IABSE UK NEWS

Newsletter of the British Group of the
International Association for Bridge and Structural Engineering

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Olympics Special

London 2012 Stadium, picture courtesy of London 2012

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IABSE British Group News

Editorial

Welcome to *IABSE UK News*, the newsletter of the British Group of IABSE.

There's a distinctly topical flavour to this edition, with a report on Tony Aikenhead's Annual Lecture, on the subject of delivering the London Olympic Stadium, as well as an abridged version of a paper on the same project, originally delivered to the London IABSE Symposium last year. The development of the main athletics stadium has been well documented, but many of the other Olympic structures less well so, including several which are dramatic, state-of-the-art or otherwise fascinating enterprises. It might be hoped that the Olympics can yet offer more engineering tales to tell.

As always, this newsletter is reliant on its readers for material. Please consider submitting:

- conference reports
- project reports and abridged papers
- personal news, awards, appointments, profiles

Regards, Brian Duguid, Editor

Events

Date	**Time**	**Event**
13 September 2012		Young Engineers' Conference *"Future of Design"* Organised by IABSE British Group University College, London
19-21 September 2012		IABSE Symposium – Seoul *Innovative Infrastructure – Towards Human Urbanism* Final invitation issued
8 November 2012	6pm	Milne Medal Lecture Details to be announced
14-15 February 2013		IABSE Workshop - Helsinki *Safety, Failures and Robustness of Large Structures* Call for papers by 30 September, 2012
6-8 May 2013		IABSE Conference – Rotterdam *Assessment, Upgrading and Refurbishment of Infrastructures* Full papers due by 15 October, 2012
24-27 September 2013		IABSE Symposium – Kolkata *Long Span Bridge and Roof Structures – Development, Design and Implementation* Abstracts due by August 30, 2012

Unless noted otherwise, all events take place at the Institution of Structural Engineers, 11, Upper Belgrave Street, London. Tea is usually served before evening lectures and meetings from 5.30pm.

IABSE on the Internet

The website of the British Group can be accessed at http://www.iabse-uk.org/, where proceedings of Henderson Colloquia and back editions of *IABSE News* are available in downloadable form. We remain grateful to the Institution of Structural Engineers for their continued generosity in hosting the website.

I am still looking to add further papers or summaries from past Henderson Colloquia to the website, so if anyone can assist by supplying copies, please get in touch (brian.duguid@mottmac.com).

The international website of IABSE at www.iabse.org contains comprehensive information on IABSE organisation, activities and publications.

The IABSE website includes online versions of a number of the Structural Engineering Documents. The following are available to members who log in (the first four are otherwise out of print):

SED 1 – *Concrete box-girder bridges*
SED 2 – *Dynamic response of reinforced concrete buildings*
SED 3 – *Vibrations in structures*
SED 4 – *Ship collision with bridges*
SED 12 – *Case studies of rehabilitation, repair, retrofitting and strengthening of structures*

A historical archive of documents from IABSE conferences and journals, from 1929 to 1999, is also available, and is free to both members and non-members: http://retro.seals.ch/digbib/en/browse5_2

Disclaimer

The views and opinions expressed in IABSE UK News are those of the respective authors and not those of either the Executive Committee of the IABSE British Group or the Editor. Whereas effort has been made to ensure the accuracy of statements and acknowledgements, we reserve the right to be as wrong as everyone else.

Member News

Many congratulations are due to IABSE member Naeem Hussain, of Arup, who was recently announced as the recipient of a Prince Philip Gold Medal from the Royal Academy of Engineering. Naeem joined Arup in London in 1970 but has been based in Nigeria and Hong Kong as well as London. In recent years he has headed the Arup Global Bridge Business and has had leading roles in Stonecutter's Bridge and The Forth Replacement Crossing. He is Chair of the Hong Kong Group of IABSE.

Naeem also chairs IABSE Working Group 3, responsible for producing International Guidelines for Bridge Design Competitions. The IABSE British Group is also represented on the Working Group by Angus Low, Brian Duguid and Roger Buckby. The content of the guidelines has been finalised, and they are now at the pre-production stage, with publication anticipated for later this year.

