Soil Dynamics

Lecture 16

Diaphragm Theory - Part II

In a Problem Format

Question #01.

Rigid diaphragms distribute the lateral force to the resisting elements proportional to the,

A. relative rigidities of these elements.

B. tributary areas of these elements.

C. base shear.

D. deflection of those elements.

Answer to #01.

A.

Rigid diaphragms distribute lateral forces in proportion to the rigidities of vertical resisting elements. They do not distribute lateral forces on a tributary load basis, as do flexible diaphragms.

Question #02.

Which of the following sentences are true regarding rigid roof diaphragms?

A. They distribute the lateral story shears to the resisting elements.

B. They transmit torsion to the resisting elements.

C. They do not deform when they are subjected to the lateral loads.

D. All of the above answers are true.

<u>Answer to #02.</u>

D.

Rigid diaphragms, such as concrete slabs and concrete on metal deck floor systems, do not bend due to lateral loads. They distribute lateral story shears to vertical resisting elements. As opposed to flexible diaphragms, rigid diaphragms transmit torsion to the vertical resisting elements.

Question #03.

Which of the following diaphragms would be considered rigid diaphragms?

A. Plywood floors.

B. Wood sheathed floors.

C. Light metal decks.

D. Metal decks with concrete fill.

Answer to #03.

D.

Metal decks with concrete fill are considered rigid diaphragms because they are structurally relatively thick and heavy, and will not change shape under lateral loads.

Question #04.

What measure can be taken to minimize the deflection of a wood structural panel roof diaphragm?

A. Decrease the plywood thickness.

B. Use double studs at the corners.

C. Decrease the nail spacing.

D. Increase the diaphragm span.

Answer to #04.

C.

CBC provisions limit diaphragm deflection by specifying maximum diaohragm dimension ratios in table 23-II-G.

One way to further minimize diaphragm deflection is to decrease the nail spacing along the edges of the diaphragm. The nail spacing determines the shear resistance across the diaphragm when it is subjected to lateral loads.

Question #05.

Torsional effects can be critical for elements located in which of the following areas?

A. On the center of rigidity.

B. Close to the center of rigidity.

C. Far from the center of rigidity.

D. None of the above.

Answer to #05.

C.

1) **The *center of rigidity* is the point which the resultant of the resistance to the applied lateral force acts. It is called the center of rigidity because the individual elements resist the lateral force in proportion to their rigidities.**

2) **The *center of mass* is the point through which the applied lateral force acts.**

3) ***Eccentricity* is the distance between the center of rigidity and the center of mass (measured perpendicular to the direction of the lateral load).**

4) ***Accidental eccentricity* is equal to 5% of the building dimension that is perpendicular to the direction of the lateral load.**

5) **The *torsional moment* equals to the applied lateral force, multiplied by the sum of the eccentricity and accidental eccentricity. The torsional moment is resisted by individual walls and columns in proportion to the distance from the center of rigidity.**

Question #06.

Which of the following elements resist torsional shear?

A. Parallel walls.

B. Perpendicular walls.

C. All walls.

D. All walls and columns.

<u>Answer to #06.</u>

D.

Torsional shear stress occurs whenever centers of mass and rigidity do not coincide. The implication here is that diaphragms are rigid.

Rigid diaphragms, as opposed to flexible diaphragms, transfer torsion to the vertical resisting elements. Resisting elements consist of columns, shear walls (parallel and perpendicular), braced frames, moment-resisting frames and connections.

Question #07.

Torsional design moment should be the moment resulting from,

A. eccentricity.

B. accidental torsion.

C. eccentricity and accidental torsion.

D. bending moment.

Answer to #07.

C.

CBC Section 1630.7 states that the torsional design moment should be the moment resulting from eccentricity and accidental torsion.

Question #08.

A plan view of a flexible roof diaphragm is shown below. The transverse loading to the diaphragm is w (in lb_f/ft).

