DESIGN OF WIND AND EARTHQUAKE RESISTANT REINFORCED CONCRETE BUILDINGS

Somnath Ghosh and Arundeb Gupta

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Dedicated to our parents, wives and children

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Preface

Reinforced concrete as a construction material provides enormous architectural freedom. The basic concepts for the design of Reinforced Concrete structural elements are, fundamentally, more or less the same, but students and practicing engineers have access to a number of computer software packages, hundreds of textbooks, articles and research papers and large amounts of online information. It is difficult to recommend the best and most appropriate design resources. The present engineering education system focuses more on computer-based mathematical models without understanding their shortcomings. However, such analyses would be more powerful and useful if they had been developed in the light of realistic engineering concepts. Intuitive skill and experience, along with computer-aided mathematical analysis, need to be given due attention. The design concept needs to be cost-effective and better than its alternative if it is to be accepted.

This book explains the wind and seismic design issues of Reinforced Concrete buildings in brief and provides design examples based on the recommendations of the latest Indian Standard (IS) codes, which are essential and mandatory documents for industrial design and in order to achieve an acceptable common platform of understanding. It also provides detailed working drawings; several such typical design examples of buildings are given. The book provides the basic insights necessary for the effective development of a design. The most intricate issues of Reinforced Concrete design are discussed, supplemented by a number of real-life examples for deeper understanding of the subject.

Guidelines are presented for evaluating the acceptability of wind-induced motions of tall buildings. A design methodology for members or the structure as a whole to deform well beyond their elastic limits, which is essential under seismic excitation, is discussed in depth. Detailed considerations for such nonelastic behavior, in order to formulate simple procedures to accommodate design objectives that receive due attention in the code provisions, are also critically discussed.

The target readers of this book are the practicing structural engineers and architects, students and teachers of Civil engineering and Architecture, striving to understand the design of wind- and earthquake-resistant Reinforced Concrete buildings. This book explains the concepts on behavior of Reinforced Concrete buildings against wind and earthquake forces. It is an attempt to respond to some of the frequently asked questions by architects and structural engineers regarding the design of reinforced concrete buildings against wind and earthquake forces. Detail design calculations and reinforcement detailing as per recommendation of different relevant codes of practices have been furnished. Reinforcement detailing in the form of working drawings are also included so as to reduce the gap of understanding between different groups of professionals in structural engineering. The book is intended to serve as a comprehensive reference for the wind and earthquake-resisting design calculations and details of Reinforced Concrete buildings inline with the latest IS codes. It is a user-friendly complete package for all who deal with Reinforced Concrete design, explaining the wind and seismic design issues of Reinforced Concrete buildings and providing numerical design examples, along with working drawings based on the recommendations of the latest IS codes.

Professor (Dr.) Somnath Ghosh
Dr. Arundeb Gupta

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Somnath Ghosh is serving as Professor in the department of Civil Engineering Department at Jadavpur University in Kolkata, India. He was Dean of the Engineering Faculty and Head of the Civil Engineering Department at Jadavpur University, India. Dr. Ghosh obtained his B.E. in Civil Engineering from Jadavpur University and his M.Tech and Ph.D from the Indian Institute of Technology Kharagpur, India. He is a member and chartered engineer of the Institute of Structural Engineers in the United Kingdom. He has carried out research in the United States and Australia and delivered invited lectures in the United Kingdom, Australia, Singapore, Malaysia, Thailand and the United States. He has also delivered a huge number of lectures as a resource person in different Indian Institutes of Technology, National Institutes of Technology and universities. He has served as an expert member on several occasions for many institutes and universities. He has served as a member of several high-powered committees in the All India Council for Technical Education, the University Grants Commission, the Council of Scientific and Industrial Research, the Union Public Service Commission, etc. and at Jadavpur University level. He has contributed significantly in the areas of structural engineering and materials. He has also been a structural consultant to a number of key projects at the national level. Based on his research works, Dr. Ghosh has published a number of papers in peer-reviewed national and international journals and also published six monographs at international level. Apart from his research activities, Dr. Ghosh has demonstrated his technical skill by providing advice on industrial projects, and these have been implemented successfully. The repair and restoration techniques adopted for the earthquake-damaged structures of Kandla Special Economic Zone through his expertise deserve special mention. His other noteworthy contribution is the restoration of the earthquake-damaged assembly building in Sikkim. In addition, his skill in computer-aided structural analysis has been demonstrated through the design of a 52-meter tall Buddha statue at the top of a hill at Rabangla, Namchi, Sikkim, and a cricket stadium at Guwahati, Assam. His selection as country head for a division of a multinational company in Nigeria, speaks volumes about his administrative abilities as well as his academic skill and expertise;