Structural Engineering International

The ongoing opportunity exists for all members to have articles published in *SEI*, the international journal of IABSE. Rules for publication are available through the IABSE website at www.iabse.org. Brian Duguid is the UK Correspondent for *SEI* and can offer assistance to prospective authors (see Directory). Forthcoming issues are expected to include the following themes:

August 2012 – General reports and papers on climatic structures *(submissions closed)*
November 2012 – Fire engineering / fire protection *(submissions closed)*
February 2013 – Recent structures and research in India *(submissions closed)*
May 2013 – Seismic engineering *(submissions closed)*
August 2013 – General reports *(abstracts due 10 Dec 2012)*
November 2013 – Assessment, Upgrading, and Refurbishment of Infrastructures *(abstracts due 10 Dec 2012)*

Milne Medal Lecture, November 2011

Ed Clark: *“Roller coaster”*

Reported by Stuart Alexander

While Ed was being presented with the Milne Medal for 2011 by David Nethercot, we in the full house audience were trying to understand the woven gold structure framing the main entrance of the V&A Museum in South Kensington. More of this later.

Ed kicked off by explaining three themes that inform his approach to design, starting with ‘Form and configuration’. This he illustrated by iconic structures including Nervi’s giant hangar at Orvieto, Candela’s thin parabolic roofs in Valencia, and Frei Otto’s sophisticated Munich cable net, and brought up to date with the Olympic velodrome. He then showed his own 2009 Serpentine Gallery pavilion (figure 1), emphasising the thinnest possible roof (1 inch) and thinnest possible columns (2 inches).

Figure 1: Serpentine Gallery pavilion, London, 2009

His second theme was ‘Use of materials’, explained through glass as used in an early iron-framed conservatory and a modern see-through staircase, Eladio Dieste’s butterfly shell canopy made of prestressed masonry, and timber used in the Rothschild Foundation building. His own work was shown by the façade wall of Selfridges in Birmingham, constructed in storey-height ‘ribbons’ of sprayed concrete (figure 2) and finished off with 15 000 aluminium discs.

The third theme was ‘God is in the details’. Close-ups of the juxtaposition of timber laths and steel cables in the Mannheim gridshell, the gerberette at the Pompidou Centre in Paris, and the supporting cables ‘hidden’