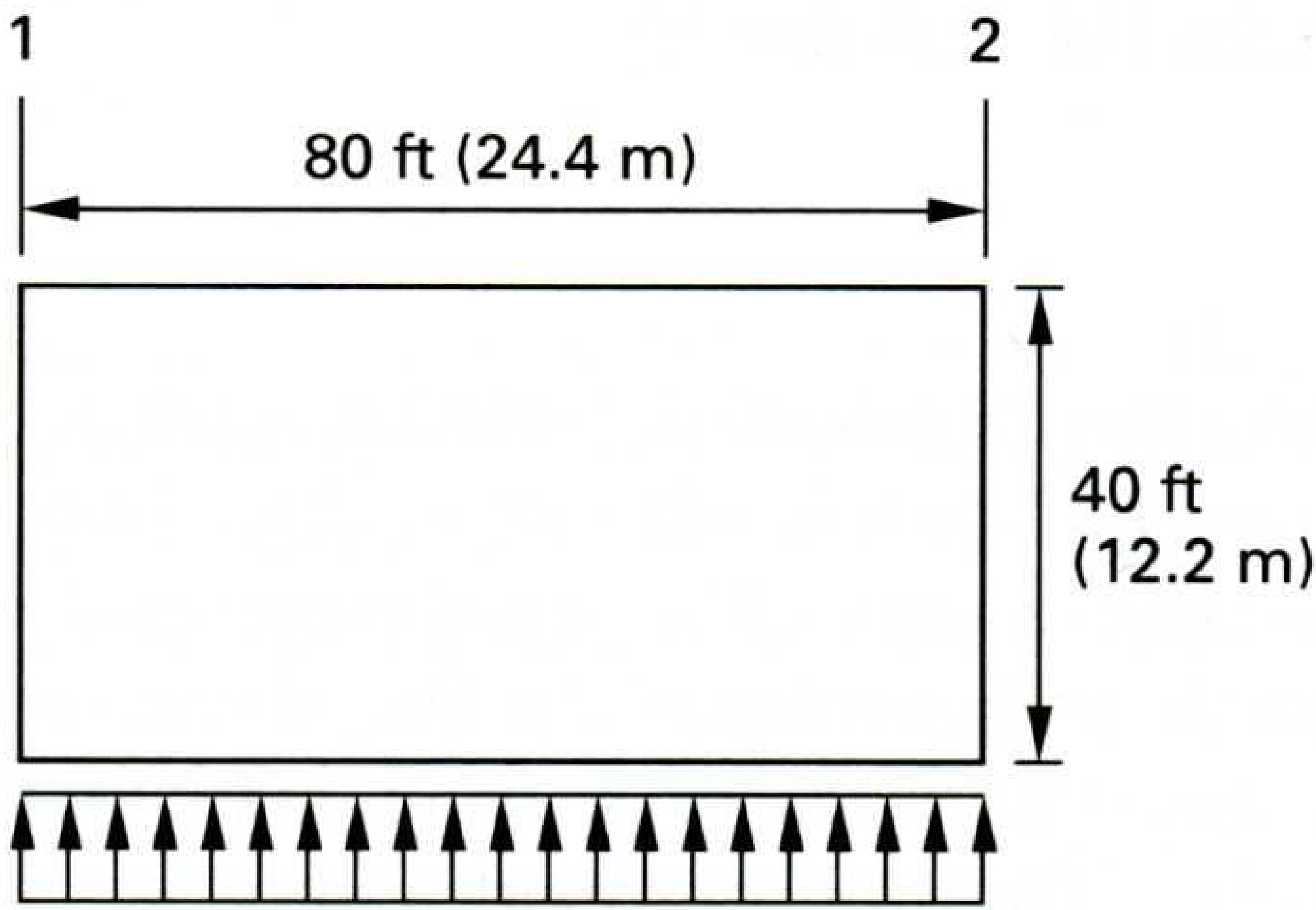
What will the shear stresses be at lines 1 and 2 (in lb_f/ft)? Assume $\rho = 1$.

