BUILDING SEPARATION FOR WOOD FRAMED BUILDINGS

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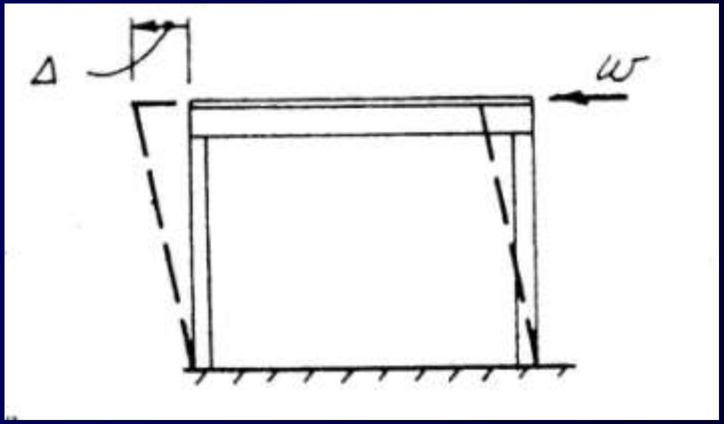
1997 UBC Requirements

- Determine Elastic Deflection (Δ_s)
- Calculate Δ_m per UBC Equation 30-17
  $\Delta_m = 0.7*R*\Delta_s$
- Calculate Building Separation per UBC Equation 33-2 – $\Delta_{mt} = ((\Delta_{m1})^2 + (\Delta_{m2})^2)^{1/2}$

Plywood Shear Wall Deflections

- UBC Section 23.223

$$\Delta_s = \frac{8vh^3}{EAb} + \frac{vh}{Gt} + 0.75he_n + \frac{h}{b}d_a$$

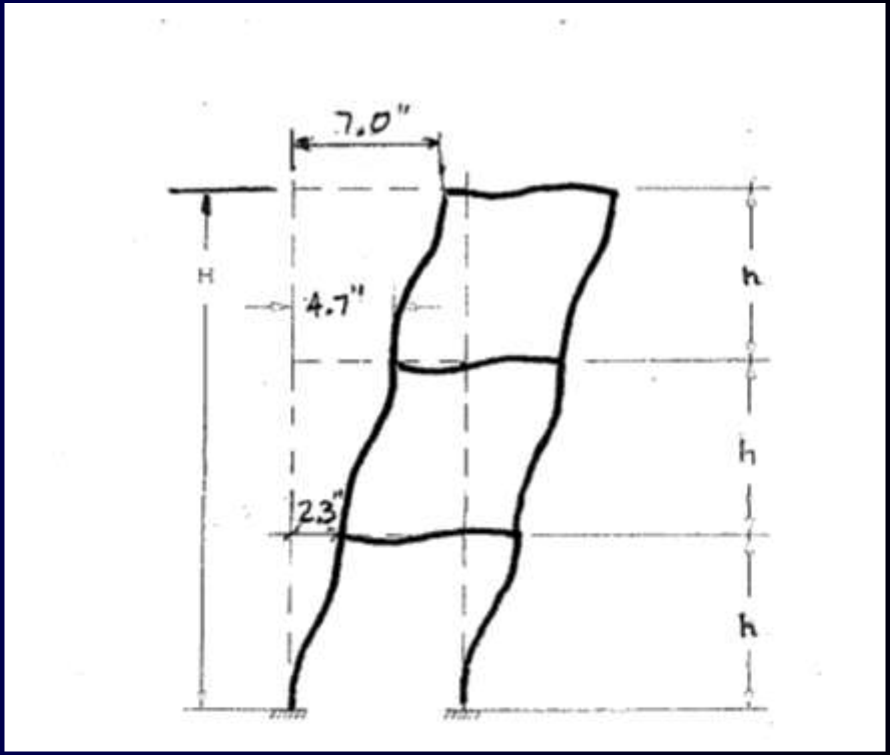


Plywood Shear Wall Deflection

- Plywood Shear Wall Example
  - ½" plywood sheathing
  - 8d commons at 4 inches on center
  - 9ft high wall
  - 8ft long wall
- Δ_s = 0.61" per level
- $\Delta_{s@roof}$ = 1.83" per level

Inelastic Response Displacement

- $\Delta_m = 0.7 * R * \Delta_s$
- $R = 5.5$
- $\Delta_m = 0.7 * 5.5 * 0.61''$
- $\Delta_m = 2.35''$



