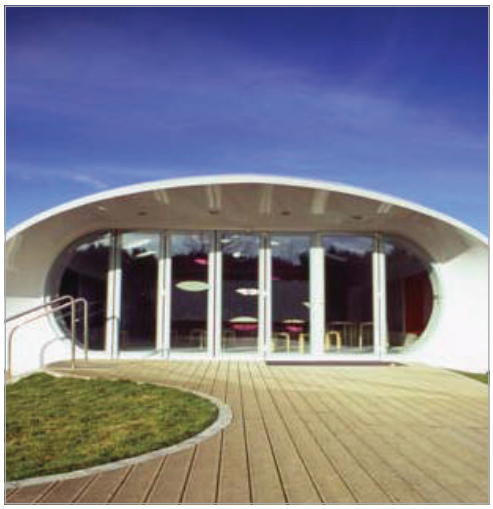
Using Optimization to Improve the Design of a Reproducible Classroom Environment



Key Highlights

Industry
Architecture

Challenge
Structural form finding for a shell-like under standard load actions

Altair Solution
Design optimization methods used to suggest the ideal layout of the structure's roof reinforcements

Benefits
- Identified areas of high stress
- Reinforcement areas accommodate electrical and mechanical systems
- Structure's stiffness increased

The qualities of the environment in which we learn – in particular light, space and sound – make a real difference to how quickly we learn and how much we enjoy the learning experience. That is the view of architecture firm, Future Systems, who led the development of the 'Classroom of the Future'.

The aim was to make the classrooms high quality, beautiful and inspirational spaces where children and adults will want to learn. The classrooms were designed to challenge the traditional roles of teacher and learner, and to encourage creativity.

The spaces allow pupils to use the widest possible range of new technologies creatively and cooperatively. As far as possible, the infrastructure is 'future-proofed', and will allow teachers and pupils to bring any communication device into class and connect it to the building's systems.

The students are able to display their work all around the classroom and there is a real connection between inside and outside. The partly-covered terrace can be used for performance, individual or group study, and wireless technology enables all the ICT to be accessed on the terrace, as well as inside.

The classrooms would be prefabricated in glass reinforced plastic (GRP) to a high standard, and are energy efficient, durable and eminently replicable.

Keywords: Architecture, optimization

Success Story

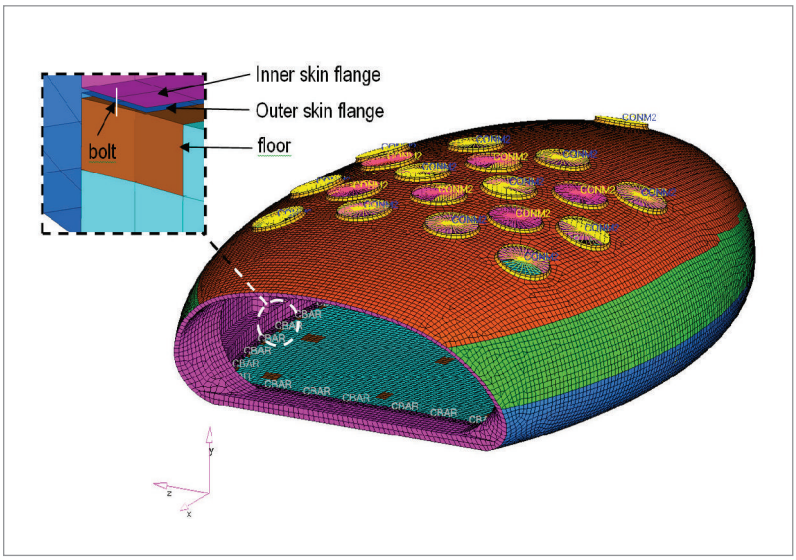
"Using analysis data, the Altair ProductDesign team were able to suggest where the best locations for the mechanical and electrical systems as well as the roof ducts would be, aligning then with the with topology result to maximize the stiffness of the overall structure."

The design includes a service area for toilets, coats, storage, etc and a large curved teaching space lit by ventilating windows in the roof, with a wall of glass opening onto a terrace. The environmental control strategy of the building makes full use of natural ventilation and day-lighting.

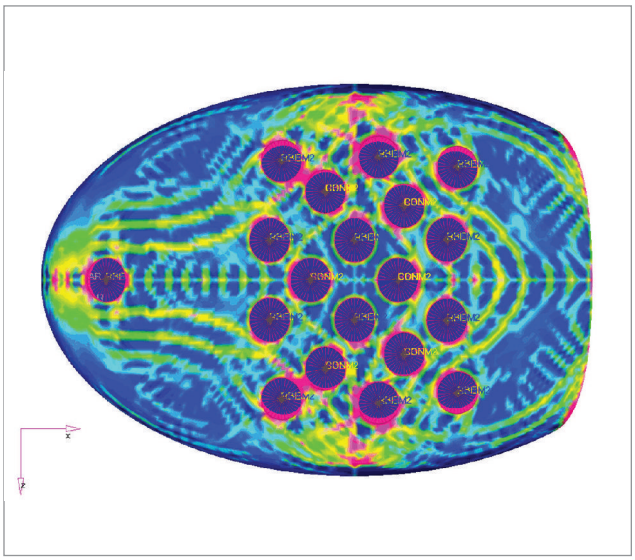
The ellipsoidal envelope keeps the level of embodied energy low and minimizes surface area and therefore heat loss.

