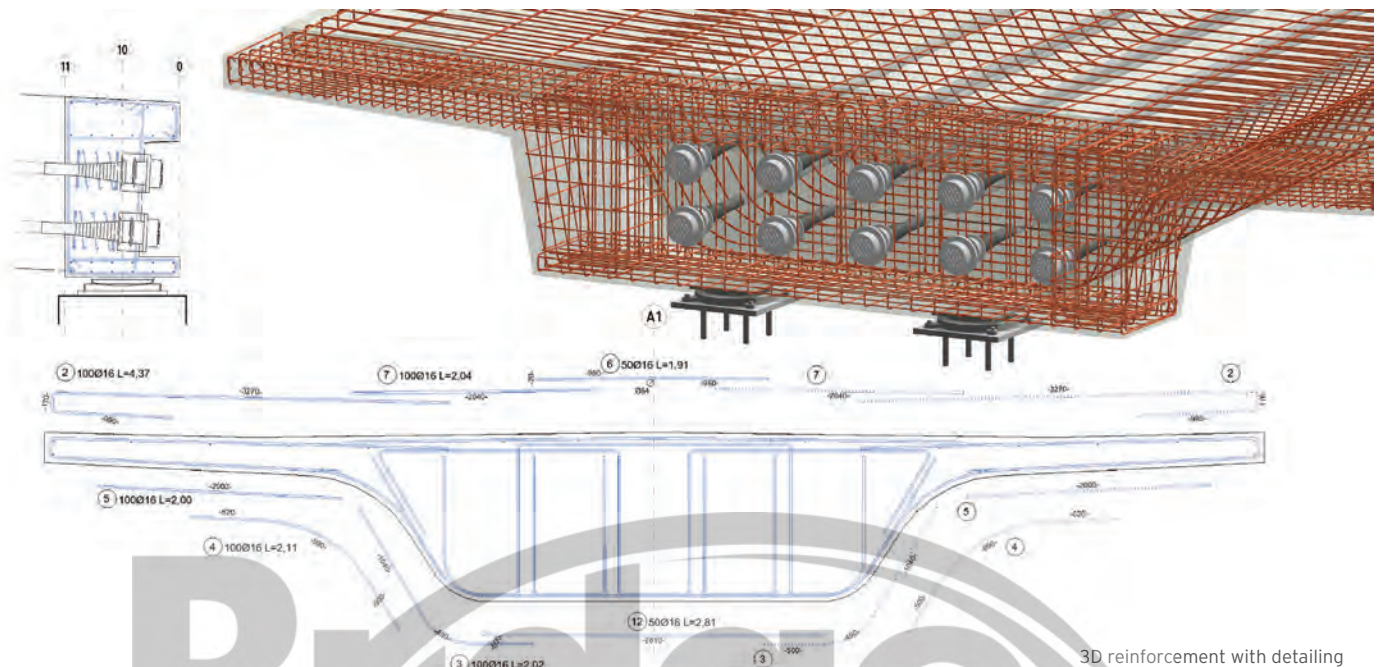


MODEL BEHAVIOUR



The complex nature of bridge design means new tools are required to fully take advantage of the benefits of bridge information modelling, report **Georg Pircher** and **Jakub Bielski**

Building information modelling is the next step of digitalisation in the construction industry, with the benefits in design workflows already proven by a number of pilot projects. With application and further development of BIM already well advanced in the building industry, the infrastructure sector wants to follow the trend and is showing interest in the benefits of putting it into practice, a movement being backed by authorities and government departments on a national level.

Being aware of BIM's potential, the UK government took a decision to encourage its development from early design stage through to implementation and maintenance by establishing BIM level 2 as an obligatory concept of design for public investment, from 2016 onwards. Germany is now taking up this approach and plans to set BIM standards as common practice for infrastructure projects.

Sofistik has offered a BIM workflow tool to the construction industry for some seven years, and is currently developing a new workflow and new tools that implement the same approach. Sofistik uses the Autodesk product Autocad as a platform for structural modelling and 2D drawings. Due to Autodesk Revit's strong market position and technical potential, this is the platform used for BIM workflows.

The focus has been - and still is - on structural analysis and design in combination with the creation of shop drawings. BIM has many aspects that are not used in this context but which need to be covered by the general platform. Being aware of the importance of the implementation of BIM concepts in infrastructure design, Sofistik has developed a new solution that closes the gap between analytical and geometrical models, called Sofistik Infrastructure Extensions (Six).

