

Earthquake Disaster Simulation of Civil Infrastructures

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Earthquake Disaster Simulation of Civil Infrastructures

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.

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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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During the writing up stage, Drs. Xiao Lu, Zhen Xu, Linlin Xie, Chen Xiong, Mr. Kaiqi Lin, Xiang Zeng, Qingle Cheng, and Ms. Yaning Zhu helped to finalize all the figures and proofread the entire manuscript. Their contributions are also gratefully acknowledged.

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.

Beijing, China
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Contents

1	Introduction	1
1.1	Research Background	1
1.2	Significance and Implication of Earthquake Disaster Simulation of Civil Infrastructures	3
1.3	Research Framework and Contents	4
2	High-Fidelity Computational Models for Earthquake Disaster Simulation of Tall Buildings	7
2.1	Introduction	7
2.2	Fiber-Beam Element Model	8
2.2.1	Fundamental Principals	8
2.2.2	Uniaxial Stress–Strain Model of Concrete	10
2.2.3	Uniaxial Stress–Strain Model of Steel Reinforcement	14
2.2.4	Validation Through Reinforced Concrete Specimens	18
2.2.5	Stress–Strain Model of Composite Components	22
2.3	Multilayer Shell Model	26
2.3.1	Fundamental Principal	26
2.3.2	High-Performance Flat Shell Element NLDKGQ	28
2.3.3	Constitutive Model of Concrete and Steel	36
2.3.4	Implementation of Multilayer Shell Element in OpenSees	38
2.3.5	Validation Through Reinforced Concrete Specimens	40
2.3.6	Collapse Simulation of an RC Frame Core-Tube Tall Building	42
2.4	Hysteretic Hinge Model	45
2.4.1	Overview	45
2.4.2	The Proposed Hysteretic Hinge Model	45
2.4.3	Validation of the Proposed Hysteretic Hinge Model	49

2.5	Multi-scale Modeling	50
2.5.1	Overview	50
2.5.2	Interface Modeling	50
2.6	Element Deactivation and Collapse Simulation.	52
2.6.1	Element Deactivation for Component Failure Simulation	52
2.6.2	Visualization of the Movement of Deactivated Elements Using Physics Engine.	53
2.7	Summary	58
3	High-Performance Computing and Visualization for Earthquake Disaster Simulation of Tall Buildings	59
3.1	Introduction	59
3.2	GPU-Based High-Performance Matrix Solvers for OpenSees	59
3.2.1	Fundamental Conception of General-Purpose Computing on GPU (GPGPU).	59
3.2.2	High-Performance Solver for Sparse System of Equations (SOE) in OpenSees.	60
3.2.3	Case Studies	62
3.3	Physics Engine-Based High-Performance Visualization	64
3.3.1	Overview	64
3.3.2	Overall Visualization Framework	67
3.3.3	Clustering-Based Key Frame Extractions.	67
3.3.4	Parallel Frame Interpolation.	70
3.3.5	Case Study	75
3.4	Summary	77
4	Earthquake Disaster Simulation of Typical Supertall Buildings	79
4.1	Introduction	79
4.2	Earthquake Disaster Simulation of the Shanghai Tower	79
4.2.1	Overview of the Shanghai Tower	79
4.2.2	Finite Element Model of the Shanghai Tower.	81
4.2.3	Earthquake-Induced Collapse Simulation.	89
4.2.4	Impact of Soil-Structure Interaction.	101
4.3	Earthquake Disaster Simulation of the Z15 Tower	109
4.3.1	Introduction of the Z15 Tower	109
4.3.2	The Finite Element Model.	111
4.3.3	Earthquake-Induced Collapse Simulation of the Half-Braced Scheme	117
4.3.4	Earthquake-Induced Collapse Simulation of the Fully Braced Scheme	123
4.3.5	Comparison Between the Two Design Schemes	133
4.4	Summary	136

