White Paper

Parametric Modelling, a basic B.I.M. property implemented in SCIA•ESA PT 3D Modeller

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Introduction

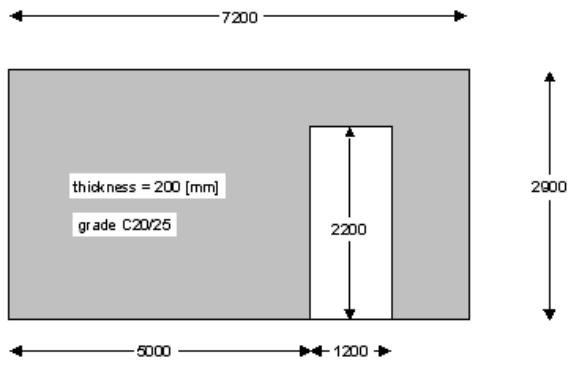
This white paper is a further step in the explanation of the Building Information Modelling (B.I.M.) and introduces the concept of Parametric Modelling.
This document explains the benefits and the technology of parametric modelling in the SCIA•ESA PT platform and in Nemetschek - Allplan. B.I.M. is essentially creating, communicating & reviewing information on a construction project, from design to construction (and maintenance). ***Round-trip Engineering*** is the seamless integration between architectural, structural, analysis and detailing models and the intelligent link between those models (see white papers from Dr. Ir. J.P. Rammant, Ir. H. Oogink). The SCIA•ESA PT platform is the engineering design environment; Nemetschek Allplan deals with construction drawings and documentation. Together the integrated solutions constitute the most advanced structural information modelling software on the market today.

Engineers working in the construction industry today are facing the problem of increased cost-efficiency and shorter design cycles. Three major trends in the engineering profession can be easily recognised: the time that is available for an engineer to design a structure is decreasing, the complexity/size of projects is increasing and the complexity of the calculation is high. In other words, today's engineers have to design, calculate and check more complex structures with detailed and sophisticated calculations in less time than yesterday.

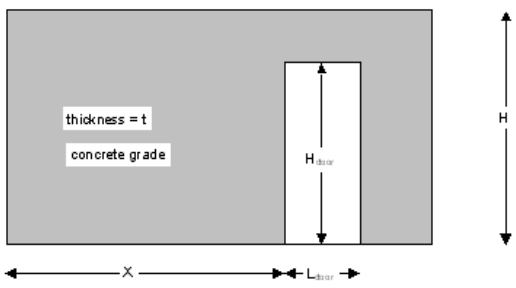
Without innovations in the information technology such a task would not be achievable. Using B.I.M. technology on synchronized architectural, structural and analysis models, and using ***Round-Trip Engineering*** as offered by Nemetschek and SCIA, the designer is already helped by basic steps in obtaining huge efficiency gains. With ***Parametric Modelling*** the user obtains another tool to increase the efficiency, productivity, quality and cost-effectiveness.

What is Parametric Modelling?

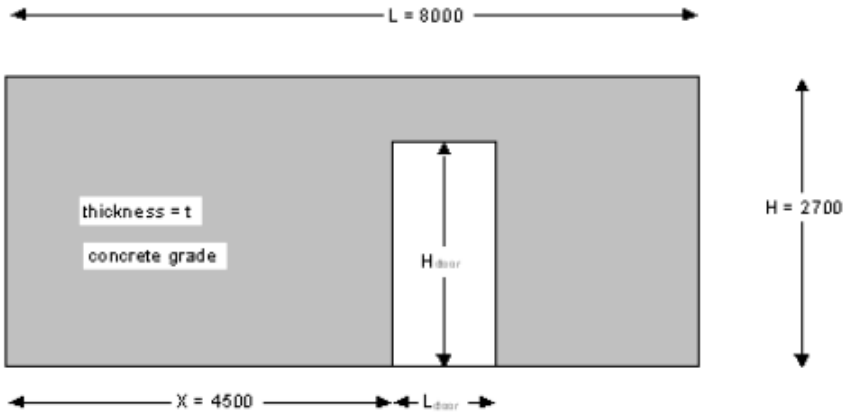
Parametric modelling is the design concept in which the absolute values of a model or part of it, like the height of the structures, the loading at the top surface, the thickness of a web, the grade of the concrete or the time of casting, are replaced by relative parameters, see picture 1 and 2. These parameters may be defined in all kinds of models: either analysis, detailing or structural. After the parameters are defined, they can be easily adjusted by the engineer to new values/settings, see picture 3. Consequently, the engineer obtains either a relatively small or maybe even a big change in the structure. The initial design shape, however, is not changed fundamentally.



