Design of facetted hex-dominant polypropylene shell structure

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As an undergrad Andreas trained as a structural engineer with a speciality in Architectural Engineering. In 2011 Andreas graduated from Bath University with an MPhil in Digital Architectonics.
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1. Design

Figure 1: Polypropylene shell pavilion structure

This paper adresses the design of a small scale pavilion for an international exhibition in Amsterdam in July 2015. Eventhough the pavilion is small in scale, the complexity of the geometry required the use of advanced computation and structural engineering.
A parallel design approach was used where structural analysis and geometric optimisation were highly intergrated. The main challenge was the use of a very flexible and thin material. The panels consist of 1,5 mm thick recycled polypropylene sheet material folded into more than 200 distinct boxes. The boxes were parametrically defined from an input surface by a series of mesh operations and planarisation algorithms. The resulting surface mesh was a planar hex-dominant mesh with internal angle constraints to enforce regularity of the panels.
Foldable torsion-free flaps along the hexagonal panel edges were introduced to further strengthen the shell and avoid buckling of the polypropylene sheets. To further avoid lateral buckling of the flaps an inner surface was introduced. This design resulted in a higly complex geometry where all surfaces were kept planar.
In the design process of the shell structure, multiple tools was used ranging from hand sketching, parametric modelling, physical model making, digital analysis, 3D printing and laser cutting of tests elements ending with full scale prototyping.
Different fabrication methods were investigated and the fabrication finally achieved using our in-house lasercutter. By carefully controlling the power and speed settings of the laser is was possible to define smooth, sharp fold lines by cutting half way though the thin sheet material.
The pavilion is an example of a topologically optimized design realized using digital fabrication where parametric tools were used in all phases of the design. This workflow combined with the innovative use of polypropylene sheets for a shell structure shows that interesting freeform pavilions can be made in a light and translucent material.

Figure 2: Close-up picture of pavilion and rivet connection details

It was shown how a complex structure can be realised within a reasonably short time frame and with limited resources, using state of the art digital design tools.
The design process furthermore highlighted the importance of full-scale prototyping in an innovative design process. Computational design methods can help to overcome very complex design problems, however the complexity of the design increase the rate at which errors can occur. Some of these errors are very difficult to detect without the use of physical models and prototypes.