Editorial

Wei F. Lee PhD

Chief Executive Researcher, Facilities and Assets Management Center for Infrastructures, National Taiwan University of Science and Technology, Taipei, Taiwan

Forensic engineering is not the last phase of structural design. It is the beginning of engineering design and the evolution of civil structures.

Most important design theories used in civil engineering come from investigation of failure and the need to avoid future incidents. Classic examples include Rankine's earth pressure theory, bending moment diagrams of structure members, soil piping theory for safe excavation, and many others. Engineers discover the limitations of theories and learn the critical behaviour of structures from forensic investigation. Looking at the life cycle of civil structures, forensic engineering is the beginning of methodologies rather than its closing remarks – modern structures are therefore designed and manufactured only after engineers have understood where previous boundaries fell.

Advanced forensic engineering should not be limited to only the autopsy of failure. It should also be extended to maintenance engineering, and even life cycle engineering of civil structures. Forensic engineering was originally developed to prevent failure, but now can and should be applied to inspecting early signs of malfunction (as well as monitoring probability of failure).

The public today have no tolerance of failure, but demand more and more from the serviceability and reliability of infrastructure. Forensic engineering can be applied into this area of life cycle maintenance and asset management of infrastructure. Forensic engineers often apply their experiences learnt from investigating 'causes of failures' to diagnosing 'symptoms of inefficiency' and, most importantly, providing proper mitigation strategies. This concept would provide a broader application of forensic engineering to areas such as performance monitoring, structural behaviour modelling, and retrofitting.

Recently, pioneer researchers and engineers have been trying to integrate forensic engineering, maintenance engineering, and information technology to further push the limits of forensic engineering. Building information modelling (BIM) is no longer a new term in civil engineering, yet infrastructure information modelling (IIM), which aims to cover the design, construction and operation phases of infrastructures, has become the most demanded and rising research interest of

civil engineering applications. As the operation phase is the most important and longest period of an infrastructure's life cycle, avoiding serviceability and reliability problems has been recognised as one of the most vital tasks of IIM. IIM is designed to document maintenance records and historical damage/hazard data, describe structure performance and monitor fatal critical components, and predict possible functional distress or material degradation tendencies. These major functions of IIM require extensive forensic study of failure or malfunction and a well-established forensic information model (FIM) that can simulate possible failure scenarios and their consequences. Knowledge learnt from forensic engineering such as critical behaviour of structures, influential factors of serviceability failure of structures, and fatal critical member of structures, are the major elements used to develop FIM. Under the framework of IIM, FIM can document characteristics of structures so that serviceability and reliability may be recorded, analysed, and even predicted throughout the life cycle of the maintained infrastructure.

The papers in this issue of *Forensic Engineering* are presented in a sequence documenting the critical behaviour of infrastructures, collection of the historical performance data of structures, methodology of extrapolating critical structural behaviour using experimental process and models, as well as consequence analysis of specific structure. This order of papers validates the concept of how FIM can be formulated and utilised.

Recently, climate change has tested civil engineering infrastructure to its limit. Engineers face the challenges of mitigating environmental as well as consequential analysis of infrastructure failures caused by multiple environmental hazards. In this context, historical damage data becomes essential when performing risk analysis of, for example, bridges and their immediate surrounding area. Documenting such damage will be very important for retrofit design, mitigation strategy, and future design of bridges (Lee, 2012).

Bridge falsework often significantly affects construction cost, scheduling, and engineering safety. Such influences become more significant for maintenance and retrofit works of bridges. However, design quality and construction risk of such temporary systems are often ignored and not well-studied. The data collected

and analysed by André *et al.* (2012) provides valuable information to improve safety and design efficiency of bridge falsework.

Forensic investigations often follow tragic accidents. However, process failure is not as obvious, especially when the scene of a failure does not allow easy access and investigation. The experimental assessment of materials, products, and construction systems could provide valuable insights to the failures and verify fracture critical components of the investigated cases. The presented paper by Bregulla (2012) is an excellent case study describing small- to full-scale tests. In addition to the valuable test results, the well-organised testing program, designed to resolve the legal dispute, will be of great benefit to the profession.

Returning to my introductory statement, new infrastructures like offshore wind farms could have more than a dozen serviceability issues that engineers have never seen before. Even the subsea cabling that has been considered to be a relatively low risk part of an offshore farm could, in reality, require significant research. Boehme and Robson (2012) diagnose incidents and highlight areas in need of greater attention. Fundamental issues addressed in the paper are not only for forensic analysis but also important elements in the maintenance of such infrastructure. Challenges such as lack of practice standards and general guidelines of maintenance require extensive effort and inter-organisation collaboration. By introducing the advanced concepts of IIM and FIM, forensic engineering practices for new infrastructures such as wind farms could cover the life cycle of every important component to aid communication among stakeholders, key performance indices and their criteria, and even verification or certification frameworks.

Finally, an interesting discussion closes the November 2012 issue and this journal's second year of publication (Lewis and Warburton, 2012). Although the discussion touches upon some engineering details of the London Millennium Footbridge, it also addresses important concepts of how forensic study may connect design to maintenance.

In our discipline, there is nothing too small, and nothing too big to look at. Forensic engineers should be trained to consider the smallest detail, as well as the big picture, to determine how failures or defects could possibly have been ignited or preceded.

Scientists investigate that which already is; Engineers create that which has never been. (Albert Einstein)

Forensic engineers investigate distress and failure to diagnose what might have been overlooked or over-stretched. Most importantly, they should apply the invaluable lessons learnt from failure to create new standards of reliability, availability, maintainability, and serviceability. Forensic engineering is the state of the art, merging both science and engineering.

REFERENCES

- André J, Beale R and Baptista AM (2012) A survey of failures of bridge falsework systems since 1970. *Proceedings of the Institution of Civil Engineers – Forensic Engineering* **165(4)**: 161–172, <http://dx.doi.org/10.1680/12.00012>.
- Boehme T and Robson DJ (2012) Offshore wind farm cabling: incidents and required learning. *Proceedings of the Institution of Civil Engineers – Forensic Engineering* **165(4)**: 185–197, <http://dx.doi.org/10.1680/12.00013>.
- Bregulla J (2012) Using experimental process and models in failure analysis. *Proceedings of the Institution of Civil Engineers – Forensic Engineering* **165(4)**: 173–183, <http://dx.doi.org/10.1680/12.00007>.
- Lee WF (2012) Briefing: Bridges at risk from multi-hazards. *Proceedings of the Institution of Civil Engineers – Forensic Engineering* **165(4)**: 157–159, <http://dx.doi.org/10.1680/12.00002>.
- Lewis WJ and Warburton HB (2012) Discussion: The question of structural form: educational aspects. *Proceedings of the Institution of Civil Engineers – Forensic Engineering* **165(4)**: 199–200, <http://dx.doi.org/10.1680/12.00019>.