A. $0.25w$

B. $0.50w$

C. w

D. $2w$



Answer to #08.

C.

Each of the two parallel walls carries half of the applied load in shear. The total load on the diaphragm is,

$$V_{diaphragm} = w \text{ (80 ft)}$$

The load on each parallel walls is,

$$V_{wall} = \text{(80 ft) } w / 2 = \text{(40 ft) } w$$

The shear stress per foot of wall is,

$$\upsilon = V_{wall} / \text{b} = \text{(40 ft) } w / \text{(40 ft)} = w$$

Question #09.

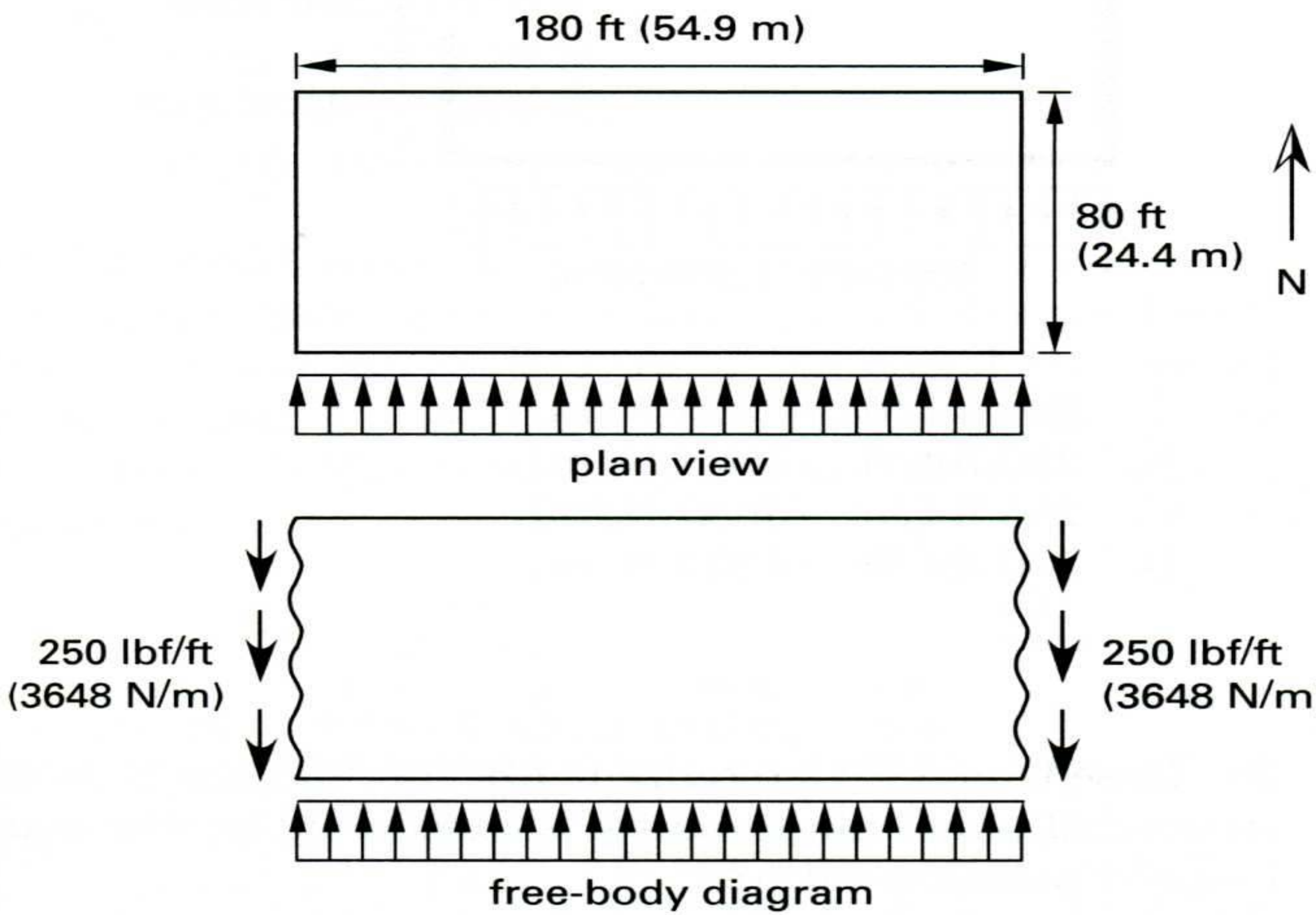
A plan view of a one-story wood structure with a wood structural panel rood diaphragm is shown. The distributed roof diaphragm shear stress in the north-south direction is 250 lbf/ft. Determine the lateral force. Assume $\rho = 1$.