There are some fundamental differences that prevent simple adaption of existing BIM workflows into infrastructure projects from being sufficiently efficient, and sometimes even make it impossible.

Research and understanding of the needs of engineers plays a crucial role in the early stages of concepts and further development of solutions. While designing a building, structural engineers and drafters are operating on storeys based on local, or sometimes global, elevation, using as references grids that are usually in straight lines. Infrastructure projects require a plan with precise axis definition and elevation, along which the construction of the bridge, tunnel or road will progress. For complex structures, an axis-based input is required as well as possible consideration of a geographic information system.

Building designers face challenges related to multi-statically indeterminate structural systems and cross-sections of structural elements that are mostly standard, usually rectangular and circular. The models are large but the geometry is often simple.

For bridges, models are usually smaller but with a complex geometry. Consequently, the workflow, the tools, as well as the technical information that is transferred between software packages connected to a basic BIM platform are very different in comparison.

The structural engineer's requirements from a BIM bridge model contain certain challenges that need to be considered.

To create the analytical model, the geometric model needs to be simplified. Things like crossfall, drainage, kerbs, guardrails and so on are in most cases not considered in the analytical model. For the global structural system, bearings and cross-beams are simplified while deviation blocks and many others are ignored. Other crucial requirements are tendon geometry; parametric sections (one section plus variables and formulae from which to derive resulting sections); effective width; eccentric joints (load displacement curves for springs and/or dampers); even section properties for wind dynamics. It is up to the engineer to decide whether the finite element model should be made of beams, 3D-shells or a combination of both.

A good tool for defining many geometrically difficult areas such as axes or section

definition is Revit's Dynamo plug-in. While in many cases the resulting Revit model will be highly satisfactory in the geometrical aspect, the structural engineer will meet significant difficulties in the definition of tendon geometry as well as several other areas mentioned above. While Dynamo can create a complex bridge geometry, in most cases Revit does not support the corresponding analytical information.

These are all areas that require consideration prior to the geometrical modelling. If everything can be defined upfront, it is just a question of the engineer communicating with the modeller, who should then establish a modelling process flexible enough to allow all these structural choices at the time the analytical model is set up.

To illustrate the process of executing infrastructure-BIM without running into these problems, consider a simple three-span beam bridge, representing a more typical example than a 1,000m-span suspension bridge.

The workflow function allows two models to be generated; an optimised one for structural analysis purposes and a highly detailed model for drafting and further documentation. The process is made smoother by the high degree of compatibility between the Revit and Sofistik databases. This is important because the more compatible the databases, the less need to either use external files such as IFC format or to do manual and repetitive adjustments, which are the largest source of errors and wasted time when it comes to the BIM process.

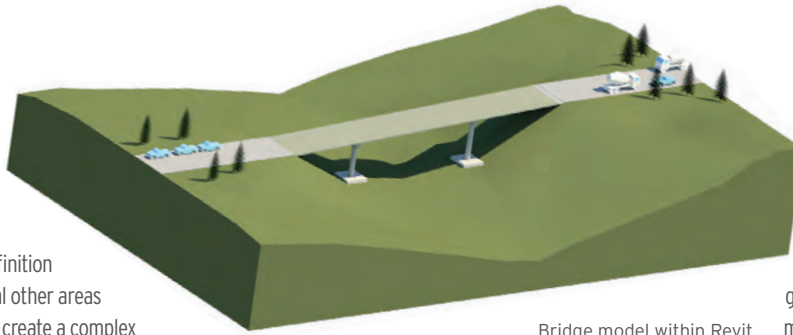
The basic concept for parametric bridge geometry modelling was made available many years ago using Autocad as a base. Computer-aided bridge design enhances the modelling and analysis of bridge structures. The resulting bridge model is based on and relative to the main and secondary axes. All axes are defined by straight parts, curves, spirals and parabolas for plan and elevation. All locations along the axes are referred to as stations, which are used for various points of interest called 'placements', such as support positions, cross-section changes, construction joints and cable connection points.

Variable dimensions of cross-sections also refer to the available axes. Formulae, functions and variables can be defined by linking the 'station-along-the-axes' with a value, and interpolating the cross-section between the stations. Typical variables can be the cross-section height, web thickness, roadway width or effective width, amongst others. These variables are then linked to the corresponding dimension of the basic cross-section shape and, as the model is meshed into a structural finite element model, all intermediate sections are derived and interpolated. This principle applies to all materials and section shapes as well as all element types such as shells or beams and also includes the prestressing definition if available.