Optimizing the Classroom Structure

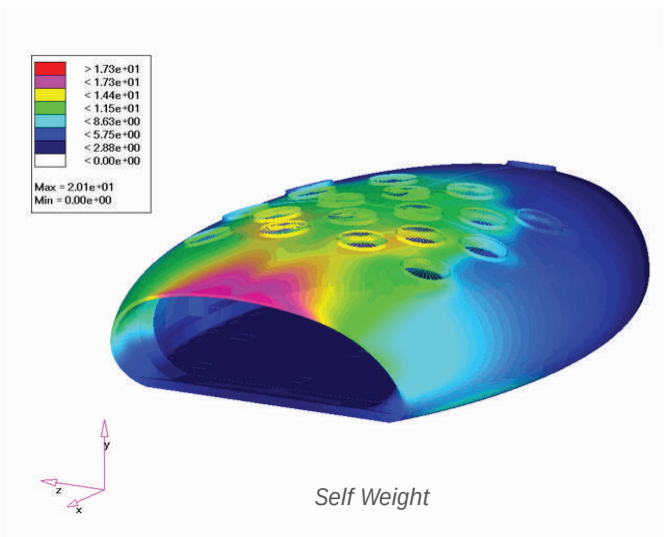
Topology optimization is the process of using finite element analysis to determine the optimum material layout for a given design space which takes into any number of design constraints. The technology had been used extensively in the aerospace and automotive markets to minimize the material used in structural components. Future Systems and its structural engineering partner, Creactive Design, wanted to explore the possibility of utilizing topology optimization technologies

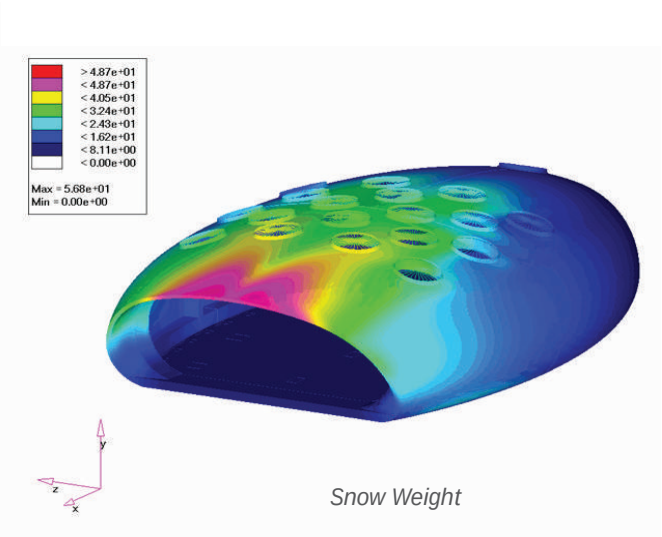


Finite Element Model of the World Classroom



Load Paths On Outer Skin Indicating Optimum Layout for Ducting





Displacement Contours Under Applied Loads

to improve the design of the innovative, cross-functional roof of the World Classroom.

Creactive approached Altair and its product development division, Altair ProductDesign, to assist in this explorative project due to Altair's reputation for developing the market leading optimization software solution, OptiStruct, part of the HyperWorks suite of simulation technologies.

Altair ProductDesign was tasked with determining where reinforcement would be needed in the roof of the classroom and which reinforcements could also double up as mechanical and electrical systems routing. The reinforcements needed to provide maximum stiffness to the overall structure while avoiding the use of excessive material.

"Using topology optimization during the design process gave the team valuable insight into the behaviour of the structure and increase confidence that the final design would operate as intended once built."

To achieve this goal, Altair ProductDesign defined critical load cases comprising dead and live loads including the weight of the roof itself along with extra loads from wind, snow and potential impact and abuse. The team used the HyperWorks suite to develop a finite element (FE) model of the classroom structure and applied the critical load cases that had been identified.

Maximizing Roof Stiffness

The analysis process identified which areas of the classroom structure were under the most stress during the self-weight, snow, wind and abuse loading conditions, and suggested that the first set of bolts which hold the structure together around the curved outer rim would carry the bulk of the resulting forces. In addition, the use of OptiStruct gave insight into where the stiffeners in the roof structure would be required to meet the performance goals.

Using this analysis data, the Altair ProductDesign team were able to suggest where the best locations for the mechanical and electrical systems as well as the roof ducts would be, aligning then with the with topology result to maximize the stiffness of the overall structure.

Using topology optimization during the design process gave the team valuable insight into the behaviour of the structure and increase confidence that the final design would operate as intended once built.

Since this project took place, the World Classroom has been installed at London's Richmond - Meadlands Primary School, Grey Court Secondary School and Strathmore Special Needs School in the UK.

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About Altair ProductDesign

Altair ProductDesign is a global, multi-disciplinary product development consultancy of more than 700 designers, engineers, scientists, and creative thinkers. As a wholly owned subsidiary of Altair Engineering Inc., this organization is best known for its market leadership in combining its engineering expertise with computer aided engineering (CAE) technology to deliver innovation and automate processes. Altair ProductDesign firmly advocates a user-centered, team-based design approach, and utilizes proprietary simulation and optimization technologies (such as Altair HyperWorks) to help clients bring innovative, profitable products to market on a tighter, more efficient time-scale.

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