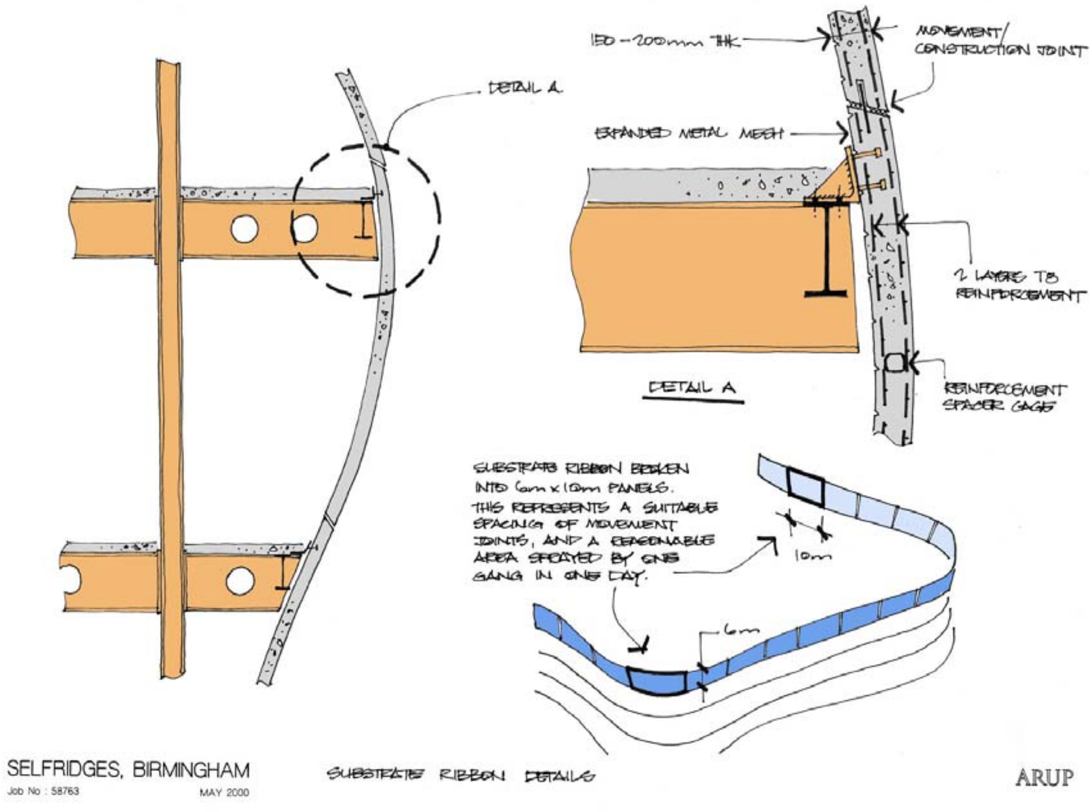


Figure 2: Details of Selfridges, Birmingham, 2000

behind the joints in the huge glass façade of Schlaich's Kaplinsky hotel in Munich, showed this very clearly.

This led onto the 'roller coaster' design process as experienced on the V&A Timber Wave gateway. The aim was to showcase American red oak glulam bent to its minimum radius. The start of the process is always exciting - ideas, searching to find the right form and way to use the material - everyone on a high! Then testing, comparing configurations, but needing a tie, then struggling with section sizes, all against a deadline, two more dips and climbs. Then to detailing: irregular geometry means connections are all different, much hard work before issue for fabrication. Then to erection: small assemblies doesn't work because the flexibility prevents accurate jointing, so to larger lifts but needing more temporary works. At the end the late realisation that the pavement slopes, but overcome to end at last back on a high.

Figure 3: Timber Wave gateway, V&A Museum, London, 2011

Questions from the audience included 'What brings you back to not doing the easy thing?', 'Would it be boring without the roller coaster?' and 'How do you evaluate the best solution?', showing that Ed had taken us all with him on the roller coaster.

Presentation of the Milne Medal to Ed Clark by Prof. David Nethercot

IABSE Annual Lecture, May 2012

Tony Aikenhead: *“Designing and Constructing the London 2012 Stadium”*

Reported by Ian Liddell

The 2012 Stadium was a design and build project with a team (Team Stadium) lead by Sir Robert McAlpine with Populous – architects, Buro Happold – engineers and H&D – landscape architects. The client was the Olympic Delivery Authority assisted by CLM. Tony Aikenhead gave us a detailed insight into the complexities of designing the stadium and constructing it with a special focus on the health and safety of the staff on site.

The brief was to build an 80,000 seat stadium that could be reduced to a 25,000 seat arena for IAAF events. This curious aim was to avoid the usual fate of Olympic stadia; that of becoming “white elephants” lying unused after the games and costing a fortune to build and maintain. The work started in 2006 and construction was to be complete by the summer of 2011 to allow a year for LOCOG to fit it out for the games and especially the ceremonies. The clearance and de-pollution of the island site that had a number of old industrial buildings on it was done in separate enabling works before the main contract started.

Tony told us the outlines of the story of the development of the design; the order of importance of the stakeholders - the pecking order being lead by the athletes requirements and those of the media especially TV, the attempts to find an economic way of transforming the stadium from 80,000 to 25,000 seats including one idea of having hydraulically movable seating sections. In the end they settled on a low cost dismantle-able scheme for the upper tiers with the lower tier providing the legacy requirements. To reduce the costs the seating was made as compact as possible with single vomitories for the very large upper rake which saved a second set of stairs and entrances. The structure is simple and repetitive allowing rapid simple fabrication and pre-casting of the terraces.

Initially the partial roof was to be a cantilever steel truss that was disliked by all in Team Stadium. Wind tunnel tests demonstrated that a full roof extending about 40m would protect the VVIP seats and reduce wind speed at track level. This last would significantly reduce the probability of the wind over the sprint lanes and long jump pit being above the critical 2m/sec for records to be ratified. The cable and fabric design for the roof with a supporting compression/bending ring was found to be an elegant way of building it. Making the roof structure independent of the seating structure eliminated the possibilities of delays caused by interaction of the designs.

