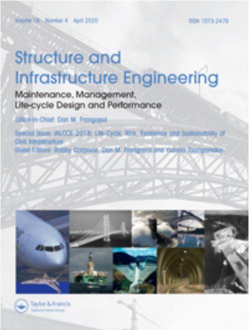

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SPECIAL ISSUE GUEST EDITORIAL

Life-cycle, risk, resilience and sustainability of civil infrastructure

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The International Association for Life-Cycle Civil Engineering (IALCCE) was founded in 2006 to create a fertile ground for promoting the study, research, and applications in the design, assessment, prediction, and optimal management of life-cycle performance, safety, reliability and risk of civil structures and infrastructure systems (http://www.ialcce.org). To accomplish this mission and following a series of International Workshops on Life-Cycle Cost Analysis and Design of Civil Infrastructure Systems held in Honolulu, Hawaii, USA (LCC1, 2000), Ube, Yamaguchi, Japan (LCC2, 2001), Lausanne, Switzerland (LCC3, 2003), Cocoa Beach, Florida, USA (LCC4, 2005), and Seoul, Korea (LCC5, 2006), it was decided to bring together the main advances on life-cycle civil engineering and related topics at the First International Symposium on Life-Cycle Civil Engineering (IALCCE'08), held in Varenna, Lake Como, Italy, 10–14 June 2008 (http://www.ialcce08.org), and afterwards at the Second International Symposium on Life-Cycle Civil Engineering (IALCCE 2010), held in Taipei, Taiwan, 27–31 October, 2010 (http://www.ialcce2010.ntust.edu.tw), the Third International Symposium on Life-Cycle Civil Engineering (IALCCE 2012), held at the Hofburg Palace in Vienna, Austria, 3–6 October, 2012 (http://www.ialcce2012.org), the Fourth International Symposium on Life-Cycle Civil Engineering (IALCCE 2014), held in Tokyo, Japan, 16–19 November, 2014 (http://www.ialcce2014.org), the Fifth International Symposium on Life-Cycle Civil Engineering (IALCCE 2016), held in Delft, The Netherlands, 16–19 October, 2016 (http://www.ialcce2016.org), and the Sixth International Symposium on Life-Cycle Civil Engineering (IALCCE 2018), held in Ghent, Belgium, 28-31 October, 2018 (http://www.ialcce2018.org).

IALCCE 2018 has been organized on behalf of the IALCCE under the auspices of Ghent University. The interest of the international civil engineering community in areas covered by the IALCCE has been confirmed by the significant response to the IALCCE 2018 call for papers. Overall, 675 abstracts from 64 countries were received by the Symposium Secretariat, and approximately 60% of them were selected for publication. Contributions presented at IALCCE 2018 included state-of-the-art as well as emerging applications related to key aspects of life-cycle civil engineering. The extended versions of selected papers presented at IALCCE 2018 and invited contributions are included in this special issue of *Structure and Infrastructure Engineering*.

The reliability-based design of structures as a system remains an issue that has not been addressed completely. This requires the assessment of the reliability of a complete structure, considering the effects of both the aleatory and epistemic types of uncertainty. Along these lines, the approach presented by *Ang, De Leon and Fan* focuses on optimal reliability-based aseismic design of high-rise buildings. *Yang and Frangopol* proposed a robust optimization approach for risk-based portfolio management of civil infrastructure assets under deep uncertainties associated with climate change. Robust optimization formulations are employed to yield intervention plans that can effectively reduce the long-term risk under different realizations of future scenarios. In general, the models used for storm surge are unsuited for probabilistic studies that require a large number of simulations. The main aim of the article by *Contento, Xu and Gardoni* is to develop a probabilistic framework for modeling the climate change effects on storm surge, using the combination of a logistic model and a non-stationary random field.

Due to environmental and loading effects, complex processes of deterioration in structural performance will be encountered in the maintenance and management of long-span bridges during their service life. *Chen, Wang, Ma and Pan* developed an efficient technique, based on data standardization, for life-cycle performance evaluation of a suspension bridge with multi-pylons. *Li, Yang and Shi* presented a detailed study on corrosion and its effects on deterioration and remaining safe life of civil infrastructure. In particular, they emphasize on corrosion effect of ferrous metals on degradation and remaining service life of infrastructure, using pipe fracture as an illustrative example. Hydraulic structures, such as ship locks and weirs, form an essential part of waterway networks. Accordingly, the study by *Geyer, Papaioannou, Kunz and Straub* highlights recent developments in reliability assessment of large hydraulic structures with spatially variable measurements. Their efficient life-cycle management is necessary to manage these large concrete structures safely and economically.

General frameworks for reliability differentiation have evolved over time and are mainly developed for buildings. However, recommendations for the safety of existing quay

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walls are lacking. Thus, target reliability indices for existing quay walls derived on the basis of economic optimisation and human safety requirements are presented by *Roubos, Allaix, Fischer, Steenbergen and Jonkman*. The paper by *Li, Dong, Frangopol and Gautam* describes the development of an efficient framework for the long-term resilience assessment of highway bridges under multiple independent natural hazards. The effects of extreme events, including earthquakes, hurricanes and floods, on the life-cycle performance of bridges are illustrated. In addition, a stochastic renewal process model of the random occurrence of hazard events is used by considering both time-independent and time varying occurrence characteristics.

