

Seismic Design of Building Structures

A Professional's Introduction
to Earthquake Forces
and Design Details

Eighth Edition

Updated to the 1997 UBC
for the CA Civil Seismic PE Exam

Michael R. Lindeburg, PE
with Majid Baradar, PE



TABLE OF CONTENTS

PREFACE	vii	10 Vertical Acceleration	13
ACKNOWLEDGMENTS	ix	11 Probability of Occurrence	13
HOW TO USE THIS BOOK	xi	12 Frequency of Occurrence	14
NOMENCLATURE	xiii	13 Attenuation of Ground Motion	14
PART 1		14 Seismometer	15
BASIC SEISMOLOGY		15 Accelerometer	15
1 The Nature of Earthquakes	1	16 Other Seismic Instruments	15
2 Earthquake Terminology	1	17 Earthquake Prediction	16
3 Global Seismicity	2	18 Other Earthquake Characteristics	16
4 Continental Drift	2		
5 Plate Tectonics	3	PART 3	
6 Submarine Ridges	3	EFFECTS OF EARTHQUAKES	
7 Submarine Trenches	3	ON STRUCTURES	
8 Earthquake Energy Release	4	1 Seismic Damage	17
9 Seismic Sea Waves	4	2 Seismic Risk Zones	17
10 Faults	5	3 Risk Microzones	19
11 California Faults	5	4 Probable and Maximum Considered	
12 San Andreas Fault	7	Earthquake Ground Motions	19
13 Creep	7	5 Effective Peak Ground Acceleration	19
14 Seismic Waves	7	6 Site Period	19
15 Locating the Epicenter	8	7 Soil Liquefaction	20
		8 Building Period	20
		9 Spectral Characteristics	20
		10 Seismic Force	20
		11 Relationship Between Spectral Values	21
PART 2			
EARTHQUAKE CHARACTERISTICS		PART 4	
1 Intensity Scale	9	VIBRATION THEORY	
2 Isoseismal Maps	10	1 Two Approaches to Seismic Design	23
3 Richter Magnitude Scale	10	2 Simple Harmonic Motion	23
4 Richter Magnitude Calculation	11	3 Stiffness and Flexibility	24
5 Energy Release and Magnitude Correlation	11	4 Rigidity	24
6 Length of Active Fault	12	5 Natural Period and Frequency	25
7 Length of Fault Slip	12	6 Damping	27
8 Peak Ground Acceleration	12	7 Damping Ratio	28
9 Correlation of Intensity, Magnitude, and		8 Decay Envelope	28
Acceleration with Damage	13	9 Damping Ratio of Buildings	28
		10 Damped Period of Vibration	29

11	Forced Systems	29
12	Magnification Factor	29
13	Resonance	30
14	Impulse Response—Undamped System	30
15	Duhamel's Integral for an Undamped System	30
16	Multiple-Degree-of-Freedom Systems	32
17	Response of MDOF Systems	32
18	Mode Shape Factors	34
19	Rayleigh Method	34
20	Participation Factors	35

PART 5

RESPONSE OF STRUCTURES

1	Elastic Response Spectra	37
2	Idealized Response Spectra	38
3	Response Spectra for Other Earthquakes	39
4	Log Tripartite Graph	39
5	Ductility	40
6	Strain Energy and Ductility Factor	41
7	Hysteresis	41
8	Large Ductility Swings	41
9	Inelastic Response Spectra	41
10	Normalized Design Response Spectra	42
11	Response Spectrum for UBC-97-Defined Soil Profiles	43
12	Drift	43
13	P - Δ Effect	44
14	Torsional Shear Stress	45
15	Negative Torsional Shear Stress	47
16	Overturning Moment	48
17	Rigid Frame Buildings	49
18	High-Rise Buildings	49

PART 6

UBC SEISMIC CODE

1	Historical Basis of Seismic Codes in California	51
2	Seismic Codes	53
3	The International Building Code and UBC-97	54
4	The Survivability Design Criteria	55
5	Effectiveness of Seismic Provisions	55
6	Applicable Seismic Sections in the UBC	55
7	The Nature of UBC Seismic Code Provisions	56
8	Wind Loads	56
9	Snow Loads	57
10	Combined Seismic, Wind, and Snow Loading	57
11	Seismic Design Criteria Selection	58
12	Seismic Zone Factor: Z	58
13	Occupancy Categories	59

