from Singapore or Korea. No more booming announcements echoing around the stadium. The seat may also contain a microphone – scanning for terms of racial abuse – to direct Stewards to areas in the crowd of developing unrest.

Inventors in the US have developed directional sound which uses an ultrasonic emitter to shoot a laser-like beam of audible sound so focused that only people within a narrow path can hear it. Imagine telling the Umpire, Judge or Referee exactly what you thought of their decision directly and immediately! Or, perhaps talking about the 100 metres result in real-time with your friends who are at the opposite end of the stadium.

Bone conducting technology being developed by Kyocera uses bone in the face to transmit sound to the ear – allowing you to listen to your phone commentary in the noisiest crowd.

Imagine the future uses of augmented reality. Point your phone (or tablet) to an athlete on the track and read through the results of his past performance, personal best times and likely chances of winning. The latest smart-phones can be unlocked using facial recognition.

Chevrolet rolled out the first Super Bowl smartphone app in 2012 that allows Big Game American Football watchers to enter a contest to win everything from pizza to a new Camaro. Coca Cola set up a Facebook page and website so viewers could see its animated polar bears – one cheering for the New England Patriots and the other for the New York Giants – reacting to the game in real time.

The day's sporting programme would not be printed in hard copy – unless as a souvenir. Rather the programme timings – which may involve various sporting activities in the same stadium – would be updated in real-time allowing the spectators to move position to watch their selected events. Imagine the historical record – with millions of crowd photographs uploaded to the Internet.

No longer are the crowds and spectators merely passive. Perhaps the crowd itself could be consulted to judge the most sporting athlete – the man of the match or game rather than just the first past the post.

Here is one I would love to see in reality. The large display screen shows replays of the sporting events. It then shows a worthy cause – for example, anti-malaria mosquito nets – and a large graph showing a target for charitable donations during the course of the sporting event – on the day or during the whole of the Games – from the crowd and the watching world TV audience. The crowd is encouraged – let's hit that target before the game ends. We watch in the background as the display grows towards a worthy target. In 2016, the target could be 100 million nets!

For a greater experience, for a truly memorable life-enhancing occasion – for the crowd itself – we need novel technology and innovation.

Let the Games begin! And let us all truly participate!

# GEARING UP

This feature first appeared in the January 2011 issue of the IOM3 publication, *Materials World*

One of the most eye catching and technically challenging arenas built for the London 2012 Olympics is the cycling velodrome, **Ruth Hopgood-Oates**, Senior Engineer at Expedition Engineering, outlines the construction process.

Cycling has inspired the concept for the 2012 London Velodrome. The bike is an ergonomic object, honed for efficiency, and the team behind the Velodrome wanted the same application of design creativity and engineering rigour that goes into the design and manufacture of the bike to be present in the building. Not as a mimicry of the bicycle but as a 3D response to the functional requirements of the stadium. By applying the same thought processes and form finding approach, the aesthetics and shape of the stadium have emerged. Tight budget constraints with stringent Olympic Delivery Authority (ODA) targets were set out in the Olympic Park materials strategy. The aim is to reduce waste through design – 90% of demolition material and site waste has to be reused or recycled, and at least 20% of this reused in permanent venues and associated works. The Velodrome is beating these targets with 95% of waste being recycled and 33% of materials made with recycled or partly recycled content. The team's design strategy has focused on creating efficient elements that perform several functions.

## RAISING THE ROOF

A doubly curved roof shape evolved as the form that would best meet the stadium's needs. The saddle-shaped roof form 'shrink wraps' the building around the track, minimising the venue's volume and reducing heating and cooling requirements. Following cross-checks against traditional schemes using arches and trusses, a cable net was found to be suitable for the form and 140m span, while providing programme and construction safety advantages.

Typical cable nets support lightweight fabric and work like a tennis racquet using a grid of cables in tension with a large compression ring at the perimeter to isolate the net's tension forces. The Velodrome cable net, however, is not typical. The indoor venue needed a weather-tight, heavily insulated roof build up, and the graceful lines of the building form, combined with the desire to reduce steel usage, necessitated a roof design without a large perimeter ring beam. This presented the biggest structural engineering hurdle on the project. The first challenge involved designing structural timber panels that infill the gaps between the cables and form the roof surface. These panels had to adapt to the movement and tolerance required for the cable net roof, whose movements are significantly larger and more complex than a standard long span roof structure. In response, clever, rational panels with an articulated connection system were developed. The second test involved transferring out high cable tension forces while avoiding a large ring beam structure. In response, the building's steel upper seating bowl and entire structure below were designed to be used to transfer out cable forces, meaning only a small ring beam structure was required. As a result of this design, the team made a large materials saving compared with traditional roof systems. The roof weight including cables, ring beam and finishes, is only 30kg/m2. The delicate cable net roof employs pairs of 36mm diameter cables arranged in a 3.6m grid spacing, with the prefabricated structural timber panels, known as cassettes, filling the gaps. The 1,050 cassettes are interspersed by rows of roof lights to provide natural light. A vapour barrier, followed by insulation, overlay the hollow cassettes with a final layer of standing seam metal cladding containing 95% recyclable aluminium. A further benefit of the standing seam is channelling rain falling on the 1.4Ha roof, delivering it to specially modelled hoppers and gutters in a manageable way. Much of the rainwater is then collected for greywater use.

## AGAINST THE CLOCK

To keep to the two-year construction programme, all elements were designed with constructability in mind. Sheet pile walls, which were initially proposed as temporary works in the basement, became permanent structures. Approximately 600 of the 1,000 piles were precast, used instead of open-bored piles in lightly loaded areas to improve installation speed and eliminate the need to dispose of contaminated spoil. Sensible sequencing was used in the placing of concrete, to allow early age thermal movement to occur and enabling the next phases of construction to begin at one end of the building, while concrete works were completed at the other.

Above the concrete floor slabs, the use of prefabricated structural elements improved speed, minimised requirements for working at height, cut down on waste and improved quality. The roof design enabled early weather tightness, enabling internal dry works to commence. The 16km of cables used for this project were cut to length and fabricated in Germany. Once on site, the cables were laid out at ground level and the 1,000 or so nodes at cable crossover points clamped to form the net. The net was then jacked into place on top of the steel upper seating bowl in a carefully designed sequence, before being locked into position. This sequence eliminated the need for temporary works. The entire on-site cable net construction process took eight weeks. With the cable net in place, the prefabricated timber roof panels were craned into place and the remainder of the roof added.

## THE FINISHING LINE

Efficiency in all aspects of design together with the careful selection of materials led to low levels of embodied carbon in the building. It is estimated that the total embodied $CO_2$ for structural elements, including concrete, steel and roof timber, is approximately 7,400t. This is less than 1,250kg per spectator seat, which Expedition believes sets a new benchmark for best practice. The venue is naturally ventilated with humidity and temperature being carefully maintained to create exactly the right conditions for track cycling.