Tony went on to talk about the construction stage, the foundations and concrete work up to podium level, steel work from Watson steel for the upper bowl and compression ring. Construction of all the areas proceeded around the bowl making for very efficient construction. The last section of the compression ring was fitted in with about 10mm tolerance. The installation of the cable net was explained, how the inner tension ring laid out on a scaffold platform with an extra platform for the strand jacking equipment. The lifting process was described with the aid of a time delay movie showing the ring slowly rising to its final level.

Completion of the cable net was followed by the installation of the fabric and then by the installation of the triangular lighting towers, another movie. All exciting stuff but fitting it all in to the one hour lecture time meant that much of the complexities had to be left out. However we did get a glimpse into the problems with the cable terminations for the larger cables that had been cast in Shanghai and did not come up to specification for crack propagation resistance. Those for the primary 80mm suspension cables had to be recast to ensure their reliability.

In summing up Tony said that their greatest achievement was to have constructed an Olympic stadium without a fatality and with only three reportable accidents. Apparently this was a first, which is worrying about the others. He explained the processes they had to go through to get their on-site staff fully committed to safety leadership

There were a number of questions but one that seemed to be worrying one questioner was “who was the engineer primarily responsible for the design work whose removal would have affected the outcome”. It was explained that the design and construction team was exceptionally well integrated. They had all worked together before on 3 or 4 projects and there was not a single individual without whom the project would have been adversely affected.

As often happens with the best regulated projects Tony claimed that is was completed on time and within budget. The latter was no surprise as he started by stating that there was no specific budget. It always helps if the budget is determined once cost certainty is established through the procurement system. He also said that the agreements of the team members included a target cost arrangement whereby there were rewards for the cost coming below the target and penalties if it was above.

The Chairman thanked Tony for an excellent and informative presentation and we rounded off the evening with an excellent dinner.

Project feature

London 2012 Olympic Stadium – Concept and Philosophy

Abridged with permission from the paper originally presented to the IABSE-IASS Symposium, London 2011, by Ian Crockford (ODA), Mike Breton (Sir Robert MacAlpine), Paul Westbury (Buro Happold), Philip Johnson (Populous), Fergus McCormick (Buro Happold) and Tony McLaughlin (Buro Happold).

Introduction

On 6 July 2005 the 2012 Summer Olympic and Paralympic Games was awarded to London. The London bid had very much focused on regenerative possibilities of the Games and opportunities for inspiring younger generations to sport.

Already therefore London was proposing a new type of experience for the Games: acknowledging the interest and spirit of the Games Event itself, but ensuring that legacy and post-Games would be given important consideration.

'Team Stadium' was appointed as an Integrated Design and Construction Team [IDCT] in April 2008 for the Main Stadium. From appointment, 'Team Stadium' worked closely in collaboration with the client stakeholders through the Olympic Delivery Authority [ODA] to develop and interpret the brief. A key part of the project was converting the strategic goals of the Olympic bid into philosophies for the Main Stadium such that all believed they were delivering a stadium fit for, and appropriate for, a London Olympic Games.

Brief

A key challenge in design was preventing the Stadium becoming an underused white elephant post Olympic Games. The Brief as presented to the Design Team was therefore unusually composed of two parts: an 80,000 seat stadium for the Olympic and Paralympic Games incorporating sustainable and intelligent responses through conversion into a smaller venue of a 28,000 seat stadium in Legacy.

The considerations for the Legacy were challenging and innovative. The phrase developed was that of a ‘Living Stadium’: both a sporting legacy and key part of the new social infrastructure for the area. The aim was for a flexible, multi facetted venue capable of accommodating World Cup Athletics, Grand Prix Athletics, Elite Athletes with Disabilities Events, Football, Rugby, Concerts, Other Community Sports and Cultural Events.

Through this two stage process, the delivery of infrastructure for the Olympic and Paralympic Games and for the Legacy venue, the aim was to provide the platform for the most significant and positive long-term impact on the quality of townscape and public realm in London’s recent history, with the Olympics the catalyst for real change in the UK as a whole and in the Lower Lea Valley in particular.