Arundeb Gupta serves as Principal Structural Consultant for Skematic Consultants, in Kolkata, India. He obtained his B.E. and Ph.D in Civil engineering from Jadavpur University, India and has now built up around 30 years' industrial experience. He has designed several critical structures in highly seismic hilly terrain, as well as special structures, such as multipurpose cyclone shelters in coastal areas. Dr. Gupta has also carried out the restoration and designed the retrofitting of several earthquake-damaged structures. He has completed a large number of projects in health care, education, heavy industry, residential sectors, etc. at the national level. Dr. Gupta has published several papers in peer-reviewed national and international journals and he also serves as guest faculty in the Civil Engineering Department of Jadavpur University, India.

Notation

p_d	design wind pressure
K_d	wind directionality factor
K_a	area averaging factor
K_c	combination factor
p_z	design wind pressure
V_z	design wind speed
k_1	risk coefficient
k_2	height and terrain factor
k_3	topography factor
k_4	importance factor cyclonic region
V_b	basic wind speed
C_{pe}	external pressure coefficient
C_{pi}	internal pressure coefficient
A	surface area of structural element or cladding unit
C_f	force coefficient
A_e	effective frontal area
H	height of the building
B	width of the building
L	length of the building
F_z	design peak along-wind load on the building structure at any height z
$C_{f,z}$	drag force coefficient of the building structure corresponding to the area A_z
p_d	design hourly mean wind pressure
V_{zd}	design hourly mean wind speed at height z, in m/s
A_z	effective frontal area of the building structure at any height z, in m^2
G	gust factor
r	roughness factor
g_v	peak factor for upwind velocity fluctuation
B_s	background factor
b_{sh}	average breadth of the building/structure
L_h	measure of effective turbulence length scale at the height, h, in m
Ø	factor to account for the second order turbulence intensity
$I_{h,i}$	turbulence intensity at height h in terrain category i
H_s	height factor for resonance response
S	size reduction factor
E	spectrum of turbulence in the approaching wind stream
N	effective reduced frequency
f_a	first mode natural frequency of the building/structure in along-wind direction, in Hz
V_{hd}	design hourly mean wind speed at height, h in m/s
ß	damping coefficient of the building/structure, for Reinforced Concrete structure
g_r	peak factor for resonant response

k_{21} hourly mean wind speed factor for terrain category 1
z height or distance above the ground
z_{0i} aerodynamic roughness height for ith terrain
$F_{z,c}$ across-wind load per unit height at height z
K mode shape power exponent for representation of the fundamental mode shape
f_c first mode natural frequency of the building/structure in across-wind direction in Hz
b breadth of the structure normal to the wind in m
p_h hourly mean wind pressure at height h, in Pa
C_{fs} cross wind force spectrum coefficient
M_b P-wave magnitude
M_s surface-wave magnitude
M_0 seismic moment
M_w moment magnitude
M_L Richter magnitude
D average fault displacement
A total area of the fault surface
M average rigidity with respect to the shearing forces of the rocks
A_h design horizontal seismic coefficient
Z zone factor
I importance factor
R response reduction factor
S_a/g design acceleration coefficient
T_a fundamental translational natural period
V_B base shear
W seismic weight
Q_i design lateral force at ith floor level
w_i seismic weight of ith floor level
h_i height of ith floor measured from base
n number of floors including roof
M_k modal mass of k^{th} mode
P_k modal participation factors of k^{th} mode
Q_k design lateral load for ith floor mode k
V_{ik} story shear for ith floor mode k
p_t percentage of tension steel
d effective depth
D overall depth
l_x maximum shorter span of a slab panel
l_y longer span of a slab panel
α_x positive shorter span coefficient of the bending moment of a slab panel
α_x' negative shorter span coefficient of the bending moment of a slab panel
α_y positive longer span coefficient of the bending moment of a slab panel
α_y' negative longer span coefficient of the bending moment of a slab panel
M_u ultimate design bending moment
M_{u1} ultimate uniaxial bending moment capacity in the presence of axial compressive load