

APPENDIX E DESIGN EXAMPLE

This example demonstrates the design methods for analysis of the lateral force resisting system of a one-story house (Figure E1). The design lateral load is distributed between the shear walls according to two methods: flexible diaphragm method and rigid diaphragm method (see Appendix C for description of the methods). Figures E2 and E3 show a graphical representation of analytical models for both methods. Then, the shear resistance of Wall 4 (Figures E1 and E4) is analyzed using three methods: segmented shear wall method, perforated shear wall method, and Ni-Karacabeyli's method (see Appendix D description of the methods).

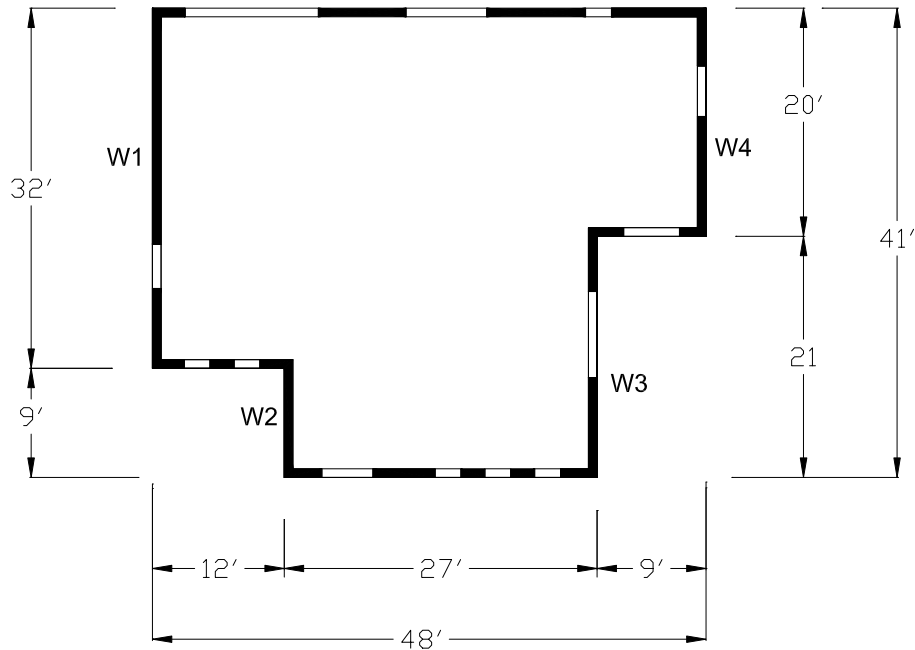


Figure E1
Shear Wall Schedule for a One-Story House

DESIGN INPUT

Design Format	ASD
Load Direction	North-South (NS)
Wind Load in NS direction	20,000 lb (assumed)
Design Basis	Capacity
Reduction Factor	0.5 (Table 4.2)
Load Duration Factor	1.0 (Wind Load)

Shear Wall Parameters:

Structural Sheathing Panels	Structural OSB panels
Sheathing Nails	Common nails
Lumber Species	SPF (SG = 0.42)
Stud Spacing	16 inches o.c.

Shear Wall Height 8.1 ft
 Interior Sheathing none
 Wall configurations See Table E1

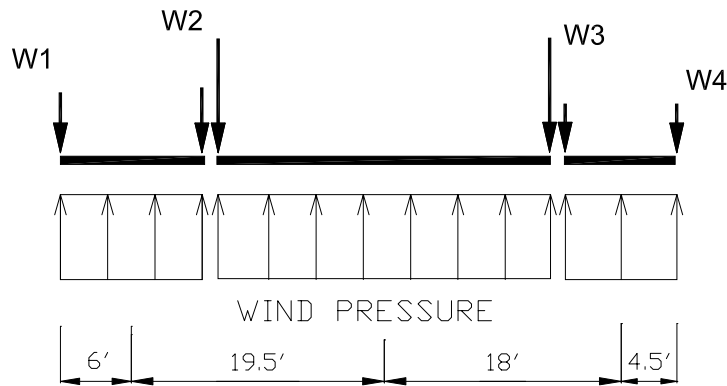
**TABLE E1
 WALL CONFIGURATIONS**

Parameter	Wall 1	Wall 2	Wall 3	Wall 4
Total length	32 ft	9 ft	21 ft	20 ft
Number of openings	1	none	1	1
Opening type	Window		Window	Door
Opening length	3 ft		6 ft	4 ft
First segment	6 ft		9 ft	11 ft
Second segment	21 ft		6 ft	5 ft

LATERAL LOAD DISTRIBUTION

Flexible Diaphragm Method

The total lateral load is distributed between the shear walls based on the tributary areas associated with each wall on a purely geometric basis. Figure E2 is a graphical representation of the mechanical model based on a simple beam approach. Table E2 summarizes individual shear wall loads.



