Oasys

YOUR IDEAS BROUGHT TO LIFE

GSA

"THE FUTURE OF US"

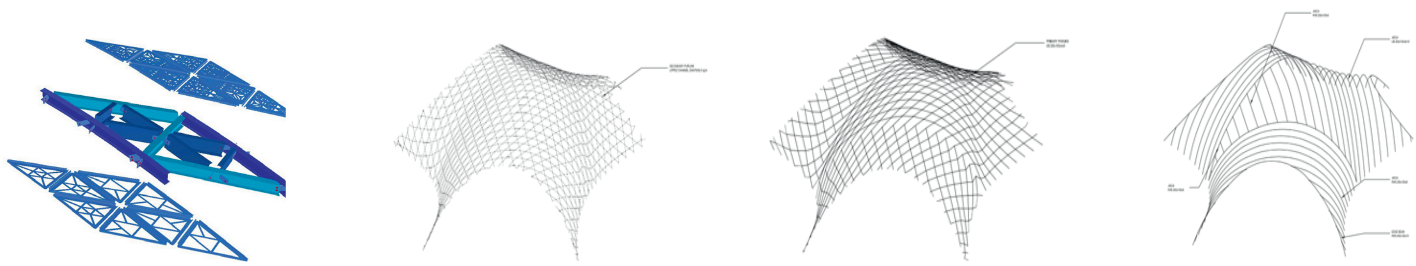
RESOLVING GRIDSHELL BUCKLING RISKS TO BRING THE ARCHITECT'S IDEAS TO LIFE FOR SINGAPORE'S GOLDEN CELEBRATION

Singapore's Future of Us exhibition closed in March 2016 having captured the imagination of the public and inspired more than 400,000 of them to record their hopes, dreams and promises.

Events were spread across four domes linked by a large-span shell structure, a building envelope engineered by Singaporean firm Passage Projects. Their design meant that, as well as the exhibits in the domes, visitors experienced a stunning display of light and shade cast by the gridshell's metal lattice structure. This was exactly what Architects at the Singapore University of Technology and Design Advanced Architecture Laboratory had intended and created the illusion of a walk through an imaginary forest – but its design proved challenging for engineers, with the issues being resolved using Oasys GSA analyses.

Structure overview

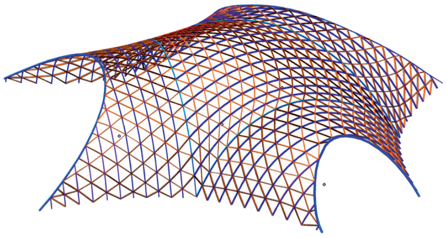
The steel structure, spanning approximately 50m and rising to 16m, supports 11000 perforated aluminium panels. The structure consists of primary arches and a secondary bracing structure. Most of the connections are bolted, allowing for fast construction cycle of just below 5 weeks.

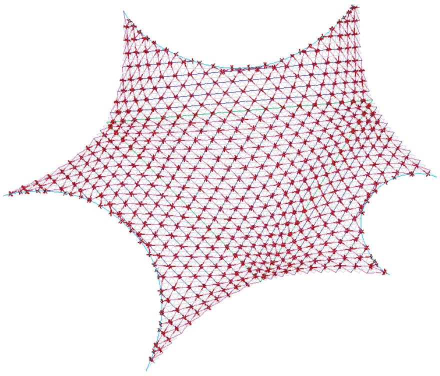


Aluminium panels top and bottom are supported by the steel structure Exploded view of the steel structure

Structural modelling

The global analysis of the steel structure was carried out using Oasys GSA. The structure was first modelled in Rhino and imported into the GSA software seamlessly using the AutoCAD DWG/DSF import tool.