For the designers, this was a real challenge: stadia have been converted before, but nothing on this scale has ever been attempted. Additionally the conversion was to acknowledge the short 18 months life of the 80000 capacity stadium, from Test events to Games, and having materials and components considered for the Olympics building to be reusable, re-locatable and recyclable wherever possible. Whereas the Legacy stadium was to be appropriate for a permanent sports venue ensuring durability and low maintenance and energy costs.

Seating Bowl

A number of Legacy seating bowls were discussed, but the solution settled on a single uniform tier sunken into the landscape. As such, the Architects quickly developed a seating bowl section for the Olympic Stadium mode largely formed of two key triangles having 25000 permanent seats in a lower tier with a temporary structure for 55000 seats in an upper tier.

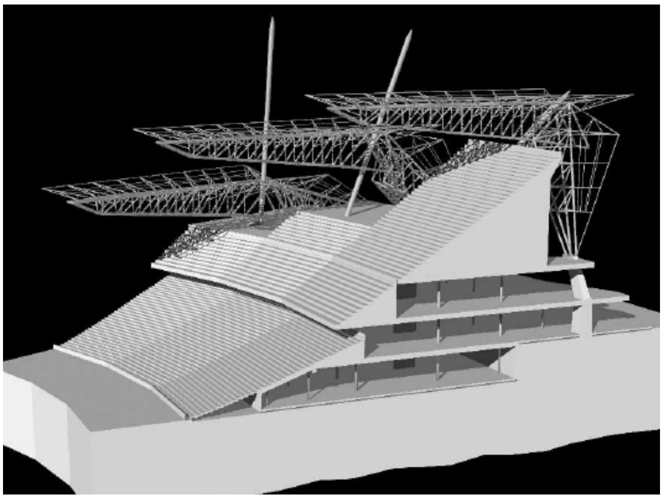
Concrete was developed as the conventional material for the lower bowl offering a durable permanent feel and initially it was imagined the upper temporary bowls would be scaffold.

Preliminary Deployable Concept

The first solution developed by ‘Team Stadium’ formed around a hinged deployable roof over the upper tier, illustrated below and overlead. It had the advantage of being able to be converted readily down from 80000 to 28000, but also converted back upwards to a capacity of 55000 which was considered as a potential size for a World Athletics Championship.

The design was well received for its innovation and style, but deemed too expensive. The Brief was simplified and the option for capability of multiple potential conversions of the stadium to many different capacities was removed.

"Embrace the temporary"



The single most important decision in the design development was to "embrace the temporary" and remove the majority of spectator facilities from within the stadium and locate them in self-contained pods around the island. This enabled a dramatic reduction in the scale and mass of the building as well as the embodied energy of the construction with, for example, far fewer heavy concrete concourses. The decision helped minimise costs of transformation after the Games. Additionally, it enabled the stadium to fit on the island site with sufficient circulation around it.

Bowl steelwork engineering for temporary tiers

Early engineering concepts were sketched with the notion of scaffold type supports for the upper tier and a number of discussions were also held with temporary seating suppliers. The problem with both solutions was that the market has its available capacity of rentable materials which is self-regulating according to a number of major regular sporting events in the calendar. Renting temporary solutions for a capacity as large as 55000 seats was not possible and thus these options had no philosophical advantage, in sustainable terms, when compared to a bespoke system.

Additionally scaffold solutions felt inappropriate from a structural viewpoint for such a large seating tier and compromised circulation space at podium and ground level. Simple systems offered by a number of temporary suppliers were inherently ill-equipped to deal easily with an elliptical geometry. Additionally, in fact, both solutions were expensive. Discussion with these suppliers took place, but it was clear that a first principled structural design was going to be the most attractive solution.

The perimeter section and columns of the stadium became steeply inclined to create the now recognisable distinct aesthetic of the stadium. But this had a functional purpose too as, together with a carefully optimised seating tier and bowl form; it helped provide a minimal volume to allow clear circulation around the stadium perimeter on the island site.

Developing concepts

The notion of roof cantilevers that had been initiated for the deployable design remained in a number of the design developments.

Also at this time, the designers recognised the opportunity given by the stadium location on an island site to allow the security lines to be on river bridges removed from the stadium. This would allow a perforate light design to the stadium perimeter and the Architects started to explore the idea of the external façade being akin to a stage set and formed in fabric. Consideration was given to this facade being formed of a double layer enveloping a dark, black serviced zone into which back-of-house distributions for ductwork and cabling could be located. A number of solutions were developed along this theme.

