# Maillart's design methods and sustainable design

**Denis Zastavni**
Architect & Building Engineer, Prof. Ph. D.
University of Louvain [UCL],
B-1348 Louvain-la-Neuve,
Belgium
*zastavni@arch.ucl.ac.be*

Denis Zastavni, born in 1973, studied architecture and engineering at the University of Louvain-la-Neuve (UCL), Belgium. He has worked as a structural engineer and architect for several years. His PhD was on Maillart's design methods.

## Summary

This paper examines the design methods of Robert Maillart (1872-1940), drawing mainly on his well-known Chiasso Shed (1924). It shows that Maillart's stiffened arch probably could not have been defined through structural analysis alone, which implies that sound structural principles would have had to precede any geometrical definition. His analogical design-based geometry demonstrates a good structural behaviour. Maillart achieved a reliable structure while relying mostly on graphics. It appears that the design maintains the concrete structure under at least partial compression or minimising traction.

We conclude that preliminary sound structural principles and Maillart's graphic methods for geometrical definition could help to design a durable and reliable structure with advantages comparable to contemporary goals of sustainable design.

**Keywords:** Maillart (Robert); concrete; design methods; calculations; computer analysis; morphogenesis; graphic methods; reinforcement steel; sustainable design.

## 1. Introduction

Robert Maillart is one of the most remarkable engineers of his time. To the engineer's trained eye, his structures are a very clever synthesis of all the requirements and common tasks fulfilled by a "good" structure: economy of material, cost-saving efficiency, a well-conceived procedure for construction and remarkable durability over time.

## 2. Tools and methods behind the design of the Chiasso Shed

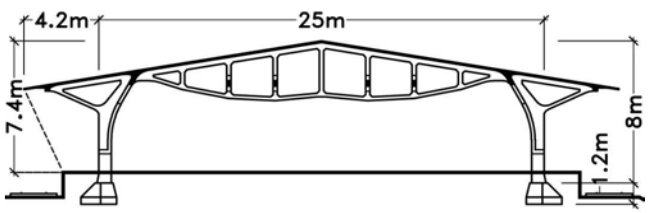


*Fig. 1: section in Maillart's Chiasso Shed, 1924*

In a recent paper, the author suggests that Maillart's Chiasso Shed (Fig.1) has been designed using a graphic procedure – a procedure using graphic statics, to be precise[1]. Having accepted the intrinsic logic of the structure's typology of an arch stiffened by the deck, a question emerges concerns its design: "Would a classical design procedure today based on structural analysis therefore naturally result in this form?" It is likely that the answer would be: "Probably not."

To look for the genesis of the form of the stiffened arch, based on analytical results we used an undifferentiated geometric canvas and examples of loadings used by Maillart. We get major bending moments in the columns of the kind found in Vierendeel-like structural behaviour.

We could consider that columns are not supposed to be the masterpiece of an arch structural system and force the model to re-equilibrate the bending moments on the deck and the arch. Therefore, we

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forced the dimensions of the columns to remain modest compared to those of others components: it means that we go against what the analysis is telling us. But even so, an iterative process will in any case make the section of the arch greater than those of the deck, and a principle of an inverse ratio of dimensions between the arch and the deck will not emerge.

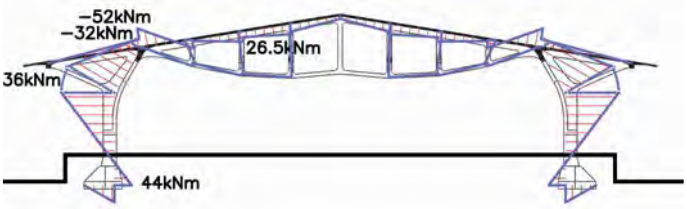


*Fig. 8: Bending moments in the Chiasso Shed structure under dead loads and snow*

Considering the structure of the Chiasso Shed, when we examine the steel reinforcement of all members, and evaluate their resistance, it appears that the role of the columns in supporting bending becomes anecdotal. Using a computer program to analyse the structure – with an upper chord belonging to the concrete roof – it demonstrates a structural behaviour where bending is mostly encountered in the upper chord, just as in a stiffened arch bridge.

## 3. Implications for the methods and characteristics of the structure

So what are Maillart's methods and principle used to achieve this principle?

Since we are aware that there were no tools suitable for analysing structures, Maillart used approximations or simplified structural mechanisms and combined them as tools to achieve a structural typology. The simplicity of the mathematical model gives him the freedom and opportunity to think a great deal when taking into account construction phases to minimise costs, to integrate parts of the work together with the same aim and consider the various aspects of the design. He also used graphic statics to calculate forces and moments but most profoundly, he used graphic statics to define the geometry of his structures. It implies that he was thinking in terms of struts and ties – mostly favouring struts – which leads to an expectation of a good durability. Simultaneously, it allows him to reduce the amount of steel reinforcement (and costs).

The simplicity of his methods gives him far more freedom to shift his attention to other issues like construction methods. His methods permitted him to master his design to maximise the savings in materials, reduce building costs and achieve very long-lasting structures. And it will not be difficult to prove that the longer a structure's life, the greater the savings in terms of resources and costs – in other words, how sustainable the design has been.

## 4. Conclusions

### 4.1 Maillart's teachings

What is characteristic about Maillart's methods is that he was relying on an association of simple structural models and graphic statics for designing structures, which allows him to master every aspect of the structural question (with an element of 'local' involvement in the design: he argued in favour of concrete structures in Switzerland since – except for cement and reinforcement steel – all the resources required were already on site [2].

This mastery of the final geometric features permits good structural behaviour, which in turn gives reliability and structural safety and, as a consequence, durability. In relation to our modern methods, we could assume that all design procedures and tools allowing invention ought to give us a similar degree of design freedom to the kind Maillart arranged for himself. Let us be critical. We could also suppose that thinking in terms of clear structural behaviour is quite obviously one of the better ways of achieving reliability and therefore sustainability as well.

### 4.2 References

[1] ZASTAVNI D., "The structural design of Maillart's Chiasso Shed (1924): a graphic procedure", *Structural Engineering International*, Vol. 18, No. 3, 2008, pp. 247-252.

[2] BILLINGTON D., *Robert Maillart's Bridges, The Art of Engineering*. Princeton, NJ, Princeton University Press, 1979, p. 10.