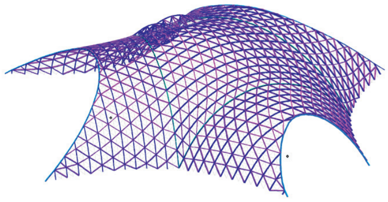


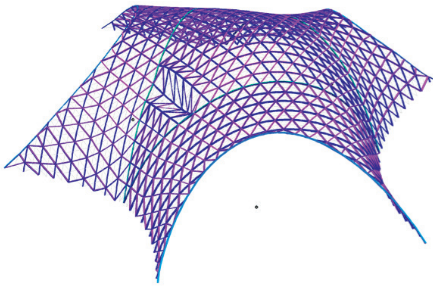


Analysis model in GSA Plan view of the analysis model - All primiary purlins are pinned to the arches

Instabilities investigations

A modal buckling analysis was carried out under ULS loadings. In some locations, arch buckling modes were found to have a buckling factor smaller than 3. The arches at these locations are very flat and are subject to high compression forces. The GSA analysis helped to identify the arches requiring additional stiffness. It was decided to stiffen these flat areas of the gridshell by fixing all the primary purlins to the affected arches. This increased the buckling factor from 3 to 8.

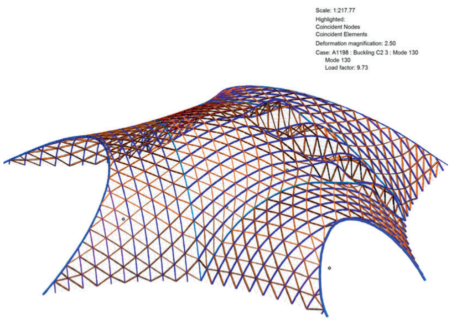


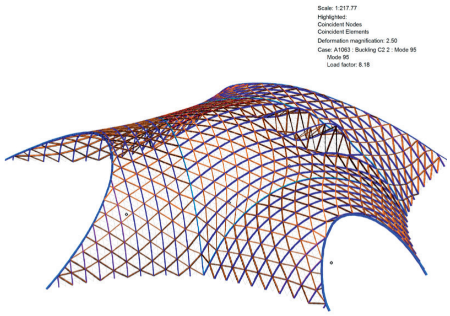


Buckling of flat arches with a buckling factor smaller than 3

Instabilities and Geometrical imperfections

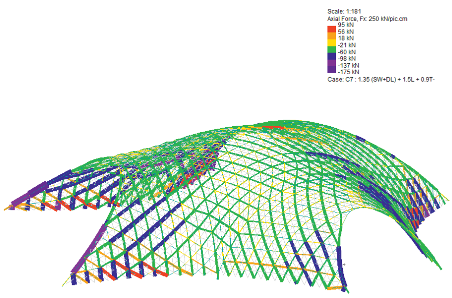
However three global buckling modes remained with a buckling factor lower than 10. To resolve these issues, a geometrically non-linear elastic analysis was done. Global imperfections were included in the model and local imperfections taken into account through members checks.

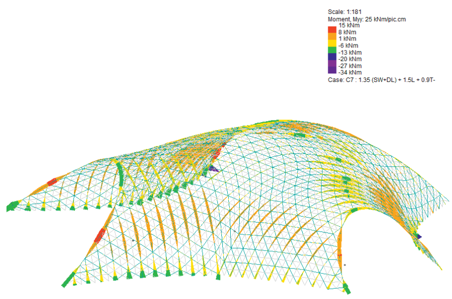




Buckling mode – buckling of arches

Engineers were able easily to include these global imperfections in their calculations because GSA has built-in tools to create a new model from deformed geometry. This used the deformed shape of the first global buckling mode, with the maximum amplitude of the global imperfection limited to 30mm. A non-linear analysis was then carried out on this new model and the results used to check the structural members.





Axial force - ULS Moment - ULS

Conclusion

An ArchDaily review praised the way the resulting building works with “daylight factors and prevailing winds to provide a structural building skin that generates shading and visual effects reminiscent of a tropical forest.” It went on to say that “The project reinvents the experience of a tropical space by providing a comfortable, unique, multi-sensorial and climatically appropriate experience to be enjoyed by everyone.”