

CONCRETE QUARTERLY

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JUST ADD WATER

Zaha Hadid's aquatics centre scores a perfect 10 for use of concrete – from its tricky foundations to its six majestic diving boards

SUPER BOWL

How the Olympic stadium designers used 12,000 tonnes of concrete to create 80,000 of the best seats on Earth

HOMES OF HEROES

The concrete-clad housing at the athletes' village is set to begin its new life as London's most sustainable neighbourhood



A GREAT EXHIBITION



The Olympics is not only a fantastic event, but a great showcase for the UK construction industry.

The project teams and material suppliers may need to stay anonymous for a little longer, but the achievements are no less impressive.

Concrete is the second most consumed material in the world, so its use on the site would be expected, but the variety of mixes and applications and its beauty and sustainability credentials have really come to the fore on this amazing project.

The responsible sourcing standard BES 6001 was developed for the Olympics and now over 90% of concrete produced in the UK is certified to this level (see right). The use of recycled and secondary aggregates and cement replacements such as fly ash are also more commonplace following their use on the Games venues.

Concrete has provided strength in the Olympic park's tunnels and foundations, an exposed tactile surface for paving and interiors, and terracing and structures for venues, as well as the concrete framed and clad athletes' village.

We hope that the golden glow from the sporting success will soon be reflected on the contribution of the concrete and construction industries.

[Guy Thompson](#)

Head of architecture and housing
MPA The Concrete Centre

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The Concrete Centre is part of the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, lime, mortar and silica sand industries.
www.mineralproducts.org

92% of UK concrete meets Olympic gold standard

Over 90% of the concrete produced in the UK meets a stringent responsible sourcing standard developed for the 2012 Olympic Games, according to data due to be published in October.

The concrete industry's 2011 performance data will show that 92% of concrete produced in the UK meets BRE Environmental and Sustainability Standard (BES) 6001, which was implemented by the Olympic Delivery Authority (ODA) to ensure that the construction projects for the London 2012 Games used only responsibly sourced materials.

BES 6001 was devised in response to a 100-page bespoke policy document produced by the ODA setting out a range of environmental and social sustainability criteria for suppliers. These included water usage, waste and recycled content, as well as employment, welfare and health and safety.

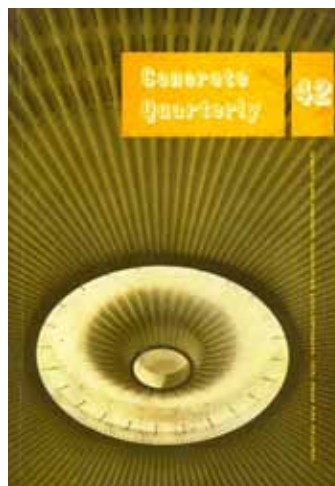
Under BES 6001, products are rated "pass", "good", "very good", or "excellent", depending on how many points they accumulate under the system. In general, the more transparency a company can demonstrate, the more highly it will score.

Concrete is a local material, ensuring traceable and highly regulated supply chains. Additional points are awarded if a management system meets an international standard, if it is externally certified, if there are improvement targets in place, if these are in the public domain, and if the process is externally verified.

Further points can be awarded depending on whether 60%, 75% or 90% of a product's constituent materials meet the criteria concerned.

For more information, go to www.sustainableconcrete.org

ARCHIVE



RETRO CONCRETE: AUTUMN 1959

Nervi's Games ... More than half a century ago, the legendary Italian engineer Pier Luigi Nervi was laying down the marker for Hadid, Hopkins and co by creating some of his most celebrated and lasting buildings for the 1960 Rome Olympics. CQ reckoned the Palazzo dello Sport, a basketball arena with a "huge spreading flower" of a ribbed concrete dome (above left), was "perhaps Nervi's greatest building to date". It was similarly approving of the Flaminio Stadium (above right), which hosted the football: "The finish of the whole structure is superb ... and depends largely upon the fine quality of the natural concrete."



Photo: tristanpoyser.com

David Chipperfield's Hepworth Wakefield is one of five shortlisted buildings to feature concrete

Concrete dominates Stirling list

The shortlist for this year's RIBA Stirling prize, announced in July, has again proved to be a celebration of the aesthetics, performance and, not least, the versatility of concrete.

The material plays an important role in five out of the six buildings, on a list that spans a broad range of building types, from a theatre to a laboratory, a corporate tower to an art gallery, and a cancer centre to an Olympic stadium. The nominees are:

- The Hepworth Wakefield art gallery in Yorkshire, by David Chipperfield Architects
- The Lyric theatre in Belfast, by O'Donnell + Tuomey
- Maggie's cancer care centre in

Gartnavel, Glasgow, by OMA

- New Court bank headquarters in central London, by OMA with Allies and Morrison

- The Sainsbury laboratory in Cambridge, by Stanton Williams

- The Olympic stadium in east London, by Populous.

