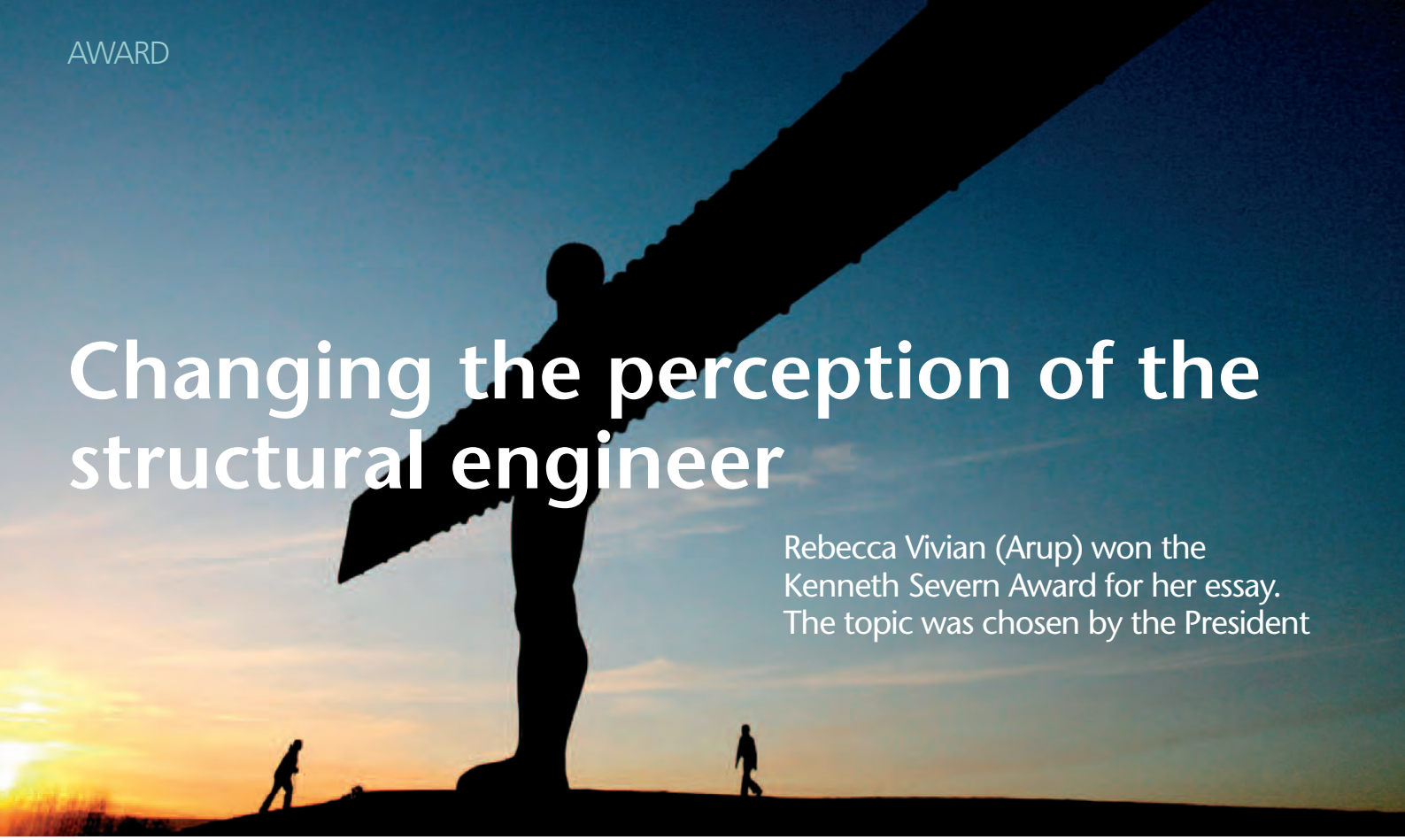
Changing the perception of the structural engineer

Rebecca Vivian (Arup) won the Kenneth Severn Award for her essay. The topic was chosen by the President



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'The natural world is full of examples of structure and design which have influenced the development of structural engineering; however while nature and evolution's role is 'unseen', so is the role of structural engineers in shaping the modern world' – IStructE

Evolution over time happens so slowly that changes are often imperceptible. The subtle lessons that nature has to offer seem to go unnoticed, so much so, in fact, that we are forgetting to use these in modern-day constructions as new ideas with regards to architecture, design and the urban condition absorb us.

