

“Educating Engineers to Create Good-looking Bridges” by Paul Gauvreau

Published in *Structural Engineering International (SEI)* vol. 26(3):198–206.

Discussion on paper

Ignacio Paya-Zaforteza, Associate Professor. Dr., Universitat Politècnica de València, Spain. Contact: igpaza@cst.upv.es

DOI: 10.2749/101686616X1461

Prof. Gauvreau has written a very interesting article on how to enhance the engineering curriculum to teach engineers how to create good looking bridges. He believes changes in the curriculum should focus on improving the visual characteristics of practical bridges (i.e. bridges for which no funds have been allocated additional to what is required to perform their required practical function) and that the key to success lies in increasing the capacity of engineers to design bridges that embody new ideas that create economic value.

I must say I share many of Prof. Gauvreau's ideas, but I also think that the curriculum needs a lot of radical changes to give structural engineering students a much broader view of the subject. As Billington [1] stated years ago, our structures are multidimensional as they have a scientific dimension (related to their efficiency), a social dimension (related to their cost) and a symbolic dimension (related to their elegance). The structures also have a value (see e.g. Duguid [2] and Paya-Zaforteza [3]) and this value is not only financial but also symbolic. Few structures can be found to match the value of the Golden Gate Bridge. This structure has an economic value due to the service it provides, the collected tolls, the operating and maintenance costs and other concepts, but it also has an incalculable symbolic value. Is there any way to measure what the Golden Gate represents for the city of San Francisco and even for mankind as a whole? The Golden Gate has become a collective icon, and, in fact, has often been the objective of attacks or destroyed in the movies (see e.g. “It came from beneath the sea” (1955), “X-Men: the last stand” (2006), “Pacific rim” (2013) or “Godzilla” (2014) to name a few), because destroying this bridge is like destroying a very important part of

civilization. Innovation is another factor that should also be considered. Innovative bridges, such as those that introduce new construction materials or new design concepts, can be more expensive than traditional designs. However, after a detailed study, they can be worth building because they can create value and contribute to advances in construction techniques, especially if we take into account that what is expensive today, can be much cheaper in the future if we face the challenge of building it. Finally, the life cycle of our structures, and therefore their maintenance and demolition stages, should be considered in addition to their planning and construction.

Therefore, any attempt to improve engineers' education needs to take into account the multidimensional character of our structures. Teaching the ideals of structural art (economy, efficiency and elegance) combined with the concepts of value, innovation, and life cycle, provides an excellent way of doing this and does not require a large amount of time: one or two hours can be enough to teach the basics. Of course, the more time spent on this the better, and examples exist of very successful courses combining structural art, construction history, structural analyses and field trips (see e.g. Glisic *et al.* [4], Paya-Zaforteza and Lázaro-Fernández [5], Paya-Zaforteza *et al.* [6] and the websites about F. Khan [7], German shells [8] and Spanish bridges [9]). Field trips are especially important and have an extraordinary value: they provide a unique opportunity to “feel” the structures with all our senses, to meet bridge designers and to have discussions that give students a unique opportunity to practice their communication skills and become passionate about structural engineering.

I also think that some of Prof. Gauvreau's ideas need wider discussion. In

my opinion, the distinction between premium and practical bridges should not be too strict or be based on the money spent on aesthetic aspects, but on whether this extra cost is justified. In this respect, I agree with Sobrino [10], who has pointed out that “a rational increase of cost to select a visually attractive bridge is always justified and it is unnecessary to rigidly fix this increase. Instead, the consideration should be grounded in the ethical and specific circumstances of the project”.

Secondly, I do not think that the teaching effort should focus exclusively on practical bridges or that premium bridges should be left out of the engineering curriculum. My view is that premium bridges also deserve attention, as they provide unique opportunities to explore different solutions and conduct “compare and contrast” activities that help to develop critical thinking (see e.g. Huynh and Paya-Zaforteza [11], Garlock [12], and Paya-Zaforteza [3] for some examples). These can be very powerful “alarm clocks” for our students. Prof. Maria Garlock and I carried out an interesting experiment that showed the value of premium bridges as learning tools. In the 2015 edition of the “Structures and the Urban Environment” course taken by both engineering and liberal-arts students at Princeton University, we showed them two pictures of bridges built at the same time in Seville (Spain) and having a similar context: the Alamillo Bridge and the Barqueta Bridge. We asked the students which they preferred and the vast majority chose the Alamillo. We then told them how much each had cost (Alamillo \$19,800 per m² and Barqueta \$2,400 per m² in 2012 prices according to [12]). We then repeated the same question asking the students to consider the cost of the bridges to

the citizens and most of them changed their preference to the cheaper Barqueta Bridge!