The winner will be announced at a ceremony in Manchester on 13 October.

For more on the Olympic stadium, go to pages 10-11, and take a closer look at the Sainsbury Laboratory on page 12. You can read last autumn's cover feature on the Hepworth Wakefield gallery in the archive at www.concretecentre.com/cq

More Olympics highlights ...

As this special issue shows, concrete has played a leading role in many of the main buildings around the Olympic park. But it has also been a key material in many of the less celebrated venues and structures, both in and outside the park.

These buildings have been instrumental in the success of the London Games, and will continue to be important in ensuring a lasting legacy. Some notable examples include:

- The frame of the media and press centre, which consists of more than 30,000 tonnes of concrete.
- The Make Architects-designed

handball arena, where the foundations are formed by 200 concrete columns drilled 25m into the ground, with 55 pile caps and 550m of concrete ground beams.

The structure features 30 10m-high precast concrete walls and more than 1,000 precast concrete planks used for the concourse, upper concourse and upper tier.

- The 300m Olympic course and 160m intermediate courses at the white water rafting centre in Broxbourne, Hertfordshire, formed from 5,350m³ of concrete.



Photo: Will Pryce

Make Architects' Old Road Campus building in Oxford features two scissor staircases

THE ART OF CASTING

The design aesthetic and texture of concrete casting will be examined at a forthcoming Concrete Elegance evening lecture to be held at The Building Centre, Store Street, London, on 26 September 2012.

Graham Haworth of Haworth Tompkins architects will discuss the second phase of the new Dyson Building at the Royal College of Art's campus in Battersea, London. Conceived as a "creative factory" with a mix of teaching facilities, workshops, gallery and lecture spaces, the use of cast exposed concrete blends the institutional with the commercial. A particular feature is the concrete main staircase, which was cast in situ.

Justin Nicholls from Make Architects will present the Old Road Campus research building in Oxford, which brings together six different cancer research institutions. Linked ribbons of concrete balustrades, low-level walls and two feature scissor staircases emphasise the fluidity of the internal spatial configuration, designed to maintain the unity of the organisation and prevent the formation of departmental territories.

For further information visit www.concretecentre.com/events

OTHER EVENTS

CONCRETE INNOVATIONS

24 October, 6-8.15pm
Theme: Formwork and fine finishes
The Building Centre, London

CONCRETE ELEGANCE

21 November, 6.30-8pm
Theme: To be confirmed
The Building Centre, London

GET A CLOSER LOOK

For project videos, case studies and plenty more design inspiration, go to www.building.co.uk/concrete-quarterly

Over the shoulders of Sue Barker and Gary Lineker, a number of intriguing structures competed for our attention this Olympic summer. There was the tangled height of the Orbit tower; the cupcake of the Olympic stadium. But perhaps most eye-catching of all was the incredible Zaha Hadid-designed aquatics centre. With its swirling roof flanked by enormous stands of temporary seating, it looked like a vast stingray gliding among the teeming thousands of visitors to the Olympic park.

It remains one of the architectural stars of the show, and is also an impressive demonstration of the sheer versatility of concrete, and its ability to perform across a surprisingly wide variety of applications. Beneath the centre, for example, are immensely strong reinforced concrete transfer structures that carry the weight of the building across deeply submerged power lines. Above ground, the giant, swirling, exposed concrete walls perfectly complement the astonishing curves of roof. And, right at the centre of the action, the graceful lines of the diving boards – as smooth as a Tom Daley plunge – show off concrete's capacity to create sculptural shapes to the finest of tolerances.

The grace of the finished product belies little of the monumental task that faced contractor Balfour Beatty back in 2008. To make way for the aquatics centre, 11 industrial buildings had been demolished, four prehistoric skeletons removed and 160,000 tonnes of polluted soil dug out. Providing a stable base for the building was never going to be easy but, as project director Stuart Fraser explains, it was the buried power lines that posed the trickiest problem. "Obviously we had to avoid any loading on the power tunnels," he says. "The solution involved an extensive system of piles, pile caps and transfer structures to support the weight of the building."

This involved sinking some 1,800 continuous flight auger piles around the site and "bridging" over the tunnels with the two transfer structures – effectively enormous reinforced slabs 3m thick. The volume of the larger one was 1,832m³.