- 5 Simplified Models for Earthquake Disaster Simulation of Supertall Buildings 137**
 - 5.1 Introduction 137
 - 5.2 The Flexural-Shear Model 138
 - 5.2.1 Fundamental Concepts of the Flexural-Shear Model 138
 - 5.2.2 Application of the Flexural-Shear Model for Supertall Buildings 140
 - 5.3 The Fishbone Model. 144
 - 5.3.1 Fundamental Concepts of the Fishbone Model 144
 - 5.3.2 The Fishbone Model of the Shanghai Tower. 145
 - 5.3.3 The Fishbone Models of the Z15 Tower 163
 - 5.4 Summary 179
- 6 Engineering Application of Earthquake Disaster Simulation of Supertall Buildings 181**
 - 6.1 Introduction 181
 - 6.2 Ground Motion IM for Supertall Buildings. 181
 - 6.2.1 Background 181
 - 6.2.2 A Brief Review of the Existing IMs 182
 - 6.2.3 An Improved IM for Supertall Buildings. 184
 - 6.2.4 Comparison of Different IMs. 188
 - 6.2.5 Comparison of Different IMs Through IDA-Based Collapse Simulation 194
 - 6.3 Minimum Base Shear Force for Supertall Buildings. 196
 - 6.3.1 Background 196
 - 6.3.2 Provisions of Minimum Base Shear Force in Chinese Codes. 197
 - 6.3.3 Comparison with the Corresponding Provisions in the US Design Codes 198
 - 6.3.4 Case Study of a Hypothetical Supertall Building. 199
 - 6.4 Optimal Design of the Z15 Tower Based on Collapse Analysis 214
 - 6.4.1 Optimal Design of Minimum Base Shear Force 214
 - 6.4.2 Optimal Design of Brace-Embedded Shear Wall. 221
 - 6.5 Summary 224
- 7 Comparison of Seismic Design and Performance of Tall Buildings Based on Chinese and US Design Codes. 225**
 - 7.1 Introduction 225
 - 7.1.1 From Performance-Based Design to Resilience-Based Design 225
 - 7.1.2 The Rationale of Comparison 227
 - 7.2 Comparison of the Seismic Designs of Typical Tall Buildings Based on the Chinese and US Design Codes 229

7.2.1	A Brief Overview of the Benchmark Building	229
7.2.2	Seismic Design Load.	231
7.2.3	Comparison of the Design Outcomes	234
7.2.4	Discussion on the Design Outcomes	239
7.3	Comparison of the Structural Performance of Tall Buildings Designed Based on the US and Chinese Codes	240
7.3.1	Nonlinear Finite Element Models of Buildings 2A and 2N	240
7.3.2	Pushover Analysis	240
7.3.3	Nonlinear Time-History Analysis	242
7.3.4	Collapse Analysis Based on IDA	245
7.4	Comparison of the Seismic Resilience of Tall Buildings Designed Based on the US and Chinese Codes	246
7.4.1	Quantification Method for Seismic Resilience	246
7.4.2	Failure Probabilities	250
7.4.3	Repair Costs	250
7.4.4	Casualties	253
7.4.5	Repair Time	253
7.5	Summary	256
8	Nonlinear MDOF Models for Earthquake Disaster Simulation of Urban Buildings	257
8.1	Introduction	257
8.1.1	The Probability Matrix Method	258
8.1.2	The Capacity Spectrum Method	258
8.1.3	The Simulation Method Based on Nonlinear MDOF Model and Time-History Analysis.	259
8.2	Nonlinear MDOF Shear Model of Multi-story Buildings	260
8.2.1	Overview	260
8.2.2	Nonlinear MDOF Shear Model	261
8.2.3	Parameter Determination for Multi-story Buildings in China	262
8.2.4	Parameter Determination for Backbone Curve Based on the HAZUS Data	272
8.2.5	Calibration of the Hysteretic Parameter	273
8.2.6	Damage Assessment Method	274
8.2.7	Validation of the Proposed Parameter Determination Method.	276
8.3	Nonlinear MDOF Flexural-Shear Model of Tall Buildings	278
8.3.1	Overview	278
8.3.2	Nonlinear MDOF Flexural-Shear Model	280
8.3.3	Parameter Calibration Based on Building Attribute Data	282
8.3.4	Validation and Application of the Proposed Model to Individual Tall Buildings.	291

