Performance Evolution and Control for Engineering Structures

—Proceedings of the 9th Asia-Pacific Young Researchers and Graduates Symposium (YRGS 2019)

工程结构性能演化与控制

——第九届亚太地区青年学者和研究生论坛

Editors CHEN Jianbing YU Qian-Qian PENG Yongbo
陈建兵 余倩倩 彭勇波 主编

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内 容 提 要

工程结构在服役过程中经历反复荷载和环境介质的长期作用，不可避免地会产生损伤累积、性能退化、风貌丧失等问题，需要对其进行性能评估与修复加固。工程结构性能演化与控制已成为当前国际学术研究的前沿和热点。本书是第九届亚太地区青年学者和研究生论坛（the 9th Asia-Pacific Young Researchers and Graduates Symposium YRGS 2019—Performance Evolution and Control for Engineering Structures）的论文集，收录了来自丹麦、韩国、美国、意大利、印度、日本和中国的各位作者的76篇论文和扩展摘要，反映了近年来工程结构性能演化与控制的国际国内最新进展。本书可供土木工程专业的教师、研究人员、研究生和高年级本科生及工程师参考。

图书在版编目(CIP)数据

工程结构性能演化与控制：第九届亚太地区青年学者和研究生论坛 = Performance Evolution and Control for Engineering Structures — Proceedings of the 9th Asia-Pacific Young Researchers and Graduates Symposium（YRGS 2019）：英文/陈建兵，余倩倩，彭勇波主编. —上海：同济大学出版社，2019.12

ISBN 978-7-5608-8854-5

Ⅰ.①工… Ⅱ.①陈… ②余… ③彭… Ⅲ.①工程结构—结构性能—国际学术会议—文集—英文 Ⅳ.①TU31-53

中国版本图书馆CIP数据核字(2019)第259109号

Performance Evolution and Control for Engineering Structures — Proceedings of the 9th Asia-Pacific Young Researchers and Graduates Symposium (YRGS 2019)

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责任编辑 陆克丽霞 李 杰 **责任校对** 徐春莲 **封面设计** 陈益平

出版发行 同济大学出版社 www.tongjipress.com.cn

（地址：上海市四平路1239号 邮编：200092 电话：021-65985622）

经 销 全国各地新华书店、建筑书店、网络书店

排 版 南京文脉图文设计制作有限公司

印 刷 当纳利(上海)信息技术有限公司

开 本 787 mm×1092 mm 1/16

印 张 17

字 数 424 000

版 次 2019年12月第1版 2019年12月第1次印刷

书 号 ISBN 978-7-5608-8854-5

定 价 98.00元

Preface

The Asia-Pacific Young Researchers and Graduates Symposium (YRGS) is primarily a platform for early-stage structural engineering professors, research scientists, professional engineers, postdoctoral fellows and postgraduate students to present their latest findings within the context of wide structural engineering discipline. The symposium features oral presentations predominantly from early-career structural engineering people but also includes talks from leading figures in the field. It provides an opportunity for learning about future career paths and networking with fellow researchers. The previous YRGSs has been held in Kunsan, Korea since 2009, then in Hangzhou (China), Taipei (China), Hong Kong (China), Jaipur (India), Bangkok (Thailand), Kuala Lumpur (Malaysia), Tokyo (Japan) from 2010 to 2017. Up to now, it has been successfully organized for 8 times. With 10 years' development, the YRGS has become attractive to many elites and young scholars all over the world with its distinct characteristics and features.

The 9th Asia-Pacific Young Researchers and Graduates Symposium-Performance Evolution and Control for Engineering Structures (YRGS 2019) will be held in Shanghai on 19 - 20 December 2019. It is sponsored by College of Civil Engineering, Tongji University, Key Laboratory of Performance Evolution and Control for Engineering Structures of Ministry of Education of China and Asia Concrete Federation (ACF), to promote close international communication and cooperation, and to figure out the future development of structural engineering. The objectives of the upcoming symposium (YRGS 2019) are again to provide a forum to deal with the state of the art as well as emerging concept and technology, e.g., multi-scale and multi-field methodologies, super-computing, big-data and AI, etc., related to research and practice, particularly in the theme of performance evolution and control for engineering structures, which has been receiving increasing attention due to its important role in sustainability-oriented life-cycle performance civil engineering and resilience of city and countryside.

Over 80 abstracts from 9 countries and regions were submitted to the symposium and accepted for publication in the abstract proceedings of YRGS 2019. The authors are from China (including Hong Kong and Taiwan), Denmark, India, Italy, Japan, South Korea, and USA. On behalf of the YRGS 2019 organizing committee and Tongji University, the chairs of the Symposium would like to cordially welcome all the authors and participants. We also take this opportunity to express our sincere thanks to the distinguished keynote

lecturers—and to all the members of the Advisory Committee, International Scientific Committee and International Steering Committee.

