

**A METHODOLOGY FOR  
SEISMIC DESIGN AND CONSTRUCTION  
OF SINGLE-FAMILY DWELLINGS**

**SEPTEMBER, 1976**

**by**

**Ralph W. Goers & Associates  
Structural Engineers**

**for**

**Applied Technology Council**



**Department of Housing and  
Urban Development**

**Office of  
Policy Development & Research**

**Division of Energy, Building Technology and Standards**

# PREFACE

Observations and investigations of earthquake damage have revealed that contemporary empirical design and construction practices for single-family residences have not in all cases proven adequate. Recognizing this, the Department of Housing and Urban Development engaged the Applied Technology Council, San Francisco, to review available damage information as well as existing design and construction requirements for the purpose of developing a methodology for improved seismic design and construction for single-family dwellings, thereby reducing future seismic losses and life-loss risks.

The Applied Technology Council (ATC) is a nonprofit corporation, established by the Structural Engineers Association of California, and has as its goal the protection and enhancement of the public welfare through the advancement of technological developments for application in daily practice in the fields of structural design and construction. In particular, the objectives of ATC are to gather, coordinate, and disseminate technical data in order that it may be made available for use by engineers, other design professionals, code-enforcing officials, and builders.

The ATC organization fills a unique need for the design professionals, providing a means to assemble expert talent to solve special problems as they arise. ATC does not have a staff of researchers. Instead, all work is performed under subcontracts or agreements with qualified individuals, institutions or firms. The system makes it possible to bring current state-of-the-art techniques and methodology together with seasoned experience of practicing professionals.

To develop the information needed to improve seismic resistive construction practices for single-family residences, ATC engaged a structural engineer subcontractor well-experienced in residential construction and earthquake engineering, plus an advisory panel consisting of prominent structural engineers and a representative of the Building Industry Association (San Fernando Valley Chapter).

Principal Investigator/Subcontractor

Ralph W. Goers PE

Ralph W. Goers & Associates, Structural Engineers  
Sherman Oaks, California

# TABLE OF CONTENTS

ABSTRACT .....	iii
PREFACE .....	v
EXECUTIVE SUMMARY .....	vii
<b>PART I INTRODUCTION</b>	
Chap. I-1 Introduction .....	1
Purpose .....	1
Types of Design and Construction Materials .....	2
Basis of Methodology .....	2
Limitations on Design .....	3
New Concepts and Procedures .....	4
Limitations on Use of Publication .....	4
Organization and Coverage .....	4
Chap. I-2 Earthquake-Caused Damage to Residences .....	7
Summary of Earthquake-Caused Residential Damage .....	18
<b>PART II BASIC SEISMIC ANALYSIS FOR SINGLE-FAMILY RESIDENCES</b>	
Chap. II-1 Principles of Seismic-Resistive Design of Dwellings .....	1
Earthquake Forces (Inertia Forces) .....	2
Effects of Earthquake Forces on Structures .....	2
Lateral Force Resistance Systems for Dwellings .....	4
Methodology .....	16
Chap. II-2 Locating Shear Walls and Determining Tributary Areas .....	19
Locating Shear Walls .....	20
Determining Tributary Area .....	21
Model Homes .....	22
Model A .....	23
Model B .....	31
Model C .....	39
Model D .....	47
Summary of Locating Shear Walls and Determining Tributary Areas .....	54

## PART II BASIC SEISMIC ANALYSIS FOR SINGLE-FAMILY RESIDENCES

Chap. II-3 Determining Dead Loads and Seismic Loads .....	57
Model A .....	58
Model B .....	64
Model C .....	70
Model D .....	76
Veneer Loads .....	84
Wind Loads .....	85
Snow Loads .....	86
Chap. II-4 Wood Frame Shear Wall Design .....	87
Use of Calc Form 8 (or 9) .....	87
Capacity of Shear-Resisting Materials .....	88
Sill Bolt Spacing .....	88
Overturning .....	89
Model A .....	94
Model B .....	100
Model C .....	107
Model D .....	115
Zone 2 Calculations – Wood Frame Shear Wall Design .....	125
Chap. II-5 Masonry Exterior Walls – Shear Wall Design .....	133
Wall Designs .....	141
Chap. II-6 Miscellaneous Structural Considerations .....	143
Basic Layout Principles .....	143
Diaphragms .....	144
Shear Resisting Materials .....	146
Shear Transfer Details .....	146
Hold-Down Anchors .....	148
Struts .....	149
Chords .....	150
Wood Framing .....	150
Garages .....	153
Masonry .....	153
Chap. II-7 Non-Structural Items .....	155
Glazing .....	155
Damage to Cabinets and Bookshelves .....	156
Fireplaces .....	156
Veneer .....	157
Mechanical Equipment .....	157
Water Heaters .....	157
Floor Furnaces .....	158
Roof Coolers .....	158
Gas Shut-Off Valves .....	158