Pict. 1 General drawing



Pict. 2 Choice of parameters



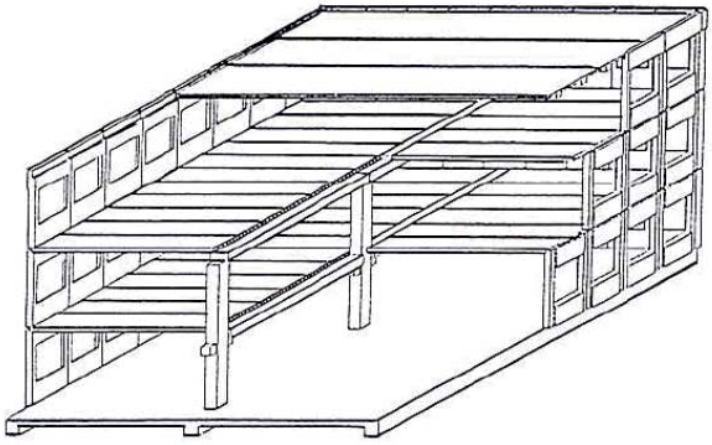
Pict. 3 Regenerated model with changed values for the parameters

In the SCIA•ESA PT platform it is possible to parameterize almost all input data for structural and analysis models. Even more, the user is able to parameterize extensive detailing parts (like reinforcement cages or strand patterns) as a single entity. We distinguish general design parameters (such as loading) and structural objects parameters. The choice of the parameters is fully open to the user, no programming is needed since the user interactively indicates the parameters and the SCIA•ESA PT platform accordingly generates a table to describe and input starting values of the parameters. The user can add a schematic drawing to this table.

The use of these parameters within the design model (for geometry, materials, loading, ...) then leads to:

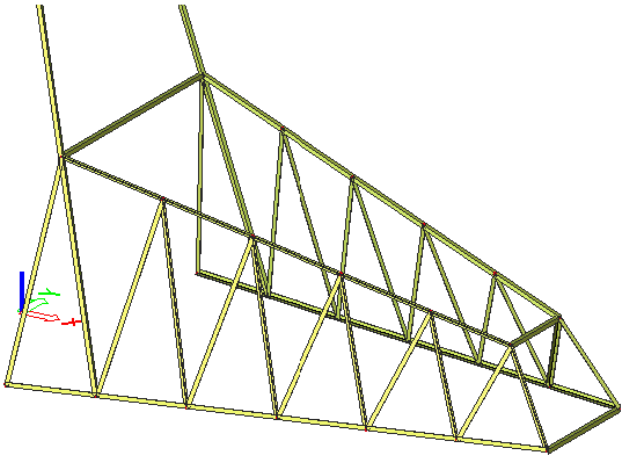
- a rapid design (new design models are easily rebuilt from similar shapes / parametric parts can be re-used in other objects or projects)
- access to more complexity (parameters are calculated out of formulae or derived from other parameters, e.g. generation of the geometry of towers)
- sensitivity studies (by studying the effect of changing parameters).

Based on a continuous repetition, the user is able to perform a rapid design through the adjustment of a predefined set of input data like in steel frames or hollow core slabs. But even more complex structures are designed by using parameterized user templates or so-called blocks. Using the parametric blocks like Lego pieces, the engineer will build a new structure very fast, for example tower masts or portal frames.
A similar approach is used in the prefabrication of a concrete building: a simple precast wall with openings is used in various configurations. Thus the engineer obtains a complete concrete building quite easily, see picture 4.