**Figure E2
 Flexible Diaphragm Method Model**

**TABLE E2
 SHEAR WALL LOADS ACCORDING TO FLEXIBLE DIAPHRAGM METHOD**

Shear Wall #	Tributary Area of Associated Wall, ft ²	Fraction of Total Tributary Wall Area	Shear Wall Load, lb
Wall 1	(6.0)(8.1) = 48.6	0.125	2,500
Wall 2	(19.5)(8.1) = 157.95	0.410	8,125
Wall 3	(18)(8.1) = 145.8	0.375	7,500
Wall 4	(4.5)(8.1) = 36.45	0.090	1,875
TOTAL	388.8	1.0	20,000

Rigid Diaphragm Method

The total lateral load is distributed between the shear walls based on the relative capacities. Figure E3 is a graphical representation of the mechanical model based on a continuous rigid beam approach. For the first iteration, the segmented shear wall method is used to determine the wall capacities. Table E3 summarizes individual shear wall loads.

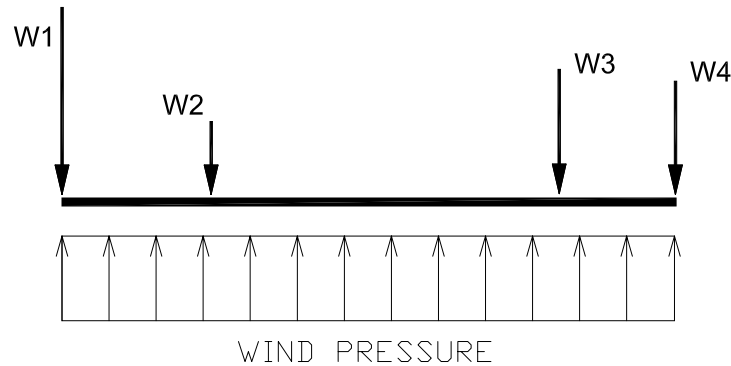


Figure E3
Rigid Diaphragm Method Model

TABLE E3
SHEAR WALL LOADS ACCORDING TO RIGID DIAPHRAGM METHOD

Shear Wall #	Segmented Shear Wall Length, ft	Fraction of Total Wall Length	Shear Wall Load, lb
Wall 1	29.0	0.42	8,400
Wall 2	9.0	0.13	2,600
Wall 3	15	0.22	4,400
Wall 4	16	0.23	4,600
TOTAL	69.0	1.0	20,000

Table E4 compares results of flexible vs. rigid diaphragm methods. The flexible diaphragm method both underestimates and overestimates the shear wall loads as compared to the rigid diaphragm method. While providing a more conservative design, the flexible diaphragm method requires an impractical shear wall schedule for this building configuration (Figure E1). For example, Wall 2 has to be excluded from the analysis, because it is impractical to design a short wall segment that accounts for only 13 percent of the total shear wall length of the building in the North-South direction to resist as much as 41 percent of the total story shear load. Although Walls 3 and 4 have practically the same lengths, according to the flexible diaphragm method, Wall 3 should have capacity four times greater than that of Wall 4. The differences between the two methods diminish in significance for simple rectangular buildings that resist shear loads by only two exterior walls. Appendix C discusses the methods of lateral load distribution and examines aspects and limitations of various methods of analysis.

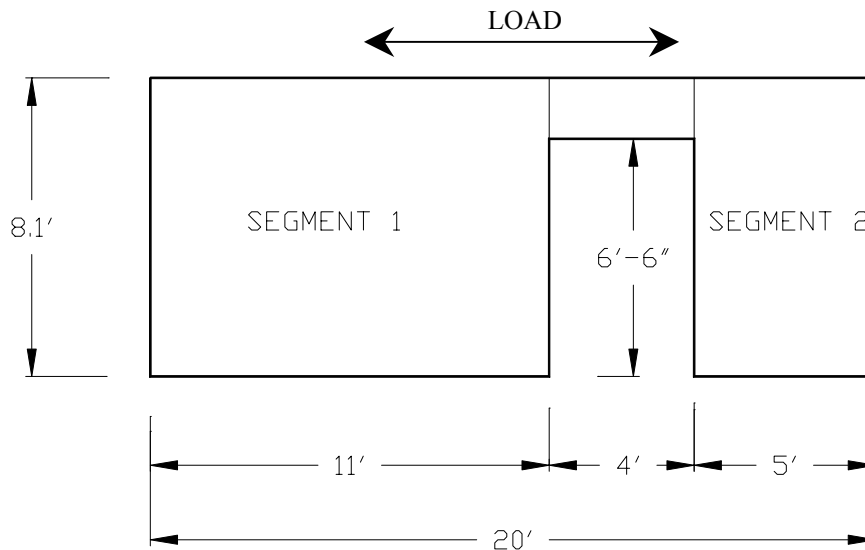
**TABLE E4
COMPARISON OF FLEXIBLE AND RIGID DIAPHRAGM METHOD**

Shear Wall #	Shear Wall Load, lb		Absolute Difference, lb	Relative ¹ Difference, %
	Flexible Diaphragm	Rigid Diaphragm		
Wall 1	2,500	8,400	5,900	70
Wall 2	8,125	2,600	-5,525	-213
Wall 3	7,500	4,400	-3,100	-70
Wall 4	1,875	4,600	2,725	59
Total	20,000	20,000		

¹Rigid diaphragm method is used as a basis.

