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Resilience Engineering for Urban Tunnels

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Contents

Preface v
Acknowledgments vii
Attendees and Affiliations ix
Introduction xi

Keynote Speaker Papers

Enhancing Civil Infrastructure Resilience with Structural Health Monitoring 3
Yunfeng Zhang, Bilal Ayyub, and Hongwei Huang

Reliability Analysis and Real-Time Predictions in Mechanized Tunneling 13
Günther Meschke, Ba Trung Cao, and Steffen Freitag

Non-intrusive Inspection and Real-Time Monitoring for Tunnel Structural Resilience 29
Hongwei Huang and Dongming Zhang

Efficient Reliability and Risk Analysis of Complex Interconnected Systems 43
J. Behrensdorf, M. Broggi, and M. Beer

Enhancing Resilience of Traffic Networks with a Focus on Impacts of Neuralgic Points Like Urban Tunnels 55
Katharina Klemt-Albert, Robert Hartung, and Sascha Bahlau

Reliability of Critical Infrastructure Networks: Challenges 71
Konstantin M. Zuev and Michael Beer

Decision Aids for Tunneling 83
Herbert H. Einstein

Breakout Session Reports

Topic 1: Monitoring for Resiliency of Urban Tunnels 89
Topic 2: Robust Design of Tunnels 95
Topic 3: Modeling and Management of Uncertainties 99

Research Recommendations

1. Monitoring for Resiliency of Urban Tunnels 105
2. Robust Monitoring and Maintenance for Durability.....107
3. Resilience Engineering at System Scale 109

Index.....115

Preface

This report addresses the area of resilience engineering with specific emphasis on urban tunnels and their embedding into civil infrastructure systems. It provides bases for developing a comprehensive overall approach to resilience of urban tunnels. The contributions in this report cover the state of the art from various relevant perspectives, as well as conclusions made for perspective developments. As such, this report provides a source for students and researchers interested in resilience of urban tunnel and infrastructure to get a quick impression on the state of development. It may also serve as a resource for practitioners to adopt recent developments for current and future engineering projects to address and increase resilience. Eventually, the report will increase awareness of the significant importance of resilience among authorities to implement requirements to ensure sustained societal and economic benefits.

The state of the art is represented in seven invited papers. The paper by Zhang and Ayyub describes pathways for using integrated structural health monitoring to enhance the resilience of civil infrastructure. Meschke, Cao, and Freitag report on recent developments for controlling mechanized tunneling using real-time predictions for ensuring structural reliability. An advanced technology for real-time monitoring of tunnels is presented by Huang and Zhang, where non-intrusive inspections are used to ensure tunnel resilience. These three contributions demonstrate the current level of achievement in the area using advanced engineering models and technologies. In addition, they provide a perspective for further developments expanding from this platform. The remaining papers address selected specific challenges and ideas for solution that seek their synergetic marriage with the broad powerful platform to form a comprehensive overall framework to address resilience of urban tunnels at large. Behrensdorf, Broggi, and Beer explore a numerical concept for assessing the reliability of complex interconnected systems. Klemt-Albert, Hartung, and Bahlau discuss the criticality of neuralgic points in traffic networks in view of enhancing resilience. Zuev and Beer highlight issues and potential solutions when assessing reliability of networks of critical infrastructure. Eventually, Einstein documents the importance of decision aids in tunneling with respect to risk and resilience.

The second part of this report is built on the discussions from the First International Workshop on Resiliency of Urban Tunnels (Reston, Virginia, USA, September 1, 2016) and the conclusions drawn for perspective developments. This part is structured in conclusions from three breakout session reports, and three structured research recommendations on the key topics are identified. The first breakout session report concerns the monitoring for resiliency of urban tunnels. The second report refers to robust design of tunnels. Third, the modeling and

management of uncertainties is considered. The reports in these three topic areas summarize synergetic findings and advice from expert discussions as a guide for future developments. They were used as a basis to develop three structured research recommendations, which were rolled out after the breakout session reports. The first recommendation is focused on developments on monitoring for resiliency of urban tunnels. The second concerns robust monitoring and maintenance for durability. The third is devoted to resilience engineering at a system scale. These recommendations are intended to be developed into large-scale research programs.

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Bilal M. Ayyub, University of Maryland, College Park, USA

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Sez Atamturktur, Clemson University, USA
Konstantin M. Zuev, California Institute of Technology, USA
Herbert H. Einstein, Massachusetts Institute of Technology, USA
Bill Bergeson, Federal Highway Administration, USA
Brian Wolfe, Maryland Transportation Authority, USA

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Introduction

Urban tunnels nowadays play a quite significant role in transportation systems, not only to make transportation more efficient avoiding congestions but also to improve the quality of life in metropolitan areas by removing traffic from the living environment. As the number of urban tunnels increases incredibly, questions and concerns regarding their safe operation, potential vulnerability and recovery after intentional or unexpected disruption have become central issues not only among engineers and stakeholders but also in the society and governmental administration. Clearly, this situation is calling for a generalized structured approach not only for assessing, mitigating and managing risk but actually for a comprehensive resilient design and operation. However, in practice, operation and maintenance of tunnels is largely realized through heuristic approaches. Current research and practice show a key deficiency: while significant efforts have been made on risk assessment, only little has been done for risk control including resilience of underground structures, thus resulting in unexpected economic losses. An application-oriented method for dynamic risk control and resilient design is of great necessity for the safe operation of our underground systems. As a particular technical challenge, this approach needs to combine elements from structural engineering and systems engineering. Moreover, it needs to include a large monitoring component, and it needs to be dynamic to account for rapid changes in system states and conditions. In operating such ever-growing infrastructure systems, the risk associated with tunnels has become a focus of the government and the public in the world. Since this situation does not only apply to one country or society but is a global problem, it can be addressed best with joint forces.

With this mission in mind, we have brought together more than 30 selected researchers in the areas of geotechnical, structural and system risk from the United States, China, Germany, and with diverse responsibilities from academic, industrial, and governmental perspectives. To identify a clearly structured research agenda for the development of a dynamic risk control and resilient design approach, the workshop covered three major topics including smart sensing, robust design and uncertainty modeling. Seven keynotes covering the aforementioned three topics were delivered by distinguished researchers in each area. After a seed discussion, seven subtopics were identified with the goal of driving projects in global collaborations. The first topic covers monitoring for urban tunnel resilience. The second topic addresses robustness against uncertainties in the construction. The third topic puts efforts on the integrated robust design through modularity and adaptability. The fourth topic is devoted to robust monitoring and maintenance for durability. The fifth topic concerns generalized modeling for

resilience engineering with a component scale and a systems scale perspective. The sixth topic covers resilience-informed decision making, and the last topic addresses multisector interdependencies in the resiliency modeling.

With this structure the workshop was cumulated in the development of large-scale research proposals by the attendees, which are all synchronized. In combination of the developments we then aim for a comprehensive overall approach to resilience of urban tunnels to be established within a reasonably short time. To monitor the developments and their interaction, this workshop is expanded into a series of annual meetings around the world, rotating between America, Europe, and Asia.

Michael Beer, Chair