Profile

"My career has been all about good fortune," says Arup Deputy Chairman Tristram Carfrae. From early years assisting mercurial genius Peter Rice to acting as engineer for man-of-the-moment Thomas Heatherwick's Garden Bridge in London, he has worked with the greats of engineering and architecture. Now Carfrae, the designer of the stunning Beijing Olympic Aquatic Centre, is confirmed as one too, as the 2014 recipient of the Institution's Gold Medal. Interview by Jackie Whitelaw.

Tristram Carfrae is unique among structural engineers in being able to say that one of his projects has been judged more desirable even than lipstick and high heels. That scheme was the Beijing Olympics Aquatic Centre – the Water Cube – and in 2008 women's magazine *Marie Claire* placed it in top spot in its list of the world's 101 most sexy things.

It is an accolade he is incredibly proud of, because the beauty of structural engineering received mainstream recognition and because it demonstrated that the right design can resonate positively with the public – something which he believes all engineering design should be doing.

As he said when his Gold Medal award was announced, "The next decade will be full of opportunity for structural engineers; engineering will become more relevant to ordinary people's lives as we respond to challenges like climate change and sustainability, designing the new, resilient structures required for increasingly challenging environments – while also attempting to improve people's lives and to make a better built environment."

The digital revolution which is improving the ability of structural engineers to work closely with architects and contractors will, he said, "compel structural engineers to think more creatively, as well as focusing on analysis, risk and reliability. Of course we must remain the trustworthy guardians of public safety – but I think we need to join the debate on what people want – rather than telling people what they need. Doing so will make clients and the general public respect us a good deal more."

The Beijing Aquatic Centre, he says, is his best engineering solution to date and it evolved by bringing engineers of all disciplines together with the architects even before the design got started or the bid was won.

"We did something then that no one had ever done before," he says. "We got the engineers to tell the architects what the perfect swimming centre would look like." That included the acoustic engineers saying they didn't want a glass box as it reflects sound, but the mechanical engineers saying they needed a glasshouse to keep the costs of heating the water down. Out of that came the solution to use ETFE [ethylene tetrafluoroethylene] plastic, which let the sound out and the light in.

"The right engineering solution led to the right structure," as Carfrae says, and the deep blue box of bubbles became for the public the enduring symbol of the 2008 Games, more so even than Arup's other triumphs, the Bird's Nest stadium and the CCTV tower.

The Aquatic Centre was, if you'll excuse the pun, something of a watershed moment for Carfrae himself. Use of ETFE, if you look back over his career, was inevitable given that he had pioneered and developed lightweight structures since the early 1980s. "But up until Beijing, all my structures had been about efficiency. Afterwards, I became more poetic," he says.

Singapore's Marina Bay Helix Bridge, the AAMI Park Stadium in Melbourne and 111 Eagle Street, Brisbane are all late-flowering Carfrae designs.

Carfrae is now 55 and has spent his whole career with Arup, which he joined fresh from a Cambridge degree in mechanical sciences. "I'd had to take a year out to do the entrance exam as my local comprehensive in Devon didn't normally put people in. I was the little nerd but good at maths and easily bored." So good at maths and so easily bored that he was sent to study on his own, but was the go-to man at school to help out everyone else.

"You don't realise how special Cambridge is when you are there," Carfrae says. "I spent all my time trying to get out and I joined the car club when I discovered that meant you were allowed a car (it's bikes only for undergraduates) and then toured all the local country pubs. "I'm a goody two shoes but I'm not a worker – clever, quick, lazy is how I'd sum myself up. But I didn't judge it right for the degree; I came out with a 2:1. Luckily, Arup had been told I'd get a first and stuck by the offer of a job."

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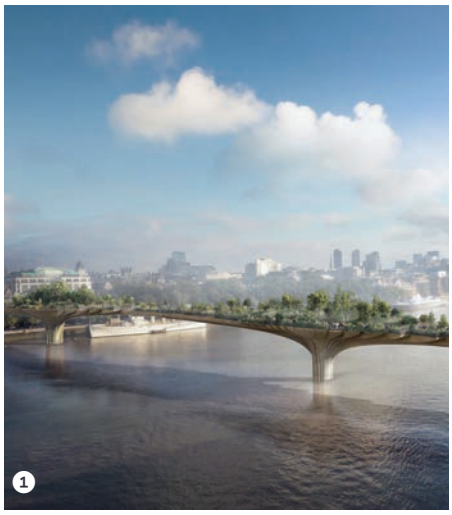
His decision to study engineering was the result of seeing his mother at work as an architect. "I remember clearly saying to my mum at 16 that I fancied being an architect. She took one look at me and said 'no, no, no! You are not arty enough but you could be an engineer and work with a firm like Arup who collaborate well with architects'. I'd forgotten that until I joined Arup and then it all came back to me."

His whole career, he says, has hinged on what happened in the first week at Arup in 1981. In those days, all the new graduate employees gathered together for a residential two-week induction. "Someone stood up during that and talked to us about lightweight structures," Carfrae remembers. "A week later they asked who wanted to join and I was one of about 15 who put their hand up.

