Preface

This book deals with geotechnical earthquake engineering and prediction and assessment of blast induced vibrations along with assessment and mitigation methods. The damage due to earthquakes and blasting are caused mainly due to the vibrations caused by waves. But there are differences in the types of vibrations in both the cases. In the case of earthquake, the frequency of waves will be less and its amplitude will be more. However for the vibration created during blasting, the frequency will be high and the amplitude will be lower. Moreover, the duration of vibration due to earthquakes will last longer than that due to blasting. This book examines the effects of vibrations (due to earthquake and blasting) on both soils and jointed rock mass.

The soil is a granular material, whereas the jointed rock mass consists of interlocking angular blocks separated by surfaces of discontinuity. This books deals with the effects of vibration in both these materials. The damages, which occur due to earthquake vibration, can be reduced using mitigation steps. The effective seismic hazard mitigation steps include identification of vulnerable seismic sources, evaluation of source, path characteristics, assessment of induced effects (like site amplification, liquefaction, landslides, etc.), and designing the structures for the estimated forces. The material properties of soil and rocks depend on the strain level, and in most of the cases, the variation will be nonlinear. Two of the important parameters, which will depend on the strain rate and which need to be evaluated accurately are the shear modulus and the damping. These two parameters depend heavily on the strain rate and are showing a nonlinear variation with strain. The same is the case with the pore pressure development in saturated soils.

This book is divided into fourteen chapters in two sections. The first section consists of seven chapters in the field of Geotechnical Earthquake Engineering and the second section consists of seven chapters dealing with various aspects of blast induced vibrations. The various chapters in section 1 discuss probabilistic seismic hazard analysis, site effects, seismic microzonation, liquefaction studies, cyclic triaxial test, model experiments, analysis of super structure stiffness and retaining walls, and static and dynamic modulus of jointed rocks. Section 2 of this book covers the topics of simulation of rock fracturing in blasting, blasting in tunnels, blast damage prediction, blast and impact assessment using dynamic tensile test, blast vibration prediction, damage due to repeated blast vibrations, blast induced vibration in long hole open stoping, and static and dynamic elastic modulus of jointed rock mass.

Section 1, Geotechnical Earthquake Engineering (GEE), involves multidisciplinary research. This area of research involves aspects of geology, seismology, geotechnical engineering, risk analysis, et cetera. The ultimate goal in the area of GEE is to assess seismic hazard and reduce the risk to acceptable limits. The earthquake damage is mainly caused due to the ground shaking and regional subsidence. The secondary effects of earthquake damage are due to liquefaction, landslides, tsunami, et cetera. The local site conditions will influence the frequency content, duration and amplitude of the ground motion. The geometry and material properties of the subsurface soil and the properties of the input motion will have significant influence on the site amplification. The severe effects of site amplification were observed during Niigata, Mexico, San Francisco, and Bhuj earthquakes. There has been considerable development in the field of Geotechnical Earthquake Engineering in the recent years. Still more research need to be undertaken in the area of liquefaction, site response, ground failure, and collapse of geotechnical structures. The geotechnical aspect of seismic hazard assessment involves evaluation of liquefaction potential, landslide hazard, site response, and site amplification. The outcome of the GEE study needs to be used for seismic hazard mitigation – in the form of settlement assessment for a particular site, selection of appropriate type of foundation, slope stabilization, ground improvement, et cetera.