Shear Wall Analysis

Results of the rigid diaphragm analysis are used to design Wall 4 (Figure E4). The shear wall is designed using three methods: segmented, perforated, and Ni-Karakabeyli's (see Appendix D for description of the methods).



**Figure E4
Wall 4**

Load: $P = 4,600$ lb (Table E3)

Segmented Shear Wall Method

Minimum required unit shear wall capacity:

$$v = \frac{P}{\Omega (l_1 + l_2)} = \frac{4,600}{0.5 (11 + 5)} = 575 \text{ lb/ft}$$

where:

- P , lb = load;
- $\Omega = 0.5$ = reduction factor for ASD design format (Table 4.2);
- $(l_1 + l_2)$, ft = total length of wall segments.

Characteristic unit shear wall resistance adjusted for lumber species:
 (650) [1- (0.5-0.42)] = **598 lb/ft** (Table B1 of Appendix B)

Wall Characteristics:

Structural sheathing	5/16 wood structural panel
Nail size	6d common (D = 0.113 inch)
Nail spacing	6 inch o.c. on perimeter and 12 inch o.c. in field
Stud spacing	16 inches o.c.
Lumber species	SPF lumber
Holddowns:	at the end of each segment – four holddowns overall for two segments

Perforated Shear Wall Method

Empirical perforation reduction factor, F:

$$F = \frac{r}{3-2r} = \frac{0.83}{3-(2)(0.83)} = 0.62$$

$$r = \frac{1}{1 + \frac{A_o}{H \sum l_i}} = \frac{1}{1 + \frac{(4)(6.5)}{(8.1)(5+11)}} = 0.83$$

where:

- A_o = total area of openings;
- H = shear wall height;
- Σl_i = summation of lengths of all full height wall segments.

Minimum required unit shear wall capacity:

$$v = \frac{P}{\Omega L F} = \frac{4,600}{(0.5)(20)(0.62)} = 742 \text{ lb / ft}$$

Characteristic unit shear wall resistance adjusted for lumber species:
 (820) [1- (0.5-0.42)] = **754 lb/ft** (Table B1 of Appendix B)

Wall Characteristics:

Structural sheathing	15/32 wood structural panel
Nail size	8d common (D = 0.131 inch)
Nail spacing	6 inch o.c. on perimeter and 12 inch o.c. in field
Stud spacing	16 inches o.c.
Lumber species	SPF lumber
Holddowns:	at the wall corners – two holddowns overall

Ni-Karacabeyli's Method

The wall is analyzed in both directions:

Direction of Loading: Left-to-Right (Figure E4)

Segment 1:

Segment length	$l_1 = 11$ feet
Uplift restraint effect:	$\phi_1 = 1.0$ – holddown bracket is installed
Capacity ratio:	$\alpha_1 = 1.0$ – segment is fully restrained

Segment 2:

Segment length	$l_2 = 5$ feet
Uplift restraint effect:	$\phi_2 = 0$ – no overturning restraint at door opening
Segment aspect ratio:	$\gamma_2 = 8.1/5 = 1.62$
Capacity ratio:	

$$\alpha = \sqrt{1 + 2\phi\gamma + \gamma^2} - \gamma = \sqrt{1 + 2(0)(1.62) + 1.62^2} - 1.62 = 0.28$$

Minimum required unit shear wall capacity:

$$v = \frac{P}{[\alpha_1 l_1 + \alpha_2 l_2] \Omega} = \frac{4,600}{[(1.0)(11) + (0.28)(5)](0.5)} = 740 \text{ lb/ft}$$

Direction of Loading: Right-to-Left (Figure E4)

Segment 2:

Segment length	$l_2 = 5$ feet
Uplift restraint effect:	$\phi_2 = 1.0$ – holddown bracket is installed
Capacity ratio:	$\alpha_2 = 1.0$ – segment is fully restrained

Segment 1:

Segment length	$l_1 = 11$ feet
Uplift restraint effect:	$\phi_1 = 0$ – no overturning restraint at door opening
Segment aspect ratio:	$\gamma_1 = 8.1/11 = 0.75$
Capacity ratio:	

$$\alpha = \sqrt{1 + 2\phi\gamma + \gamma^2} - \gamma = \sqrt{1 + 2(0)(0.75) + 0.75^2} - 0.75 = 0.50$$

Minimum required unit shear wall capacity:

$$v = \frac{P}{[\alpha_2 l_2 + \alpha_1 l_1] \Omega} = \frac{4,600}{[(1.0)(5) + (0.50)(11)](0.5)} = 874 \text{ lb/ft}$$

The Right-to-Left direction governs the design.

Characteristic unit shear wall resistance adjusted for lumber species:
(1040) [1- (0.5-0.42)] = **956 lb/ft** (Table B1 of Appendix B)

Wall Characteristics:

Structural sheathing	15/32 wood structural panel
Nail size	8d common
Nail spacing	4 inch o.c. on perimeter and 12 inch o.c. in field
Stud spacing	16 inches o.c.
Lumber species	SPF lumber
Holddowns:	at the wall corners – two holddowns overall