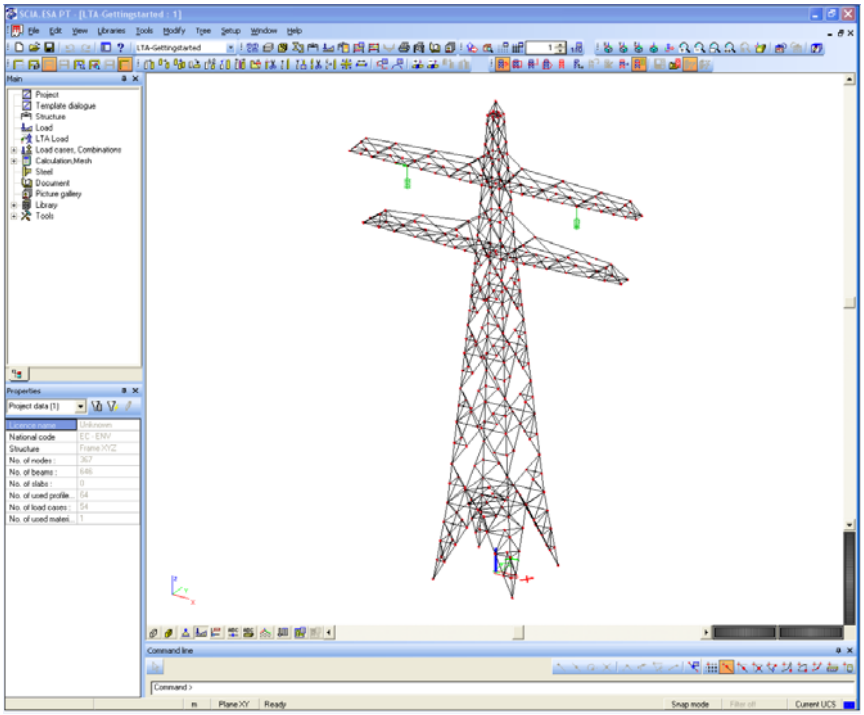


Pict. 4 Typical example of a precast concrete building (from 'Gebouwen in geprefabriceerd beton' by Prof.dr.ir. J.C. Walraven & Ing. J.P. Straman, TU Delft)

Using mathematical formulae the user is also able to obtain relatively complex structures in an easy way. The main user, mostly the lead engineer, defines the formulae once, and afterwards the engineer or draftsman enter the proper input data for the formulae. The lead engineer uses parametric templates for different parts of the structure, the basic users can assemble the complex structure based on the parameterized block, see picture 5 and 6.



Pict. 5 Example of a parameterized arm of a lattice tower: the various hooks and angles are parameterized, the complex geometry is calculated out of 'hidden' formulae.



Pict. 6 An assembled complex lattice mast (action performed by the basic user). Example composed of more than 10 different parametric blocks

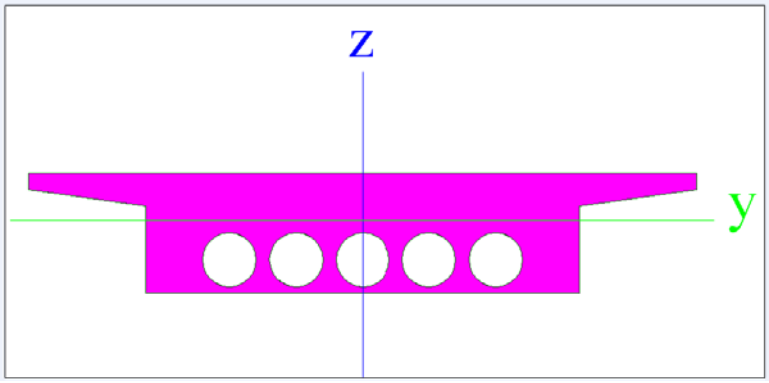
Finally the user is able to manipulate the parameters in such a way that a sensitivity study can be performed. The user defines the range of the parameters and introduces the incremental step for the parameters. Using the calculation power of today's PC's, the user is able to review the whole range of design problems for each value of each parameter - thus obtaining the full insight into the behaviour of the structure. Moreover, a special solver is used in order to ***AutoDesign*** the structure for multi parameter optimization.

For daily practice the parametric modelling option in SCIA•ESA PT and Nemetschek Allplan enables the creation of user-libraries of frequently used construction components: beams, walls, joists, trusses, braces, foundations, precast concrete libraries, concrete rebar schemes, castellated beams, steel joints, metal deck systems, etc. This creates maximum flexibility for the design and detailing.

The data structure underlying the parametric model is such that changes propagate throughout the entire model; the change engine ensures that related elements reflect the changes of chosen parameters.

