Elegant structures

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Synopsis

Good structures are an important part of our quality of life. They contribute to what in German is called *Baukultur* – the culture of building. It is the responsibility of structural and civil engineers to furnish buildings and our built technical infrastructure – bridges, towers, roofs – with good (i.e. high-quality) structures to make a positive contribution to the culture of building and to satisfy ourselves.

In this article, adapted from a keynote lecture at the IABSE 2015 Conference in Nara, Japan, The Institution of Structural Engineers' 2015 Gold Medallist, Mike Schlaich, explores the idea of 'elegant structures' and asks whether elegance is an ingredient of a high-quality structure.

Introduction

Not much has been written about elegant structures and one might think that this is because elegance is not an issue to be concerned with when engineering structures. Once we identify elegance as a part of beauty, we arrive in the field of aesthetics, i.e. how matters move our senses, and the aesthetic quality of our structures is clearly of importance.

The intent of this paper is the – admittedly personal – definition of structural elegance, to show that it is clearly an ingredient of good structures and to demonstrate what we engineers must do to achieve them.

What is elegance?

Like many other terms, 'elegance' has changed its meaning over time. The word stems from the Latin verb *eligere* (select), which later appeared in the French noun *élégance*. We use it today when we want to describe something of selected beauty. It is more than beauty only. Although subjective, we relate elegance to:

- beauty plus selected taste, like a stylish fashion model or a famous actress
- beauty plus lightness, transparency and movement, like a graceful ballet dancer
- beauty plus streamlined shapes, like a noble sports car
- beauty in the sense of sensual purism, of being reduced to the bare minimum, like a black-and-white nude photograph

Very importantly, elegance appears effortless[1]. We find that something is elegant when we feel, but do not see, all the work that was needed to achieve it. Sometimes superficial luxury is mistaken for elegance. Then the word loses its allure; consumerism has had its day.

Following the definitions given here, are the actresses shown in Figures 1 and 2 beautiful? Are both elegant? Looking at furniture, the Lounge Chair by Ray and Charles Eames (Figure 3) is most beautiful (and very comfortable), but many would agree that the Barcelona Chair by Ludwig Mies van der Rohe (Figure 4) is more elegant.

I am sure that aesthetics are looked at quite differently in different cultures. What does elegance mean in different languages, how is it translated? I am told that in Japanese and Chinese the word for elegance is the same: 優雅 . It is just pronounced differently: 'yuga' in Japanese; 'you ya' in Chinese. In Arabic it is completely different: أناقــة ('anaka'). Does this affect the way we define and design elegant structures? Such thoughts require further and deeper analysis than is possible here.

Is elegance desirable?

What are the ideals of good structures? When we study landmark structures, we find that

Figure 1
Marilyn Monroe

ALAMY

Figure 2
Audrey Hepburn

ALAMY

Figure 3
Lounge Chair by Ray and Charles Eames

Figure 4
Barcelona Chair by Ludwig Mies van der Rohe

engineers and architects try to follow similar principles.

The Roman architect Vitruvius, perhaps the most cited writer in this context and certainly one of the first to write about structural design, coined the terms *firmitas*, *utilitas* and *venustas* as the fundamentals of good structures as early as 25BC. Firstly, they must stand up (*firmitas*); secondly, they must be useful in the sense of durability and robustness (*utilitas*); and, finally, they should be pleasing (*venustas*)[2].

Volkwin Marg, a contemporary German architect, defines the culture of building as the synthesis of two sides of a coin – technology and art – which, he says, can only be achieved when architects and engineers creatively work together. He reaches back to the Platonic triad: truth, goodness and beauty. Intellectual truthfulness where structure and form coincide; goodness in the sense of our buildings' contribution to society and its individuals; and, finally, beauty in the aesthetic sense which starts to shine when goodness and truthfulness are successfully combined[3].

In the context of this article, lightweight structures seem especially interesting and the German engineer Jörg Schlaich identifies them as ecological (green), social and cultural. They are green in the true sense of sustainability, as they minimise the use of our resources and they are easy to assemble and to recycle. They are social because they require the employment of a proportionally high number of skilled designers and well-trained workers. Finally, they "can make a significant contribution to enrich the architectural spectrum". Refined lightness triggers positive emotions and we like the beauty of lightweight structures because we understand them, as nothing is hiding the flow of the forces. They are an "integral part of the culture of building"[4].

In the 1980s, David Billington, an American engineer, coined the term 'structural art' – the art of structural engineering parallel to architectural art. He defines the ideals of structural art as efficiency, economy and elegance. He notes that engineers are not scientists, as they invent rather than discover. They invent good bridges, towers, long-span roofs and high-rise buildings by successfully combining minimised use of materials at minimal cost with conscious aesthetic decisions[5].

The Japanese architect, Tadao Ando, does not list a triad when he writes about elegance and the aesthetics of simplicity as part of the Japanese way of life. According to Ando, 'Wabi-Sabi' – modest and weathered – inspires elegance in architecture by minimising and minimising again until only utility and beauty are left. The Wabi-Sabi house is the result of "modest living, learning, being pleased with a life that does without anything superfluous and living in the moment"[6].

