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Analysis and Design

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Edited by
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DEDICATION



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May 17, 1932 to May 31, 2019

Dr. Wright was a research professor of civil and environmental engineering at the University of Maryland, College Park, the past chair of ASCE's Committee on Adaptation to a Changing Climate, a member of the ExCom of the Infrastructure Resilience Division, and a member of the ASCE Committee on Sustainability, as well as the chair of its Sustainable Infrastructure Education Subcommittee. He was a distinguished member of ASCE and a member of the National Academy of Engineering.

He received his bachelor's and master's degrees from Syracuse University and his doctorate from the University of Illinois at Urbana-Champaign, all in civil engineering. He worked as the director of the Building and Fire Research Laboratory of the National Institute of Standards and Technology (NIST) and a professor of civil engineering at the University of Illinois at Urbana-Champaign. He was the president of the International Council for Research and Innovation in Building and Construction (CIB) and the president of the Liaison Committee of International Civil Engineering Organizations.

Dr. Wright's professional honors include the Gold Medal of the Department of Commerce (1982); Federal Engineer of the Year from the National Society of Professional Engineers (1988); Mahaffey Award from the National Conference of States on Building Codes and Standards (1998); Michel Award for Industry Advancement of Research from the Civil

Engineering Research Foundation (1999); election to the National Academy of Engineering (2003); International Award of the Japan Society of Civil Engineers (2003); University of Illinois, College of Engineering, Alumni Award for Distinguished Service (2006); President Medal of ASCE (2010); and the Hans Oser Standards Alumni Association Distinguished Service Award (2014).

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FOREWORD

ASCE has established the Grand Challenge as a way of recognizing the need for increasing investment in the infrastructure on which our society is built. The systems on which we rely to provide safe transportation, clean water, secure structures, and reliable energy and telecommunications are increasingly frail as they reach the end of their design lives.

However, it is not enough to simply replace old with similar. Limitations on natural and fiscal resources, a changing climate, and expectations of modern infrastructure to have a low life-cycle cost and increased longevity are making the ways of the past obsolete. Today's civil engineers need to consider new design and construction approaches incorporating new materials and emerging technologies. We must ensure that the next generation of infrastructure systems not only meets nominal expectations but also has the resilience to perform during and recover rapidly after exposure to hazardous conditions.

Recognizing this, ASCE has established roughly two dozen policy statements (PS) related to infrastructure development and disaster mitigation. PS 500, *Resilient Infrastructure Initiatives*, was adopted to

> … support initiatives that increase resilience of infrastructure against man-made and natural hazards through education, research, planning, design, construction, operation and maintenance. Development of performance criteria and uniform national standards that address interdependencies and establish minimum performance goals for infrastructure is imperative.

This policy goes on to note that

> … an all-hazard, comprehensive risk assessment that considers event likelihood and consequence, encourages mitigation strategies,

> monitors outcomes, and addresses recovery and return to service should be routinely included in the planning/design process for infrastructure at all government levels.

Similarly, PS 518, *Unified Definitions for Critical Infrastructure Resilience,* establishes consistent terminology to allow a clear characterization of critical infrastructure, hazards, and resilience. In this vocabulary, resilience refers to

> … the capability to mitigate against significant all-hazards risks and incidents and to expeditiously recover and reconstitute critical services with minimum damage to public safety and health, the economy, and national security.

Subsequent to this, and in continued response to the need to promote programs leading to design, construction, and maintenance of robust infrastructure systems, ASCE formed the Infrastructure Resilience Division (IRD) under the Committee for Technical Advancement (CTA). The charge for IRD is to develop "… products and services to include … manuals of practice … to advance resilient practices related to civil infrastructure and lifeline systems …".

After a significant investment of time and resources by ASCE members working through IRD, this document was developed, reviewed, and finalized. We feel you will find that the publication is noteworthy in the depth and breadth of its address of the topics of infrastructure resilience. It is the hope of IRD, CTA, and ASCE that you and others will find the Manual of Practice (MOP) to be an effective reference for engineers and others interested in the diversity of issues related to the planning, design, analysis, and construction of hazard-resilient infrastructure systems.

One will recognize that this MOP is significant in content which, in turn, may limit immediate application of the concepts and approaches included herein by those in small organizations or who have had less exposure to the contemporary issues facing the nation's infrastructure replacement needs. However, the authors submit that to make it less comprehensive would be an injustice to the topic and to those wishing to include robust system design in their practice. Further, with time, the utility of this document is expected to increase and the information contained herein become a standard of practice.

Before concluding, one must acknowledge that the creation of an MOP requires an immense effort by a cadre of volunteers. This team hopes of providing the user with an important reference resource to address 21st century system challenges. It is also worth noting that whereas many contributed significantly to the production of this document, a substantial effort in making the MOP a reality was invested by Dr. Bilal Ayyub, P.E.,

Dist.M.ASCE, Hon.M.ASME. Dr. Ayyub is a professor of civil and environmental engineering and director of the Center for Technology and Systems Management at the University of Maryland. Many involved with the project have suggested that, in no small way, his vision, leadership, and commitment to this project is a major factor that resulted in the completion of this MOP. It is the dedication to sharing best practices of our craft by volunteers like those involved in this project that allows ASCE to stand globally at the front of our profession.

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PREFACE

This publication titled, *Hazard-Resilient Infrastructure: Analysis and Design*, was prepared by the ASCE Infrastructure Resilience Division during 2018 to 2020.

Benefits of enhancing resilience go well beyond cost savings and include important considerations such as the health, safety, and welfare of the public and socioeconomic well-being. Resilient systems should be developed to meet sustainability requirements defined by the three pillars of sustainability of environmental, social, and economic, by reconciling environmental, social equity, and economic demands, respectively. This MOP has primary objectives of providing guidance for the design of hazard-resilient infrastructure systems and enhancing the resilience of existing ones for the purpose of meeting community resilience goals. It secondarily contributes to the development and enhancement of standards for infrastructure analysis and design, as well as regulations and building codes that refer to them, in a world in which risk profiles are changing. This MOP and such efforts contribute to achieving hazard-resilient infrastructure.

This MOP offers a framework for creating consistency across hazards, systems and sectors. It offers an opportunity to prepare a series of hazard-specific MOPs on topics such as (a) earthquake, (b) flooding, (c) tornado and extreme wind, (d) fire, (e) climate, and others. MOP 140, *Climate-Resilient Infrastructure* already exists, prepared by the ASCE Committee of the Adaptation to a Changing Climate. This MOP could be used as a basis to prepare earthquake-resilient infrastructure MOP. In addition, it offers an opportunity to prepare a series of multi-hazard sector or system specific MOPs on topics such as (a) electric power distribution, (b) transportation (e.g., mass transit networks), (c) water distribution, (d) communication,

(e) marine transport and navigation, and others. For example, this MOP could be used as a basis to prepare a publication on resilient-electric power distribution infrastructure. Combinations of these two types are worthy of pursuits, such as an earthquake resilient-electric power distribution infrastructure MOP.