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Forensic Engineering

Editorial: Digital forensic structural engineering in civil infrastructure

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In recent years, the field of civil engineering has faced mounting pressures from both natural and man-made hazards, rapidly evolving technologies, and increasingly complex structures. Within this landscape, forensic structural engineering has emerged as an essential discipline – not only in the aftermath of structural failures but also as a proactive framework for resilience, sustainability, and informed decision making. The growing integration of digital tools and analytical methods into forensic investigations marks a transformative step towards a more predictive and intelligent built environment. Recognising this momentum, the editorial panel chose digital forensic structural engineering as the theme for this special issue of *Forensic Engineering*.

Our motivation lies in the convergence of three critical needs. First, the growing frequency and intensity of hazards due to seismic, thermal, environmental, or accidental – underscore the importance of post-event assessment, retrofitting, and resilience planning. Second, there is a clear demand for innovative materials, methods, and technologies to address sustainability, durability, and efficiency. Third, the digital revolution – through building information modelling (BIM), geographic information systems (GIS), advanced simulations, and non-destructive testing – has opened new possibilities for how we assess, maintain, and reconstruct our infrastructure. Civil engineers must not only understand the immediate causes of failures but also anticipate and prevent them using a comprehensive digital forensic framework.

This themed issue brings together six papers that exemplify diverse and innovative approaches within this emerging domain. Each paper applies digital or experimental forensic methodologies to tackle a unique engineering challenge, offering valuable insights to researchers and practitioners.

1. Effect of negative stiffness devices on seismic retrofitting of soft-storey RC frames

Soft-storey failures remain one of the most devastating vulnerabilities in reinforced concrete (RC) frames, especially during seismic events. This paper explores the use of negative stiffness devices (NSDs) to enhance seismic retrofitting. The authors present a novel analytical approach where NSDs are strategically introduced to redistribute loads and dissipate energy. The research demonstrates that these devices can significantly reduce inter-storey drifts and enhance global stability without extensive structural modification. This aligns with the forensic engineering goal of minimising intervention while maximising resilience.

2. Thermal degradation and crack analysis of self-compacting geopolymer concrete

As engineers strive for sustainable alternatives to ordinary Portland cement, geopolymer concrete has attracted considerable attention. However, its performance under extreme conditions, such as high temperatures, remains underexplored. This study investigates the thermal degradation and crack patterns in self-compacting geopolymer concrete using both experimental testing and digital image analysis. The findings are critical for forensic evaluations following fire events and emphasise the importance of understanding material behaviour in extreme scenarios – particularly for new, sustainable construction materials.

3. GIS and BIM integration for assessing and maintaining existing buildings: a review

The integration of GIS and BIM offers a powerful toolkit for structural health monitoring and maintenance planning. This review article systematically explores how these technologies can work together to digitise, visualise, and assess building performance across its lifecycle. The authors highlight how forensic investigations benefit from spatial-temporal data, three-dimensional modelling, and scenario simulation. The paper provides a roadmap for combining geospatial and structural data to enhance diagnostics and long-term asset management – bridging the gap between reactive forensics and proactive engineering.

4. Combining experimental and computational approaches for post-fire safety assessment of RC warehouse

This paper presents a hybrid forensic methodology for evaluating the residual strength of a reinforced concrete warehouse after fire exposure. The authors combine physical testing (e.g. core sampling and visual inspection) with computational modelling to understand the extent of material degradation and loss in load-carrying capacity. The integrated approach exemplifies the digital forensic process, where data from multiple sources inform a reliable and cost-effective safety assessment. Such frameworks are essential for guiding repair decisions and preventing further failures.

5. Forensic investigation of a damaged concrete building: causes and remedial measures

Traditional forensic engineering remains at the core of this themed issue, and this paper presents a classic case study involving structural deterioration due to construction errors and material deficiencies. The investigation employs a combination of visual inspection, structural assessment, and material testing to trace the root causes. Importantly, the paper also offers remedial solutions based on digital modelling, ensuring that lessons learned are actionable. Such case studies remain foundational for the continuous improvement of codes, practices, and engineering education.

6. Addition of spent coffee grounds to reduce cement usage and increase cement mortar strength

Sustainability and forensic analysis intersect in this study, which investigates the use of spent coffee grounds as a partial cement replacement. The researchers use mechanical testing and microstructural analysis to assess strength performance, with encouraging results. While unconventional, the work underscores the potential of by-product materials to improve durability, reduce carbon footprint, and lower lifecycle costs. In forensic contexts, such materials require careful evaluation to ensure long-term reliability – a challenge this paper addresses head-on.

Taken together, the papers in this special issue illuminate the breadth and depth of digital forensic structural engineering. Whether through novel materials, advanced retrofitting devices, hybrid analytical techniques, or digital integration platforms, each contribution reinforces the idea that structural failures and their prevention must now be understood through a multidimensional lens.

For civil engineers, this thematic collection offers not only a snapshot of current capabilities but also a vision for the future: one in which forensic insight is embedded throughout the design, construction, and maintenance cycles. As our infrastructure ages and climate risks intensify, the ability to diagnose, adapt, and innovate will be our most powerful defence.

I hope this special issue stimulates further research, collaboration, and practical innovation in the evolving field of digital forensic structural engineering. Congratulations and sincere appreciation to all the contributing authors for their valuable work. Your contributions have enriched this special issue, and I wish you continued success in your scholarly endeavours and future research. A deep gratitude to the editorial panel and especially to the Chief Editor for their continued guidance, commitment, and support throughout the editorial process. Their leadership has been instrumental in upholding the standards and scientific rigour of the *Forensic Engineering* journal, which remains a vital platform for advancing knowledge and practice in this highly specialised and impactful discipline.

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