A. 110 lb_f/ft

B. 220 lb_f/ft

C. 330 lb_f/ft

D. 440 lb_f/ft



Answer to #09.

B.

$$\upsilon = \frac{V}{b} \qquad \therefore\ V = \upsilon b \qquad and \qquad V = \frac{wL}{2}$$

Therefore,

$$w = \frac{2V}{L} = \frac{2\upsilon b}{L} = \frac{(2)(250\ lb_f / ft)(80\ ft)}{(180\ ft)} = 220\ lb_f / ft$$

Question #10.

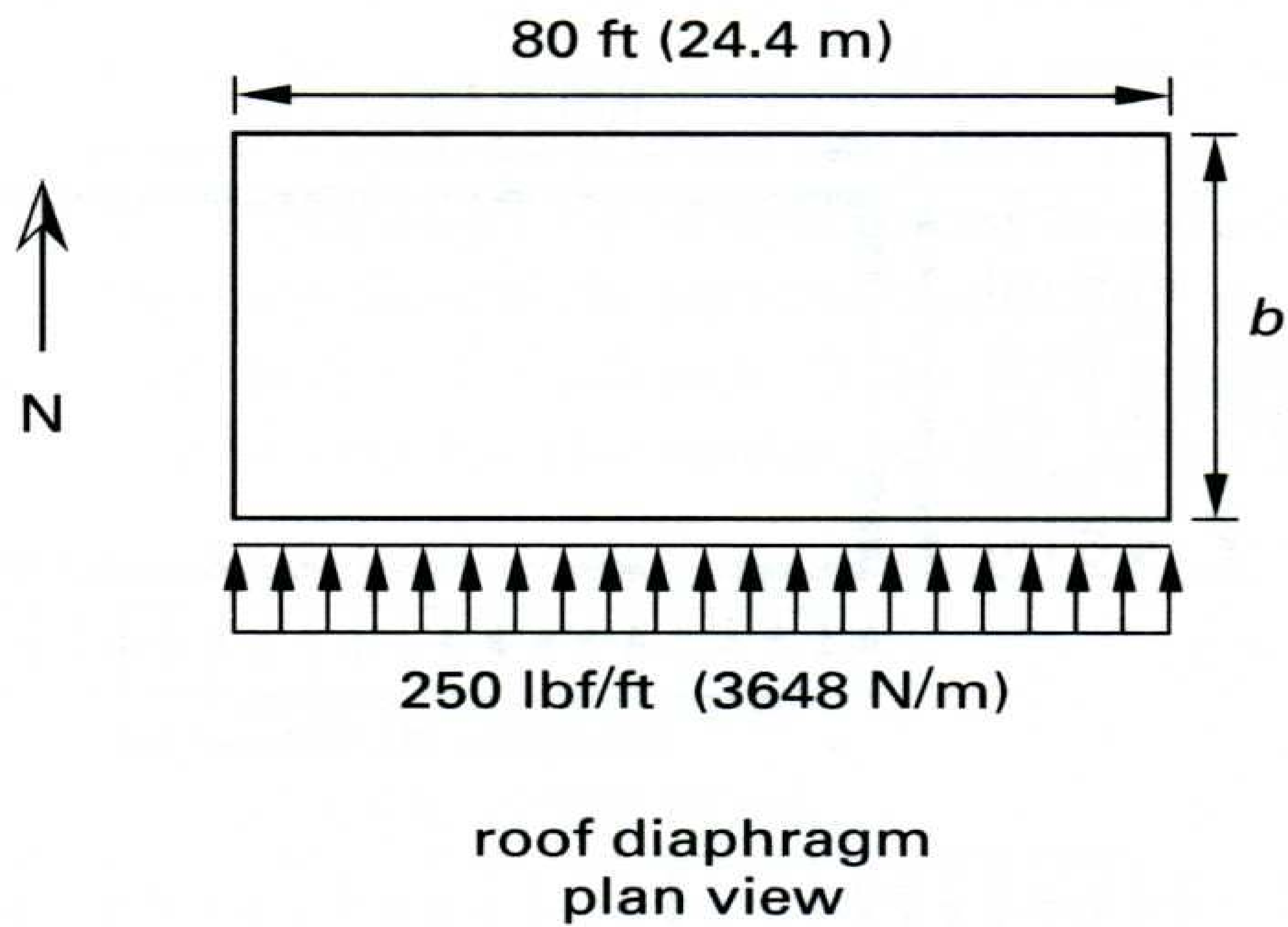
The one-story wood structure shown below, has a 400 lbf/ft diaphragm shear capacity. What should be the minimum east and west wall lengths? Assume $\rho = 1$.