"I was chosen apparently because I knew about steel, and lightweight structures rely on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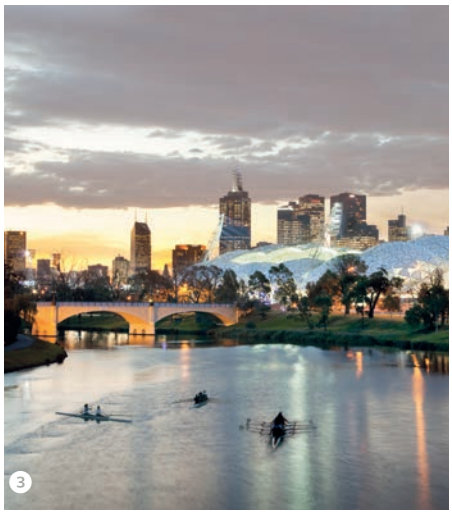
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JOHN GOLLINGS


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Selected awards

2001
Professional Engineer of the Year
Engineers Australia

2006
Milne Medal
International Association for Bridge and Structural Engineering

2006
Royal Designer for Industry
Royal Society for the encouragement of Arts, Manufactures and Commerce

2014
Gold Medal
Institution of Structural Engineers

steel. But all I had said was that I knew nothing about concrete. In fact, I knew nothing about either!"

Starting out in a whole new field suited him down to the ground. "There were no codes of practice, no regulations; you had to work everything out from first principles. And we were just moving from physical models to using computer analysis, so I became a computer programmer. I helped write something then that I am still using now – the Fablon non-linear analysis program. That was just a list of numbers to start with, numerical co-ordinates for the structure, fine for engineers but not good for explaining the structure to clients and architects.

"But I found a colour VDU sitting idle – no one had worked out what to use it for – and managed to make it draw lightweight structures. Then I photographed the screen with a Polaroid camera on a tripod under a black sheet like a Victorian. Even then, I could only get an image by taking the photograph after dark with the lights off."

Carfrae spent a year with lightweight structures, but with no live projects moved on to join the team on Richard Rogers' Lloyd's of London building. It was his first spell working with Sydney Opera House roof engineer Peter Rice who, with John Thornton, was leading the Lloyd's engineering team. Carfrae helped design the steel for the atrium using U-frame theory for the stability of the out-stand truss chords. As he says, "a common enough technique for bridge design then, but rarely used in buildings".

In 1983 he was back working on lightweight structures, this time on a real project, Michael Hopkins' research laboratory for Schlumberger in Cambridge, which was the first major use of PTFE-coated, woven glass fibre fabric in the UK. "That was very exciting; I wrote the program to calculate the cutting patterns."

It was a startling first three years of his career in hindsight. Are there the same opportunities for young people now? "That's difficult to answer," Carfrae says. "Arup was a smaller place and scale changes culture whether you like it or not. You could move about more freely, but we are by no means stolid now.

"But I was incredibly fortunate to be part of the first generation using computer design. I know we haven't fully explored its use yet, but there won't be the same vertical curve.

"That said, what is changing is that engineers are able to work faster. Ove Arup always said that if architects, engineers and builders could talk to each other more, there would be better buildings. The problem in the past has been that engineering calculations take a long time and we were out of the loop. Now we have become faster, we can get more involved."

By the mid-1980s, after working on buildings like Norman Foster's competition-winning design for a new BBC radio headquarters and Ropemaker Place in London ("not the current one, the one before," he says ruefully), Carfrae was ready for a big change.

"I wasn't enjoying London and suggested to my mentor Bob Emerson that perhaps I could go to Hong Kong. He laughed and said 'if you


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don't like London you won't like Hong Kong, but how about Sydney?'"

Carfrae grabbed the opportunity. "Almost as soon as I landed, Arup won Sydney Football Stadium with architect Philip Cox and they needed me to sort out the roof, so I was given a fantastic project on a plate.

"That's the advantage of moving place; you don't have a whole history burdening you. People thought I was more experienced than I was and I took the chance offered."

During that initial year in Australia, he met his wife Jane; they then married back in England. And it was back in the UK that Carfrae joined Peter Rice for three years.

"Was that my most formative experience?" he wonders. "Certainly Peter worked better with young people, people with free ideas. Some people say all the ideas had to be Peter's, but that's not true; he just always made the final decision. I certainly never felt constrained."

When the Carfrae's first child arrived, they decided to go back to Australia to be close to Jane's parents. "That was the early 90s and it was a tough time economically. I was asked if I minded stopping off in Japan for six months on the way to help build the Arup business. There was no office, I was out pounding the streets, but Peter Rice did come out a lot as he was working on Kansai airport."

From 1991, Carfrae was almost permanently in Australia and rekindled contact with Philip Cox, who was to become a close friend as well as a regular client and collaborator.

"My most formative job in Australia was the Brisbane Convention and Exhibition Centre," Carfrae says. "It introduced me to the way construction is done. A lot of major public jobs are tendered for design and construct, so the biggest and most reputable contractors all compete and their reputation depends on them doing a good job. They get their architects and engineers involved right from the start and it's all about speed, efficiency and cost control.

