Earthquake Disaster Simulation of Civil Infrastructures

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From Tall Buildings to Urban Areas

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Preface

Earthquake is a natural disaster that severely threatens the safety of people. In consequence, increasing the seismic resistance and resilience of civil infrastructures and cities through in-depth research of earthquake engineering has significant value for safeguarding life and property. Note that since the devastating Tangshan Earthquake in 1976, no severe earthquake has taken place for more than 40 years in the eastern and central cities of China. Experiences gained from the previous earthquakes obviously cannot satisfy the latest development of structures and urbanizations. Considering the capacity limitations of physical testing facilities, an accurate, efficient, and realistic numerical simulation of seismic damage to structures and cities is critically needed for developing rational and practical engineering solutions and mitigation strategies to reduce the impacts of earthquakes.

The authors of this monograph have systematically studied the earthquake disaster simulation of civil infrastructures for more than 12 years. The outcomes of their work are summarized in this monograph, covering the novel computational models, high-performance computing methods, and realistic visualization of tall buildings and urban areas, with particular emphasize on collapse prevention and mitigation in extreme earthquakes, earthquake loss evaluation, and seismic resilience. Typical engineering applications to several tallest buildings in the world and selected large cities in China are also introduced to demonstrate the advantages of the proposed computational models and techniques. It should be recognized that extensive studies related to earthquake disaster simulation have been conducted by many other researchers. This monograph is intended to present the work completed by the authors and their coworkers only.

The contents covered in this monograph include the research outcomes of many important research projects sponsored by various research agencies, including the Excellent Young Scientist Fund of the National Natural Science Foundation of China (NSFC) (No. 51222804), the Key Research Plan of NSFC (No. 90815025, 91315301), the NSFC-NSF US Major International (Regional) Joint Research Project (No. 51261120377), the General Projects of NSFC (No. 51178249, 51378299, 51578320), the National Key Technology R&D Program of the Ministry of Science and Technology (MOST) of China (No. 2006BAJ03A02,

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The work presented in this monograph is completed by the authors and their co-workers, including Professors Lieping Ye, Aizhu Ren, Song Cen, and Peng Pan of Tsinghua University, Professor Muneo Hori of the University of Tokyo; Professor Kincho H. Law of Stanford University; Dr. Xuchuan Lin of the Institute of Engineering Mechanics of China Earthquake Administration; Professors Wuhui Qi, Weibiao Yang, and Wei Zhen of the Beijing Institute of Architectural Design; Dr. Yuli Huang of Arup Ltd.; Professor Halil Sezen of the Ohio State University; Professor Tony Yang of the University of British Columbia; and Professor Cheng Yu of the University of North Texas. Many graduate students of Tsinghua University also contributed extensively to the development, analysis, and simulation work presented in this monograph. They include doctoral graduates: Drs. Xunliu Wang, Zhiwei Miao, Qianli Ma, Yi Li, Zhe Qu, Zhen Xu, Xiao Lu, Wei Shi, Chen Xiong, and Linlin Xie; master graduates: Wankai Zhang, Bo Han, Mengke Li, Bin Liu, and Lisha Wang; and current graduate students: Xiang Zeng, Kaiqi Lin, Yuan Tian, Zhebiao Yang, Qingle Cheng, and Donglian Gu. In addition, Professors Jiaru Qian, Jingbo Liu, Linhai Han, Zuozhou Zhao, Xiaodong Ji, and Peng Feng of Tsinghua University also provided many valuable advices to this work. The China Academy of Building Research, the Beijing Institute of Architectural Design, the Institute of Engineering Mechanics, the Institute of Geophysics of China Earthquake Administration, Xi'an University of Architecture and Technology, and the THUPDI Ltd also provided generous support to this research.

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Given a significant amount of research being conducted in the related areas, the work presented in this monograph is just a small contribution. There must be some limitations and errors in the contents of this monograph. Any comments and suggestions from the readers are warmly welcomed.

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Abbreviations

ACI	American Concrete Institute
AEBM	Advanced Engineering Building Module
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
BIM	Building information model
CBD	Central business district
CEA	China Earthquake Administration
CFST	Concrete-filled steel tube
CMR	Collapse margin ratio
CPU	Central processing unit
DBE	Design basis earthquake
DM	Demand measure
DOF	Degree of freedom
EDP	Engineering demand parameter
ELF	Equivalent lateral force
FE	Finite element
FEMA	Federal Emergency Management Agency
GIS	Geographic information system
GPU	Graphics processing unit
IBC	International Building Code
IDA	Incremental dynamic analysis
IDR	Inter-story drift ratio
IM	Intensity measure
MCE	Maximum considered earthquake
MDOF	Multiple degree-of-freedom
NMFS	Nonlinear MDOF flexural-shear
NMS	Nonlinear MDOF shear
PEER	Pacific Earthquake Engineering Research Center
PFA	Peak floor acceleration
PFV	Peak floor velocity

PG	Performance group
PGA	Peak ground acceleration
PGD	Peak ground displacement
PGV	Peak ground velocity
RC	Reinforced concrete
RM	Reinforced masonry
RSA	Response spectrum analysis
SDOF	Single degree-of-freedom
SLE	Service level earthquake
SOE	System of equations
SSI	Soil-structure interaction
TBI	Tall Building Initiative
THA	Time-history analysis
URM	Unreinforced masonry