The first chapter deals with the evaluation of surface level peak ground acceleration values based on NEHRP site classification scheme. The seismic hazard was evaluated using a probabilistic seismic hazard analysis (PSHA) using logic tree approach. The methods to develop uniform hazard response spectrum for a particular location are discussed in this chapter. The second chapter describes the development of site specific ground motion parameters for a seismically vulnerable site. The seismic hazard was assessed based on deterministic seismic hazard assessment method. A synthetic acceleration time history was developed using deconvolution analysis method. The third chapter discusses details of the study to evaluate the seismic passive earth pressure on a rigid gravity wall based on pseudo-dynamic methods. A comparison of results obtained from the present study is done with the results obtained from other methods. The fourth chapter presents the details of pore pressure development, dissipation, and volumetric densification characteristic of sands. The results obtained from an experimental study with varying percentage of non plastic fines are discussed in this chapter. The fifth chapter presents the details of how the super structure stiffness can determine the type of liquefaction induced foundation failure. This chapter discusses the results obtained for dynamic centrifuge test result and FEM analysis to compare the foundation failure mechanism. The sixth chapter discusses the methods to simulate laboratory experiments using discrete element modelling (DEM). This chapter highlights the capabilities of simulating cyclic behaviour of granular soil using DEM. The seventh chapter gives the details of the evaluation of compressive strength/elastic modulus of jointed rock mass as a function of intact rock strength/modulus and joint factor. The details of the comparison of the results obtained from this method with the published works are also included in this chapter.

Section two concerns the use of explosives in a controlled manner to remove or excavate hard material like rocks is termed as blasting. Blasting is one of the most commonly used and economical technique for rock excavation. There has been lots of development in the area of blasting, but still, many issues related to the safety and stability need to be addressed. The structural damage due to the blast induced vibration and the human annoyance due to air blasting are common problem due to surface blasting. Blasting involves: detonation of explosives, fracture initiation and extension, rock throw and fragmentation, generation of vibration, air blast, noise, heat, and rock projectiles. Numerical modelling has emerged as one of the important area to model and understand some of the complex mechanics of blasting. The modelling of rock blasting requires proper understanding of rock properties, explosive properties, and blast design parameters. The vibration produced due to blasting is similar to that produced during earthquakes, but with high frequency and low amplitude values. It has been estimated that around 80% of the energy produced during blasting is lost in the form of vibration, air blast, and noise. Lots of research is going in the field of blasting to reduce the ill effects of the energy lost during blasting.

The eighth chapter deals with the effects of repeated dynamic loading (due to blasting) on joined rock mass. The blast induced damage was monitored using various techniques, and it was found that 60% of the damage was caused due to the repeated dynamic loading. The ninth chapter examines the various aspects of stope and slot design, blast design, and blast vibration attenuation. A detailed examination of various stope design used in metal extraction in Canada is also presented in this chapter. The tenth chapter deals with the details of development of a predictor model incorporating burden deviations in the existing predictor equations. A quantitative explanation of the increased vibration level produced by the blast rounds with excess burden is presented in this chapter. The eleventh chapter describes the development of modified SHPB technique and Brazilian test method to test the tensile strength of coal, shale, and sandstone samples. A comparison of the results obtained for dynamic and static strength of sandstone samples are presented in this chapter. The twelfth chapter discusses about an approach to simulate the rock fracturing as a result of engineering blasting. A review of existing model to compare the efficacy of element elimination technique is also presented in this chapter. The thirteenth chapter gives the details of development of rock blasting excavation model with two successive excavation steps. The details of simulation of rock fracturing process during blasting excavation are presented in this chapter. The fourteenth chapter deals with the development of overbreak predictive model (BIRD) for burn cut blasting in hard rock. To validate this new model, a multivariate statistical model was developed and this model can be applied in tunnels and mines for blast design and explosive selection.

This book is on the Advances in Geotechnical Earthquake Engineering series, which encompasses all the invited chapters from eminent academicians, practitioners, and researchers, which are published in the *International Journal of Geotechnical Earthquake Engineering* (IJGEE) Vol. 1 and 2 in the year 2010. *The International Journal of Geotechnical Earthquake Engineering* (IJGEE) contains enhanced research on the role of geotechnical engineering in soil dynamics, engineering seismology, disaster mitigation, and earthquake engineering. With international articles written by leading authors, this book, "Earthquake and Blast Induced vibrations: Research Advancements," provides the latest findings and industry solutions for all those involved in fields of earthquake and blasting vibrations. The efforts of all the authors, reviewers, and their contributions are gratefully acknowledged.

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