"For Brisbane we decided to do a hyperbolic paraboloid steel shell and I committed to using only 50kg/m^2 of steel.

"I've had luck all my life and here is where I understood that. I had specified T50 steel reinforcement to economically increase the tensile capacity of some steel tubes. But then I was told they didn't make those in Australia. They used Ys and at 40mm maximum. Before I had time to say anything to the contractor, he had called to say he'd found a stockpile of T50s that he'd bought cheap and he wanted to use. So I was seen as supremely clever."

After that introduction, Carfrae took Australia to his heart. His one big regret is that the Arup team didn't get to design the Sydney Olympic Stadium for the 2000 Games.

He came back to the UK in 1998 for a two-year interlude to help run Arup's architectural practice, Arup Associates, and some of the regrets about the Sydney stadium disappeared. "Arup Associates had just won the Manchester Commonwealth Games stadium and the roof was mine."

"Working with Arup Associates changed my approach to design," Carfrae says. "I was interested in what all the different engineers in the team did. I moved from being a technical structural engineer to an integrator, picking up expertise from all of them."

Back home in Sydney, Khalifa International Stadium, in Doha, Qatar, for the 2006 Asian Games was soon on the books and then it was on to the heights of Beijing and groundbreaking projects like the Helix Bridge and AAMI Park Stadium. Such success could not be ignored in the UK for long.

In 2007 Carfrae was promoted to be global leader of the building sector/practice and in 2011 he came back to the UK to be at the centre of the Arup business.


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"I found that a difficult transition," Carfrae says. "I hadn't realised how much a part of the Sydney industry I had become. In London I had 2500 people working with me but I was unknown to them and think I was slightly unwelcome.

"Three years on, it's becoming good and now I am deputy chairman I am out of people's everyday hair."

The developing relationship with Thomas Heatherwick has been a particular pleasure for Carfrae. "I saw his work on the British pavilion at the Shanghai Expo [in 2000] – the best space that I have ever been in – and wanted to work with him after that. The bridge is going to be the most beautiful environment. I'm working with Mike Glover, another Gold Medal winner, and the only niggle is that Thomas came up with the structural layout before we were involved, which is slightly frustrating," he says, smiling.

Carfrae will ultimately probably return to Australia, but has at least 10 years in which to make even more of a mark at Arup. "What do I want to achieve? I want to spend half my time on projects with clients to demonstrate that though we are a very large firm, Arup can still be led by people practising professionally.

"Australia taught me to be leaner, so I'd expect to see us building with less resources – buildings should consume less materials, energy, time and money while also being beautiful and genuinely useful for society.

"I am intrigued by the mechanisation of the industry too. Now we can represent accurately every element of the end product we will effectively be manufacturing. So will builders become manufacturers or will manufacturers become builders? And if we will be employing less of the 'wet' trades, how will that affect the economy, education and training?

"And I am fascinated by the potential of timber. The more timber we put in buildings the more carbon dioxide we lock up. Construction is the only place to put it that will lock it away for 50–100 years.

"Our focus as an industry and a profession could change to being carbon positive! The potential is enormous."

Tristram Carfrae: a career in 10 projects

1. Garden Bridge, London
– with Thomas Heatherwick (unbuilt)
360m long public garden spanning the River Thames supported by a cupronickel 'boat'.

2. 111 Eagle Street, Brisbane
– with Philip Cox (2012)
Computer-generated, organic structural frame working in harmony with a high-performance fully glazed façade.

3. AAMI Park Stadium, Melbourne
– with Philip Cox (2010)
Cantilever steel-shell roof using both local and global curvature to produce a single-skin structure that appears impossibly light.

4. Helix Bridge, Marina Bay, Singapore
– with Philip Cox (2010)
The helical formation appears, like a spring, to be incapable of carrying a substantial load. But a clever arrangement of delicate interconnections causes the two opposing springs to act together as a tubular truss.

5. Beijing National Aquatic Centre
– with PTW and CCDI (2008)
Design for 2008 Olympic Games based on the natural formation of soap bubbles and winner of the Royal Academy of Engineering's MacRobert Award – the highest accolade in British engineering.

6. Khalifa International Stadium, Doha, Qatar
– with Philip Cox (2006)
Very delicate membrane fabric roof, conversion from 20 000 to 50 000 seats for 2006 Asian Games.

7. City of Manchester Stadium
– with Arup Associates (2002)
Roof of box beams hung from a three-dimensional prestressed cable net.

8. Brisbane Convention and Exhibition Centre
– with Philip Cox (1995)
Hyperbolic paraboloid steel-shell roof using double curvature to carry loads both in compression and tension with inherent stability.

9. Pavilion of the Future, Seville Expo
– with David Mackay (1992)
250m long, 40m tall, load-bearing granite-arched façade stabilised by an arrangement of prestressed steel rods.

10. Schlumberger research laboratory, Cambridge
– with Michael Hopkins (1985)
First major use of PTFE-coated, woven glass fibre fabric in the UK.