Building Separation

- $\Delta_{mt} = ((\Delta_{m1})^2 + (\Delta_{m2})^2)^{1/2}$
- $\Delta_{m2} = 3.3"$
- $\Delta_{m3} = 6.6"$
- $\Delta_{mR} = 10.0"$

Building Period – Method A

- $T = C_t(h_n)^{3/4}$ - UBC Equation 30-8
- Ct = 0.02, h_n = 27 ft
- T = 0.24 Second

Building Period – Method B

$$T = 2\pi \sqrt{\left(\sum_{i=1}^{n} w_i \delta_i^{\,2}\right) \div \left(g \sum_{i=1}^{n} f_i \delta_i\right)} \qquad (30\text{-}10)$$

- Assumptions:
  - Weight of floors and roof are equal
  - Story heights are equal
  - Story drifts are equal
  - Base Shear – V = 0.20W

Building Period – Method B

- Generalized Equation
- $$T_B^2 = \frac{(n+1)}{n} * \frac{4*PI^2*\Delta_{s@roof}}{2*g*C_{BS}}$$
- T_B = 0.79 Second >> T_A = 0.24 Second

Technical Document Research

- FEMA 273
- FEMA 356
- ASCE 41
- CUREE
  - Recommendations for Earthquake Resistance in the Design and Construction of Woodframe Buildings
  - Dynamic Characteristics of Woodframe Structures

Period Calculation

- FEMA 273 – $T = C_t * h_n^{3/4}$
  - Ct = 0.060 for Wood Buildings (no commentary)
- FEMA 356 – $T = C_t * h_n^{3/4}$
  - Ct = 0.060 for Wood Buildings (no commentary)
- ASCE 41 – $T = C_t * h_n^{3/4}$
  - Ct = 0.020

Building Period

- CUREE - Recommendations for Earthquake Resistance in the Design and Construction of Woodframe Buildings
- "Estimation of building periods in accordance with UBC Method B may result in periods that are significantly greater than justified by current research data when based on the properties of the wood structure without finish materials."

Building Period – FEMA 356

- Curee – Figure 7-4 suggest that using $C_t = 0.02$ instead of 0.06 provides a much more realistic prediction of low-amplitude building period.

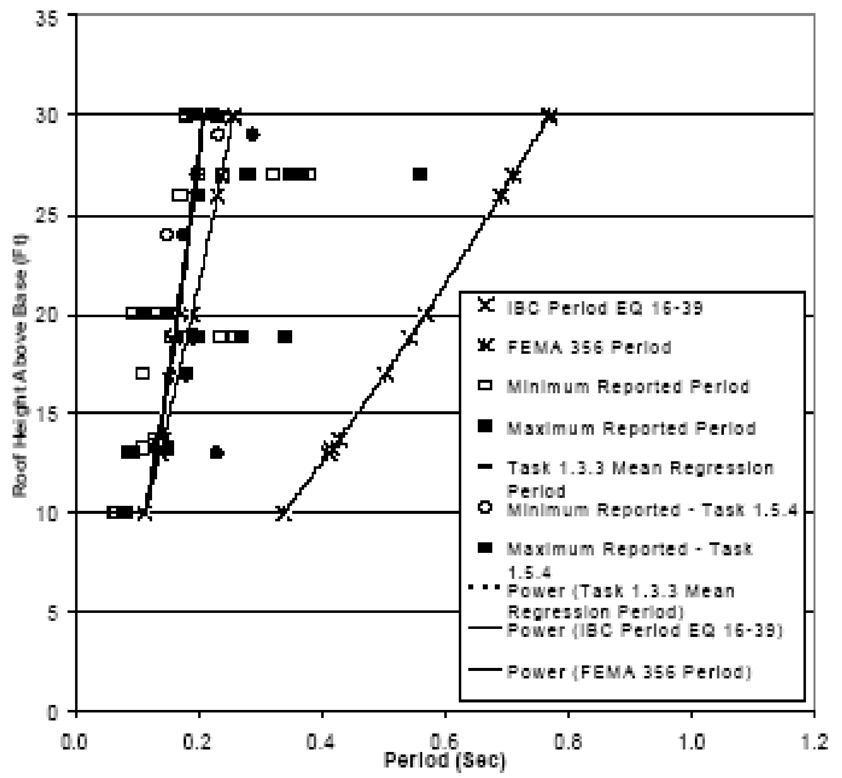


Figure 7-4. Building period versus building height, based on data from Table A-2.