## PART III SEISMIC DESIGN METHODOLOGY

Section 1	Methodology and Definitions .....	1
1.1	Methodology .....	1
1.2	Definitions .....	2
Section 2	Determination of Shear Wall Locations .....	7
2.1	One-Story Construction .....	7
2.2	Two-Story Construction .....	8
2.3	Split-Level, Discontinuous Roof, Split-Entry and Combination One- and Two-Story Construction .....	11
Section 3	Tributary Areas .....	12
3.1	Guidelines .....	12
3.2	Lines of Resistance Acting Together .....	12
3.3	Calculating Tributary Widths and Lengths .....	12
Section 4	Determination of Seismic Loads .....	18
4.1	Calc Form 1 – Summary of Roof, Ceiling and Wall Weights for Simple One-Story Residences .....	18
4.2	Calc Form 2 – Summary of Roof, Ceiling and Floor Weights (Seismic Unit Loads) – For Other Than Simple One-Story Residences .....	18
4.3	Calc Form 3 – Summary of Wall Weights and Seismic Unit Loads – For All But Simple One-Story Residences ..	21
4.4	Calc Form 4 – Adjustment of Unit Wall Loads for Height in Houses With Pitched Roof and Level Ceiling Below .....	25
4.5	Calc Form 5 – Adjustment of Unit Wall Loads for Height – Houses with Flat Roofs or Sloping Ceilings .....	26
4.6	Calc Form 6 – Tributary Areas .....	26
4.7	Calc Form 7 – Seismic Loads .....	29
Section 5	Wind Loads .....	45
5.1	Applicability .....	45
5.2	Determination of Wind Loads .....	45
One-Story or Second Floor of Two-Story .....	45	
First Floor of Two-Story .....	45	
Overhangs .....	45	
Overturning .....	46	
Section 6	Wood Frame Shear Wall Design .....	49
6.1	Calc Form 8 – Shear-Per-Foot .....	49
6.2	Sill Bolt Design and Installation .....	50
Shear-Per-Foot .....	50	
Spacing .....	50	
Anchor Bolts .....	53	
Gun Bolts (Power-Driven Studs) .....	54	

**PART III SEISMIC DESIGN METHODOLOGY**

Section 6.3	Shear Material Design and Installation .....	54
	Shear-Per-Foot .....	54
	Adjusted Shear-Per-Foot .....	55
	Installation of Shear-Resisting Materials .....	55
6.4	Overturning .....	58
	Length of Walls .....	58
	Vertical Loads .....	60
	Horizontal Load Capacity .....	61
	Total Overturning Resistance .....	61
6.5	Overturning at Two-Story High Shear Walls .....	63
Section 7	Masonry Exterior Walls – Shear Wall Design .....	143
7.1	Loads .....	143
7.2	Shear Walls .....	143
7.3	Design of Shear Walls .....	143
7.4	Masonry Wall Reinforcing .....	144
Section 8	Miscellaneous Structural Considerations .....	149
8.1	Considerations Applicable in Both Zone 2 and Zone 3 .....	149
	Roofs .....	149
	Floor Diaphragms .....	149
	Chords .....	150
	Sole Plates at Non-Designed Interior Walls .....	150
	Struts and Their Connections .....	150
	Cutting and Notching .....	151
	Bored Holes .....	151
	Cripple Walls .....	151
	Special Garage Front Wall Details .....	151
8.2	Considerations Applicable in Zone 2 Only .....	153
	Stud to Sole Plate Connections .....	153
	Split-Level Ties .....	Zone 2–153
8.3	Considerations Applicable to Zone 3 Only .....	Zone 3–153
	Stud to Sole Plate Connections .....	153
	Split-Level Ties .....	153
Section 9	Miscellaneous Non-Structural Items .....	155
9.1	Glazing .....	155
9.2	Cabinets and Bookshelves .....	155
9.3	Fireplaces and Chimneys .....	155
	Footings .....	155
	Veneer .....	155
	Thickness .....	155

<b>PART III SEISMIC DESIGN METHODOLOGY</b>		
Section 9.3	(Fireplaces and Chimneys)	
	Reinforcement .....	156
	Anchorage .....	156
	Cutting of Plates .....	157
	Lintels .....	157
Section 9.4	Veneer .....	157
	Anchored Veneer .....	157
	Adhered Veneer .....	158
	Grout .....	159
Section 9.5	Mechanical Equipment .....	159
	Water Heaters .....	159
	Floor Furnaces .....	159
	Other Mechanical Equipment .....	159
	Gas Valves .....	159
<b>PART IV CONSTRUCTION DETAILS</b>		
	Commentary on Details .....	1
	Index to Details (Table 4.1) .....	3
	Details .....	8
<b>PART V GUIDELINES FOR PLAN-CHECKERS AND INSPECTORS</b>		
Chap. V-1	Plan-Checking .....	1
	Checking Calc Forms .....	1
	Checking Predesigned Details .....	3
	Checking Revised Details .....	4
	Provision for Engineering .....	4
	Local Acceptable Standards .....	4
Chap. V-2	Inspection .....	5
	Common Field Errors .....	6
	New Construction Requirements .....	10
<b>APPENDIX A</b>	<b>EXAMPLE DESIGN FOR A SPLIT-ENTRY HOME</b>	
<b>APPENDIX B</b>	<b>ADDITIONAL EXAMPLES FOR DETERMINATION OF TRIBUTARY AREAS</b>	
	<b>APPLIED TECHNOLOGY COUNCIL PROJECTS AND REPORT INFORMATION</b>	