Piling started in August 2008, and in April 2009 the transfer structures were created during the largest concrete pours undertaken anywhere on the Olympic park. These provided a secure base for the building's north-east and north-west cores, each of which would act as a support for the centre's famous steel and timber roof.

"The roof is supported at only three points – from the two cores and a supporting wall at the southern end," says Fraser. "No transfer structure was needed for this, because, to the south, the power tunnels diverge, leaving enough room in between for the piling and pile caps to support the wall directly. The north-west core is an oval shape containing lift shafts and staircases, and so it had to be high quality in appearance. This was our first opportunity to get the kind of finish we were looking for from the concrete."

This was not as straightforward as it might seem,

PROJECT TEAM

Architect Zaha Hadid Architects

Contractor Balfour Beatty

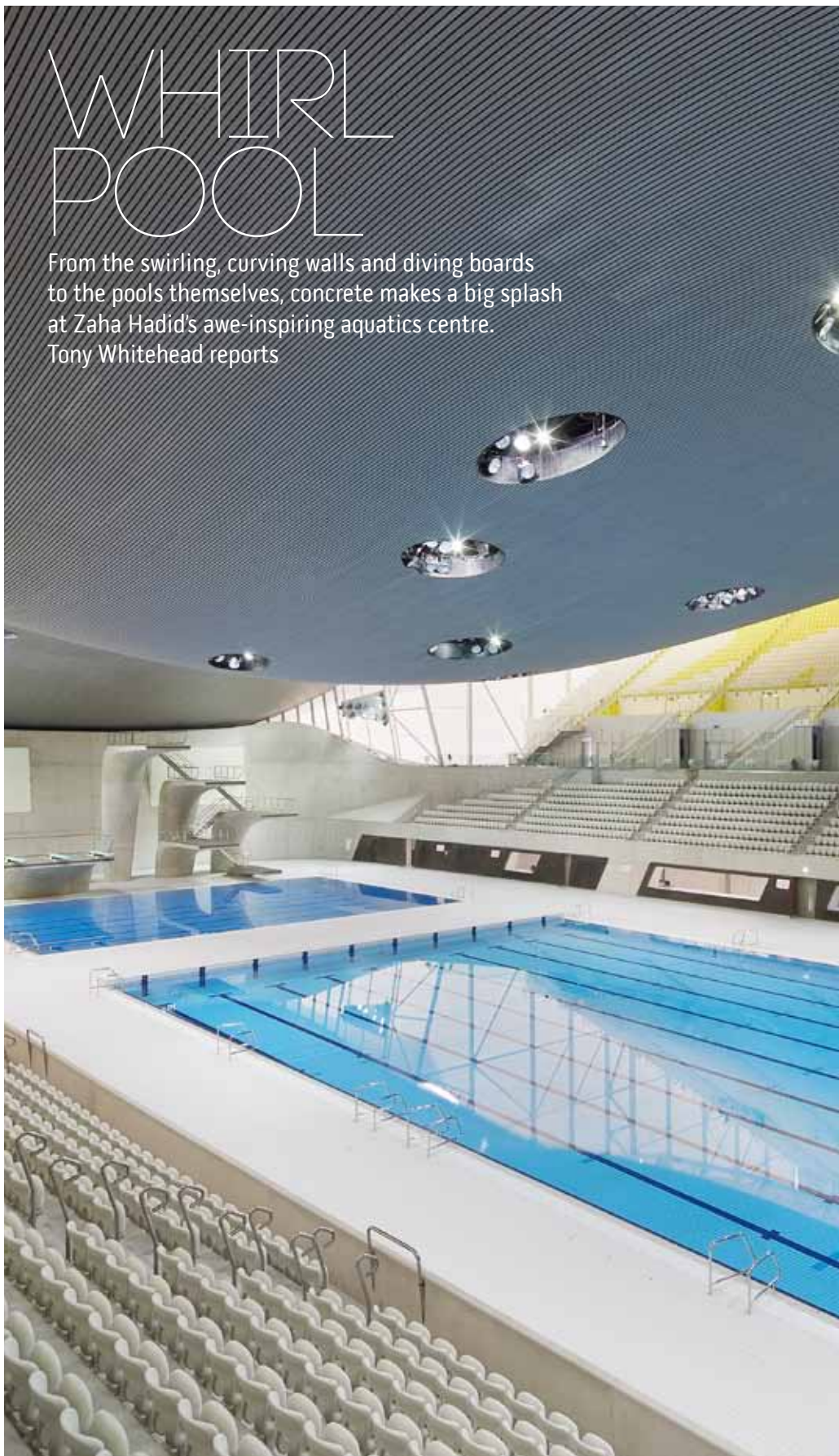
Engineer Arup

Concrete contractor Morrisroe

WHIRL POOL

From the swirling, curving walls and diving boards to the pools themselves, concrete makes a big splash at Zaha Hadid's awe-inspiring aquatics centre.