14	Seismic Importance Factor: I	59
15	Soil-Profile Types: S_A Through S_F	60
16	Seismic Source Classification	61
17	Near-Source Factors: N_a and N_v	61
18	Seismic Response Coefficients: C_a Through C_v	62
19	Response Modification Factor: R	64
20	Seismic Force Amplification Factor: Ω_O	65
21	Structural Systems	65
A	Bearing Wall Systems	65
B	Building Frame Systems	67
C	Moment-Resisting Frames	67
D	Dual Systems	67
E	Cantilevered Column Building Systems	68
F	Shear Wall-Frame Interaction Systems	68
G	Undefined Systems	68
22	Reliability/Redundancy Factor: ρ	68
23	Regular/Irregular Structures	70
24	Vertical Structural Irregularities	71
25	Plan Structural Irregularities	73
26	Building Period: T	74
27	Earthquake Loads: E_h and E_v	76
28	Load Combinations	76
29	Total Seismic Dead Load: W	79
30	Seismic Base Shear Coefficient	80
31	Lateral Force Procedures	83
32	Static Lateral-Force Procedure	83
33	When the UBC Permits a Static Analysis	85
34	Simplified Lateral-Force Procedure	86
35	Vertical Distribution of Base Shear to Stories	88
36	Simplified Vertical Distribution of Base Shear to Stories	89
37	UBC Provisions for Vertical Ground Acceleration	91
38	UBC Provisions for Direction of the Earthquake	91
39	UBC Provisions for Horizontal Torsional Moment	92
40	UBC Story Drift Determination	92
41	UBC Provisions for Building Separations	95
42	UBC Provisions for Overturning Moment	96
43	UBC Provisions for P - Δ Effects	97
44	Seismic Force on Elements of Structures, Nonstructural Components, and Equipment Supported by Structures	99
45	UBC Provisions for Ties and Continuity	104
46	Nonbuilding Structures	104
47	UBC Provisions for Deformation Compatibility	108
48	Penalties for Structural Irregularity	109
49	UBC Provisions for Scaling of Results	109
50	UBC Dynamic Analysis Procedure	110
51	Allowable Stress Levels	111

PART 7**DIAPHRAGM THEORY**

1	Diaphragm Action	113
2	Seismic Wall and Diaphragm Forces	113
3	Wall Shear Stress	114
4	Rigid Diaphragm Action	115
5	Calculating Wall Rigidity	116
6	Flexible Diaphragms	120
7	Framing Terminology	120
8	Collectors	120
9	Collector Force	120
10	Columns Supporting Parts of Flexible Diaphragms	121
11	Flexible Diaphragm Construction	121
12	Flexible Diaphragm Torsion	121
13	Diaphragm Shear Stress	121
14	Diaphragm Flexure	122
15	Deflection of Flexible Diaphragms	122
16	Chords	123
17	Chord Force	124
18	Chord Size	124
19	Overtaking Moment	124

PART 8**GENERAL STRUCTURAL DESIGN**

1	Distributing Story Shears to Members of Unknown Size	129
2	Portal Method	129
3	Cantilever Method	130
4	Spurr Method	132
5	Frame Member Sizing	132

PART 9**DETAILS OF SEISMIC-RESISTANT
CONCRETE STRUCTURES**

1	Concrete Construction Details	135
A	Orthogonal Effects	136
B	Connections	136
C	Deformation Compatibility	136
D	Ties and Continuity	136
E	Collector Elements	137
F	Concrete Frames	137
G	Anchorage to Concrete and Masonry Walls	137
H	Boundary Elements of Shear Walls and Diaphragms	137
I	Seismic Hooks, Crossties, and Hoops	137
J	Strength Reduction Factor	138
K	Combined Loading Load Factors	138
L	Concrete Strength	138
M	Steel Reinforcement	138
N	Frame Flexural Members	139
O	Top and Bottom Reinforcement	139
P	Tension Lap Splices	140

