Engineers bridge the gap

Professor Robert Wheen uses bridge building to explain how engineers work in integrated teams

Roads and Traffic Authority of New South Wales

Seacliff Bridge - 80 km south of Sydney

WHY DON'T BRIDGES COLLAPSE under the weight of heavy traffic? The simple answer is that the structural engineer makes sure it won't. But how can they do that? That's not so simple. Large bridge projects are usually beyond the capacity of one individual. Invariably, teams of people get involved.

If you think about it, the purpose of a bridge is to carry a road or railway line across some obstacle in its path. It may be a river or another road but always the challenge is to leap over without blocking the river or road below. Otherwise one would simply fill in the gap to create an embankment across.

The most elementary of bridges can be created by felling a tree over a river or by placing stones spanning across between a series of stones placed in the river bed. It is essential that the river continues to flow unimpeded. So one of the first questions is whether a sufficiently clear opening can be provided to allow for the largest expected flood. The engineer needs to draw on a knowledge of hydrology or flood flows for these first answers.

As the span, or distance between the supports, increases not only does the tree need to get longer but it needs to be thicker as well lest it sags unduly under the "traffic" that crosses. The earliest of engineers used their experience to make choices of dimensions. If they got it wrong the tree bridge sagged or broke and they'd try something stronger. They would have understood that it must be strong enough for the purpose but it is wasteful of good trees to use a larger one than necessary. The same is true for large stones.

The other difficulty is that there are limits on the size of stone or tree that can be moved into place by humans or large animals like elephants. The methods of building, the equipment needed to move and join pieces of the structure, the workforce necessary to achieve them; all may be thought of as the precursors to modern day construction engineering. The challenges are the same, the repertoire of possible methods is many times greater today.

Timber and stone masonry were the earliest of bridge building materials but today there is a vast range of choices. Concrete and steel are predominant because they are strong and economical, but their 200 year existence is relatively short in the history of bridges. So a keen understanding of materials science, of the nature of the materials, is important. Not only do we need to know how strong the materials are but also how long they will last. Preventing the rusting of steel is an ever-present challenge. There are 2000 year old stone arch bridges still in existence but no significant timber bridges of that age remain.

Early engineers gradually discovered that they could shape stones to create arches, and that they could weave natural fibres to create ropes. This explains how different bridge forms began to be used. If we leap forward to the 21st century we find concrete and steel arch bridges having spans in excess of 500 metres. The Golden Gate suspension bridge spanned an impressive 1280 metres when it opened in 1938. The largest of the world's suspension bridges, the Akashi Kaikyo in Japan now spans just under 2 kilometres (1991m) and there are proposals for a bridge across the Straits of Messina from Italy to Sicily to span 3 kilometres in one giant leap.

The larger the bridge, the more challenging the foundations are. The massive loads from the bridge must eventually find their way to firm support. If there is rock near the surface the task is relatively easy, but usually we are not that fortunate. The work of engineering geologists is important here. The geotechnical engineers need to understand the strength properties of the soil and rock. They can then decide whether they spread the load near the surface or drive piles down to bedrock. Many solutions involve clever combinations of these ideas.

Obviously, the primary purpose of a bridge is to carry the loads that are to cross it but there are many other loadings to be considered. The loads do not just quietly pass over. Imagine the effect of a freight train thundering across. Often bridges are placed in open windswept areas so they must resist the largest hurricane that can be expected. Bridge design engineers contemplate the effects of possible earthquakes and devise ways of allowing the bridge to survive. Snow loads, flood loads on piers, the effects of debris piled up in floods, possible ship impacts, temperature effects as the bridge heats and cools; all these and many more loadings must be considered.

From the earliest days of try-it-and-see construction to today, giant strides have been made in designing and building bridges. In the 1920s it took many structural engineers well over a year to carry out the design calculations and analysis for the Sydney Harbour Bridge. Today the analysis, once formulated, can be done by powerful computers in a matter of seconds. For the Sydney Harbour Bridge every detail, down to the last rivet, was meticulously drawn by hand. The drawings were works of art in themselves. Today computer-aided drafting can accomplish the same result in a fraction of the time. The drawings can be transmitted electronically back and forth across the world if need be.

With these powerful tools at their disposal the engineers are freed up to spend more time thinking about the social, economic and environmental aspects of the bridges they devise. They can explore alternative forms of construction and different construction methods.

The construction engineers charged with the task of turning the design drawings into reality face impressive challenges too. Usually they have tight deadlines and budgets to work to. They have won the right to build the bridge in competition with other companies. In very short time they must marshall the resources they need; the manpower, the machines, the materials and the money. Invariably they have to deal with the vagaries of the weather. Project engineering has become so sophisticated that it is not uncommon these days for major projects to be completed before time and under budget.

It is common nowadays for collaborative teams made up of people with complementary expertise to work together in devising the best possible solution. A perfect example is the Lawrence Hargrave Drive Bridge (now known as Seacliff Bridge) south of Sydney that safely snakes its way around some of the most unstable cliff faces at the sea shore to be found anywhere in the world. The structural engineers worked with the geotechnical engineers and the construction engineers to create this most ingenious solution to an almost impossible problem.

Bridge engineering in the 21st Century is a highly sophisticated art. This is the nature of all engineering. You rarely see an unhappy engineer. They just love their work.

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