A few illustrative examples of parametric design

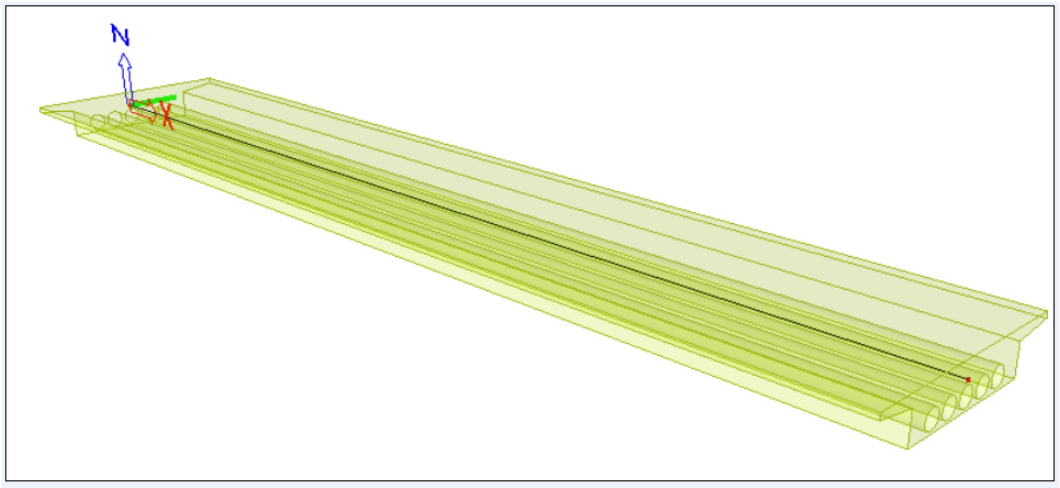
In the following example we will explain the parametric modelling in detail. Assume that the engineer is designing a single span post-tensioned bridge. The cost-efficiency requires the minimal (optimal) amount of concrete mass and the minimal depth of the bridge. However, the number of parameters influencing those two main design criteria is quite big: concrete quality, height of the cross-section, number of tubes in the cross-section (to reduce weight), diameter of the tubes in the cross-section, size of the cross-section near the supports, concrete cover, etc. In picture 7 you can review the initial cross-section used in the design.



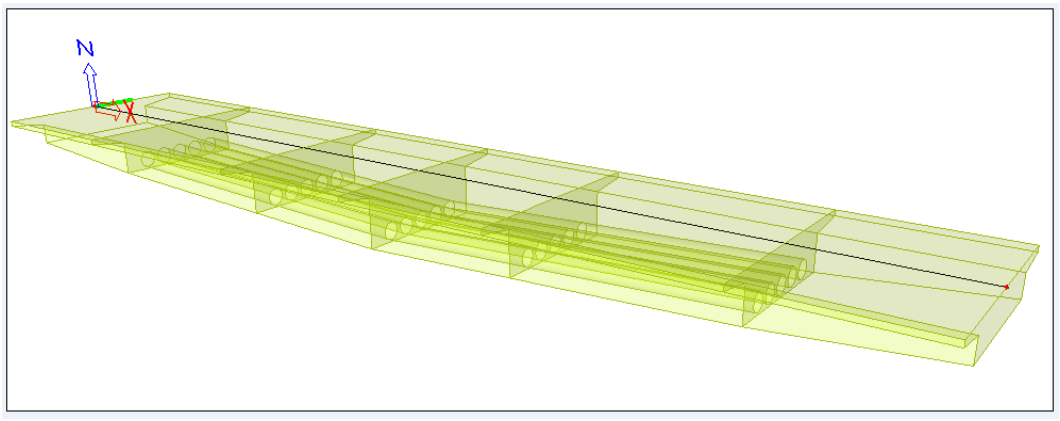
Pict. 7 Cross-section for a post-tensioned single span bridge. (From SCIA•ESA PT)

We assume that the loading of the bridge is independent of the cross-section shape and that the engineer bases the required number of tendons and possible soft steel reinforcement on both the allowable stresses in the concrete and the bending moment capacity. Consequently the design of the reinforcement will easily follow the input parameters set by the user.

The user changes the location of the weight reducing tubes as well as the diameter of the tubes. Immediately complex calculations are run in the background and detailed checks are performed. The new data become available to the user. Automatic picture generation allows a quick *SnapChecking* of the structure; consequently a quick validation of the results is obtained. The user proceeds until he has achieved enough insight in the structural behaviour and an optimal design is achieved within the design criteria.

