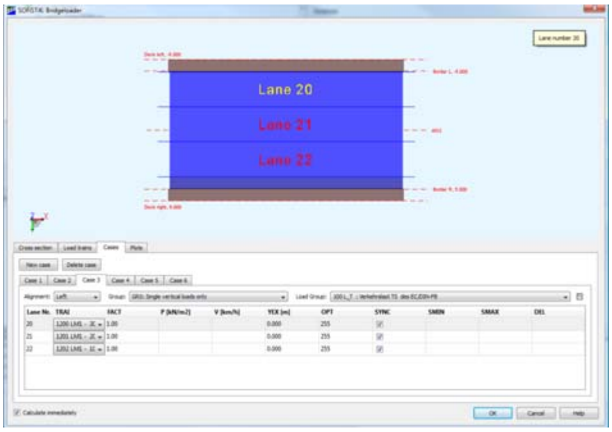

Figure 5: Traffic Loader; Traffic-Lane Layout for EuroCode

Construction Methods, Enveloping and Design

At the end of the process, the time dependent effects of creep, shrinkage and relaxation can be investigated utilizing the 'Construction Stage Manager' (CSM), which enables the simulation of all kinds of construction methods as well. The construction process is managed graphically in a table using an abstract timeline with automatic recognition of pre-stressing stages. Powerful result enveloping and interactive graphical representation of the different reactions lead to the final step, the structural design. The design procedure includes ULS design for beam- and shell-elements and various SLS stress checks of all materials in different stages. A broad range of international design codes (e.g. EC, BS, AS, AASHTO) with their different design requirements and procedures can be chosen by the user. Interactive graphical and numerical post-processing supports the report generation and allows for individual plots and data-transfer to other tools and spread-sheets.

With all its components, the CABD-concept offers the most powerful way to generate and design bridge structures within the high-end FE framework of the SOFiSTiK software. Especially the open parametric structure will enable the user to adapt the workflow whenever required, as graphical and numerical components work hand in hand. In the future this concept will provide a strong basis for all new developments by SOFiSTiK and its partners in the field of bridge design and engineering.