Q	Welded Splices and Mechanical Connections	140
R	Members with Bending and Axial Loads	141
S	Columns Carrying Discontinuous Walls	142
T	Diaphragms	142
U	Minimum Column Size	142
V	Joints	142

PART 10**DETAILS OF SEISMIC-RESISTANT STEEL
STRUCTURES**

1	Steel Construction Details	143
A	Design and Construction Provisions	143
B	Seismic Provisions for Structural Steel Buildings	143
C	Loads and Load Combinations	143
D	Steel Frames	143
E	Steel Properties	144
F	Member Strengths	144
G	Column Requirements	144
H	Ordinary Moment Frames	145
I	Special Moment-Resisting Frames	145
J	Special Truss Moment-Frame	146
K	Welded and Bolted Connections	147
L	Girder-Column Joint Restraints	148
M	Braced Frames	148
2	Eccentrically Braced Frames	149
3	Steel Stud Wall Systems	150

PART 11**DETAILS OF SEISMIC-RESISTANT MASONRY
STRUCTURES**

1	Masonry Structures	151
A	Design and Construction Provisions	151
B	Seismic Provisions for Structural Masonry Buildings	151
C	Loads and Load Combinations	151
D	Masonry Construction Details	151
E	Masonry Moment-Resisting Wall Frames	152
F	Allowable Shear Stress	152

PART 12**DETAILS OF SEISMIC-RESISTANT WOOD
STRUCTURES**

1	Wood Structures	155
A	Design and Construction Provisions	155
B	Seismic Provisions for Structural Wood Buildings	155
C	Loads and Load Combinations	155

2	Wood Shear Wall and Wood Structural Panel Diaphragm Design Criteria	155
A	Framing	156
B	Wood Structural Panels	156
C	Requirements for Resisting Horizontal Forces in Concrete/Masonry Buildings	156
3	Wood Structural Panel Shear Walls	157
4	Diaphragm Ratios	158
5	Wood Structural Panel Diaphragm Construction Details	158
6	Blocking	158
7	Subdiaphragms	158
8	Connector Strengths	159
A	Nails	159
B	Bolts	159
C	Ties	164
9	Flexible Diaphragm to Wall Connection Details	164
10	Cross-Grain Loading	165
11	Framing for Diaphragm Openings	165
12	Cripple Walls	166

PART 13

TILT-UP CONSTRUCTION	167
--------------------------------	-----

PART 14**SPECIAL DESIGN FEATURES**

1	Energy Dissipation Systems	169
2	Base Isolation	169
3	Seismic-Isolated Design Details	171
4	Damping Systems	171
5	Architectural Considerations	172
6	Upgrading Existing Construction	173

PART 15**PRACTICE PROBLEMS**

1	Earthquakes in General	175
2	Buildings	175
3	Structural Systems	177
4	UBC	178
5	Concrete and Masonry Structures	179
6	Steel Structures	181
7	Soils and Foundations	181
8	Design Problems	181
9	Qualitative Problems	202

APPENDICES

A	Conversion Factors	A-1
B	Definitions	A-2
C	Chronology of Important California Earthquakes	A-4
D	Rigidity of Fixed Piers	A-6
E	Rigidity of Cantilever Piers	A-7
F	Accelerogram of 1940 El Centro Earthquake (North-South Component)	A-8
G	Seismic Acronyms	A-9
H	Standard Welding Symbols of the AISC/AWS	A-10
I	Commercial Wood Framing Straps and Holdowns	A-11
J	Allowable Shear for Wind or Seismic Forces in Pounds per Foot for Wood Structural Panel Shear Walls with Framing of Douglas Fir-Larch or Southern Pine	A-15
K	Occupancy Category	A-16
L	1994 Northridge Earthquake: Performance of Steel Moment Frame Connections	A-17

INDEX	I-1
-----------------	-----

INDEX OF FIGURES AND TABLES	IFT-1
---------------------------------------	-------

INDEX BY UBC SECTION	IUBC-1
--------------------------------	--------