Editorial

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The most shocking statistic in the papers in this issue is the fact that 45% to 60% of construction accidents are down to poor design. Given that engineers have a duty of care, this suggests, at best, the design guidelines and codes of practice they are using are incorrect and, at worst, the engineers have failed to appreciate the hazards and their consequences. It is hazards, both natural and anthropogenic, that are the common thread that runs through the four articles in this issue, with the emphasis being on the need to identify the hazards and undertake a risk assessment as part of the design process to take account of all consequences over the life cycle of a project from inception, through development, construction and operation, to decommissioning. This comprehensive approach applies not only to the asset but also to the natural, built and social environments in which it sits.

The first full-length paper (Kumaraswamy *et al.*, 2018) argues that core management frameworks for disasters should be formulated in advance. Any disaster, whether natural or anthropogenic, creates a turbulent environment in which many stakeholders operate. Thus to improve resilience, there is a need for public–private–people partnerships to mobilise private finance and expertise, and social capital. It requires non-governmental organisations, communities, professional bodies, trade associations, government and media to work together to a common goal at all stages in rescue, recovery and regeneration as these stakeholders are central to resilience both of the environment and the people who use it. Management frameworks that include procurement and delivery frameworks need to be prepared in advance to avoid unnecessary delays following a disaster. While design focuses on ultimate and serviceability limit states, durability and cost, the resilient characteristics of an asset need to be understood to assess its vulnerability and, therefore, the consequences of a hazard.

A case study, which applies these principles, is the subject of the second full paper (Mowll and Russell, 2018) which focuses on the vulnerability of the road networks around Wellington, New Zealand if subject to an earthquake, a highly likely event. Rescue, recovery and regeneration are critically dependent on the road network. A multi-stakeholder approach to produce a strategic plan based on hazard mapping was used to enhance resilience of the infrastructure and produce an emergency plan with a defined level of service. Stakeholder engagement allowed issues to be understood from all perspectives to enable targeted interventions post-disaster.

While the effects of natural and anthropogenic disasters are uncertain, planned intervention on existing assets, the subject of the remaining two articles, also creates uncertainty because of the legacy capacity of the asset and the effect of loading during operation for which they were designed.

The paper by Lohmann (2018) covers the top-down demolition of buildings in which the floor loads due to debris and plant, and the change in structural form due to demolition create uncertainty. This is controlled destruction as opposed to uncontrolled destruction due to natural hazards. Failure modes due to overloading and weakening include flexure, punching shear, buckling and progressive collapse. The characteristics of the structure at all stages of the demolition need to be understood. The structures could have been designed to different standards than exist today, and the standards that exist today may not be relevant to demolition according to the author.

Design standards are important as they provide a framework to produce an outcome at a minimum acceptable level. However, standards are based on historical data, which means they may not be relevant especially now as the effects of climate change are starting to have an impact. Further, civil engineering assets, typically, have a design life of 100 years, which means they will be subject to change in use and technological change, which are difficult to predict.

The briefing by Williams (2018) addresses this issue by considering safety over the whole life of a project. The author notes that there are numerous standards, guidelines, regulations, risk registers and codes of practice but accidents still happen. The author introduces a concept, Safe by Design (SbD), used by Network Rail, an organisation that deals with structures built over the last 180 years that still function today. These structures were originally built using experience and, more recently, to standards which have changed over time using a full range of construction materials in various configurations. Any intervention must be delivered while maintaining the performance of the network. The principles of SbD are good engineering practice but, based on published evidence of construction accidents, current engineering practice leaves a lot to be desired.

The approach starts with an assessment of the hazards through the life of an asset and necessary mitigation to reduce risk.

Implementation is through design change management, ensuring collaboration between all parties and adequate site knowledge. This requires professional values and leadership. Since all civil engineering projects are unique, it is necessary to apply the same principles and not make assumptions without supporting evidence. However, learning from previous work is critical, ensuring organisational memory and leading to continuous improvement.

Thus, this issue of *Forensic Engineering* provides some key lessons to reduce the effects of uncertainty and ensure civil engineering design is both safe and resilient. The impact of natural and anthropogenic hazards is increasing because of population growth, urbanisation, climate change and changes to technology. Civil engineers, part of a multi-stakeholder network, are expected to deliver projects that are fit for purpose throughout the life of the project. This means they must deal with uncertainty. Therefore, taking a risk-based approach, advocated by these four articles, is critical to increase resilience and reduce vulnerability of civil engineering assets and the changing environment in which they operate; that is, engineers have a role in not only designing,

creating, operating and maintaining the infrastructure but also in raising awareness and providing leadership both in a political and social context to ensure that communities and infrastructure on which they rely are resilient with built-in redundancy that can be rapidly restored in a resourceful manner.

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