2023-7 **Skew Bridges**

Skew bridges are one of those subjects which illustrate the 18th century evolution of civil engineering, as discussed in my recent book on ***Technology, Economics and Canal Development***, published in 2021 by the Society. At that time, British civil engineering was designed and overseen primarily by craftsmen, experienced in the practical aspects of construction. On the European mainland, academically trained military engineers formed the initial basis of the civil engineering profession. Their comparative high social standing made it difficult for them to engage with the practical men actually undertaking the work, though technically they were undoubtedly years ahead of engineers in the UK in theoretical understanding. European engineering publications at this time often note the practical experience on British engineers, suggesting that more importance should be given to this amongst engineers on the continent.

With regard to the skew bridge, published technical design seems to date back at least to 1530 when Nicolò, called *Il Tribolo*, described his skew bridge over the river Mugnone, near Porta Sangallo, at Florence, on the main road to Bologna.[1] The best overview of the development of early skew bridge design is probably Poncelot's 1832 paper, ***Comptes rendus hebdomadaires des séances de l'Academie des sciences***. Looking at European technical literature, it is surprising how little specific work on skew arches was published prior to the mid 19th century. Derand did publish a few ideas in 1643, followed by Lahire in 1695, but subsequently most works were on the simple arch, which had to be fully understood before moving on to more complex structures.

As a result, there are few 18th century European skew bridges, and though there is some discussion on their design in technical publications, European engineers were more interested in understanding the simple arch and its behaviour, before moving on to the skew arch. For example, Meerwien[2] looks at structural failure of a simple arch in detail. It was the British craftsman engineers who were most involved in putting ideas for the skew bridge into practice. The mathematics required was fairly simple, and any good trained stone mason could build some sort of skew bridge, and understand their limitations when it came to that type of structure.[3] I have come across quite a number of false skew arch bridges on English canals, which are probably the result. Although Chapman almost certainly built the first true skew bridges with winding stonework, over the canal near Naas, the skew bridge built subsequently, Shee Bridge on the Grand Canal, is a false skew, using random stonework, rather than a true skew design.

Why was the skew bridge used more extensively in the UK than elsewhere in Europe? Land ownership could be seen as a factor, with the UK, particularly in the north of England, divided into numerous small holdings, possibly due to the copyhold system. This meant structures had to be fitted into smaller pieces of land, with designs which avoided having to buy extra land. Cost could also have resulted in the false arch, whose simple stonework would have been much cheaper than the winding stonework of the true arch. This certainly influenced the specific type of design used, later. By the railway age, three main methods of constructing the winding stonework needed for a skew bridge had been identified, but it was only by the 1870s that there seems to have been some agreement on the benefits of the various solutions, comparing cost with strength.

This brief overview indicates that British development was craftsman led, while the Europeans were very much more theoretical. In some way, the skew arch could be considered a defining moment in engineering history, marking the change from empirical design, based on practical knowledge, to a more academic theoretical design, a change from building something which

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[1] ***Lives of the most eminent Painters, Sculptors and Architects***, Giorgio Vasari, trans. Mrs Jonathan Foster, vol IV, 1851, p204-5. I often find such old technical descriptions difficult to interpret — why use one word when a sentence is possible!

[2] Meerwein, Carl Friedrich, ***Beytrag zur richtigen Beurtheilung der Eigenschaften und der Wirkungen der Gewölbe***, 1802.

[3] Buck and Nicholson (see Bibliography) seem to have had an argument over whose system was best in the early 1840s, with correspondence in the 1840 and 1841 ***Civil Engineer and Architect's Journal***.

engineers expected would fulfill the objective, to one where there was far more certainty that requirements would be achieved.

Good engineering design requires creating the maximum possible benefit without a failure of the structure. On-the-job training would give a craftsman an overview of how strong the structure he was building would be. However, improving on those limitations required detailed mathematical understanding through technical education, widely available on the continent, but not in the UK until the second half of the 19th century. Even after this, we had to wait until the mid-20th century for effective solutions for problems such as those of soil mechanics, while formulae related to skew bridges are now being considered through computer-aided calculation.

To understand the development of the skew bridge, and engineering generally, you need to understand the difference between that which a craftsman can build and that which an academically-trained engineer can design. The difference marks the change between the age of 'Art/Craft' and 'Science/Technology', though the dividing line is not as simple as that.

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It is interesting to note that books in English tend to be practical guides for stonemasons, whilst the European books are far more academic.

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