The double layer was simplified towards a more single skin fabric; however the notion of a black space as part of the theatre of the event arrival and event journey remained in the architectural colour concept that emerged for painting the bowl steelwork black. This would contrast with light and colour used in other devices such as the vomitory stairs enhancing, and appropriate for, a festival approach to the Games.

Wind engineering studies

The Team examined carefully the need, if at all, for a roof for such a temporary event venue and the notion of any covering and its size was the subject of much debate. The Engineers proposed to the client to undertake a special study on windiness at track and field level for the athletes. The 100m sprint is one of the most significant events of the Olympic Games and the one at which athletes times are most closely watched to see if they have broken world records. Much attention can be given to the perceived success of a Games in terms of records for some of these events such as the 100m. While strong cross winds would be detrimental to performance, tailwinds must be below 2.0m/s to allow records to be deemed 'wind legal'. However it was not just wind speeds for certain record criteria that were subject to scrutiny, but also an understanding of general windiness.

The Engineers developed a 3D virtual wind tunnel to evaluate the wind performance against a number of parameters including roof area. This allowed rapid assessment of a range of options at the preliminary design stage, well in advance of the later wind tunnel testing, carried out at detailed design stage. The study considered wind exceedance over 2m/s and general comfort conditions of athletes and spectators.

For the majority of wind directions studied, the wind rising up over the stadium drove a re-circulating zone of air within the stadium. A reduction in the roof opening gave a smaller area over which to drive this recirculation, reducing the wind speed within the stadium. The results showed that a partial covering was significant in attenuating wind speeds at track level.

The partial roof was chosen and interestingly therefore its main purpose is not so much to shield against rain but to minimize wind on the track and its provenance and design is a direct result of wind engineering.

Roof engineering

The work on the wind engineering had needed to consider parameters of different roof area ranging from zero area to full coverage over all the seated spectators. The need to consider the full roof, along with a number of other factors led to exploration of a cable net roof as an alternative to the cantilever as it was inherently thought to be more economic for the longer spans of the full coverage.

It quickly became apparent that the cable net enabled a better, lighter perimeter to the whole building both structurally and aesthetically. Additionally the engineers proposed solutions for potential transformation of the Olympic Event cable net to a roof geometry and coverage over the 28000 seat Legacy stadium (even though this requirement had been removed from the Brief).

A detailed costing and programming was undertaken for the two alternative solutions of cable net and cantilever for a range of parameters in parallel with the wind engineering studies. The results for all the engineering and construction analyses were synthesized and appraised together.

Examination of the results led to the selection of the cable net option for partial coverage.

Final Concepts

The final concept is of an innovative lightweight Olympic Stadium that can be reduced in size through designed-in demountability after the Games from the 80000 seat capacity for the Olympic Event to a 28000 seat legacy stadium for local athletics. The design response fits the challenging Brief in an unusual, distinct and elegant way (see Front Cover picture).

Reduced Embodied Carbon

Carbon content embraces both the in-use carbon emissions of the stadium released during the operational lifetime of a building and the embodied carbon content in its construction. In a stadium for which much of the building had potential short life span covering Olympic warm-up events and the five weeks of the Games themselves, then in overall terms it is the embodied carbon that is the most significant part of the emission from the development. In general for some low use buildings, it might take 100 years before the operational emissions outweigh the embodied energy. However the team aimed to challenge both parts of the carbon emission equation via high-level conceptual decisions and via detailed value engineering.

By far the most significant decisions influencing embodied carbon are those associated with the designers' acknowledgement to "embrace the temporary" enabling a compact design and lightweight construction throughout. The requirement for temporary seating drove lightweight middle and upper sections of the stadium structure, through efficient use of materials and optimisation of the design structure.

The ODA and 'Team Stadium' carefully interrogated the required roof coverage and optimised a lightweight, low carbon, minimum area solution.

Logistics

The Olympic Stadium is a huge construction site situated on a small 'island'. The logistics of a site like this are complex. Close attention was paid to how the materials were transported to site. Less than 50% of building materials were transported by road through the use of the canal and rail networks. This minimised pollution, but also ensured that local roads were not overburdened.

