

Preface

Geo-disasters accompanied by large deformation and flow failure of geomaterials are a regular occurrence around the world. These disasters include landslides, debris flows, dam-breaks, soil liquefaction, seepage damage, and dynamic erosion. The disasters seriously damage infrastructure, resulting in casualties and heavy economic losses. To reduce the damage, one of the priorities for governments and researchers is to determine the probability of geo-disaster occurrence, devise hazard maps, and take protective measures. Therefore, there is an urgent need to study disaster mechanisms and simulate kinematic characteristics of the geomaterials during disaster evolution, such as runout distance, velocity, and impact force.

With consideration of the devastating impacts of geo-disasters, this monograph has the goal of presenting a Smoothed Particle Hydrodynamics (SPH)-based approach to geo-disaster modeling and analysis, thereby satisfying the needs of geo-disaster prevention and control efforts.

The monograph was assembled by systematically screening, sorting, and categorizing the authors' research work on the theory of the SPH method and its applications to geo-disasters. The basic SPH principle and algorithm are discussed, calculation programs based on elasto-plastic mechanics and fluid dynamics are coded, and visualization software is developed. Geo-disasters such as flow-like landslides, lateral flow of liquefied soil, and flow failures of solid waste in landfills are simulated and analyzed. Disaster evolution and dynamic characteristics are described. The monograph thereby provides a means for mapping hazardous areas, estimating hazard intensity, and identifying and designing appropriate protective measures.

The monograph has seven chapters, with Chap. 1 as the introduction. This describes certain catastrophic geo-disasters and their characteristics. Advantages of the SPH method are detailed and its applications to geo-disasters are reviewed.

Chapter 2 presents SPH theory and development history. Governing equations and constitutive laws are discretized based on SPH approximations. Important numerical techniques are introduced, such as the neighboring particle search algorithm, boundary treatment, and integration schemes. Then, SPH models for geo-disasters are established.

In Chap. 3, a computer procedure based on the SPH model is developed in the FORTRAN language environment, which is applicable to geo-disaster analysis and modeling. The function of each module in the procedure is explained via calculation flowcharts. Based on these calculation procedures, visual simulation software is developed through a Windows interface, and SPH computational efficiency is greatly improved.

In Chap. 4, a series of validations for the SPH numerical models are conducted. These include the dam-break model, soil flow model, simple shear, and soil non-drained shear tests. Results are compared with an analytical solution, test results from the literature, and solutions from other numerical methods.

The next three chapters focus on SPH applications to geo-disaster modeling and analysis, including municipal solid waste (MSW) flow slides in landfills (Chap. 5), lateral spreading of liquefied soil (Chap. 6), and flow-like landslides triggered by earthquakes (Chap. 7). In the above simulations, the dynamic behaviors of geomaterials are captured, such as flow velocity, runout distance, and impact force, and potential hazard areas are predicted. These are all useful for the prevention and control of geo-disasters.

The work uses the SPH method to study in detail the failure mechanism of geomaterials and geo-disaster formation and evolution. The reasons for selecting this method are as follows.

(1) SPH is one of the earliest mesh-free methods. It has clear advantages in dealing with problems of free surface, deformation boundary, motion interface, and extremely large deformation, which are involved in geo-disasters.

(2) Because of constant revision and improvement, the accuracy, stability, and adaptability of SPH have all met the requirements of practical project applications.

(3) SPH has a very wide range of applications, from continuous to discrete systems and from the micro-scale to macro-scale. It is even applicable to scales of astronomy. SPH has been successfully incorporated in commercial software packages and used in practical engineering.

The theoretical methods and related applications described in this monograph will benefit graduate students, engineers, researchers, and professionals in the fields of geologic, geotechnical, civil, and hydraulic engineering, as well as in computational mechanics. The monograph is simple to read. Background knowledge such as theories of the finite element method, finite difference method, and discrete element method are helpful but not necessary for readers to understand the theories and methods herein.

Our research group began SPH study in 2006 with the cooperation of Prof. Atsushi Yashima and Dr. Hideto Nonoyama (currently at Nagoya University, Japan) from the Department of Civil Engineering, Gifu University, Japan. We also received tremendous help from Prof. Kazuhide Sawada and Dr. Shuji Moriguchi (currently at Tohoku University, Japan). The authors would like to extend their heartfelt thanks to all of them.

After the 2008 Wenchuan earthquake in China, our group members traveled to the damage sites for survey. During the survey period, we had enthusiastic support

from Prof. Qiang Xu's research group at Chengdu University of Technology, which the authors greatly acknowledge.

This monograph was completed with the joint efforts of all members in our research group at Tongji University. This group included graduate students Mr. Liang Hao, Mr. Pan Xie, and Mr. Chen Jin, who were involved in the comprehensive research work. Writing and editing were done with assistance from Ph.D. students Ms. Hualin Cheng, Mr. Chongqiang Zhu, and Ms. Yangjuan Bao.

The research work presented in the monograph was supported by the National Natural Science Foundation of China (Grant Nos. 40841014, 40802070, 41072202, 41111130205, 41211140042, 41372355), National Basic Research Program of China (973 Program) through Grant No. 2012CB719803, National Key Technologies R&D Program of China (Grant No. 2012BAJ11B04), State Key Laboratory of Geohazard Prevention and Geo-environment Protection (Grant No. DZKJ-0808), Key Laboratory of Engineering Geomechanics of the Chinese Academy of Sciences (Grant No. 2008-04), Shanghai Municipal Education Commission and Shanghai Education Development Foundation (Shu Guang Project No. 08SG22), Program for New Century Excellent Talents in University (Grant No. NCET-11-0382), Fundamental Research Funds for the Central Universities, and the Kwang-Hua Fund of the College of Civil Engineering at Tongji University. The authors express cordial acknowledgments to these organizations.

Although this monograph presents much of our research work, it represents only the first step in this field. Many relevant problems remain. All the authors hope that this monograph will attract more research interest in this area. If readers are interested in the basic program codes or visualization software, they may contact the first author, Prof. Yu Huang, at yhuang@tongji.edu.cn. Readers may use partial or full code at their own risk, as long as a proper reference and acknowledgment are given.

Because of our limited knowledge, there will be some inevitable omissions and mistakes in the monograph. Therefore, we welcome constructive criticism and correction toward continuously improving the work.

Shanghai, China
June 2014

Prof. Yu Huang

Geo-disaster Modeling and Analysis: An SPH-based
Approach

Huang, Y.; Dai, Z.; Zhang, W.

2014, XXIV, 189 p. 130 illus., 8 illus. in color., Hardcover

ISBN: 978-3-662-44210-4