Perhaps, then, one might consider the above statement in another sense – people living within modern societies are forgetting to 'see' nature as technological advances have created a world with an abundance of man-made images and distractions.

Seeing nature

'If you will cling to nature, to the simple in nature, to the little things that hardly anyone sees, and that can become so unexpectedly big, and beyond measuring.' – Rainer Maria Rilke

Nature is a fine example of a 'pure structure', a structure that has reached perfection through adaptation in response to context. Think of a tree and its leaves (Fig 2), or a mountainous landscape and its strata.

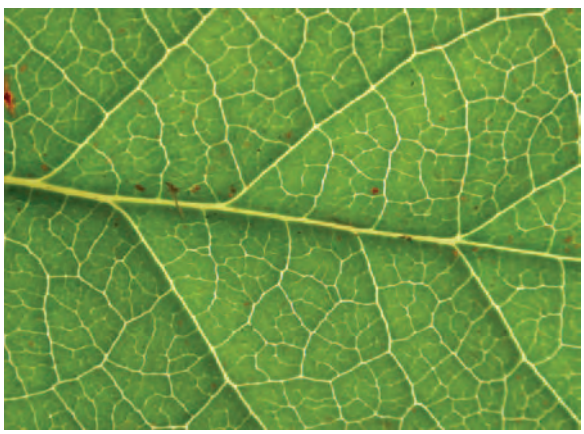

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Fig 1. The Angel of the North; structure creates sculpture *(Photo: Owen Humphries/PA Wire)* / Fig 2. A leaf is a natural example of pure structure evolved for purpose (*Photo: www.imageafter.com*) / Fig 3. The perhaps clumsy engineering remains hidden behind the socially pleasing façade, almost like the scaffolding behind a stage set as is shown in these images; front (© *Vlastimil Juricek*), back (© *Jeremiah Wilson*)

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Function and form are perfectly balanced, nothing is superfluous or without reason. And in their honest, visibly authentic design lies their beauty.

If we are to follow nature's example, a truly successful design would be a result of well considered integration of architecture and engineering. One could then look at its form and generally understand how it worked, and there would be a transparency in the design allowing the structure to be expressed.

This is generally not the case for many modern-day buildings where the structure supporting the architect's aspirations is often a separate entity; the perhaps clumsy engineering remains hidden behind the socially pleasing façade, almost like the scaffolding behind a stage set (Fig 3). In the context of a society fascinated with celebrity and surface image, there is little hope for engineers to be recognised for their work. But in fact there have been many times that engineers have been acknowledged for their contribution to society.

'The real thing remains hidden, no one ever gets to see it.' – Peter Zumthor

Great engineers

If we were to try to compile a list of famous structural engineers, perhaps we could think of a handful of names from the 1800s to present day: Thomas Telford, Isambard Kingdom Brunel, Gustave Eiffel, Sir Benjamin Baker, Felix Candela, Sir Ove Arup, Eladio Dieste, Santiago Calatrava, Peter Rice. So already, we see that there have been, and are currently, some influential people in the structural engineering world. These individuals are triumphant innovators, taking advantage of new materials to exploit existing typologies or creating new forms, pushing technology of the time to the limit.

The Industrial Revolution brought with it the introduction of steel, iron and the need for transportation which created a prime opportunity for many British engineers to influence the infrastructure of the country (Figs 4, 5). The results are still witnessed today with the numerous structures built during this period remaining in the UK.

One could claim that this was structural engineering in its prime, performing to meet the demands of a changing society with new and innovative designs which have now become famous and well loved landmarks. One could say that it was the era of the engineer.

An example, where a key development of this is evident is train stations. Here we see pioneering design from the engineer with the long-span trusses creating a canopy above the concourse – a structure easily read and understood by the users (Fig 6). There is a clear difference in design approach of the architect, however, favouring a conservative neo-classical style for the main building. Although the building still functions to its client's brief, the obvious difference in design aspirations suggests little or no language between the parties involved – accomplished integration, however, is a key issue when considering the success of a building, reflecting our lessons learned from nature.

Total design

With the apparent schism within design of buildings, perhaps we would benefit from looking at nature and buildings whose design occurs more naturally in response to cultural and environmental requirements.