Tony Whitehead reports





Star jumps: how the diving boards took shape



Above: The six boards were all based on a single original mould

Various likened to the stamens of an exotic flower, a splash or even poised cobras, the dramatic lines of the aquatics centre's six diving boards have attracted much interest – not only as a natural centre of attention during the Games, but because they are visually fascinating in themselves.

ZHA project architect Sara Klomps explains that the distinctive shape of the boards was designed using Rhino 3D modelling software, and a “positive” of the 10m board was cut from Styrofoam using a CNC (computer controlled) router. The Styrofoam shape was then used to create large, heavy-duty fibreglass moulds in 2.5m-high sections.

“This is quite an expensive process but we were able to make all of the moulds from one Styrofoam positive created in the shape of the largest, 10m board,” says Klomps.

By “missing out” one of the lower 2.5m blocks it was possible to create the 7.5m board, and to create the lower boards the team used only the top and “knuckle” moulds. “Although we did, for logistical reasons, require more than just the four basic moulds, they were at least all made from the single original shape,” says Klomps.

The construction technique is evident from the appearance. On the 10m board, for example, it can be seen that the structure has been poured (in situ) in the 2.5m mould sections. The pour lines give the impression that sculpted concrete blocks have been placed one on top of another, even though the knuckle and top sections were poured

monolithically for each of the boards.

What visitors to the aquatics centre cannot see is that inside each tower is a surprisingly dense network of reinforcement, for although the boards support only their own weight (and occasionally that of a diver), they cantilever off the ground at an angle and the forces acting upon them are considerable. “As a result they have to be very strong and securely anchored,” says Klomps. “The extra reinforcement also helps to reduce vibration to a minimum, which is one of the requirements from FINA [the body that regulates international competitive swimming]. It is also important that there is minimal settlement over time, because the high board, for example, has to remain exactly 10m from the water – another FINA requirement.”

The reinforcement posed a potential problem, however, with the fear that voids would occur where concrete failed to flow around the dense tangle of steel. “Because of this, we chose a special mix that was able to ease the concrete around the dense reinforcement.”

This was a highly fluid self-compacting mix including 30% GGBS and 10mm carboniferous limestone aggregate. Some 462 tonnes was needed to construct all six boards. “Besides the environmental targets, the GGBS was used to reduce pour temperature and the carboniferous limestone to reduce the coefficient of thermal expansion of the concrete, limiting thermal movement and assisting with crack control.”

as building for the Olympics required very high environmental targets to be met. A variety of concrete mixes were used, but if all the Olympics sustainability promises were to be kept, overall a very high proportion of recycled aggregate and cement replacement was needed. In the end almost 100% of all aggregate used was recycled and the use of ground granulated blast-furnace slag (GGBS) reduced cement requirements by 50%.

Balfour Beatty worked closely with concrete contractor Morrisroe to arrive at a workable mix that both met environmental requirements and provided a top-class finish. “We experimented a lot before we got it just right,” says Fraser. In the end, the team settled on a mix with 40% GGBS replacement cement content and 76% china clay stent secondary aggregate from Cornwall, which went on to be used for most of the visual concrete areas.

Once the cores were complete, Morrisroe turned its attention to creating the training pool situated behind the northern cores and beneath the land bridge that carries pedestrians from the nearby railway to the venue's entrance. The merging of pool and bridge meant a new set of considerations as far as the concrete was concerned. Sara Klomps, project architect at Zaha Hadid Architects (ZHA), explains: “While the centre itself has a 60-year design life, the training pool forms part of a bridge structure and must have a 120-year design life.”

This, she says, involved more reinforcement, and a special high-strength visual concrete mix for the training pool walls and ceiling, the welcome zone ceiling and the roof supports. The concrete mix here was based on a cement replacement of 60% GGBS with 10% stent secondary aggregate.

The most striking feature of the training pool is its beautiful coffered ceiling. This was poured in sections as a 1.2m-deep slab but using special formers to create the attractive petal-shaped lighting troughs. These both dominate the design and decrease the ceiling weight. Fraser adds: “The roof spans over 25m, but its depth, together with the use of high-strength concrete and 40-50mm high-tensile bar reinforcement makes it immensely strong and self-supporting.”

