INNOVATION AND AESTHETICS IN BRIDGE ENGINEERING

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Robert Maillart's Salginatobel Bridge, built in Switzerland in 1930, epitomizes a tradition of bridge design in which an efficient flow of forces, low construction cost, and rich aesthetic significance are embodied in a single structure. This bridge defies the commonly accepted belief that it is necessary to spend more money to make bridges elegant, i.e., that beauty is something that has to be added to a minimum-cost skeleton of functionality. Rather, in the design of this bridge, Maillart responded to the challenge of minimizing cost by creating an entirely new structural system, which created economic value far in excess of what would have been gained had he merely attempted to refine material quantities in a conventional structural system. This technical innovation in turn gave Maillart new opportunities for visual expression which he, as a gifted designer, used to create Salginatobel's bold visible form. In Maillart's bridges, therefore, technological innovation provides the crucial link between an economic imperative and aesthetic significance.

Salginatobel Bridge

Maillart is not the only engineer to have designed bridges that link economy and aesthetic significance through engineering innovation. He is part of what David P. Billington (2003) refers to as a "grand tradition" of structural design, which includes engineers such as Thomas Telford, Gustave Eiffel, and Othmar Ammann (Billington 1983). In the work of all of these engineers, we recognize bold, unique visible forms that were created under challenging economic conditions, and significant technological advances relative to their contemporaries. It is significant that all of the designers within this tradition are engineers, for if we accept that technological innovation is the link between the need to minimize cost and new opportunities for aesthetic expression, then it follows that only those people who understand the technical aspects of bridges can follow the creative process thus defined.

The visual impact of the Salginatobel Bridge is strong enough to ensure that the bridge's aesthetic significance would be broadly recognized, regardless of how much it cost. The fact that it would never have been built had it not been the lowest cost option, however, enriches its significance and transforms it from a merely beautiful bridge into a vivid symbol of the strength of the human creative spirit. The fact that

it was designed without any intervention from architects or other creative consultants makes it particularly relevant to all civil engineers.

Notwithstanding the compelling nature of Salginatobel, it is difficult to find its successors among bridges built in recent years. Although many bridges from the past decade have been recognized for particular aesthetic merit, they share little in common with the work of Maillart. In these bridges, instead of economy, we find extravagance. Instead of clean and efficient load paths, we find flows of forces that are indirect and inefficient. Instead of design leadership by engineers, we find architects playing key roles in defining the primary characteristics of the structural system.

The Esplanade Riel Bridge, completed in 2003 in Winnipeg, is an example of such a bridge. Given the presence of a restaurant housed in a semicircular platform at the tower, there is little doubt that the architect on the project, Gaboury Préfontaine Perry, would have played an important role in defining the main features of the bridge with engineer Wardrop Associates. The inclined tower, which is arguably the most distinctive visible feature of the structure, must resist significant bending moments under dead load. This indirect load path required reinforcement that was significantly greater than what would have been needed had the tower been plumb and concentric with the girder.

Esplanade Riel Bridge, Winnipeg (Source: City of Winnipeg)

The bridge cost 21.5 million dollars to build (Welch 2003), which corresponds to approximately $12,000 per square metre of deck. In comparison, a vehicular bridge (the piers of which are visible in the figure) built adjacent to the Esplanade Riel Bridge and completed in 2002 cost approximately $5500 per square metre (O'Brien 2001). Assuming that a pedestrian bridge could have been built at a similar unit cost, the premium that was paid for the Esplanade Riel Bridge compared to a low cost option was approximately 12 million dollars. On this basis, we can reasonably conclude that the design of the Esplanade Riel Bridge was not significantly influenced by the discipline of economy.

For these reasons, therefore, it can be stated that the Esplanade Riel Bridge stands outside of the tradition defined by the Salginatobel Bridge. Most of the so-called "signature" bridges that have been built in recent years, examples of which include London's Millennium Bridge (Dallard 2001) and the Sundial Bridge in California (Brown 2004), likewise stand outside this tradition.

Should we be concerned? None of these bridges could be called a bad bridge. The Esplanade Riel Bridge, for example, is apparently performing its function well and can reasonably be expected to do so for its entire design life. By all accounts, it is well liked by the people of Winnipeg.

What causes concern is not so much the individual bridges, but rather the perspective on bridge design that underlies them, which holds that minimum cost structures cannot be aesthetically significant. If this is true, then aesthetic quality is something that must added to minimum cost structures, and hence will add cost. From a philosophical point of view, this proposition is simply incorrect. The bridges of Maillart provide the definitive counterexample.

From a more pragmatic perspective, it is evident that the conventional wisdom on aesthetics can result in very expensive bridges. This is especially true when the primary means to create visual impact is to arrange structural members so as to produce indirect flows of forces, as was the case in the Esplanade Riel Bridge. When structural systems are determined on the basis of preconceived notions of what will look good, the effect on cost can be significant. When the premium that is paid to create a specific aesthetic statement is in the tens of millions of dollars, one is certainly justified in questioning what was gained for the money spent.

