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Editorial

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It is an inescapable lesson of human history that lessons are as quickly unlearned as they are learned. A recent discussion paper revived the so-called '30 year cycle of failures' (Brady, 2013) echoing a paper published 36 years ago (Silby and Walker, 1977). Yet this time scale flies in the face of the evidence: structural failures of similar types happen much more frequently than that. Unfortunately, engineers looking at existing structures that have suffered a minor failure are not always good at recognising the evidence to be found in existing structures, or distinguishing between established belief and measureable fact. While the response to a failure occasionally includes serious experimental study and improved understanding, it more usually leads to a proliferation of codes and, particularly, design procedures which tend to emphasise the most recent failures at the expense of other, earlier ones. Yet even when lessons learned from failures are cumulative, it is not always the case that they will prevent future failures.

The most spectacular failures are typically in bridges, and especially big bridges. In steel structures buckling lies at the core of most disasters and most buckling failures have happened at places where the designer did not consider it. We may, with hindsight, label such errors as foolishness and even, occasionally, as hubris, but it is unlikely that they would have been avoided by writing or rewriting procedure or codes.

Many design errors may remain undiscovered because they do not lead to disaster. There may, for example, be alternative load paths that have not been considered or foreseen, or a structural element might, by chance, prove to be strong enough to carry unintended loads. Every such gap in thinking or calculation is, however, an opening for future problems.

A related, but different issue is the use of computer models that do not represent reality with sufficient reliability. In my own main field of arch bridges this is almost universal. The models on which codes of design practice are predicated are often deeply flawed, for example in representing masonry arches as fully elastic structures, which they are not; they may also imply a structural form which is rarely present in real structures. The question that should be asked about a damaged structure is one that is now taught to primary school children 'is it a fair test?' False evidence may simply arise from a misunderstanding of the structural form

- the bridge was damaged
- we did this repair
- the bridge did not fall down
- the repair obviously worked.

Not necessarily; it is more likely that the repair was not necessary in the first place. Not only is that not a fair test, it is no test at all. Similarly, there is an argument in defence of the antiquated military engineering experimental establishment (MEXE) method of masonry bridge assessment that 'no bridge has ever failed that passed MEXE' (Wang and Melbourne, 2010). However, this is demonstrably untrue since many masonry bridges suffer damage and are repaired or replaced without acknowledgement that the assessment may have been, or was, wrong (Heyman, 2010).

The two-dimensional thought processes used today are not capable of distinguishing between sound and weak structures; and resorting to expensive computer analyses usually does not help. Which brings us back to history.

All structures are systems of interconnected stiffness. The stiffnesses in masonry bridges are much greater than those we usually deal with in steel and concrete structures, but there are still questions of relative stiffness. Offered the alternatives of a stiff but weak load path and a soft but strong one, a load will always choose the stiffer path until it fails. It is legitimate to say there is a stronger path that will prevent overall failure, but we need to be able to predict when the first path will fail and whether there will be significant consequences. That cannot be done if the computer model of the structure does not relate closely to reality. If we model how we think the structure might be, rather than how it is, the result will be without value. Far better simply to take a view and apply engineering judgement. To model a masonry bridge as an arch plus soil fill when it is actually an arch with internal diaphragm walls will lead to a false result. We need to know how the bridge was built and make sensible assessment of the properties and load paths before any analysis is done. And that requires an understanding of the development of masonry bridges, as well as a detailed study of the actual bridge being repaired. In the UK, since at least 1750, many arch bridges have been constructed with internal walls. The destruction of the Mostar Bridge (constructed in Herzegovina in 1566) in 1993 revealed that it too had internal walls. In modern-day Turkey there are remains of a Roman bridge over the River Aesepus, dating from about 400 AD which also has internal walls (http://en.wikipedia.org/wiki/Aesepus_Bridge); its construction is little different from a bridge designed by a 19th century railway engineer. Despite this history, modern engineers blithely accept the results of analyses based on the assumption that the arches are soil-filled, for even the most massive structures. In order to understand the behaviour of an existing structure the engineer must find out how the bridge is actually constructed and how its designer intended it to work as a structure, both in overall terms and at the level of the details and interfaces between structural elements. It will always be dangerous to assume that a bridge has been constructed in a certain way without checking the structure itself. And here a knowledge of history can help, if only by providing evidence that engineers at all periods of history have devised many different ways of building structures that may, from the outside, look very similar.

This issue of *Engineering History and Heritage* contains a fascinating story of how a failing structure was rescued from collapse through an understanding of its actual construction. Gwilym Roberts (2013) describes the early 20th century underpinning of Winchester Cathedral. One tends to think of these as modern times but they are very clearly not. The courage required to work in turbid water under poorly understood foundations is not to be underestimated.

Richard Parry (2013) presents a useful summary of classical writings on construction. Far too many modern engineers assume that technical understanding was negligible even 300 years ago. These ancient writings show how engineering was a thoughtful process.

Nicholas Bill (2013) is correct in believing that timber lattice girders are a largely forgotten form. The scale of some of those he describes is surprising. Finding timber to build such things today would be very difficult.

John Vignoles has a family interest in suspension bridges, descended as he is from Chares Blacker Vignoles who designed the one in Kiev. That is no doubt reflected in his joining with Sandor Vaci to write about the Chain Bridge between Buda and Pesth (Vaci and Vignoles, 2013). The history of flooding and ice that preceded its construction provides a useful background and perhaps explains why engineers would be brought so far to build a bridge of relatively modern construction.

Dermot O'Dwyer (2013) is one of very few academics who specifically use history in their teaching. The examples of failures he cites are valuable lessons to us all.

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