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SCIENCE IN CULTURE

Beijing bubbles

The Olympic Aquatic Centre will be housed in a giant block of foam.

Philip Ball

For architects in Beijing, anything is now possible. In the past two decades the city has been redesigned beyond recognition, and with the impending Olympic Games in 2008, no architectural innovation seems too grand or ambitious that China's energetic labour force cannot rise to the challenge. A swimming pool housed within a block of giant foam, then, is a breeze.

In the Water Cube — the Olympic Aquatic Centre designed by the Australian architectural company PTW in conjunction with the China State Construction and Engineering Company and design consultants Arup — an intricate network of steel struts forms a framework for transparent plastic panels that interlock into a mesh of bubble-like polyhedra (pictured), sliced into slabs 3.6 metres thick in the walls and 7.2 metres in the ceiling. There are 22,000 of these struts in the entire structure; laid end to end they would stretch for 90 kilometres.

The result, now largely built and scheduled for completion in October, may look flimsy, but the interlaced foam geometry offers surprising resilience: Arup claims that the low, flat-roofed enclosure could be stood on its end without deforming.

This lightweight, translucent shell provides heat insulation, acting as a kind of ornate greenhouse. According to the designers, a fifth of the incident solar energy will be trapped to heat the interior and the pools themselves. During the day, enough sunlight penetrates the roof to cut lighting costs by more than half, relative to conventional pool halls. And the aim is to capture and recycle 80% of the water falling on the roof or lost from the pools. The Water Cube thus embodies a spirit of water conservation that is becoming increasingly pertinent to northern China, where water scarcity is approaching a crisis that has prompted an awesomely ambitious and costly project to reroute water from the Yangtze River for more than 1,000 kilometres.

The bubbles of the roof and walls make up no ordinary foam. To the casual glance the network looks rather random and disorderly. But there is deep symmetry to it, for its 'unit cell' — the fundamental repeating element — consists of eight polyhedral cells. Six have 14 faces, the other two have 12, and these are comprised of regular hexagons and irregular pentagons with differing side lengths and angles. This might seem a strange choice — it is much more labour-intensive to create than one of the several networks that can be made from single, symmetrical cell shapes. The structure is, however, ostensibly that for which the total surface area of 'bubble' wall is the smallest known.

This structure was discovered in 1993 by physicists Denis Weaire and Robert Phelan at Trinity College in Dublin. Surprisingly, their complicated aggregate of cells fills space with slightly less total surface area than the unit cell long assumed to be optimal, a 14-sided polyhedron described by Lord Kelvin in 1887. This, in turn, trumped earlier candidates for an 'ideal' minimal foam cell, such as the rhombic dodecahedron and the truncated octahedron. There is still no formal mathematical proof, however, that Weaire and Phelan's solution cannot itself be bettered.

As triumphs of economy go, this one is rather Pyrrhic: the saving in surface area over Kelvin's foam is at best a mere 0.3%, which is scant recompense for the increased complexity of fabrication and assembly. In fact, the problem is made worse by the fact that the Water Cube design involves rotating the Weaire and Phelan foam and then taking a cut through it, creating 100 or so different 'part bubbles'.

Perhaps the real gain is aesthetic, the subtle blend of order and irregularity providing a tantalizing stimulus for the eye — which, as the designers point out, will be best enjoyed by competitors in the backstroke events. PTW architect Chris Bosse says that the designers liked the 'organic quality' of the Weaire and Phelan foam compared with the crystalline sterility of Kelvin's.

So although the polyhedral construction principle aligns the Water Cube with the faceted domes of Richard Buckminster Fuller, the notion of using an area-minimizing surface prompts comparison with the architecture of Frei Otto, whose tent-like canopies were designed by looking at the shapes of soap films draped over wire frames. It is fitting, then, that Otto's designs too were used for an Olympic swimming stadium, that in Munich in 1972.

The foam principle also makes the Water Cube part of the tradition of biomimetic architecture, evoking the bee's honeycomb (whose double layer of interlocking cells has also posed a long-standing problem in surface minimization) and the spittle bug's use of a foam to protect its larvae from predators. ■

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