



## Doing more with less!

**Altair Engineering has had to resort to truly innovative design analysis solutions to handle the complexity of modern signature structures, says David Chadwick**

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That's the problem with innovative designs. The signature buildings that architects love to put up these days might be designed to enhance the architect's reputation along with the skyline of the client city, but their increasing complexities of shape pose significant challenges for the builders.

In the first instance such large projects are never single sourced. They rely on close integration between a number of partners, each addressing significant issues. Secondly, they come with demands for shorter development times with increased pressure to reduce engineering costs (engineering, because of the complexity of the projects, being a major cost element).

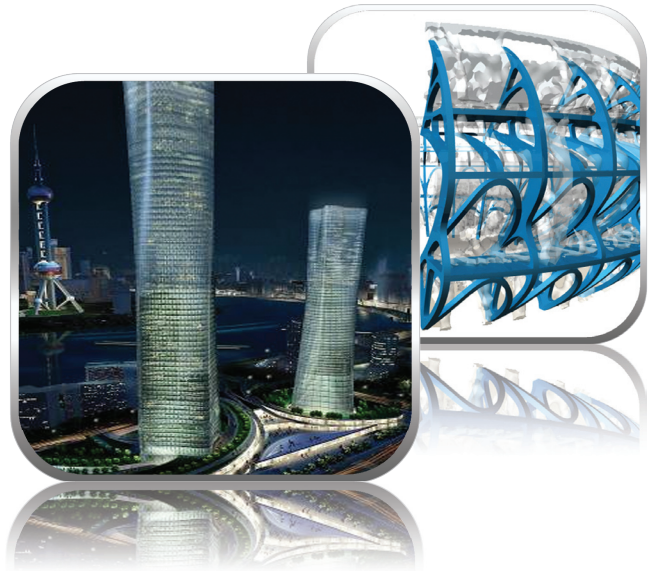
To be able to meet these challenges, engineering software developers have to deliver innovative design solutions. To prove the point, Altair Engineering, one of the leading analytical software companies, has developed software tools that revolutionise the way in which structural elements are placed in a complex structure. They recently demonstrated a couple of these tools in a bracing webinar that stretched my imagination to the limit - even though I had recently returned from the Smart geometry conference!

### Optimisation of Structural Members

Take the first application, for instance. If you design a skyscraper with a couple of twists in it as a design feature, the initial tendency is to over-engineer the supporting steel structure to compensate for the unconventional shape. With the appropriate software, however, you can reduce the member count, and with it, hopefully, the overall weight of the structure and cost of building it.

Standard structural analysis software won't help you here. Instead, you can export the model into a separate software package, OptiStruct, and apply load cases to cater for things like lateral winds and deadweight loads etc., ultimately aiming for a sound structure with a minimum displacement at the top of the building.

A series of custom-developed genetic algorithms can then be run to show up load paths within the evolving structure - load paths where support is required to sustain the non-conventional shape of the building. Non-supporting



Skyscraper image courtesy of Skidmore, Owings & Merrill LLP

elements can then be removed from the structure, and as the structure evolves throughout the iterations, some real world components to the structure, such as lift shafts, can be inserted into the building and tested within the model.

You can even isolate and view specific parts of the structure, to solve complex problems, and additional structural elements can be manually inserted - bracing structures to increase stability at key points, instead of obscuring windows - to pander to the architectural design.

The aim of the whole optimisation process is to find out what supporting structures are required to cope with a structure of a given shape and size. Given a degree of design freedom, the software can also be used to change the shape of a structure based on the constraints applied. Once all the load paths have been located and the model fully optimised, it can be reimported into the CAD software for conversion of the elements into steel members - and available for full structural analysis.

Does it work? Decidedly so, as one particular structure was originally designed with several hundred bracing elements. Using free-form optimisation, that was brought down by a factor of 4 - a colossal saving in weight and material consumption, not to mention a significant reduction in construction time too. It didn't need a supercomputer to handle the optimisation either, as the iterative routines were run, after the genetic algorithms were set up, in a matter of minutes on a standard workstation.

The second application shown was the one I initially found more difficult to grasp. The creation of free-form shapes out of nothing! But before I attempt to explain that, you need to know where all this is coming from.

## Altair HyperWorks

The webinar was presented by Dr Royston Jones, President of Altair ProductDesign. Altair are, of course, the developers of the widely used HyperWorks Suite, the World class CAE design technology which incorporates advanced linear, non-linear analysis and third party CFD tools for all categories of user within the engineering industries.

HyperWorks' product range also includes model builders and visualisation technology such as HyperMesh, which includes preprocessors for a variety of analysis codes and purposes, HyperView for post-processing and visualisation and, of course, OptiStruct, the optimisation software described above.

Altair Engineering has around 1500 employees working at its HyperWorks software division in Michigan, and a further 500 employed in Altair ProductDesign - pioneering the use of the HyperWorks suite.

## Free-form Optimisation with OptiStruct

UK-based Dr Jones elaborated on how their optimisation software works, specifically for material removal and structural weight reduction. The structural steel model of a building can be extracted from the developing software and run through the optimisation programme, covering a number of linear static constraints such as the buckling factor, etc., based on member sizing from standard beam catalogues using universally available beams and columns.



The optimisation is run to reveal which structural elements, or beams, are redundant - showing them floating in space. After they have been removed, the model is then re-imported into the 3D model for a more conventional structural analysis. A typical optimisation run can reduce size and quantities of members, resulting in savings of more than 50%!

But what if you don't have a structural model to start off with? What if you know roughly what sort of free-form shape you want to end up with - to create a canopy over an open space for instance - but find your creative talents constrained by the need to make a strong enough structure to support itself?

Altair's OptiStruct can be used here to define your shape, literally morphing itself from the conditions you have applied to its development. The starting point, as I said earlier, is an empty space - defined by its upper and lower limits. Using genetic algorithms, again, the shape optimises and evolves through a number of iterations in a controlled way, eventually coming up with the final design. As Dr Jones explains it, the process combines the creativity of the architect with the disciplines of the structural engineer.

You can also call the process biomimicry as the optimised Harbour Shelter, designed by Italian company ISDG using the software, began to resemble the spreading branches of a tree as it evolved. Of course, you don't just kick the shape optimisation into motion and let it run - you can insert additional or alternative constraints at any time, to modify the way in which the shape is being created.

As long as you can describe the mathematical or geometric progress of the design you can incorporate it into the guiding constraints - directional symmetry, pattern recognition - or set up minimum mass, maximum strength conditions, providing a lot of freedom in the way that the software enforces the structure, which still remains, however, under control.

After the free-form optimisation process, the completed shape is postprocessed, converting it into a viable structure by transforming iso-density surfaces into geometry, and inserting correctly sized members along the stress lines shown by the optimised model.

## In Practical Use

The combination of human and machine creativity is no pipe dream - it is being used increasingly in building design, thanks to pioneers such as SOM. It can be summed up in one short phrase - constructability optimised. The next steps depend merely on how soon inhouse expertise develops within the leading construction companies, as they see the benefits unfold.

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