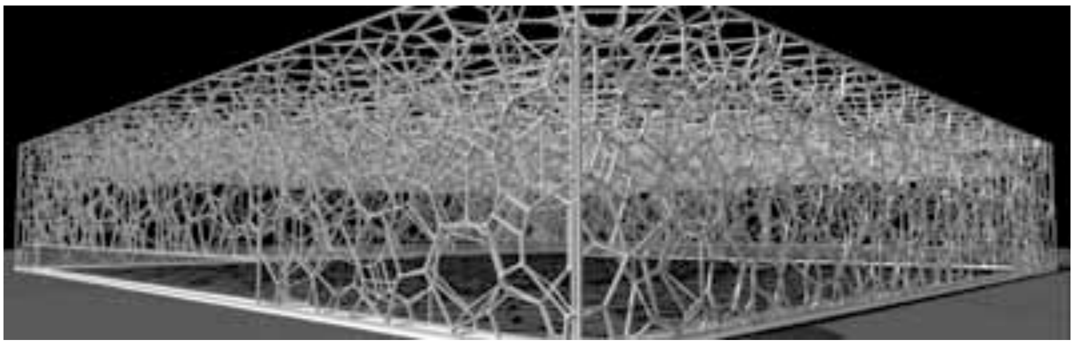
Water Cube: The Structure

A New Beginning in Design Thinking

The National Aquatics Centre in Beijing marks a new beginning in design thinking. This new thinking has been spurned on by one question: “How does structure fill space?”

A close up of the Water Cube's innovative steel structure



3D isometric view of the structural model

The structure of the Water Cube is based on the most effective sub-division of three-dimensional space - the fundamental arrangement of organic cells and the natural formation of soap bubbles. It will be clad in ETFE foil cushions, which have excellent insulation properties and will create a greenhouse effect.

Arup based the structural design on Weaire and Phelan’s (Irish Professors of Physics at Trinity College) proposed solution to the problem of “What shape would soap bubbles in a continuous array of soap bubbles be?” This problem was both initially posed and tentatively answered by Lord Kelvin at the end of the 18th century but it was 100 years before the Irish Professors proposed a better one.

How the Structure Developed – Key Considerations

- The wall cavity is 3.6m deep and the cavity forming the roof is 7.2m deep
- The structure is made of approximately 6500 tonnes of steel
- There are 22,000 steel members and 12,000 nodes
- The steel beams would stretch for 90kms
- The structure of the building is so strong that it can be stood up on its end and retains its shape
- The overall size will be 177x177x31m

An ambitious project, one of the first problems was designing a 22 000 beam structure for 190 loading conditions, where every single beam needed to be as small as possible to minimise steel tonnage. The need to minimize steel tonnage is because in long span roof structures, self-weight is critical.

The roof spends a lot of its strength simply holding itself up.

Another challenge was the need to fulfill all of the seismic design requirements of Beijing. The key question is whether to design the roof with compact sections to behave plastically under seismic loads, or whether to use stiffened slender sections to behave elastically under the loads.

To determine which system to use, a world first analysis in inelastic cross-section buckling was undertaken using key techniques developed by Arup. The final tender solution adopted compact sections, which allowed plastic ductility to be taken advantage of under level three seismic loading.