'Folk building growing in response to actual needs, fitted into environment by people who knew no better than to fit them with native feeling' – Frank Lloyd Wright

Vernacular architecture is a term used to categorise methods of construction which use locally available resources to meet specific

Fig 4. Clifton Suspension bridge, Bristol: structural engineering in its prime / Fig 5. Close up of bridge (© *Martin Turner*) / Fig 6. The schism between the engineer's and the architect's approach to design is apparent (*Photo: Natisha Joshi*)

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needs, economies and ways of life of the cultures that produce them. This type of architecture tends to evolve over time to reflect the environmental, cultural and historical context in which it exists. The examples above show unity in the structure and overall enclosure of the building.

An igloo (Fig 7) or a mud hut (Fig 8), or yurt (Fig 9) are fine examples of 'pure' structure where materials are sustainably sourced, with a small group of people responsible for the design and construction of the overall form, which is to become their home. Function and form are perfectly balanced, nothing is superfluous or without reason – nature's lesson to us. Although simple and primitive in form, we can take inspiration from this type of collective design where the building form evolves through trial and error and there is neither an architect, nor an engineer, simply the 'master builder'.

The idea of a master builder – a creative mind which takes responsibility for both the design of the architecture and its engineering – is not new. The ancient Romans were celebrated builders who pioneered the brick arch. Eladio Dieste and his Gaussian vault (a thin-shell structure for roofs in single thickness brick that derives its stiffness and strength from a double curvature catenary arch form that resists buckling failure), serves as another fine example. With regards to structure Dieste stated:

The resistant virtues of the structure that we make depend on their form; it is through their form that they are stable and not because of an awkward accumulation of materials. There is nothing more noble and elegant from an intellectual viewpoint than this; resistance through form.'

Dieste radiates an energy of innovation and desire to create beautiful, true structures, which are recognised for their obvious qualities (Fig 10). An advantage in Dieste's type of design was that he was an architect and an engineer in education, and so concept and structural design was completed by one mind, with an aesthetic vision and structural understanding.

Felix Candela, who was also both an architect and structural engineer, played a significant role in the development of Mexican architecture from the 1930s to 1960s; his major contribution to structural engineering was the development of thin reinforced concrete shells. Candela worked very hard in his lifetime to demonstrate the real nature and potential of reinforced concrete in structural engineering, proving its efficiency in a dome or shell-like shape.

Candela believed that strength should come from form, not mass and saw

'architects as engineers who possess the ability to design both great cathedrals and low cost housing'.

It was through Candela's interest in geometrical forms (Fig 11) and mathematical experiments that he influenced his contemporaries and generated a new interest in engineering amongst the public users of his iconic buildings, including many chapels, laboratories and public buildings.

These projects promote a language of 'total design' in which one clear concept is witnessed and where there is a transparency in the design which allows the structure to be expressed.

Take some modern day forms such as a timber grid-shell or steel diagrid and we begin to see similarities to natural design. Here the structure becomes part of the overall façade to demonstrate a clear connection of unity between the architecture and structure. Buro Happold has been commended for its contribution to the Weald and Downland Gridshell near Chichester (Fig 12), and has continued to create similar forms elsewhere in the UK such as Savill Gardens, Windsor.

London's Millennium Bridge and the Swiss-Ré building are also fine examples of this principle. Here, architect and engineer have worked successfully together to achieve the same ends, to great public recognition.

Realisation

When considering how structural engineers may be recognised for their role in design today, I feel that there are four key issues:

- change society's fascination with cosmetic appearance and begin to 'see' nature again;
- further research and experiments into new materials or structural systems;
- encouragement from UK planning bodies in new forms to be created in this country;
- the fundamental education of both engi neers and architects.

Examples of a 'pure' structure: Fig 7. The igloo (© *Alex Mather*) / Fig 8. The mud hut (© *Harold Churchill*) / Fig 9. The yurt *(© Zoe Chafe*)