We believe with your contribution and participation, the YRGS 2019 will be a successful event. We earnestly hope that all the participants will enjoy their stay and have a great time in Shanghai.

CHEN Jianbing YU Qian-Qian PENG Yongbo
Chairs, YRGS 2019
Department of Structural Engineering, Tongji University, Shanghai, China

Contents

Keynote Lectures

Life-cycle management of concrete structures based on sustainability framework

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Abstract

A concrete structure has to be thoroughly planned, designed, executed and maintained to keep its performance over its corresponding requirements throughout the life-cycle. However, structures suffering from serious damages in structural members have been often found due to various reasons. One of the reasons is lack of total management of the structure. The life-cycle management is an organized system to support engineering-based decision making for ensuring performance of a structure at the design, execution, maintenance, and all related work during its life-cycle. The life-cycle management is implemented according to the life-cycle management scenario in which balance of several sustainability indicators would be considered with ensuring overall sustainability. This paper presents the concept and framework of the life-cycle management of concrete structures to ensure sustainability during the life-cycle of the structure.

1. Introduction

A concrete structure is constructed with its own purposes such as supporting socio-economic activities, protecting people from disasters, and ensuring a comfortable and safe life. The structure is required to maintain its function and performance to achieve these purposes during its design service life. However, serious damages have been sometimes found, which may provoke performance degradation, and even structural collapse may be consequences. The life of a structure is made up of all the activities including planning, basic and detailed designs, execution, maintenance and intervention, and decommissioning. When coordination of those activities is not ensured, such damages may be found. Therefore, it is very important to coordinate these activities sufficiently. The life-cycle management (LCM) is the overall strategy with the aim of ensuring that the structure meets the associated performance requirements. The strategy is embodied by an LCM scenario. The scenario is formulated at the time of planning and design and may be subsequently modified at each stage of structure's life-cycle. LCM also contributes to realize a sustainable society through structures. Sustainability is defined in terms of environmental,

economic, and social aspects. During the life-cycle of structures, sustainability is generally considered with one or a few sustainability indicators. The introduction of LCM for a structure would contribute to all aspects of sustainability while maintaining the function and performance. This paper introduces the principles and framework of LCM for concrete structures. This paper has been prepared by editing the parts of the contents of author's previously published papers[1, 2].

2. Framework of Life-Cycle Management

A concrete structure passes through different stages during its life: from the planning, design, execution, use, and to the end-of-life stages. Due to its long life, it involves different parties at each stage. This implies that it is essential to coordinate all the stages with transferring important information from one stage to another in an appropriate form. LCM is systematic and coordinated activity and practice through which a structure is appropriately managed over its life cycle.

The overall framework of the LCM is summarized in Figure 1. LCM is implemented according to the LCM scenario in which balance of several sustainability indicators should be considered with ensuring performance requirements. The sustainability indicators will be determined from the social, environmental and economic points of view. The scenario should be regularly reviewed and evaluated based on the PDCA cycle[3] and be updated if necessary. As shown in the Figure 1, the LCM is an integrated concept to assist in activities managing the total life-cycle of structure based on managements of each stage to ensure structural functions and performance and to achieve sustainability. As a platform to share the information, BIM has a big potential for use[4].

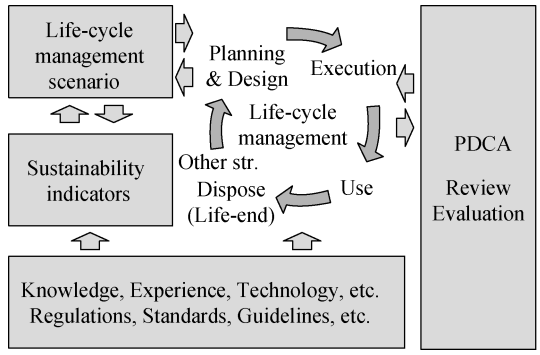

Figure 1 Framework of the life-cycle management

3. Procedure of Life-Cycle Management

Figure 2 shows the standard procedure of LCM. For a new structure, an LCM scenario should be formulated during or after the planning stage of the structure. The scenario includes the fundamental strategy on how the structure will be managed in terms of structural performance and sustainability aspects. The structure is generally designed to keep its structural function and performance without major interventions; however, planned interventions can be included in the scenario if they are required. The scenario mediates among the stages of the structural life-cycle. Design will be carried out to satisfy the scenario initially formulated. When the design outputs do not satisfy the scenario, either the scenario is modified to be consistent with design outputs and/or design is carried out

again. After the execution, initial assessment is carried out to check the conditions of the structure. When any defect is found from the assessment, interventions should be taken as required. Then, it will be judged whether the scenario is suitable for the subsequent life-cycle of the structure or not. When the scenario is found to be unsuitable, the scenario should be updated. During the use stage, the structure is periodically assessed its conditions and performance possessed, and the above procedure should be repeated. When the scenario has been updated, the updated scenario should be reflected on subsequent management. If it is judged that interventions should not be taken from the sustainability evaluation mentioned later, the structure goes to the end-of-life stage.