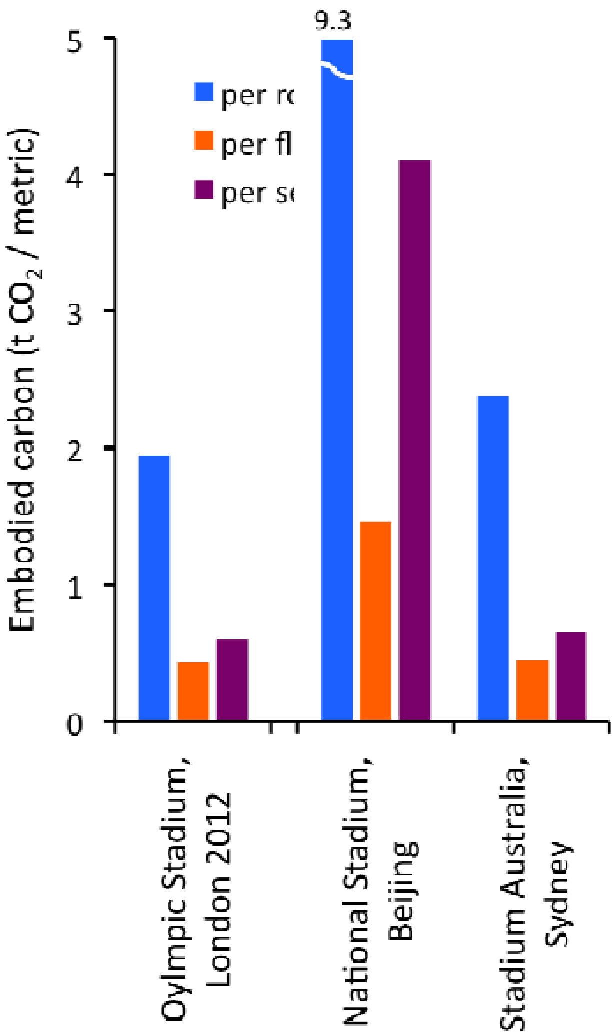
Concrete

The ODA and 'Team Stadium' worked closely to reduce the embodied carbon through low carbon concrete. As a strategy across the Olympic Park, a single energy efficient concrete supplier was specified who achieved a 5% reduction in carbon footprint against the UK average. The ready mix concrete plant was located onsite at the Olympic Park adjacent to the rail head, which eliminated 60,000 heavy vehicle movements. This equates to about 55,000 tonnes of CO2, or 15% of the total embodied carbon emissions for the Olympic Park site.

The average percentage of cement substitutions (PFA and GGBS) was raised to 32% from the UK average of 18%; using super-plasticisers to reduce total cementitious content in the concrete. The ODA set targets of 25% average recycled aggregate target for the games; however the Stadium podium topping exceeded this with 100% coarse aggregate replacement.

Roof Steel Supply

Large diameter tubes of the roof were reused from material from a gas pipeline project, which provided a carbon saving. General steel contained around 60% recycled steel which is standard UK practice.



Monitoring and Comparison

A number of key performance indicators were developed to consider the carbon savings achieved: [total carbon mass], [carbon mass/seat], [carbon mass/floor area], [roof carbon mass/roof area] and these were considered to monitor internal design development and progress through the project and also to allow benchmarking in relation to other venues and other Olympic Stadia (see diagram, above right).

Comparing the absolute embodied carbon of the main stadiums, the construction of the Sydney Stadium created 1.5 times more CO_2 emissions than the London 2012 Olympic Stadium, while the Beijing 2008 Olympic Stadium was nearly 8 times more carbon intensive.

Conclusion: "A different kind of stadium"

It is hoped that the design is seen to successfully realise a set of unusual and challenging philosophies into a building. These include a belief in good design and innovative solutions enabling a natural iconic elegance formed from integration of early inputs of a collaboration of architecture, engineering and construction. It is shown that logical bold decisions can generate iconic designs, which are light, innovative, efficient and sustainable.

The team did not seek to expend large quantities of energy and materials in an expression of wealth that may have had little afterlife and we hope that our story is seen as more appropriate given the global challenges that we know that we now face.

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