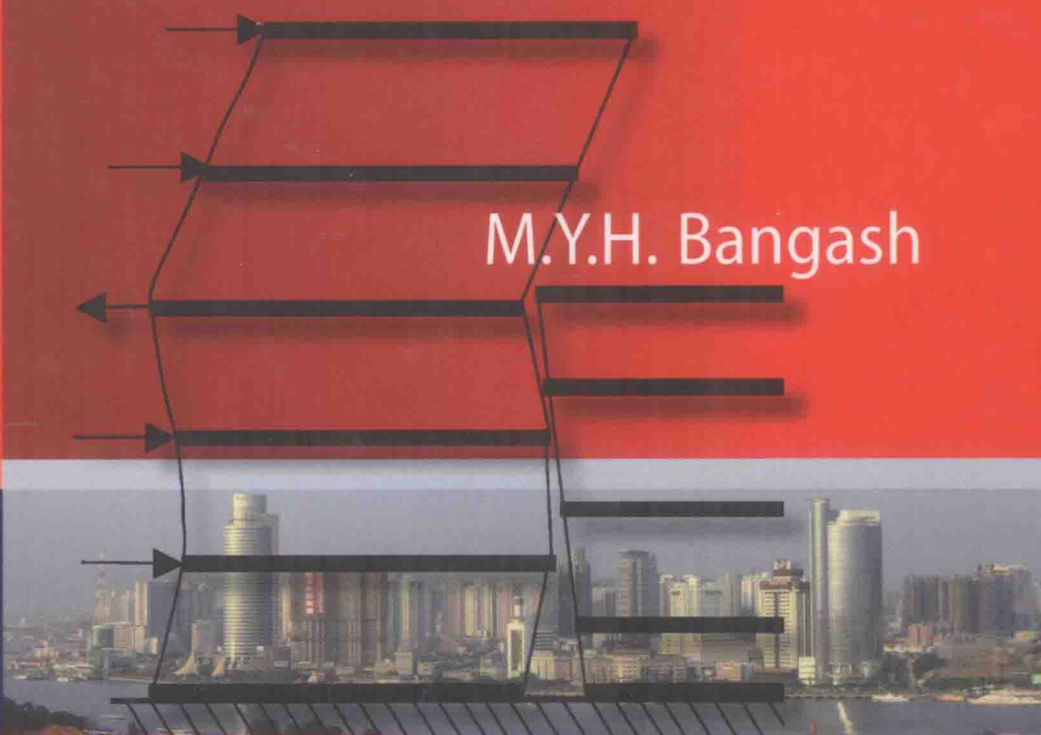

M.Y.H. Bangash

Earthquake Resistant Buildings

Dynamic Analyses, Numerical Computations, Codified Methods, Case Studies and Examples

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Earthquake Resistant Buildings

Preface

This book provides a general introduction to the topic of three-dimensional analysis and design of buildings for resistance to the effects of earthquakes. It is intended for a general readership, especially persons with an interest in the design and construction of buildings under servere loadings.

A major part of design for earthquake resistance involves the building structure, which has a primary role in preventing serious damage or structural collapse. Much of the material in this book examines building structures and, specifically, their resistance to vertical and lateral forces or in combinations. However, due to recent discovery of the vertical component of acceleration of greater magnitude in the kobes' earthquake the original concept of "lateral force only" has changed. This book does advocate the contribution of this disastrous component in the global analytical investigation.

When the earthquake strikes, it shakes the whole building and its contents. Full analysis for design layout and type of earthquakes, therefore, must include considerations for the complete building construction, the building contents and the building occupants.

The work of designing for earthquake effects is formed by a steady stream of studies, research, new technologies and the cumulative knowledge gained from forensic studies of earthquake-damaged buildings. Design and construction practices, regulating codes and professional standards continuously upgraded due to the flow of this cumulative knowledge. Hence, any book on this subject must regularly be updated. Since the effects are not the same, the earthquake forces are always problematic.

Over the years, earthquake has been the cause of great disasters in the form of destruction of property and injury and loss of life to the population. The unpredictability and sudden occurrence of earthquakes make them somewhat mysterious, both to the general public and to professional building designers. Until quite recently, design for earthquakes – if consciously considered at all – was done with simplistic methods and a small database. Extensive study and research and a great international effort and cooperation have vastly improved design theories and procedures. Accordingly, most buildings in earthquake-prone areas today are designed in considerable detail for seismic resistance.

Despite the best efforts of scientists and designers, most truly effective design methods are those reinforced by experience. This experience, unfortunately, grown by leaps when a major earthquake occurs and strongly affects regions of considerable development – notably urban areas. Observation of damaged buildings by experts in forensic engineering adds immeasurably to our knowledge base. While extensive research studies are ongoing in many testing laboratories, the biggest laboratory remains the real world and real earthquakes.