The fact that tendon geometry can be presented in Revit is a particularly interesting feature of Sofistik's software, and it is believed to be the only software with this capability. Within the computer-aided bridge design concept, all tendon and duct details for geometry and analysis are defined. Both the geometrical tendon information in Revit and the detailed analysis and design topics of structural engineering are incorporated, including construction-stage simulation and time-dependant effects such as creep, shrinkage and relaxation.

Using the Sofistik Infrastructure Extension tool, the relevant geometrical information can be extracted from the database to generate a 3D model in an Autodesk Revit project. In addition to bridge geometry, several other objects can be generated simultaneously, such as grid lines along the bridge based on the axis alignment, and also perpendicular grid lines (stations) at the position of placement; section views can be created at the position of each placement. All these functionalities offer the opportunity to get the most information out of the database to improve the bridge detailing process for the next design phases.

The transfer of all prestressing data into the Revit file via the Six tool significantly



Bridge model within Revit

accelerates the modelling and detailing of ducts and tendons, allowing for collision checks in anchorage zones while providing important information for further documentation such as a list of quantities. At this stage, both the geometrical model in Revit and the analytical model in Sofistik are available for use.

Once the superstructure's geometry has been generated, often the most complex element in bridge design, further objects such as bearings, kerbs, guardrails and pavement can be placed. New sections and views also help the modeller navigate inside the project, enabling the creation of formwork and construction drawings.

A wide range of additional Autodesk Revit functionalities can be used to generate 3D objects in the model or to load previously modelled elements, so-called Revit families. Some of the families may be found in already prepared contents or downloaded as a BIM-object library from specific manufacturers, so that the drafter can design his own object and parametrise its dimensions.

A specific strength of Revit is the capability of adding all the reinforcement fully based on 3D geometry. This includes the detailed reinforcement within the deck bodies, based on the generated cross-sections and in a logical manner that is relative to the outside shape.

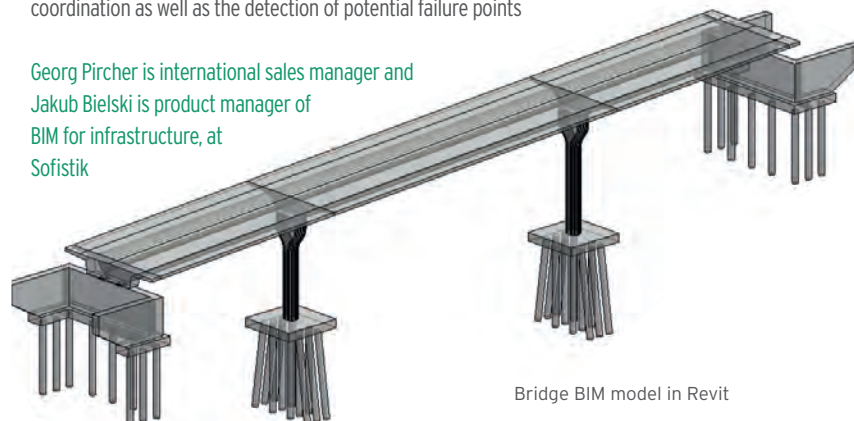
Add-ons and new features created by software developers can be added through Autodesk's application programming interface. Sofistik Reinforcement Detailing offers a pallet of useful tools and also automates the time-consuming process of sketching rebar and adjusting the dimensions along an axis.

Some of the tools are essential for placing reinforcement in the bridge structure due to a cross-section that is variable along a curved axis. Drafters can modify rebar sets according to the chosen reference of the reinforced element or generate rebar in an element according to the chosen path and host's constraints. Tools for positioning, annotation and checking of reinforcement are available, all of which significantly accelerate the preparation of 2D drawings and the creation of bar-bending schedules derived from the 3D model.

Using Autodesk Revit as a platform for the BIM model affords the possibility to enhance a project with additional information that may not be relevant for structural engineering, but which may have a large influence on overall content. Along with visualisation of the model, lists of components and quantities amongst others, it offers a definition of topography and coordinates that can be integrated with other projects and file formats. The model can be seen in a new context that reflects the project location and terrain.

Finally there is teamwork, a basic concept of BIM design and one which is facilitated between Revit users through the cloud or a server. That the workflow can be enhanced this way through design options and project phases increase a project's overall coordination as well as the detection of potential failure points

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Bridge BIM model in Revit