



## Structural Sustainability leading to Structural Elegance

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### Summary

As Roman architectures needed three elements, structural elegance of bridges is the combination of three elements of beauty, functional, structural and beauty of form. Besides, past innovations that added ingenuity and creativity to structural elegance can be considered sustainable. A structure becomes sustainable by combining structural elegance with creativity, which we called structural sustainability. What is the relationship between structural elegance and sustainability? This paper considers how to realize more elegant bridges.

**Keywords:** structural sustainability, functional beauty, structural beauty, beauty of form, structural elegance

### 1. The Three Elements of Structural Elegance

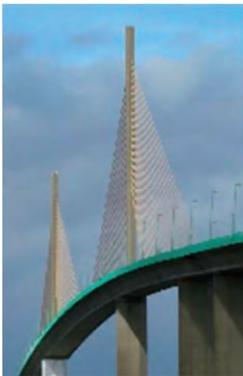


Fig. 1: Brotonne Bridge

The three elements of architecture are noted by Vitruvius in *De Architectura* in Roman times as *utilitas* (useful), *firmitas* (sturdy) and *venustas* (beautiful). This applies to bridges as well, with the three elements corresponding to “functional beauty”, “structural beauty” and “beauty of form” respectively. And these are what I believe make up the three elements of bridge structural elegance. An example of a bridge containing these three elements, as well as creativity, is the Brotonne Bridge (Fig. 1). Apart from pioneering long-span concrete cable-stayed bridges—being the first bridge to possess a span of over 300 m—with its closely-spaced colored stay cables on a plane, resembling a membrane, it is also the forerunner of later multi-type cable-stayed bridges. Along with the structure of its main girder cross section, which is not apparent from the outside, its simple, independent single pylons and transparent flow of forces are extremely rational and optimal solutions. In this way, it is the very model of structural elegance. Hence,

true structural elegance is the combination of the three elements of beauty and creativity. Functional beauty comes first in order of importance, followed by structural beauty and then beauty of form.

### 2. Structural Sustainability Concept

The structures and the construction methods for Freyssinet's Plougastel Bridge and Jean Muller's

Brotonne Bridge were the optimal solutions then, and their creativity still speaks to us today without losing their freshness through the years. What makes this possible? Out of the three elements of structural elegance, I believe that these examples, in particular, possess unsurpassed functional and structural beauties. The main factor is creativity of these entirely new and original ideas. They all utilize construction methods minimizing the environmental load with minimal materials, and hence, minimal cost. In other words, they are sustainable. From all this, I arrive at the concept of "structural sustainability," defined as the pursuit of structural elegance by putting creative power to work at the design stage on structural or construction aspects to realize a sustainable object.



Fig. 2: Seiun Bridge

For the three aspects of sustainability, minimum environmental impact contributes to the environmental aspect, minimum maintenance to the social aspect, and minimum life cycle cost to the economic aspect. To realize this, a sound design and a creative construction method are indispensable. Imagination with chronological awareness is also required to anticipate the deterioration of the structure with time. Customarily, the structure is maintained by conducting repair and strengthening throughout its design life. However, an alternative option is also conceivable in which, with a higher initial investment,

the structure is designed so that only the bare minimum of maintenance required for operation is performed over its life time. These factors are determined by the designer in consultation with the owner regarding the options with the least life cycle cost (LCC). The creativity used for keeping down the increase in initial investment in order to minimize maintenance costs leads to structural sustainability (Fig. 2).

### 3. Conclusions

Past innovations are the products of times when there were neither sophisticated software nor specifications provided as in the present. Designers then were free to think of ways to secure margins of safety, with analytical techniques that could be handled by manual calculations. Moreover, their designs still adequately perform their functions even after many years. As technology further develops, the time will come when designers will be able to accurately predict the life span of bridges. It doesn't necessarily mean, however, that such bridges will be elegant. Highly creative objects endure and continue to inspire us in the modern age. We must remember to always exercise our creativity and evolve the construction of bridges, even if only in small ways.

Qualitatively, one can understand the concepts of structural elegance and structural sustainability described here, but there are currently no indicators that can express them quantitatively. Such techniques need to be studied in the future, and will surely be a motivating tool for the designer. As in the past, the evolution of materials and construction methods will always be ahead of specifications. Only the people who happen to be present on site when such evolution occurs will be able to exercise the right to unleash challenging and stimulating creativity like the pioneers before us. It is by aiming for structural elegance with structural sustainability that we can realize a truly elegant bridge in any age.