Design decisions that affect the seismic response of buildings range from broad to highly specific ones. While much of this design work may be performed by structural engineers, many decisions are made by, or are strongly affected by, others. Building codes and industry standards establish restrictions on the use of procedures for analysis of structural behaviour and for the selection of materials and basic systems for construction. Decisions about site development, building placement on sites, building forms and dimensions and the selection of materials and details for construction are often made by so many others too.

On this respect it was necessary that the reader should look into codes of practice in certain countries prone to major earthquakes. Some codes including the Eurocode-8 are given together with numerical and analytical methods for comparative studies. This approach enhances the design quality and creates confidence in the designer on his/her work.

While ultimate collapse of the Building structure is a principal concern, the building's performance during an earthquake must be considered in many other ways as well. If the structure remains intact, but structural part of the building sustains critical damage, occupants are traumatized or injured, and it is infeasible to restore the building for continued use; the design work may not be viewed as success. However, the necessity sometimes governs. Some countries may not have sophisticated tools and resources. Others must assist to provide them.

The work in this book is mostly analytical and hence should be accessible to the broad range of people in the building design and construction fields. This calls for some compromise since all are trained highly in some areas and less – or not at all – in others. The readers should have general knowledge of building codes, current construction technology, principal problems of planning buildings and at least an introduction to design of simple structures for earthquake-prone buildings. Most of all, readers need some real motivation for learning about making buildings safer during earthquakes. Many design examples and case studies are included to make the book fully attractive to all and sundry.

Readers less prepared may wish to strengthen their backgrounds in order to get the most from the work in this book. The author gives a vast bibliography at the end of this book and a list of references after each chapter so that the reader can carryout an in-depth study on a specific area missed out in detail. The reader hopefully will understand the need for grappling with this complex subject.

This book addresses the perplexing problem of how to maintain operability of equipment after a major earthquake. The programme is often more complicated than simple anchorage. Some critical types of equipment, for example, are likely to fail operationally (false signalling of switches, etc.) even if adequate base anchorage has been provided. It is the goal of this book to point out to the reader with a plan whereby equipment must be classified and subsequently qualified for the postulated seismic environment in a manner that best suits the individual piece of equipment. In some cases this qualification and analysis can be accomplished only by sophisticated seismic testing programme, while at the other end of the spectrum, equipment sometimes may be qualified simply by adequate architectural detailing. All too often, professional design teams and owners rely on an electric plug and gravity to keep a critical piece of equipment in place during an earthquake and functional afterwards. Obviously, this is less than desirable situation. One part of the suggestion is devoted to the qualification procedures which include

- Testing
- Analyses
- Designer's judgement
- Prior experience
- Design earthquakes
- Seismic categories for equipment
- Design specification procedures

The reader can easily be advised to refer to relevant codes such as Eurocode 8 and its supplements and parts. This book does not go into details regarding the above procedures but only concentrates on the analytical/design methodology.

The discussion of these topics leaves the designer with a complete course of action for qualifying all types of equipments, such as seismic devices to control the building structures during earthquakes. The author for this reason gives a comprehensive chapter on the subject.

One major measure to mitigate the earthquake hazards is to design and build structures through better engineering practices, so that these structures possess adequate earthquake-resistant capacity. Considerable research efforts have been carried out in the USA, Japan, China and other countries in the last few decades to advance earthquake engineering knowledge and design methods. This book summarizes the state-of-the-art knowledge and worldwide experiences, particularly those from China and the USA, and presents them systematically in one volume for possible use by engineers, researchers, students, and other professionals in the field of earthquake engineering. Considering the active research and rapid technological advances which have taken place in this field, there has been a surprising shortage of suitable textbooks for senior level or graduate level students. This book also attempts to help fill such a gap.

The book consists of 10 major parts: engineering seismology and earthquake-resistant analyses and design. Special attention is placed on bridging the gap between these disciplines. For the convenience of the reader, fundamentals of seismology, earthquake engineering and random processes, which, can be useful tools to describe the three-dimensional ground motions are given to assess the structural or soil response to them. Vast chapters are included.

This is followed by describing earthquake intensity, ground motions and its damaging effects. In the ensuing chapters concerning the earthquake-resistant design, both fundamental theories and new research problems and design standards are introduced. In this book stochastic methods are introduced because of their potential to offer a new dimension in earthquake engineering applications. These two areas have been subjected to intensive research in recent years and there is a potential in them to provide solutions to some special problems which might not be amenable to conventional approaches. Appendices are given for supporting analyses. Computer subroutines, which can be used with any known packages to suit the reader.

Although this book may appear to present a daunting amount of material, it is, nevertheless, just a toe in the door of the vast library of knowledge that exists. Readers may use this book to gain general awareness of the field or to launch a much more exhaustive programme of study.

