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Mathematics has always played a strong role in bridge design and construction, but there is always the possibility of a radical innovation. A new bridge in London is an example as it uses classic geometry in a very surprising, even shocking way.

1. Introduction

Cody Dock, near where the River Lea meets the Thames in East London, is being brought back into use after years of dereliction (see Fig. 1). Thanks to designer Thomas-Randall Page and structural engineer Alfred Jacquemot, a remarkable new bridge over the waterway illustrates a mathematical principle that has never before been used in large-scale construction.

In 1849, at the age of 18, James Clerk Maxwell [XXX, p. 537] discovered that a straight line will roll smoothly on an inverted catenary. The idea was extended in 1960 by G. Robison [XXX], who showed that a square will roll smoothly on a series of truncated and linked catenaries. Stan Wagon, in 1997, constructed a full-sized tricycle to illustrate the idea of a smoothly rolling square (Fig. 2). That whimsical construction received a lot of publicity. Randall-Page designed the new Cody Dock bridge as a platform attached to two large squares; the structure can be smoothly rolled to an upside-down position that would allow boats to pass beneath it (Fig. 3). He and Jacquemot then oversaw the construction so that the inversion of the 26,400-pound structure can be carried out entirely by hand (Fig. 4, 5). There were many details to be worked out to ensure the new idea would work; for example, a large amount of concrete and steel was placed inside the two upper edges to counterbalance the weight of the bridge deck. Not only does it work, but the bridge won the 2023 Bridges Design Award [XXX].

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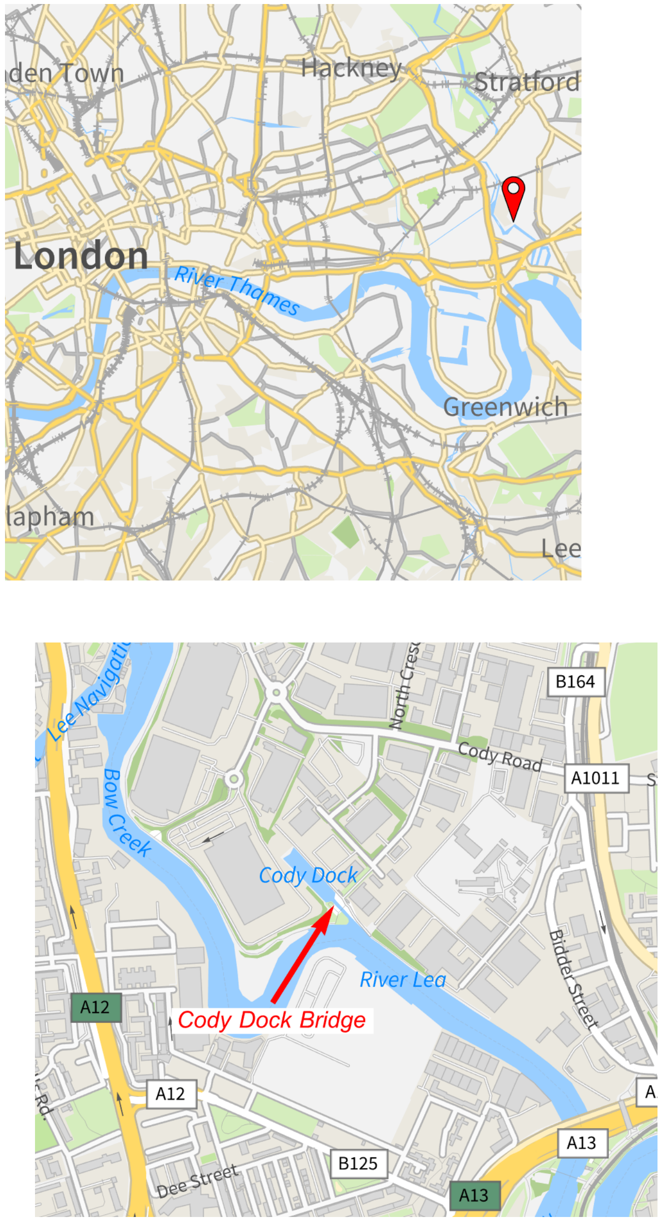

Figure 1. Cody Dock and the bridge are located just east of London.

