Life-Cycle Performance of Civil Structure and Infrastructure Systems

An International Workshop Organized by ASCE

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Structural engineering is undergoing a profound change towards a life-cycle-oriented design philosophy to fulfill the continuously increasing demand from societal, political, economic and environmental needs. In this approach, the classical point-in-time design criteria are extended to account for more comprehensive time-variant performance indicators over the entire service life. Considering this need, the American Society of Civil Engineers (ASCE) proposed the use of Life-Cycle Cost Analysis in conjunction with the Grand Challenge of reducing life-cycle costs of civil infrastructure projects by 50% by 2025.

The recent advances accomplished in the fields of modeling, analysis, design, maintenance and rehabilitation of deteriorating civil structure and infrastructure systems are hence perceived to be at the heart of a modern approach to structural engineering. These advances are of crucial importance to establish guiding policies and support decision-making processes for reliable design of durable structures and rational planning of maintenance, repair, or replacement of existing structures. Furthermore, the availability of quantitative life-cycle performance metrics provides for effectively incorporating emerging issues in structural design, such as the effects of global warming and climate change. Societal issues in adopting life-cycle concepts in the decision-making process may also play a major role within the political system to comply with the different methods, metrics, needs, and priorities addressed by public officials, civil infrastructure users, and owners.

Despite significant advances and accomplishments, life-cycle concepts are not yet explicitly dealt with in structural design codes, and the checking of system performance requirements is referred to the initial time of construction when the system is intact. In this approach, design for durability with respect to chemical-physical damage phenomena is based on simplified criteria associated with classes of environmental conditions. As an example, for concrete structures, such criteria introduce threshold values for concrete cover, water-cement ratio, and amount and type of cement to limit the effects of local damage due to carbonation of concrete and corrosion of reinforcement. However, a durable design cannot be based only on such indirect evaluations of the effects of structural damage, but also needs to take into account the global effects of the local damage phenomena on the overall performance of the structure. These considerations indicate that there is still a strong need to promote further research in the field of life-cycle performance of structural systems under uncertainty, and to fill the gap between theory and practice by incorporating life-cycle concepts in structural design codes.

The research and applications in the field of life-cycle assessment, prediction, and optimal management of structures and infrastructure systems under uncertainty are promoted within SEI/ASCE by the Technical Council (TC) on Life-Cycle Performance, Safety, Reliability, and Risk of Structural Systems (authorized November 7, 2008, and chaired by the second author). The Technical Council and its three Task Groups provide a forum for reviewing, developing, and promoting the principles and methods of life-cycle performance, safety, reliability, and risk of structural systems in the analysis, design, construction, assessment, inspection, maintenance, operation, monitoring, repair, rehabilitation, and optimal management of civil infrastructure systems under uncertainty. In particular, the purpose of Task Group 1 (TG1) on Life-Cycle Performance of Structural

Group picture of participants (ASCE Headquarters, 10th November 2015). In alphabetical order: Mitsuyoshi Akiyama, Japan; Alfredo Ang, USA; Fabio Biondini, Italy; Paolo Bocchini, USA; Sofia Diniz, Brazil; Bruce Ellingwood, USA; Dan Frangopol, USA; Michel Ghosn, USA; Emad Iskander, USA; Zoubir Lounis, Canada; Adam Matteo, USA; Ehsan Minaie, USA; Terry Neimeyer, USA; Kostas Papakonstantinou, USA; Pariya Pourazarm, USA; Arturo Rodriguez Tsouroukdissian, USA; Samantha Sabatino, USA; Mauricio Sánchez-Silva, Colombia; Mark Sarkisian, USA; Behrouz Shafei, USA; Sarbjeet Singh, USA; Ian Smith, Switzerland; Iris Tien, USA; Lucia Tirca, Canada; Andrea Titi, Italy; George Tsiatas, USA; Naiyu Wang, USA; Arnold Yuan, Canada; Wei Zhang, USA; Robert Zobel, USA.

Systems under Uncertainty is to promote the study, research, and application of scientific principles of safety and reliability in the assessment, prediction, and optimal management of life-cycle performance of structural systems under uncertainty.

The ongoing activities of SEI/ASCE TC TG1 include a Special Project approved by the SEI Technical Activities Division Executive Committee for the development of a state of the art report outlining the current status and research needs in the fields of life-cycle of civil structure and infrastructure systems. The task of the Special Project was to conduct a survey and organize an International Workshop on Life-Cycle Performance of Civil Structure and Infrastructure Systems. The objectives were to overview the advances accomplished in the field of life-cycle civil engineering, to promote a better understanding of life-cycle concepts in the structural engineering community, and to discuss methodologies and tools to incorporate life-cycle concepts into structural design codes and standards.

This International Workshop, organized and chaired by the writers of this article, was held on November 10th, 2015, at the ASCE Headquarters in Reston, VA, USA. The Workshop program included invited plenary lectures addressing the current state of research and practice, as well as breakout working sessions and group reports. Over 30 invited participants from several countries attended the Workshop (see *Figure*). The workshop was very successful in assembling information on the development and implementation of criteria, methods and tools for life-cycle design and assessment of civil structure and infrastructure systems.

The final results of both the survey and workshop complement information on the state-of-research and -practice. In particular, there is an awareness that a robust prediction of the time-variant structural performance must rely on a reliable and efficient probabilistic deterioration modeling of materials and structural components. Advanced models are well established for some of the most detrimental damage processes, such as corrosion and fatigue, and are rapidly becoming available for a wider range of deterioration mechanisms. However, deterioration models are very sensitive to the change of the probabilistic parameters of the input random variables, and their robust validation and accurate calibration are difficult tasks to be performed due to the limited availability of data. Further efforts in this direction, aimed at gathering new data from both existing structures and experimental tests, are crucial for a successful implementation in practice of life-cycle methods. In this context, inspection and monitoring activities could provide a powerful aid to reduce the level of epistemic uncertainty and to improve the accuracy of predictive probabilistic models.

Civil infrastructure systems are the backbone of modern society and among the major drivers of the economic growth and sustainable development of countries. It is hence a strategic priority to consolidate and enhance criteria, methods, and procedures to protect, maintain, and improve the safety, durability, efficiency, and resilience of critical structure and infrastructure systems under uncertainty. We sincerely hope that the effort ongoing within the SEI/ASCE TC and TG1 contributes to promoting the application of life-cycle concepts in design practice, influence the development of structural design codes and standards, and enhance the state of the civil structures and infrastructures to protect the public safety and improve the quality of life.▪