Finally, and with the roof structure complete, the competition pools themselves could be built. As you might expect, a key requirement was that they should not leak. According to Tony Henry, contract manager with Morrisroe, absolute care was taken to achieve this: “We started pouring the pools in 5m x 5m bays – small pours to reduce any shrinkage

THE AQUATICS CENTRE IN NUMBERS

50,000m³ OF CONCRETE
7,000 TONNES OF REINFORCEMENT
1,800 PILES
TWO 50M SWIMMING POOLS
10 MILLION GALLONS OF WATER
850,000 TILES
2,500 PERMANENT SEATS
15,000 TEMPORARY SEATS
3,630 PEOPLE WORKED ON THE SITE



Wall-to-wall coverage

The curving concrete walls of the aquatics centre are one of its defining characteristics. They are first seen in the centre's welcome area and provide a top and tail to the competition pools, as well as a stylish backdrop to television coverage of the diving.

The smooth curves and fine finish, even down to the neat rows of bolt plugs, are a source of obvious source of pride to the construction team. So how were they made?

"The curved parts of these walls required specialist formwork manufactured from phenolic ply in Germany," reveals ZHA project architect Sara Klomps. In effect, they commissioned something akin to a giant toy construction set of formwork. "To keep costs down, we had to break down the design into straights, verticals, and forms for straight inclined, curved vertical, and curved inclined, as this allowed at least some re-use of formwork, especially as many sections are symmetrical."

Though the corbelled curved walls sometimes give the impression of being double curvature like the roof, they are not. "If you cut a diagonal slice from a cylinder it can look this way but in fact, it's single curvature."

Morrisroe's Tony Henry calls this "an incredible feat of carpentry and design," and describes how the formwork was used to create the walls. "Because of the concave and convex shapes, there was an increased risk of trapped air creating voids, so we used a self-compacting mix and pumped the concrete into the forms from the bottom up. We had many meetings with the architect, engineer and contractor to work out the best mix and again, sample panels were made until we knew we could rely on the mix to flow effectively and also give the right appearance. It was all about attention to detail – for example, ensuring the bolt holes were all in a pattern and plugged with a proper colour-matched mix."



CLOCKWISE FROM TOP LEFT

A rear view of the diving boards, which were cast in 2.5m blocks; the training pool's coffered ceiling; the main pool and temporary stands; visual concrete is used throughout the building

and cracking. This proved too slow however, and we were able to speed up considerably by switching to 10m x 10m pours and using a resin-injected grout to seal any small cracks that did occur."

Ever careful, Balfour Beatty filled the pools early to test for leaks, and only when the water stayed put was the go-ahead received to drain the pools – and to affix the first of the 850,000 tiles.

The finished product has never been short of admirers. Culture secretary Jeremy Hunt described it as "a moment of architectural genius" and International Olympic Committee president Jacques Rogge thinks it "a masterpiece".

Now the Games are over, at some point soon the huge temporary stands will be removed. The spaces they leave will be filled with glazed facades and, with its dimensions less strained and natural light flooding in, the true beauty of the centre will finally be revealed.



Above: The walls have been left exposed and uncoated

FASTER HIGHER STRONGER LEANER

With high recycled content and low embodied carbon, the concrete used to build the homes and venues in the Olympic park was at the top of its game



ABOVE

The concrete supply was locally sourced from a single batching plant

ABOVE RIGHT

The concrete poured at the park included 22% recycled and secondary aggregate



Concrete construction has been used throughout the Olympic park and athletes' village to help London 2012 to achieve its sustainability and legacy objectives.

The bid to host the 2012 Olympic Games and Paralympic Games included a radical proposal entitled Towards a One Planet Olympics. This committed London to host the world's first truly sustainable Olympic Games. With an initial estimate suggesting that 500,000m³ of ready-mixed concrete and equivalent aggregate weighing 1 million tonnes would be required for the project, the opportunities to maximise the sustainability credentials of cement supply and concrete construction were closely examined.

The first key decision was the procurement of a

single ready-mix concrete batching plant to provide concrete to all projects within the Olympic park. This ensured a local, responsibly sourced supply and eliminated 70,000 road vehicle movements.

Then the Olympic Delivery Authority (ODA) worked with the concrete supply chain to develop a range of sustainable concrete mixes. This resulted in the use of 170,000 tonnes of recycled and secondary aggregate, such as pulverised fuel ash (a by-product of coal-fired power stations), ground granulated blast furnace slag (a waste product associated with steel manufacture) and stent (a waste product of the Cornish china clay industry). This accounted for almost a quarter of the concrete content on the project and saved 30,000 tonnes of embodied carbon dioxide. Rationalisation and design efficiency reduced the concrete demand by 65,000m³, saving further embodied CO₂.