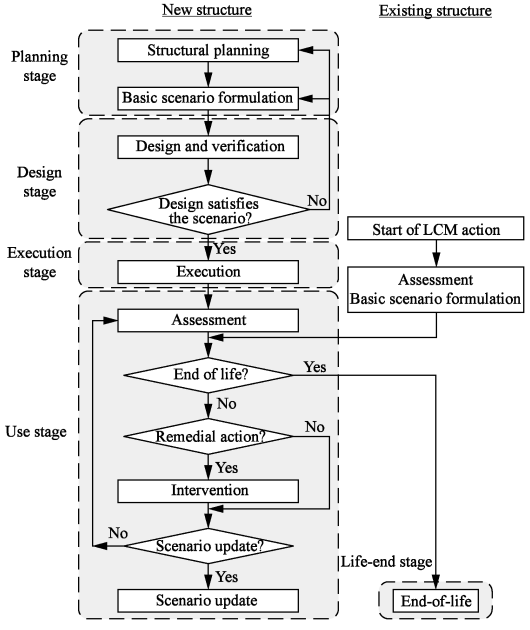

Figure 2 Standard procedure of life-cycle management

For an existing structure, the assessment should be carried out before starting the LCM procedure. The scenario is formulated according to the result of the first assessment and documents even they may not be enough. When the assessment results conclude that interventions are difficult to take to recover structural performance, the structure goes to the life-of-end stage; otherwise, the same procedure as that for a new structure can be followed.

4. Sustainability Indicators

It is necessary to choose suitable indicators to objectively evaluate LCM scenarios and make decisions. The author proposes to use sustainability indicators for this purpose. Sustainability is defined as a concept based on the environmental, economic and social aspects, and is one of the key issues in a construction sector to be well considered in the 21st century[5].

It is easy to understand that collapse of structure impairs the sustainability because the treatment of debris produced by destruction of structures needs huge energy and reconstruction of structures requires an additional amount of resources and energy. Many people might be killed or injured, and employment and production bases would be temporally unavailable. Engineers keep it in mind what might happens by phenomena that are not covered by the design. Thus, the safety margin or safety redundancy that represents the resistance of structure directly links the social sustainability. As the environmental aspect of sustainability, appropriate indicators are set for

environmental impacts in the execution and use stages of the structure, such as resource consumption, greenhouse gas emission, and impacts on the ambient environment. As the economic aspect, all the direct and indirect costs during execution and the use and at the end of life of the structure, as well as the benefits and values provided by the structure, can be set as indicators[6].

It is not so easy to find the best solution among alternatives because no comprehensive indicator exists. For example, when the margin of safety (safety redundancy) is taken more, more resources and energy may be needed for construction and higher construction cost will be consequences, as indicated in Figure 3[7]. This is the collision among the sustainability indicators. Therefore, the sufficient balance among each sustainability indicator should be achieved.

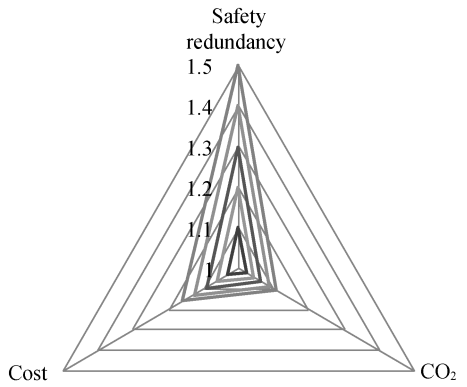

Figure 3 Balance between social (safety redundancy), environmental (CO_2 emission) and economic (cost) indicators[7]

Sustainability indicators should be well considered in the life-cycle of structure. Durability is directly related to structural performance such as safety and serviceability, while resilience and robustness are related to the safety margin and the mechanism of failure. Sustainability is systemized at each stage of life-cycle to consider in a comprehensive manner, safety and serviceability under the social aspect, cost under the economic aspect, and resources and energy under the environmental aspect. LCM allows for designers to find a good balance between social, economic and environmental indicators.

5. Conclusions

LCM is an integrated concept to assist in activities managing the total life-cycle of structures to realize sustainability. The following are concluding remarks in this paper:

(1) For doing infrastructure management, planning, design, execution, and use stages should be well coordinated, in which necessary information should be shared and transferred among the life-cycle stages.

(2) During LCM, sustainability should be well considered to formulate the scenario. Structural performance can be included in the sustainability concept.

(3) It is necessary to well consider the balance between the safety redundancy that should be considered as social sustainability and other sustainability indicators in terms of economic and environmental aspects.

(4) A concrete structure inherently has a long life when it is well designed, executed, and maintained. It can achieve