Vereecken, Botte, Droogné and Caspeele focus on reliability-based design of temporary structures, since current design procedures do not ensure that an appropriate and consistent safety level is achieved for these types of structures. More specifically, they present a reliability-based calibration of partial factors for temporary structures in combination with appropriate target reliability levels for façade scaffolds, which can lead to their optimized design. *Capacci and Biondini* presented a study on probabilistic life-cycle seismic resilience assessment of aging bridge networks considering infrastructure upgrading under seismic and environmental hazards. The proposed framework accounts for the uncertainties in damage occurrence of vulnerable deteriorating bridges and restoration rapidity of the overall system functionality. The proposed methodology is applied to reinforced concrete bridges exposed to chloride-induced corrosion and simple road networks under different earthquake scenarios.

Delgadillo and Casas investigated novel empirical vibration-based methods for bridge damage detection, localization and quantification. Their article covers alternative approaches to damage identification of bridges using empirical parameters applied to measured vibration response data obtained from two field experiments of progressively damaged bridges subjected to ambient and vehicle induced excitation. *Panenka, Nyobeu Fangue, Rabe, Schmidt-Bäumler and Sorgatz* paper aims at determining reliability assessment of ageing infrastructure in Germany utilizing a holistic concept. The proposed methodology is closely connected to ongoing discussions about proactive and sustainable maintenance strategies under increasing economic and ecological pressures. It provides a step-by-step approach for creating a profound knowledge base which is required for the reliability assessment of ageing infrastructure.

The paper by *Kawabata, Kato, Yokota and Iwanami* proposes a novel methodology for performing maintenance management planning for port mooring facilities based on cost-benefit analysis. Net Present Value (NPV) is proposed as an effective indicator for decision-making processes entailed in the development of comprehensive maintenance strategies for mooring facilities of a port with consideration of variations in states of facility deterioration, leading to preventive maintenance of such important infrastructure. The objective of the paper by *He, Supasit, Akiyama and Frangopol* is the development of life-cycle reliability-based design and reliability updating of reinforced concrete shield tunnels in coastal regions. For new shield tunnels, a reliability-based durability design criterion to determine the concrete cover and concrete quality for preventing the deterioration of structural performance during the structural service life is proposed. For existing shield tunnels, an approach to update structural reliability is established based on Sequential Monte Carlo Simulation.

Climate change may have multifaceted impacts on the safety and performance of infrastructure. Accounting for the different ways in which potential climate change scenarios can affect infrastructure is of paramount importance in determining appropriate adaptation and risk management strategies. Since bridges operate for long periods it is vital to identify the long-term effects of climate change on bridges and their possible adaptations. The contribution by *Nasr, Kjellström, Björnsson, Honfi, Ivanov and Johansson* deals with climate change impact on safety and performance of existing and future bridges. Typically, the building stock is not designed for deconstruction, and material recovery for reuse at the end-of-life of buildings is complex and challenging. *Vares, Hradil, Sansom and Ungureanu* presented the economical potential and environmental effects of reused steel structures. This is achieved via a case study, which highlights the environmental and life-cycle cost impact of reused steel structures. The study examines four scenarios of industrial steel buildings constructed with new and reused steel structures, and relevant comparisons are presented in terms of life-cycle costs and greenhouse gas emissions.

In contrast to ordinary structures, which are built using normal strength concrete, for bridge structures with increased use of high strength concrete and increase in traffic loads, fatigue verification becomes much more important for their safety. *Mankar, Rastayesh and Sørensen* focus on fatigue reliability analysis by presenting the case study of Cret De l'Anneau viaduct. Their paper presents a probabilistic approach for reliability assessment of existing bridges along with reliability-based calibration of fatigue-design-factors based on the S-N approach. The use of high strength steel may represent a significant advantage since it enables to reduce the quantity of materials required for a structure to fulfil its function. The paper by *Lemma, Gervásio, Pedro, Rigueiro and Simoes da Silva,* discusses the potential advantages of high strength steel (HSS) in bridge design, in terms of structural, environmental and economic enhancements of bridge life-cycle performance. Notwithstanding the potential benefits, the use of HSS slender plates makes I-girders more vulnerable to local bucking phenomena and fatigue issues, which are covered in this paper.

Cadenazzi, Dotelli, Rossini, Nolan and Nanni focused on cost and environmental analyses of reinforcement alternatives for a concrete bridge. For this purpose they analyzed the resilience and economical sustainability of a concrete bridge in Florida with fiber reinforced polymer rebars, focusing on life-cycle cost analysis at the design stage. Cost sensitivity analyses over specific parameters are included, namely: reinforcement cost, changes in chloride concentration levels over the bridge service life, and discount rate values. Conclusions and recommendations for standard practices and design of future alternative solutions are presented.

The guest editors wish to thank the authors and the reviewers for contributing to this special issue and hope that this collection of papers will represent a useful reference for researchers, students, and practitioners to promote and advance research and applications in the field of life-cycle civil engineering.

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