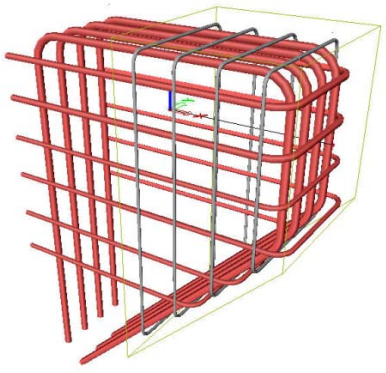


Pict. 8 Optimal economic design based on adapted parameters – part 1

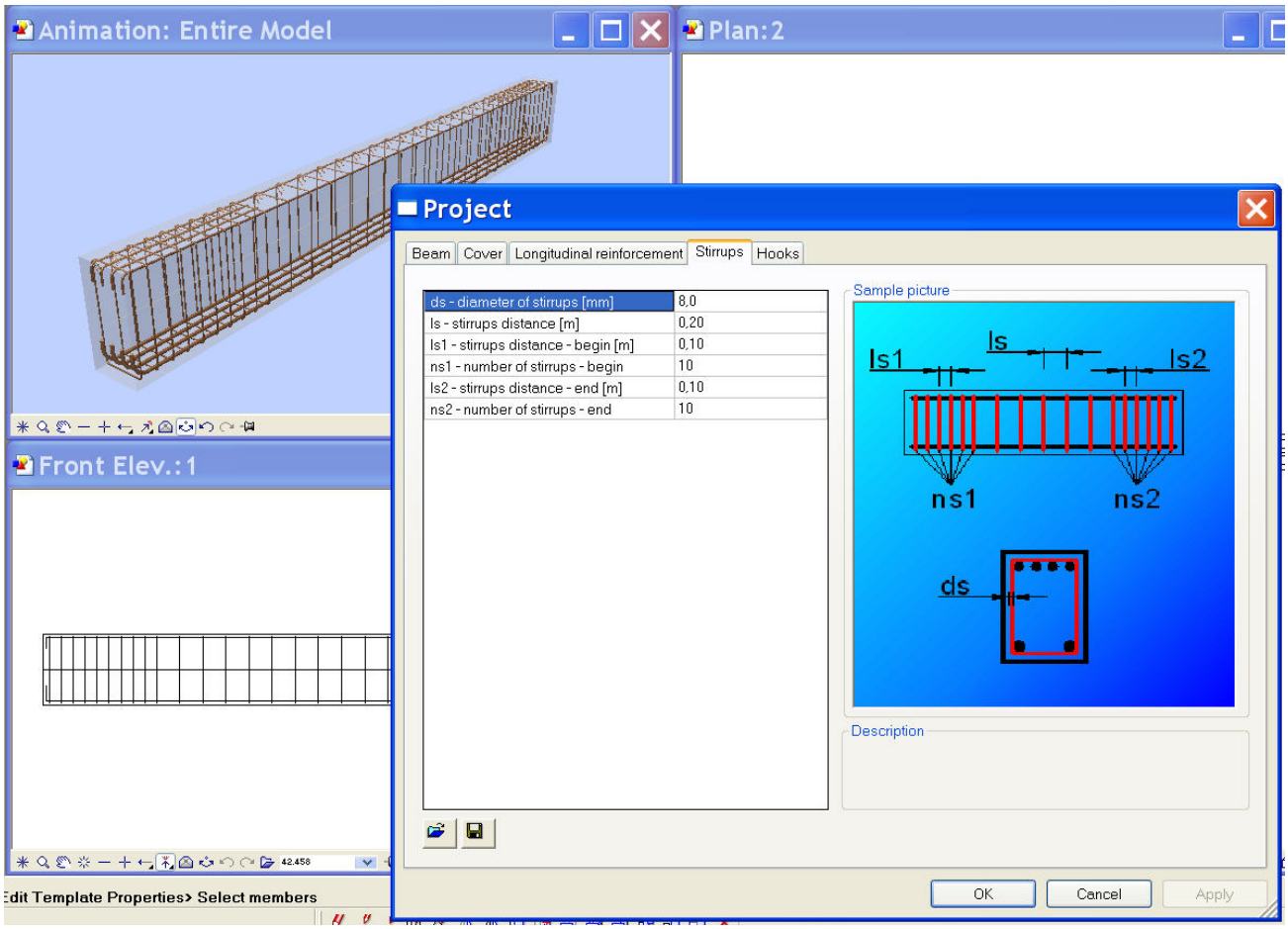


Pict. 8 Optimal economic design based on adapted parameters – part 2

Also in detailing models, as in Allplan of Nemetschek, parametric blocks or templates are used. Parametric reinforcement cages are used to quickly assemble the reinforcement layout of for example complex concrete columns. Then a parametric concrete shape is picked from a library of shapes. The user defines the parameters. After this, the user adds special shapes of reinforcement to the end, beginning and haunch of the columns, see picture 9. The blocks are defined in an intelligent way. If the parameter changes the whole shape of the detailing, the cage is adapted. Moreover, the user is still able to redesign the parametric reinforcement blocks after their installation into the structure, see picture 10.