The use of concrete will also help to reduce the operational CO₂ of the Games and its future legacy. The future homes at the athletes' village (see opposite) have been built from concrete to provide a high level of thermal efficiency and reduce future heating and cooling needs. The robustness and fire resistance of the stadium's tiered concrete seating and of the aquatics centre minimise the need for additional materials and for ongoing maintenance.

To help to meet the Games' sustainability

objectives, the concrete supply chain has also been able to call upon its Concrete Sustainable Construction Strategy. This landmark pan-industry agreement has as its central premise that "by 2012, the UK concrete industry will be recognised as the leader in sustainable construction, by taking a dynamic role in delivering a sustainable built environment in a manner that is profitable, socially responsible and functions within environmental limits". The 2010 Sustainability Performance Report found that 88% of concrete production was responsibly sourced to the BRE standard BES 6001 – higher than any other construction material sector. It also found that the industry now consumes almost 47 times more waste, by-products and secondary materials from other industries than it sends to landfill.

The Olympic park was always intended to deliver a lasting legacy for London, and to be a genuinely sustainable development. Over the long term, its success will be judged not on the bright but fleeting glory of the Games themselves but on solid improvements such as these.

For information on the Concrete Industry Sustainable Construction Strategy and annual performance reports, go to www.sustainableconcrete.org.uk

VILLAGE GREEN

The concrete framed and clad athletes' housing was built to last, and is now set for a long future as a low-carbon London neighbourhood



Photos: LDCG

Now that the Olympics and Paralympics are drawing to a close, attention can begin to turn to the intriguing afterlife planned for the athletes' village. As part of the legacy commitment, the competitors' living quarters will be reconfigured to make a mix of family homes – some 2,818 in total – with a whole London neighbourhood emerging around the new streets and public squares.

While the village feels European in scale due to the height of the perimeter apartment blocks, there are also strong echoes of London's heritage: the shared resident gardens within the buildings are reminiscent of west London mansion blocks, and there is a sense of the long, narrow terraces of the east of the city too. Each block comprises seven buildings, three of which face onto a primary road and rise to up 10 storeys above ground floor commercial space. The rest of the blocks are made up of four triplex buildings with family houses and apartments. Car parks are hidden beneath landscaped podiums.

The village is the first large-scale, high-density, high-rise scheme to be developed to level four of the Code for Sustainable Homes and it also serves as a BREEAM Communities pilot project. To achieve level four, the design had to focus on ecology and building management, as well as pollution, waste, surface water and energy. In the choice of construction materials, the emphasis was on long-term holistic performance.

Post-tensioned concrete frames, many with precast concrete cladding, are used throughout the village, providing good thermal efficiency to reduce the heating and cooling needs of the buildings over their lifetime. The concrete also includes ground

PROJECT TEAM

Client Olympic Delivery

Authority

Masterplanners Fletcher Priest,
Arup Associates, West 8, AHMM,
Patel Taylor, Vogt Landscape

Architects AHMM, CF Møller,
Denton Corker Marshall, de Rijke
Marsh Morgan, DSDHA,
Eric Parry, Glenn Howells,
Ian Simpson, Lifschutz Davidson
Sandilands, Make, Niall
McLaughlin, Panter Hudspith,
Patel Taylor, Penoyre & Prasad,
Piercy Conner

Main contractor Bovis Lend
Lease



ABOVE

The 11 residential blocks were plotted around landscaped squares

BELOW LEFT

The blocks have commercial outlets at ground level

BELOW

The village's polyclinic will continue to provide healthcare to the new community

granulated blast-furnace slag (GGBS) as a cement replacement and is sourced from the UK – local, responsible sourcing being a key element of the Olympics' sustainability objectives.

To give a varied streetscape, a number of architects were selected to design the envelope of each block. Design guidelines have ensured a visual consistency, despite the differing elevation treatments of projecting balconies, sculptured facades, impressed patterns and barcode motifs. Changing rooflines add further variety and help to break up the volume of the blocks.

This is a mass housing development that is considered and well planned. Post-Games, the village has a strong chance of developing into a real urban community, just the first stage of an eventual 11,000 homes envisaged around what will now be known as Queen Elizabeth Olympic Park.





HOW THE STAGE WAS SET

The tiered seating where 80,000 people roared on Usain Bolt is all made from concrete. So how does that work in a 'temporary' structure? Elaine Toogood explains

From the outside, the Olympic stadium appears lightweight, with its acrobatic high-level structure and cables. But pass into the arena itself and you encounter the great swoop and solidity of concrete terraces rippling down to the athletics field – a solidity that is all the more surprising given that most of the stadium was designed to be temporary.