A. 12.5 ft

B. 25.0 ft

C. 37.5 ft

D. 50.0 ft



Answer to #10.

B.

Find *V*, the total force carried by each wall. Also, determine the length needed to keep the shear stress at 400 *lb$_f$/ft*.

$$V = \frac{wL}{2} = \frac{(250\ lb_f / ft)(80\ ft)}{2} = 10{,}000\ lb_f$$

$$\upsilon = \frac{V}{b} \quad \therefore \quad b = \frac{V}{\upsilon} = \frac{(10{,}000\ lb_f)}{(400\ lb_f / ft)} = 25\ ft$$

Question #11.

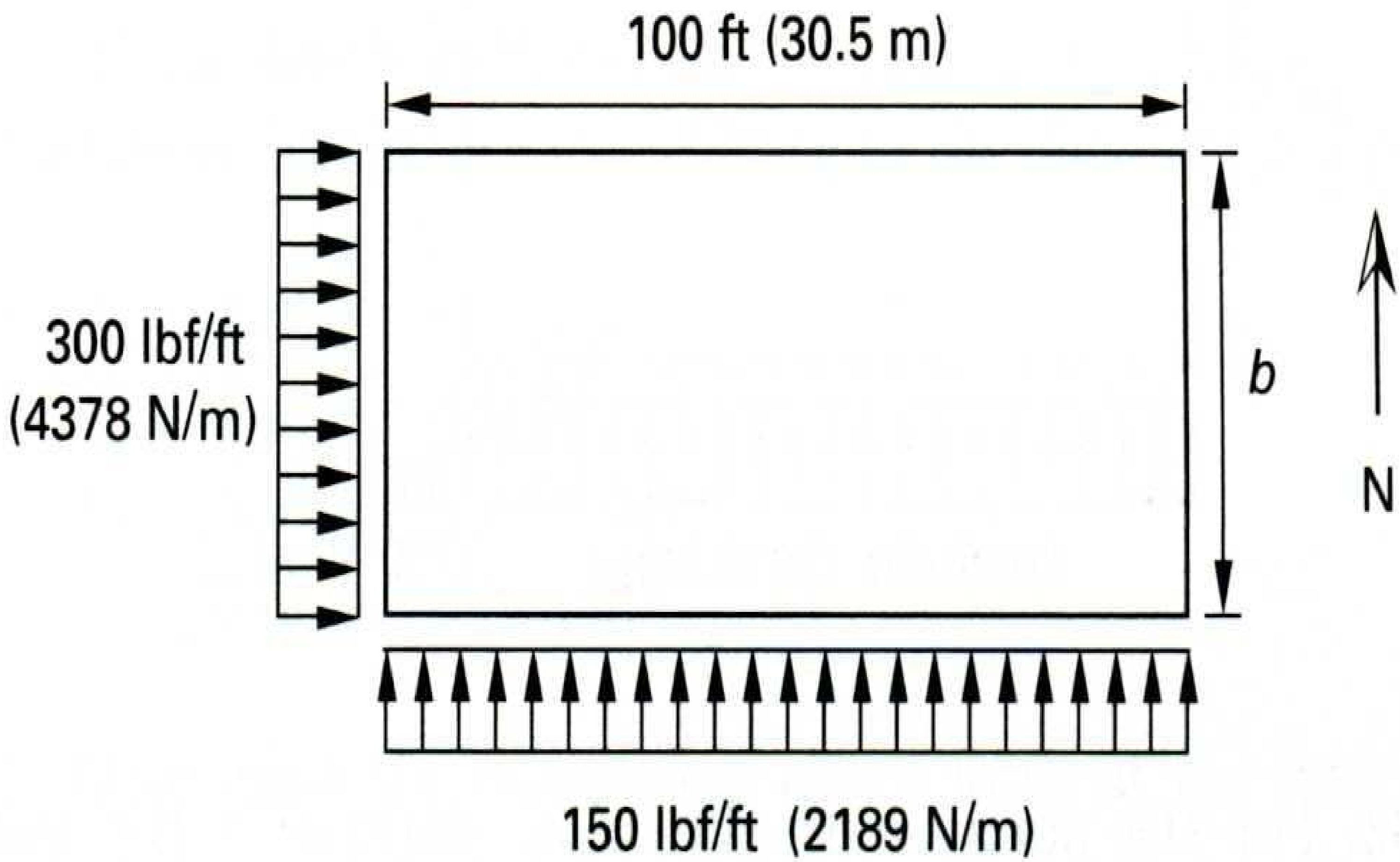
The one-story wood-frame warehouse shown below has a flexible roof diaphragm. What is the length of the east-west walls if equal unit shear stress is obtained in all walls? Assume $\rho = 1$.

A. 25 ft

B. 35 ft

C. 50 ft

D. 70 ft



Answer to #11.

D.

The equations for the unit shear stress in both directions is as follows,

In the N-S loading,

$$\upsilon = \frac{V}{b} = \frac{\frac{wL}{2}}{b} = \frac{\frac{(150\ lb_f / ft)(100\ ft)}{2}}{b} = 7{,}500\ lb_f / b \quad (equation\ 1)$$

In the E-W loading,

$$\upsilon = \frac{V}{b} = \frac{\frac{wL}{2}}{b} = \frac{\frac{(300\ lb_f / ft)(b\ ft)}{2}}{(100\ ft)} = 1.5b \quad (equation\ 2)$$

Setting both equations equal to each other,

$$\frac{7{,}500}{b} = 1.5b \quad \therefore \quad 1.5b^2 = 7{,}500 \quad \therefore \quad b = 70\ ft$$

Question #12.