It is difficult to find new opportunities for artistic expression within the discipline of economy when there is no evolution of the underlying technology. The profession has struggled with attempts to improve the aesthetic quality of well established structural systems, with little success. Precast concrete I-girders, for example, are often a cost-effective choice for short-span bridges throughout Canada. Transforming these bridges into works of aesthetic merit, however, is difficult and generally entails increases in cost. If we wish to create opportunities for artistic expression in the tradition of Maillart, then we must acknowledge the role played by technological innovation as a link between economy and aesthetics, and create conditions in which designers can move technology forward.

Designers, owners, and educators all have a role to play in creating the right conditions for innovation. To define what is needed to accomplish this objective, it is helpful to consider the conditions that prevailed during Maillart's professional life. In this regard, the following points are significant:

1. *Opportunities for innovation.* Historically, advances in materials technology have provided the impetus for innovation in structural systems. Maillart's material was reinforced concrete, which was a new material in the early twentieth century. Whereas most of his contemporaries designing concrete bridges used concrete primarily as cast-in-place masonry, Maillart developed structural systems that made effective use of the composite material's unique properties, including its capacity to resist tensile and bending stresses. If we are looking for opportunities to innovate in the twenty-first century, therefore, we should look to our own new materials. There is an abundance of new materials available to structural designers, for which suitable structural systems have not yet been developed. These should provide the starting point for designers looking for ways to move bridge technology forward.
2. *Designers who can innovate.* It is unfair to expect engineers to innovate when their education consists predominately of teaching them how to calculate forces in structural systems made with materials in common use a half a century ago. Maillart's teacher at the Federal Institute of Technology in Zurich, Wilhelm Ritter,

taught his students how to design in reinforced concrete at a time when this material was still struggling for acceptance (Billington 2003). How many civil engineering programs teach undergraduate students how to design in ultra high-performance concrete, high-performance steel, and advanced composite materials?

3. *Designers who can create works of aesthetic significance.* Wilhelm Ritter taught structural engineering on the basis of critical study of real completed structures (Billington 2003). An integral part of this approach was to give critical comment on the aesthetic qualities of structures and to relate these comments to properties of the structural systems and details. If we expect designers to create works of visual elegance, then we must not only teach them that this is important, but also give them the skills and values necessary to deal with issues related to bridge aesthetics in the design process.
4. *Owners who embrace innovation.* Innovation by necessity involves moving into unknown territory. Although the owners of the Salginatobel Bridge were not designers of the calibre of Maillart, they recognized the potential benefits of his ideas and were sophisticated enough to retain the services of impartial experts to give their assessment of Maillart's proposed concepts. On the basis of this independent counsel, they gained the confidence to proceed with construction. Current owners of bridges must find analogous ways of gaining the level of confidence needed to move forward with new ideas.
5. *Owners who are not bound by preconceived notions of aesthetics.* It is significant that none of the bridges designed by Maillart as an independent consultant was built in a major city. In the mountains of Depression-era Switzerland, people valued the Salginatobel Bridge primarily for its contribution to the local economy; there was no expectation of a "signature" structure. Unburdened by preconceived notions of what the bridge should look like, Maillart was free to use the opportunities offered by new structural systems to create visible forms that were bold and unique, and which certainly would not have conformed to the 1930s conventional vision of a "good looking" bridge.

Provided these conditions can be met, it is likely that the tradition of Maillart can be maintained into the twenty-first century. The design of aesthetically pleasing bridges does not necessarily require inclined towers and large premiums in cost relative to the minimum cost option. If engineers are prepared to move bridge technology forward, and if owners are willing to accept and reward innovation, then there will be a way to build, within the discipline of economy, aesthetically significant bridges with bold and original visible forms.

REFERENCES

Billington, D.P. 1983. *The Tower and the Bridge.* New York: Basic Books.

Billington, D.P. 2003. *The Art of Structural Design: A Swiss Legacy.* New Haven: Yale University Press.

Brown, J.L. 2004. Cable-stayed pedestrian crossing doubles as sundial. *Civil Engineering* 74, No. 3, p. 26.

Dallard, P. et. al. 2001. The London Millennium Footbridge. *The Structural Engineer* 79 No. 22, pp. 17-33.

O'Brien, D. 2001. $200M Going Downtown Council Approves Eaton's Demolition New Provencher Bridge Gets OK. *Winnipeg Free Press*. June 21, 2001.

Welch, M.A. 2003. Provencher Bridge Runs $1M More Over Budget Final Central Plaza Work Costlier than Expected. *Winnipeg Free Press*. December 5, 2003.