A major consideration for the design and construction of this project was future flexibility, and the need to transform an 80,000-seat stadium into a 25,000-seater after the Games. This concept of a demountable stadium informed all design decisions. Indeed, architect Populous adopted "Embrace the temporary" as its mantra. In fact, this degree of demountable seating was

ambitious – and had never been attempted before.

Philip Johnson, principal architect at Populous, says embracing the temporary was all about ensuring the stadium's legacy. "We came up with the term as I think the days of the 'white elephant' stadium are in the past," he explains. "We have to look at delivering something new. This is a different type of stadium which may provide a model for countries considering how they could afford to host future events. Normally, with projects of this kind, architects are concerned with permanence, but for us it was different because the stadium needed to be able to host future community athletics events."

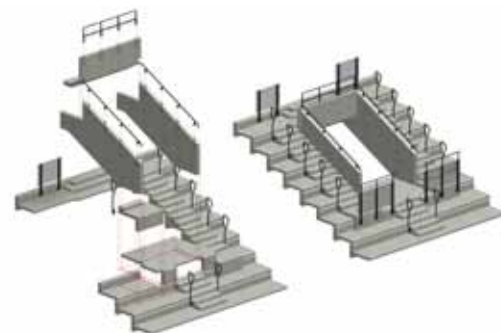
Given the mantra, the choice of concrete for

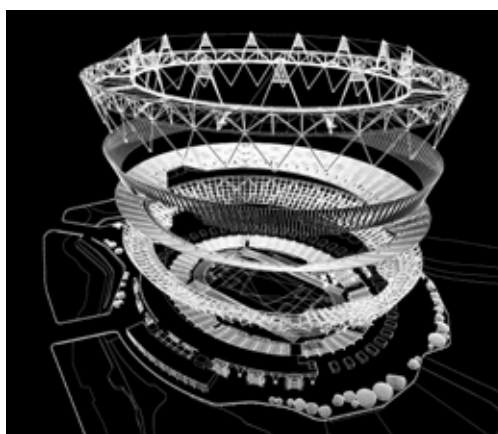
ABOVE

The stadium includes 9,250m³ of reinforced precast concrete

BELOW

An axonometric drawing showing a "vomitory" – or exit passage





demountable upper tiers might not seem an obvious one. But the short design programme drove the design team to choose concrete as a low-risk, well-understood option, which ultimately provided a high-quality result. Procurement and design development were simplified through repetition of the details from the lower tier. Of particular concern in stadium design is the effect of resonant frequency, when a structure moves due to the dynamics of crowd movement. The use of concrete is widely understood to limit this, so it was a safe choice for the upper terraces.

In all, there is 9,250m³ of reinforced precast concrete within the stadium bowl. There are also more than 4,500 reinforced concrete piles, cast in situ using concrete supplied by the batching plant specially constructed for Olympic projects. The concrete mix includes GGBS as cement replacement, which gives it a creamy white finish, as well as reducing the embodied CO₂ of the mix.

A ring of fair-faced, tapering elliptical columns form part of the upper terrace structure and were also cast in situ using large bespoke steel-faced formwork. Beams supporting the lower tiers were cast on the stadium site but not in situ. This “on-site prefabrication” method produced some very high-quality finishes and worked so successfully that the decision was taken to cast the entire perimeter embankment edging in a similar way.