Figure 2. Stan Wagon on his square-wheel bike (it is really a tricycle).

The bridge design relies on two 19th century ideas. There was the aforementioned geometrical result of Maxwell. But another factor was the use of a pre-industrial ethic. Before steam engines and electrical power, all moving things required muscle, and thus balanced systems were used, often with counterweights to minimize the energy needed. This history motivated Randall-Page to come up with a balanced bridge that can be moved by hand. Another motivation for the square was that space was limited and so a design was needed that did not occupy land on either bank. This led to a design that utilizes two catenary tracks along the channel, with no supporting structures on the banks.

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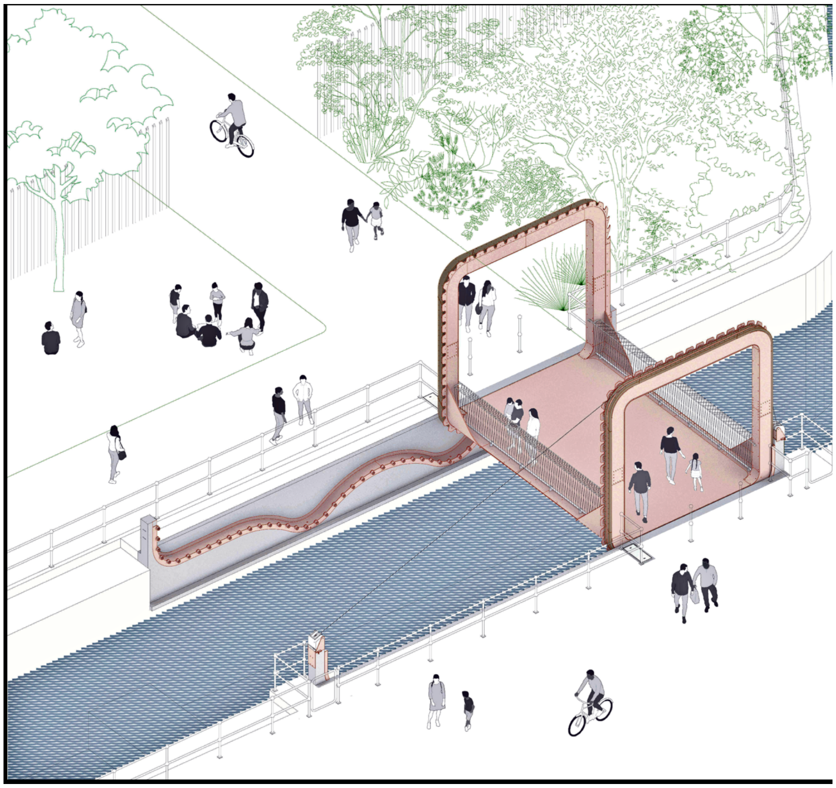

Figure 3. A sketch of the bridge with the two winches shown on the near side. Note the rounded corners on the squares and the rounded sections of the track where the catenaries meet. (Artwork by Thomas Randall-Page.)

Figure 4. The rolling square bridge at Cody Dock in East London, England. (Photo by G. G. Archard.)

Figure 5. The rolling square bridge in action. (Photo by Jim Stephenson.)

There are some surprising subtleties in the translation of a relatively simple geometrical idea to a large-scale construction. To ensure that the squares could not slide down the track, a system of gears and pins is used. These force the corners of the squares to be rounded, and that means the pure linked catenaries will not work as the road. One must work out the proper road for a circular arc, and that involves elliptic integrals. The details are discussed in §6XX.

Several videos have been produced showing the bridge in action and the details of its fabrication; see [XXX, XXX, XXX].