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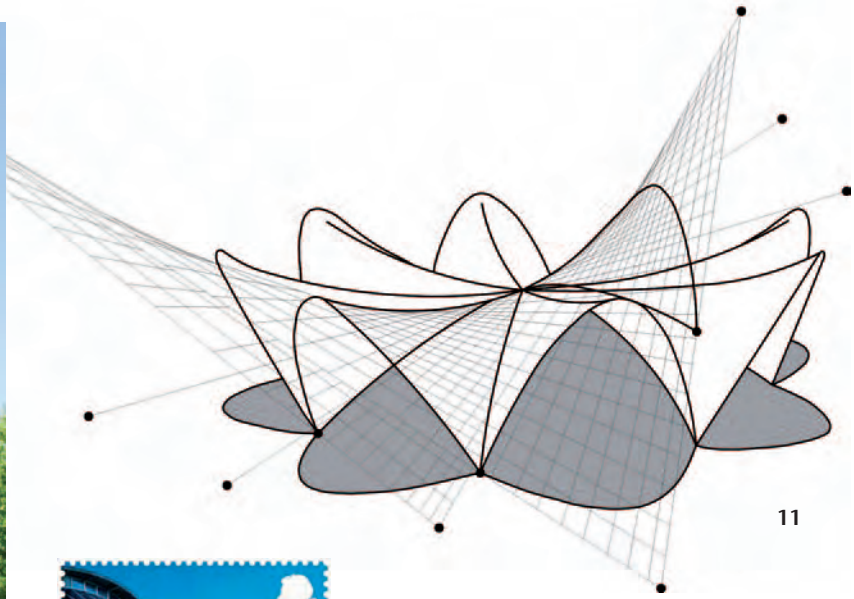

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All a façade

Contrary to the development that occurred during the Industrial Revolution, we might say that perhaps it is now architects who are pushing the formal boundaries of design and it is traditional structural engineering practices that are struggling to be relevant as new irregular and futuristic forms challenge our traditional technique of beam, column and arch construction. The architecture that I am particularly talking about is that of heroic architects; grand or ambitious in scale or planning, where individual architects make history with their buildings.

Many architects today are responding to the 21st Century and society's fascination with surface appeal. Perhaps with the perceived demand for more and more iconic buildings, architects are becoming more interested in the façade and form; the exterior of the building is clearly the highlight, and the fact that it is say, an art gallery, museum or cultural centre is often secondary. The façade in this case being the principal aspect, the structure remains hidden, almost like the scaffolding of a stage set. Thinking back to the initial argument, when forms are complete such as the leaf, the structure itself is a major part of the overall object; it is simple, beautiful, expressed and can be understood.

Anthony Gormley's sculpture, the Angel of the North (Fig 1) is a striking example of how bold structural connections can be elegant. I feel that the appropriate step is to push structural engineering to respond to these desires of the architect, yet also remind them of the natural examples of evolution all around us. We must both respond to each other.

A country of triumphant pioneers?

When we do think of the adventurous and exciting buildings of today, such as those by Santiago Calatrava, Frank Gehry, or Zaha Hadid the majority occur abroad and not in the UK. In fact, they have had few, if any, buildings constructed in the UK to date. Perhaps a fault of this country is the fact that development of structural engineering for advanced forms is not readily welcomed by the planning system.

And if we look at the buildings that have allowed structural engineers to be recognised, such as Sir Ove Arup and the Sydney Opera House, Australia, they have most likely gone over budget, which at the time created public outrage, but later those issues are forgotten and the final product is marvelled at, and in fact raises the profile of the city or country.

Due to the desire for development in China, the Beijing Olympics is showcasing a number of courageous and interesting structures, requiring the latest technology to make these forms stand up. This symbolises the current stage of development of China, similar to our Industrial Revolution.

Decisions on some of the buildings for the London 2012 Olympics tell a different story, however, for example using safe and reliable, established practices for the architecture of the arena.

If we wish to continue to promote ourselves as a respectable, exciting and vital industry in the world, we must gain the confidence of the public around us in our creation of inspiring structures.

The root of the problem

The real argument and long-term answer, however, surely comes down to education. From the discussion above, we can see that structural engineering is recognised by most when the engineer has a real understanding of either what the project architect wishes to achieve, or is in fact both the designer and the engineer. In both cases they show a desire to please themselves and the public by creating a 'pure' form, where the materials act to their best ability, creating a unified, economic and balanced structure.

This education needs to come from both sides – the architect must understand the capability of materials and simple physics; the engineer must have an appreciation for architecture, its history, and the cultural context to which the architecture responds. Far too many students focus on complex analysis methods and have a tunnel vision view of their role in society. They need to have their eyes opened to the overall picture that they are trying to create. Yes, a lot of knowledge and understanding of forms comes through experience but giving a basic education at the start of their career is essential. Then, hopefully, engineers and architects can work closely together and create great buildings like the inspiring multi-talented individuals mentioned above. And the public view of engineers will change from the grey-clothed, spectacle wearing mathematician, to the creative and adventurous individuals we are. se

Fig 10. Dieste's Atlantida Church, 1960 (© *Hugh Fraser*) / Fig 11. Candela geometry image (*Courtesy Ian Hazard*) / Fig 12. The Downland Gridshell featured on a postage stamp (© *Royal Mail*)