Pict. 9 Parametric Reinforcement Blocks in Allplan

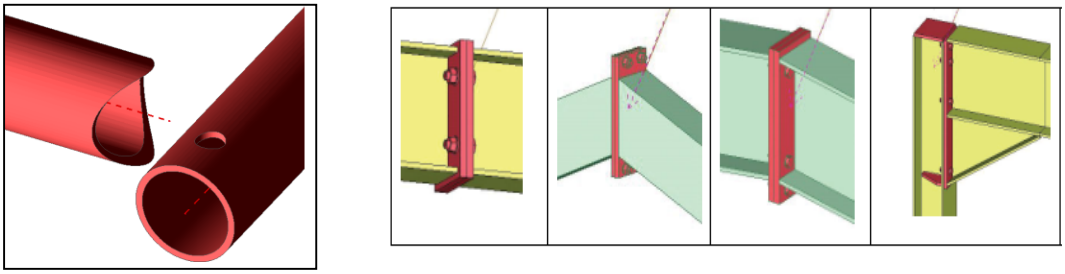


Pict. 10 Modification of Reinforcement Cages in Allplan.

The SCIA 3D Modeller keeps track of changes to the model when synchronizing the design and detailing works. The changes are illustrated directly on the model.

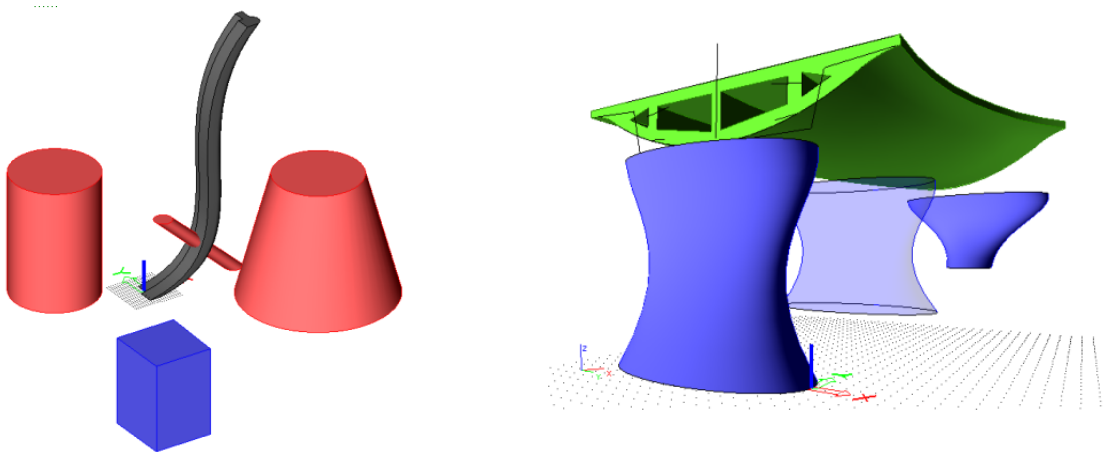
Ongoing developments

The parametric modeller is being enhanced to enable – in a more direct way – the creation of user connections for steel, concrete, mixed structures and other materials (wood, aluminium). Development will enhance the connection intelligence by adding behavioural descriptions and rules to the different parameterized connection parts (e.g. stiffener, bolt) and by adding operations (in general Boolean, in practice cutting, drilling, …), see pict. 11.



Pict. 11 Open connections in structural modelling and design

The availability of the parametric modeller in the general Allplan CAD environment opens a world of new applications in B.I.M.: user definable customisation of automatic construction documentation and drawings. The extension of SCIA 3D Modeller with volumes and freeform surfaces gives total freedom in addressing more complex structures.



Pict. 12 3D volumetric modelling and freeform surfaces

Conclusion

Parametric modelling is the essential tool to improve of the cost-efficiency and to shorten the design-cycles. For engineers working for instance on buildings and bridges it allows quick reuse of existing models and rapid redesign. The engineers that are using parametric modelling assess complex models with even more complex calculations. Parametric blocks are used to build complex models. The measured output of adopting this BIM technology is:

- a much higher efficiency in design and detailing work,
- an improved quality due to less modelling errors,
- a greater flexibility since users “master” the modelling aspects.

The SCIA product is the only engineering information modelling software among all structural software programs because of the implemented innovations on dual structural and analysis design content, parametric modelling and open access to clients.