Bridges in Motion

Tom OSBORNE
Architect
Knight Architects
High Wycombe, UK
t.osborne@knightarchitects.co.uk

Tom Osborne, born 1983, graduated with a Masters in Architecture from the University of Nottingham, before qualifying as an architect in 2010. He currently specialises in bridge design at Knight Architects.

Lee FRANCK
Structural Engineer
Arup
London, UK
lee.franck@arup.com

Lee Franck, born 1984, graduated with an MSc in Civil Engineering from the Swiss Institute of Technology in Lausanne (EPFL). She is a chartered structural engineer currently working for Arup in London.

Summary

Elegance in structures can manifest itself in a variety of ways; from visual appearance, design innovation and efficiency, construction ingenuity, to close collaboration between disciplines. This paper analyses a selection of bridges and their movement, from a rolling bascule in New Zealand to a small pedestrian bridge at Paddington Basin, in addition to the Kingsgate Bridge in Durham and a proposal for an innovative opening mechanism. It seeks to provide a commentary on their structural, mechanical and architectural approaches, and how the combination of these results in elegant designs, both statically and in motion.

Keywords: bridges; bascule; opening bridges; moveable bridges; elegant structures, innovation

1. Introduction

Moveable bridges must be designed so as to be logical, efficient and beautiful in each of their closed, moving and open states. They must be designed to work structurally, mechanically and visually throughout a series of varied states, and as such, they must exhibit these attributes both statically and dynamically in order to be seen as elegant structures.

2. The Closed Condition

Whilst the Merchant Square Bridge over Paddington Basin in London (Fig. 1) was required to open, its location dictates that it does so relatively infrequently – around once per week. As such, most pedestrians will only experience this bridge's closed condition, and so it was particularly important that this too was elegant in its own right.

For the general public, part of the interest of a moveable bridge is being able to understand how it opens. With its mechanics hidden below ground, the Merchant Square Bridge does not 'give much away' when closed, however its five sculptural counterweights provide the only evidence of the bridges ability to open. It was the intention to maintain the understated aspirations of the client, whilst providing enough information to the general public so that they may understand how the bridge operates. To this end, the counterweights are each inscribed with their tonnage at their tips.

3. In Motion

The appearance and overall elegance of a bridge in motion is primarily dictated by its opening mechanism. Whilst the list of traditional mechanisms is short, creativity and playfulness can be applied to explore inventive systems which make use of the structural degrees of freedom in new and elegant ways. Such an innovative opening mechanism has been developed for the Butterfly Bridge (Fig. 2), an arch bridge in which a vertical movement of the deck is created by the outwards rotation of the arches. This mechanism combines the traditional rotational and translational mechanisms into a new, playful and elegant mechanism inspired by the opening of butterfly wings during flight.

Fig. 1: Merchant Square

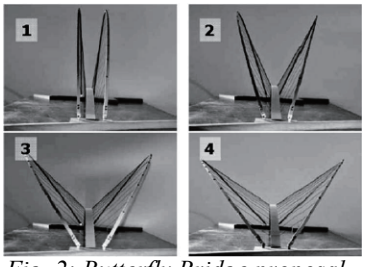

Fig. 2: Butterfly Bridge proposal

Fig. 3: Hatea Bascule

By contrast, The Lower Hatea Crossing in New Zealand (Fig. 3) is based on a very traditional mechanism, taking the form of a rolling bascule. This system was selected for its efficiency and speed of opening – key considerations as both the bridge and the river beneath it will be used with great frequency. In contrast to the bridge at Merchant Square, in its closed condition the Hatea bascule stands as a highly-identifiable motif in the harbour. Furthermore, the way in which it opens is easily identifiable when closed, with the structural and mechanical logic of the bascule completely integrated with its architectural form.

The design of moveable bridges, even more than other structures, require a close collaboration between designers of different fields of expertise to strike this fine balance between visual appearance, structural elegance and mechanical efficiency. Parametric modelling tools are instrumental in facilitating this process, by allowing the parameters and boundaries of exploration to be clearly defined and facilitating a multi-disciplinary optimisation process.

4. The Open Condition

These moving sequences culminate in the static open condition of the bridges. Here, a temporary elegance is created in this fleeting condition. In addition to the newly created form, a visual tension has been created out of the inevitable return to closed. That is not to say a moveable bridge should seem unbalanced or precarious whilst open; rather, it should appear poised, composed and even momentarily flamboyant, before reversing its performance and transitioning back from being a spectacle to a bridge.

5. During Construction

It can often be forgotten that all bridges at some point in their existence are moveable – during construction. The motion of the construction sequence is seldom an afterthought, and often becomes the driver for the design, significantly impacting the finished condition. This is the case for the well-known Kingsgate Footbridge in Durham (Fig. 4) for which its innovative construction method has led to significant economies by completely eliminating the need for scaffolding and falsework in the river where navigation had to be maintained, each half of the bridge being constructed on scaffolding on dry land each side of the river and then rotated into place. Whilst compared to other bridges discussed in this paper, Kingsgate only moved once, this movement, albeit only once, was no less elegant, and should not be forgotten.

Fig. 4: Kingsgate Footbridge

6. Conclusion

It is the setting of the bridge – its constraints, features and culture, which must be allowed to dictate the opening mechanism, and how this motion ultimately manifests itself. If considered carefully, the motion of these bridges whether regular or infrequent, will always provide a spectacle to inspire and enjoy. However, in order to be seen as truly elegant, this motion must not compromise the static quality of the bridge in either its open or closed states.