PROJECT TEAM

Client Olympic Delivery Authority

Architect Populous

Structural engineer Buro Happold

Main contractor Robert McAlpine

In situ concrete works Byrne Brothers

TOP

More than 12,000 precast elements were required for the seating steps

ABOVE

An axonometric drawing showing how the stadium can be demounted

ABOVE RIGHT

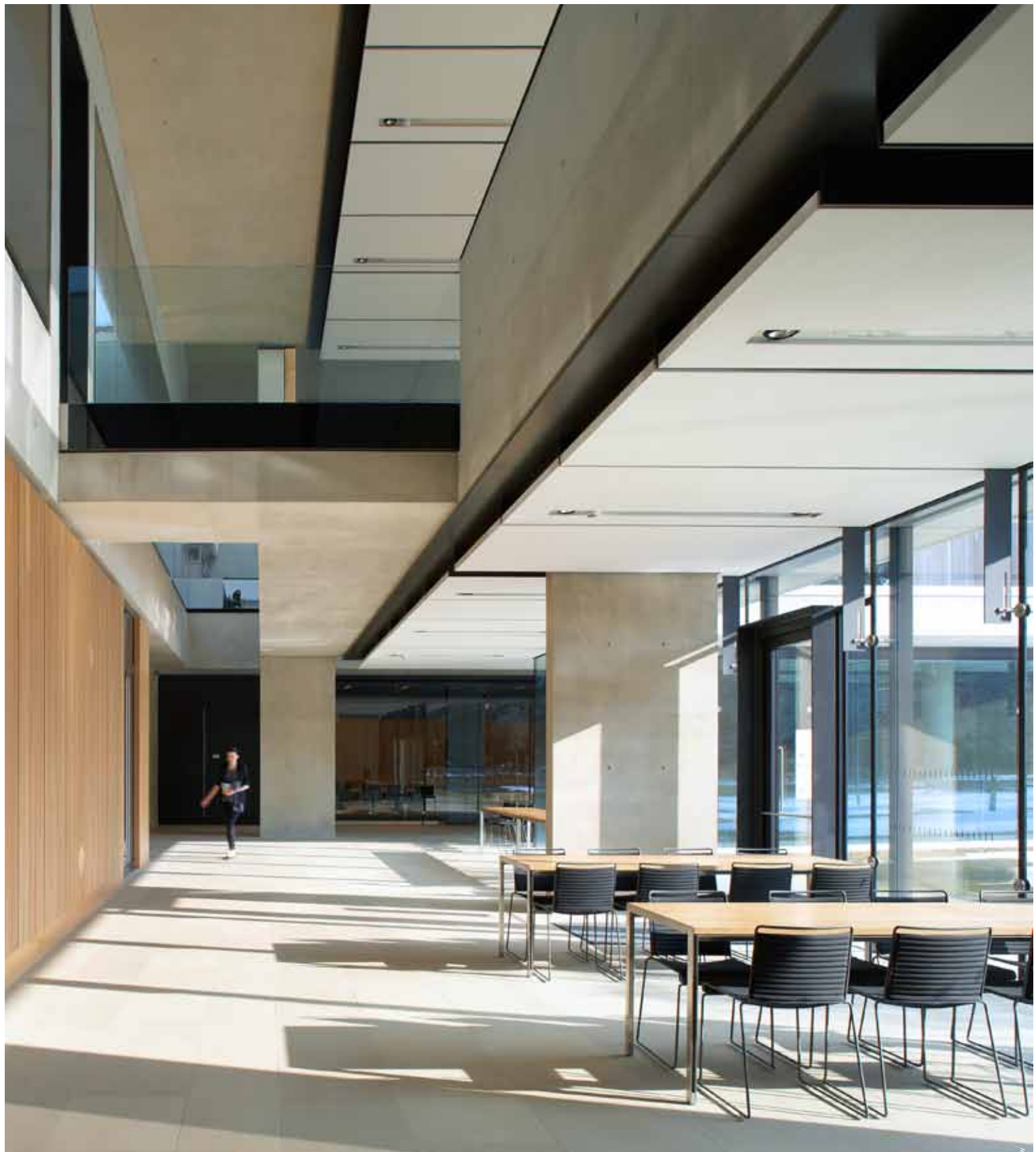
The fair-faced columns of the upper tier structure were cast in situ

The tiers themselves are constructed from a series of precast concrete T-sections, which span about 7.5m between steel beams in the upper terraces and concrete beams below. Since every face of each element was intended to be seen, considerable time and effort was spent on the design of the moulds and the concrete mix.

The tiers are parabolic in shape so each step is slightly higher than its neighbour. More than 12,000 precast elements were required for the seating steps alone. The sections were kept as simple as possible and cast at right angles to their final orientation so that the uppermost unformed face became the upstand to the rear of the seat. This face was towelled smooth by hand in the factory.

Rigorous quality control was carried out, helped by the decision to mechanically fix seating on site rather than provide cast-in fixings. Details for the fixing of the upper terraces required particular attention as they were intended to be demountable for potential use elsewhere. Balustrades were designed to slot into cast-in sleeves rather than fix onto bolts.

Though the option remains to subject the stadium to its full radical dismantling, it seems that most of the concrete terraces are likely to remain in place, making good use of their inherent durability, and supporting spectators for many years to come.



THE FINAL FRAME

The Sainsbury laboratory in Cambridge has been shortlisted for this year's RIBA Stirling prize. The Stanton Williams-designed plant research facility features finely honed concrete on exposed columns, walls and ceilings, and the courtyard elevations. The concrete and stone rear facade helps to root the building in the natural landscape of the university's historic Botanic Garden.