CUREE – Building Periods Determined from Past Earthquakes

Table 2:
Summary of Building Dynamic Characteristics From Earthquake Records

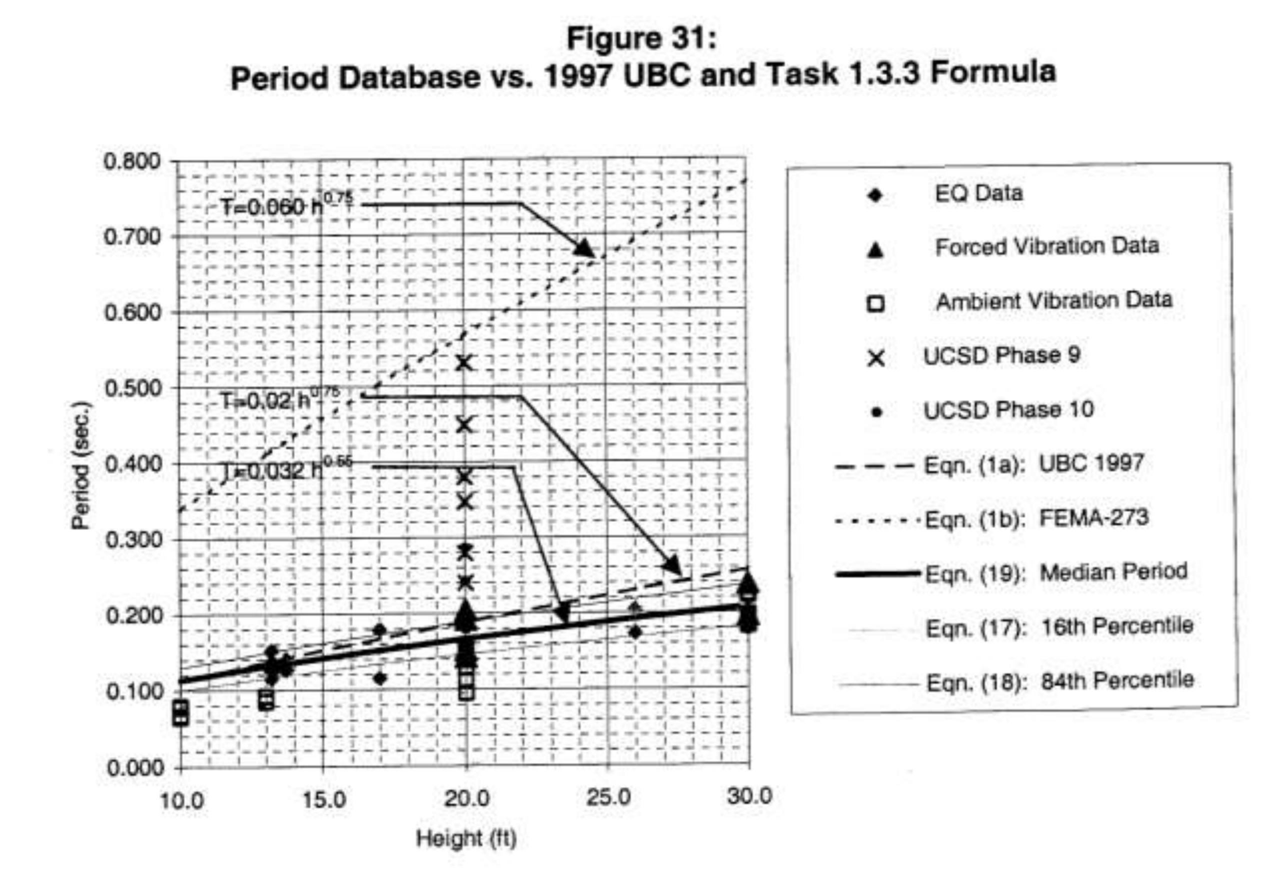
		San Bernardino			Parkfield		Bishop	Indio	Eureka
Building Height (top of roof)		29.9'			13.2'		17'	13.7'	26.0'
Length:	(Longit.)	180.5'			48'		62'	298'	80'
	(Transv.)	132'			30'		50'	148'	54'
Date of Earthquake		6/28/97	7/26/97	3/11/98	4/4/93	12/20/94	5/17/93	7/25/97	2/8/95
Magnitude (M_L)		4.2	3.7	4.5	4.2	4.7	6.0	4.9	3.9
Peak Response		9.2%g	7.8%g	7.1%g	12.3%g	20.1%g	4.4%g	8.2%g	6.2%g
Total Drift (mm):	(Longit.)	0.7	0.7	0.8	0.5	0.9	1.2	0.4	0.4
(Roof w.r.t. Base)	(Transv.)	0.6	0.7	0.7	0.5	1.5	0.3	0.2	0.5
Periods (sec):	(Longit.)	**0.22**	**0.20**	**0.23**	**0.14**	**0.15**	**0.11**	**0.13**	**0.17**
(First Mode)	(Transv.)	**0.19**	**0.21**	**0.18**	**0.11**	**0.13**	**0.18**	**0.14**	**0.20**
Frequency (Hz):	(Longit.)	4.6	5.0	4.4	7.3	6.6	8.7	7.9	5.8
(First Mode)	(Transv.)	5.4	4.8	5.6	8.7	8.0	5.6	7.1	4.9
Damping Ratio (%):	(Longit.)	13.6	14.1	7.7	11.6	10.8	12.2	8.9	16.5
(First Mode)	(Transv.)	17.3	6.9	11.7	14.2	15.3	7.0	6.3	14.9