- 8.3.5 Application of the Proposed Method to Seismic Simulation of Regional Tall Buildings 298
- 8.4 Summary 300
- 9 Visualization for Earthquake Disaster Simulation of Urban Buildings 303**
 - 9.1 Introduction 303
 - 9.2 2.5D Model for Visualization of Urban Building Seismic Simulation 304
 - 9.3 3D-GIS Model for Visualization of Urban Building Seismic Simulation 306
 - 9.3.1 Overview 306
 - 9.3.2 Proposed 3D Simulation Methodology 307
 - 9.3.3 3D-GIS Data Generation 308
 - 9.3.4 High-Fidelity Visualization Using 3D Urban Polygon Model 312
 - 9.3.5 Implementation 314
 - 9.3.6 Case Study 315
 - 9.4 Physics Engine-Based Collapse Simulation of Urban Buildings 317
 - 9.4.1 Overview 317
 - 9.4.2 Physics Engine-Based Collapse Simulation 319
 - 9.4.3 Integrated Visualization System 322
 - 9.4.4 Case Study 323
 - 9.5 Summary 325
- 10 High-Performance Computing for Earthquake Disaster Simulation of Urban Buildings 327**
 - 10.1 Introduction 327
 - 10.2 Coarse-Grained CPU/GPU Collaborative Parallel Computing 327
 - 10.2.1 Overview 327
 - 10.2.2 Computing Program Architecture 328
 - 10.2.3 Performance Benchmarking 332
 - 10.3 Seismic Simulation of Urban Buildings Using Distributed Computing and Multi-fidelity Models 338
 - 10.3.1 Various Models with Different Levels of Fidelities 338
 - 10.3.2 The Overall Computational Framework 339
 - 10.3.3 Software Implementation 341
 - 10.3.4 Case Study 344
 - 10.4 Summary 349
- 11 Earthquake Disaster Simulation of Typical Urban Areas 351**
 - 11.1 Introduction 351
 - 11.2 Earthquake Disaster Simulation of Ludian Earthquake 351

- 11.2.1 Seismic Damage to Buildings in Longtoushan Town. 352
- 11.2.2 Comparison with Field Investigation Data. 354
- 11.2.3 Comparison with Damage Probability Matrix Method 355
- 11.2.4 Visualization of Seismic Simulation 356
- 11.3 Earthquake Disaster Simulation of Beijing CBD 357
 - 11.3.1 Building Models in Beijing CBD 358
 - 11.3.2 The Ground Motion of Sanhe-Pinggu Earthquake. 359
 - 11.3.3 Seismic Damage Simulation Results 362
 - 11.3.4 Visualization of the Building Seismic Damage Results. 364
- 11.4 Earthquake Disaster Simulation of a Medium-Sized City in China 367
 - 11.4.1 Building Models of the Medium-Sized City 367
 - 11.4.2 Parallel Computing for Seismic Simulation 369
 - 11.4.3 Discussion of the Seismic Simulation Results 369
- 11.5 Earthquake Disaster Simulation of Xi’an, Taiyuan, and Tangshan Cities in China 373
 - 11.5.1 Earthquake Disaster Simulation of Baqiao District in Xi’an City. 373
 - 11.5.2 Earthquake Disaster Simulation for Taiyuan and Tangshan Cities 381
- 11.6 Summary 384
- 12 Earthquake Loss Prediction for Typical Urban Areas 385**
 - 12.1 Introduction 385
 - 12.2 Earthquake Loss Prediction for Urban Areas Based on FEMA P-58 Method 385
 - 12.2.1 Overview. 385
 - 12.2.2 Earthquake Loss Prediction Methodology 387
 - 12.2.3 Case Study: Regional Earthquake Loss Prediction of the Tsinghua University Campus 392
 - 12.2.4 Results and Discussion on Earthquake Loss Prediction 397
 - 12.2.5 Findings of the Earthquake Loss Prediction Study 401
 - 12.3 Secondary Disaster Simulation of Falling Debris and Site Selection of Emergence Shelters. 404
 - 12.3.1 Overview. 404
 - 12.3.2 The Proposed Simulation Framework 406
 - 12.3.3 Simulation Method 408
 - 12.3.4 Case Study 412
 - 12.3.5 Findings of the Earthquake-Induced Falling Objects Simulation 414
 - 12.4 Summary 416

13 Conclusions	417
13.1 Major Achievements and Contributions	417
13.2 A Future Perspective	418
References	421

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