On design sides, many codified methods have been briefly mentioned. The Eurocode EC-8 and the American codes with examples have been highlighted.

The book will serve as a useful text for teachers preparing design syllabi for undergraduate and postgraduate courses. Each major section contains a full explanation which allows the book to be used by students and practicing engineers, particularly those facing formidable task of having to design/detail complicated building structures with unusual boundary conditions. Contractors will also find this book useful in the preparation of construction drawings, and manufacturers will be interested in the guidance even in the text recording codified and newly developed methods and the manufacture of earthquake resistant devices.

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Generalised Notation

In advanced analysis and numerical modelling certain welknown notations are used universaly. These together with the ones given in the text are to be adopted. Where ever additional notations are necessary, especially in the codes for the design of structural elements, they should be defined clearly in this area.

Based on specific analyses, the analyst has the options to substitute any notations which are clearly defined in the analytical or computational work.

A	Constant
A	Projected area, hardening parameter
A_0	Initial surface area
A_{ST}	Surface area of the enclosure
A_V	Vent area
$\bar{A}$	Normalized vent area
a	Radius of the gas sphere
a_0	Loaded length, initial radius of gas sphere
B	Burden
$[B]$	Geometric compliance matrix
BG	Blasting gelatine
b	Spaces between charges
b_1	Distance between two rows of charges
C_D, C_d	Drag coefficient or other coefficients
C'_d	Discharge coefficient
C_f	Charge size factor, correction factor
C_1	A coefficient which prevents moving rocks from an instant velocity
$[C_{in}]$	Damping coefficient matrix
C_p	Specific heat capacity at constant pressure
C_r	Reflection coefficient
C_v	Specific heat capacity at constant volume
$c_a, c_1, c_\psi, c_\theta$	Coefficients for modes

D	Depth of floater, diameter
$[D]$	Material compliance matrix
D_a	Maximum aggregate size
D_i	Diameter of ice
D_p	Penetration depth of an infinitely thick slab
DIF	Dynamic increase factor
d	Depth, diameter
d_0	Depth of bomb from ground surface
E	Young's modulus
E_b	Young's modulus of the base material
ΔE_{er}	Maximum energy input occurring at resonance
E_{ic}	Young's modulus of ice
E_K	Energy loss
E_{na}	Energy at ambient conditions
E_{ne}	Specific energy of explosives
E_R	Energy release
E_t	Tangent modulus
e	Base of natural logarithm
e	Coefficient of restitution, efficiency factor
F	Resisting force, reinforcement coefficient
F_{ad}	The added mass force
$F_I(t)$	Impact
$F(t)$	Impulse/impact
F_s	Average fragment size shape factor
f	Function
f	Frequency (natural or fundamental), correction factor
f_a	Static design stress of reinforcement
f_c	Characteristic compressive stress
f'_c	Static ultimate compressive strength of concrete at 28 days
f^*_{ci}	Coupling factor
f_d	Transmission factor
f'_{dc}	Dynamic ultimate compressive strength of concrete
f_{ds}	Dynamic design stress of reinforcement
f_{du}	Dynamic ultimate stress of reinforcement
f_{dyn}	Dynamic yield stress of reinforcement
f^*_{TR}	Transitional factor
f_u	Static ultimate stress of reinforcement
f_y	Static yield stress of reinforcement
G	Elastic shear modulus
G_a	Deceleration
G_f	Energy release rate

G_m, G_s	Moduli of elasticity in shear and mass half space
g	Acceleration due to gravity
H	Height
H_s	Significant wave height
HE	High explosion
HP	Horsepower
h	Height, depth, thickness
I	Second moment of area, identification factor
$[I]$	Identity matrix
I_1	The first invariant of the stress tensor
i_p	Injection/extraction of the fissure
J_1, J_2, J_3	First, second and third invariants of the stress deviator tensor
J_F, J	Jacobian
K	Vent coefficient, explosion rate constant, elastic bulk modulus
$[K_c]$	Element stiffness matrix
K_p	Probability coefficients
K_s	Stiffness coefficient at impact
K_{TOT}	Composite stiffness matrix
K_W	Reduction coefficient of the charge
K_σ	Correction factor
KE	Kinetic energy
k_{cr}	Size reduction factor
k_r	Heat capacity ratio
k_t	Torsional spring constant
L	Length
L'	Wave number
L_i	Length of the weapon in contact
ln, $\log_e$	Natural logarithm
l_x	Projected distance in x direction
M	Mach number
$[M]$	Mass matrix
M'	Coefficient for the first part of the equation for a forced vibration
$^*M_A$	Fragment distribution parameter
M_p	Ultimate or plastic moment or mass of particle
m	Mass
N	Nose-shaped factor
N_c	Nitrocelluloid