CUREE – Forced Vibration

Table 4:
Summary of Building Parameters And Dynamic Characteristics From Forced Vibration Tests

Test Site	Building Height	Test Date	Ambient / Forced (shaker used)	Shaker Eccentricity	Direction of Shaking	1st Mode Frequency (Hz)		1st Mode Damping Ratio (%)	
						Longit.	Transv.	Longit.	Transv.
2-Story House (Pasadena)	20'	June 23, 2000	AVS	--	--	7.8	6.5	--	--
			HMC Shaker	2.5%	Transv. (EW)	5.7	5.5	5.2 %	2.6 %
			HMC Shaker	2.5%	Longit. (NS)	5.6	--	4.9 %	--
		June 27, 2000	HMC Shaker	2.5%	Longit. (NS)	5.5	--	5.0 %	--
			HMC Shaker	2.5%	Transv. (EW)	5.7	5.5	4.8 %	2.9 %
			HMC Shaker	10%	Transv. (EW)	5.2	5.1	6.0 %	2.9 %
			HMC Shaker	20%	Transv. (EW)	5.2	4.9	4.1 %	2.7 %
3-Story Apartment (Pasadena)	30'	July 7, 2000	AVS	--	--	5.5	4.5	--	--
			HMC Shaker	2.5%	Longit. (NS)	5.3	--	4.7 %	--
			HMC Shaker	2.5%	Transv. (EW)	--	4.4	--	4.7 %
		July 10, 2000	HMC Shaker	2.5%	Longit. (NS)	5.3	--	4.4 %	--
			HMC Shaker	2.5%	Transv. (EW)	--	4.4	--	4.6 %
			HMC Shaker	10%	Longit. (NS)	5.2	4.3	4.6 %	--
			HMC Shaker	20%	Longit. (NS)	5.1	4.2	4.9 %	--
			HMC Shaker	20%	Transv. (EW)	--	4.2	--	5.1 %
2-Story Office (Pasadena)	20'	Sept. 9, 2000	HMC Shaker	5%	Transv. (NS)	--	7.2	--	4.8 %
		Sept. 10, 2000	HMC Shaker	5%	Longit. (EW)	6.7	7.2	6.8 %	--
			HMC Shaker	10%	Longit. (EW)	6.6	7.0	6.4 %	--

CUREE – Period v. Height



Building Period Calculation

- $T = C_t(h_n)^{3/4}$ - UBC Equation 30-8
- T = 0.24 Seconds (C_t = 0.02)
- T = 0.71 Seconds (C_t = 0.06)
- T = 0.47 Seconds (C_t = 0.04)

Building Deflection Calculation

- Generalized Equation

$$\Delta_{s@roof} = \frac{T^2 * g * C_{BS}}{2 * PI^2} * \frac{n}{n+1}$$

- T = 0.47 Seconds (C_t = 0.04)
- $\Delta_{s@roof}$ = 0.66”

Building Separation

- Inelastic Response Displacement
- $\Delta_{m@roof} = 0.7*R*\Delta_s$
- $\Delta_{m@roof} = 0.7*5.5*0.66 = 2.54"$
- Building Separation
- $\Delta_{mt} = ((\Delta_{m1})^2 + (\Delta_{m2})^2)^{1/2} = 3.6"$
- $\Delta_{mt} = 3.6" << \Delta_{mt} = 10"$