Thirdly Prof. Gauvreau advises teachers “not to refer to the great works of bridge engineering as structural art” because “encouraging future bridge designers to think of themselves as artists increases the likelihood of shifting the focus too much towards purely aesthetic concerns, which in turn can lead to the transformation of practical bridges into premium bridges”. However, this is not correct; the tradition of structural art is a tradition of balance between economy, efficiency and aesthetics. There is therefore little risk in using the term *structural art* if the topic is properly presented. In fact, a recent study by Hu *et al.*[13] has shown how the recognition of the ideas of structural art with the help of education and certain practices can instill aesthetic motivation and improve future designs. In my experience, students trained in the ideas of structural art develop a broader view of what engineering is and can bring this view with them wherever they work. It is not about becoming the next Robert Maillart, Eduardo Torroja or Christian Menn, it is about recognizing and developing creativity, about being a sensitive engineer regardless of the scale of the work and the working position and it is also about developing a passion for the engineering profession. This is especially important, since these sensitive and passionate students may later be in the position of taking important decisions as designers, contractors or civil servants. In this regard, I think that:

(a) teaching structural art is completely in agreement with the important ideas mentioned by Prof. Gauvreau in the conclusions of his paper, and (b) this topic should be present in all civil engineering curricula. In any case, the ideas of structural art should not be taught as a dogma, and students should be encouraged not only to criticize bridges according to the ideas of structural art, but also to question structural art as a framework to criticize.

To sum up, I think that the focus should not be on educating engineers to produce good-looking bridges, but on educating to create structures of outstanding quality, where the term “quality” includes many factors. This requires an education that embraces all the dimensions of the structure, as well as the ideas of value, innovation and life-cycle. The task is not easy, but some success has already been achieved in the form of new paths for the education of the engineer.

References

- [1] Billington DP. *The Tower and the Bridge* Basic Books: New York, 1983.
- [2] Duguid B. Benchmarking cost and value of landmark footbridges. Proceedings of the 4th International Conference Footbridge, Wroclaw, Poland, 2011.
- [3] Paya-Zaforteza I. *On the development of structural criticism through case studies. In Large structures and infrastructures for environmentally constrained and urbanised areas.* IABSE (International Association for Bridge and Structural Engineering): Zurich, 2010; 192–3.
- [4] Glisic B, Garlock M, Adriaenssens S. Innovative education in engineering: a social and

multi-dimensional exploration of structures. In Proc. of the ASCE Structures Congress: ASCE, Boston, April, 2014.

- [5] Payá-Zaforteza, I., Lázaro-Fernández, C. Structural engineering is much more than formulas: Introducing a new course on philosophy of structures. In: *Engineering for Progress, Nature and People*, pp. 945-952, September 2014.
- [6] Payá-Zaforteza, I., Garlock, M.E.M., Adriaenssens, S., Glisic, B. “The art of Spanish bridge design”, a new course promoting the holistic learning of structural engineering. In: IABSE Conference, Geneva 2015: Structural Engineering: Providing Solutions to Global Challenges - Report, IABSE (International Association for Bridge and Structural Engineering), pp. 315-316, September 2015.
- [7] <http://khan.princeton.edu/>. Accessed on October 3, 2016
- [8] <http://shells.princeton.edu/>. Accessed on October 3, 2016
- [9] <http://spanishbridges.princeton.edu/>. Accessed on October 3, 2016
- [10] Sobrino J. A bridge is more than a bridge: aesthetics, cost and ethics in bridge design. *Structural Engineering International* 2013; 23(3): 340–345. <https://doi.org/10.2749/101686613X13627347099917>
- [11] Huynh T., Payá-Zaforteza, I. Thinking critically about structural engineering through role-playing games. In: IABSE Congress, Stockholm 2016: Challenges in Design and Construction of an Innovative and Sustainable Built Environment - Report, IABSE (International Association for Bridge and Structural Engineering), pp. 711-717, September 2015.
- [12] Garlock M. The Art of Structural Engineering. Bridges. Massive Open On-line Course developed at Princeton University. <https://www.edx.org/course/art-structural-engineering-bridges-princetonx-cee262-1x>. Accessed on October 3, 2016.
- [13] Hu N, Feng P, Dai G-L. Structural art: past, present and future. *Engineering Structures* 2014; 79: 407–16.

Reply to above Discussion

Paul Gauvreau, Dr.sc.techn., P.Eng., Prof., Department of Civil Engineering, University of Toronto. Contact: pg@ecf.utoronto.ca

I would like to thank Professor Paya-Zaforteza for his discussion. He has raised some excellent questions arising from several points I made in my article. I would also like to thank the editors of SEI for giving me the opportunity to respond to this discussion.

In my article, I put forth a case for focusing the curriculum on practical bridges, which I defined as works for which no funds were specifically allocated to create a visual impression,

over and above what was necessary to perform the practical function. Professor Paya-Zaforteza suggests that this focus is too narrow, since it does not account for what he calls the “multidimensional character” of bridges. He goes on to point out that limiting the focus to practical bridges will exclude some bridges that have taken on iconic status, such as his example of the Golden Gate Bridge, as well as bridges for which an increase in cost to create a specific visual impression

might have been justified because of the value that was created as a result. I was aware of all this when I made my original recommendation. As I stated in my article, focusing the curriculum on practical bridges makes sense for the following reasons:

1. The number of premium bridges built in a given year is currently negligible compared to the number of practical bridges. This situation is unlikely to change in the future.