Looking only at the few writers cited here, it is interesting to note that only one of them, the engineer Billington, uses the term elegance. What is surprising at first is also that sustainability is not explicitly mentioned. However, once we look closer, we detect that sustainable building, i.e. resource efficiency and environmental responsibility throughout the lifecycle of a structure, is an inherent feature of the principles set out here.

"It is important to create public awareness about good design of structures"

Engineers, architects and sculptors all create three-dimensional structures and, therefore, they have to follow these principles alike. The difference between them is the importance they give to each of the principles. Of course, the sculptor also has to make sure their work stands up, but no code requires a 100-year design life for the work. The sculptor can concentrate on moving the senses.

The prototype of the architect's building is the one-family house and there *firmitas* is usually easy to achieve. Social issues become more important. Volkwin Marg calls architecture a "dance in chains" because so many boundary conditions make 'dancing' much more difficult than it is for the artist, the sculptor who can freely choose which way to go.

For us engineers this is even more the case. Numerous restrictions by codes and standards provide us with the excuse to give up dancing all together, to only follow some of the principles that define a good structure. We seem to be so absorbed by dealing with the chains, by arranging them, by making them bearable and by trying not to break them, that we forget that, yes, dancing is still possible, that it is actually a must, a responsibility. If we learn how to dance in chains, there is a good chance that elegance will result. If we approach our work holistically, we will be rewarded with good structures that contribute to the culture of building.

The principles of good structures (Figure 5) all include elements of beauty and elegance and clearly show that we may not work without bearing them in mind. There is evidence for this. In all fields of engineering and architecture, elegant structures have appeared and we see and feel that elegance

Figure 5
Principles of good structures

Figure 7
F. Candela, Bacardi factory, Mexico

Figure 6
L. Mies van der Rohe, Farnsworth House, USA

does not appear alone, but rather in a package with the other principals.

Figures 6–9 present four examples of elegant structures: a house, a roof, a tower and a bridge. The books cited in the reference list show numerous other examples, but by their nature they can only show static images. We are conditioned by the media we have at hand. However, the new trend of electronic books also makes it possible to show the elegance of movable structures[7]. Will this affect the way we design?

How do we achieve elegance?

When our structures have a holistic quality, they can also become elegant. The direction we follow to achieve this, what we call the ideals and principles we want to follow does not really matter. We can follow any of the directions described here. We do not have to become dogmatic in our efforts to design good structures.

What is important, however, is that in addition to the principles we understand the design of a structure as a conscious act, an act of conceiving the solution by carefully considering the local context, the boundary conditions to our design, which can be of a topographical-physical, technical-fabricational or politico-cultural nature.

It is interesting to note that good structures often show a readable flow of forces, perhaps because they are easy to understand and because we like what we understand. Elegant structures are often lightweight structures.

It is important to create public awareness about good design of structures and there is still much to be done in this area:

- **Competitions:** design competitions for buildings should ask for teams that include engineers and there should be more design competitions for our infrastructure, especially for bridges
- **Advisory boards:** in many cities around the globe there are advisory boards which help politicians make the right decisions about new buildings. These should include engineers
- **Discussions and guidelines:** architects criticise and discuss each other's work much more than engineers do. In the community of engineers we need more discussions about the design quality of our work. The results of such an exchange could be helpful guidelines and state-of-the-art reports on good design
- **Education:** perhaps most important of all are our students. Conceptual and structural design can be taught at university level. Ten years ago 'Conceptual and Structural

Figure 8
V. Shukhov, Shabolovka Tower, Russia

Figure 9
R. Maillart, Salginatobel Bridge, Switzerland

Design' was introduced to the curriculum of the engineers at the Berlin Institute of Technology[8] and the author can confirm that it is a successful concept. In Berlin, however, at present only one-third of civil engineering students are female and none of the professors, which is certainly not enough. The author is convinced that we will see more elegant structures when these numbers increase

Conceptual and structural design of structures is a creative act based on sound theoretical knowledge and the principles described here. If the result appears to have been reached effortlessly, we have achieved an elegant structure. This is not easy to do and it requires experience. Many of the great engineers achieved their greatest successes only when they were between 40 and 60 years old. There is still hope for many of us.

Summary

In addition to *firmitas* and *utilitas*, structures need to be beautiful to become holistically good, to become a *Gesamtkunstwerk*. Good structures stimulate good life, they can add to our quality of life.

Elegance appears when the challenging task of fusing the principles of good structures seems to be achieved without much effort. If the response to a challenge appears effortless, elegance has appeared. A good life is not easy, it is a challenge, but we want to live it elegantly. My claim here is that elegant structures stimulate elegant life.

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To find out more about The Institution of Structural Engineers' Gold Medal – including 2015 winner Mike Schlaich – visit www.istructe.org/gold-medal-address

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