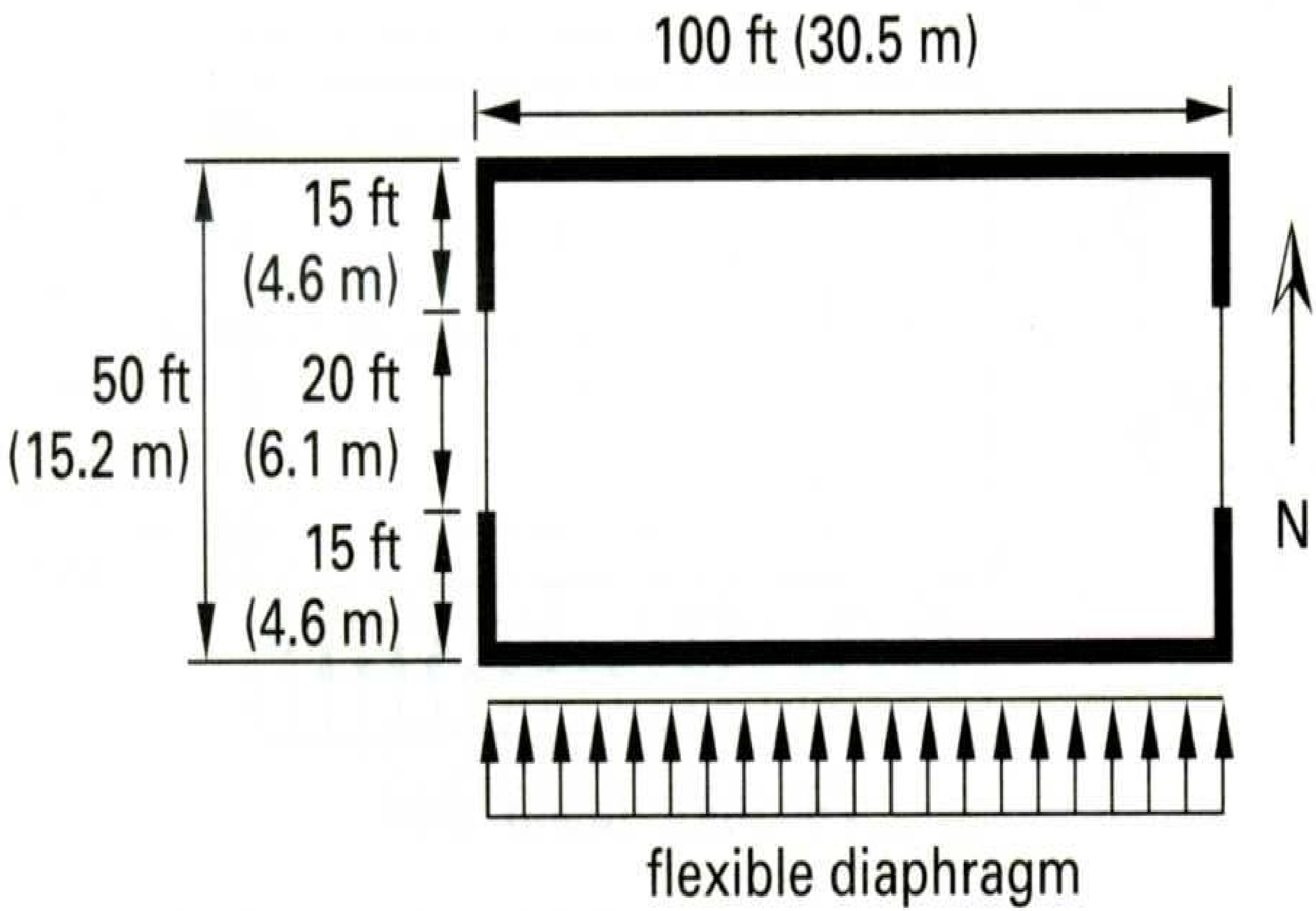
The roof diaphragm shear capacity of the structure below is 500 lb_f/ft. Determine the w, the maximum distributed force on the diaphragm? Assume $\rho = 1$.

A. 250 lb_f/ft.

B. 300 lb_f/ft.

C. 500 lb_f/ft.

D. 750 lb_f/ft.



Answer to #12.

C.

$$\upsilon = \frac{V}{b} \quad \therefore \quad V = \upsilon b = \left(500\ lb_f / ft\right)\left(50\ ft\right) = 25{,}000\ lb_f$$

$$V = \frac{wL}{2} \quad \therefore \quad w = \frac{2V}{L} = \frac{2\left(25{,}000\ lb_f\right)}{\left(100\ ft\right)} = 500\ lb_f / ft$$

Question #13.

The one-story residential building shown below has a wood structural panel roof diaphragm. This roof has a 4 foot overhang. The seismic load is in the north-south direction. Assume $\rho = 1$.

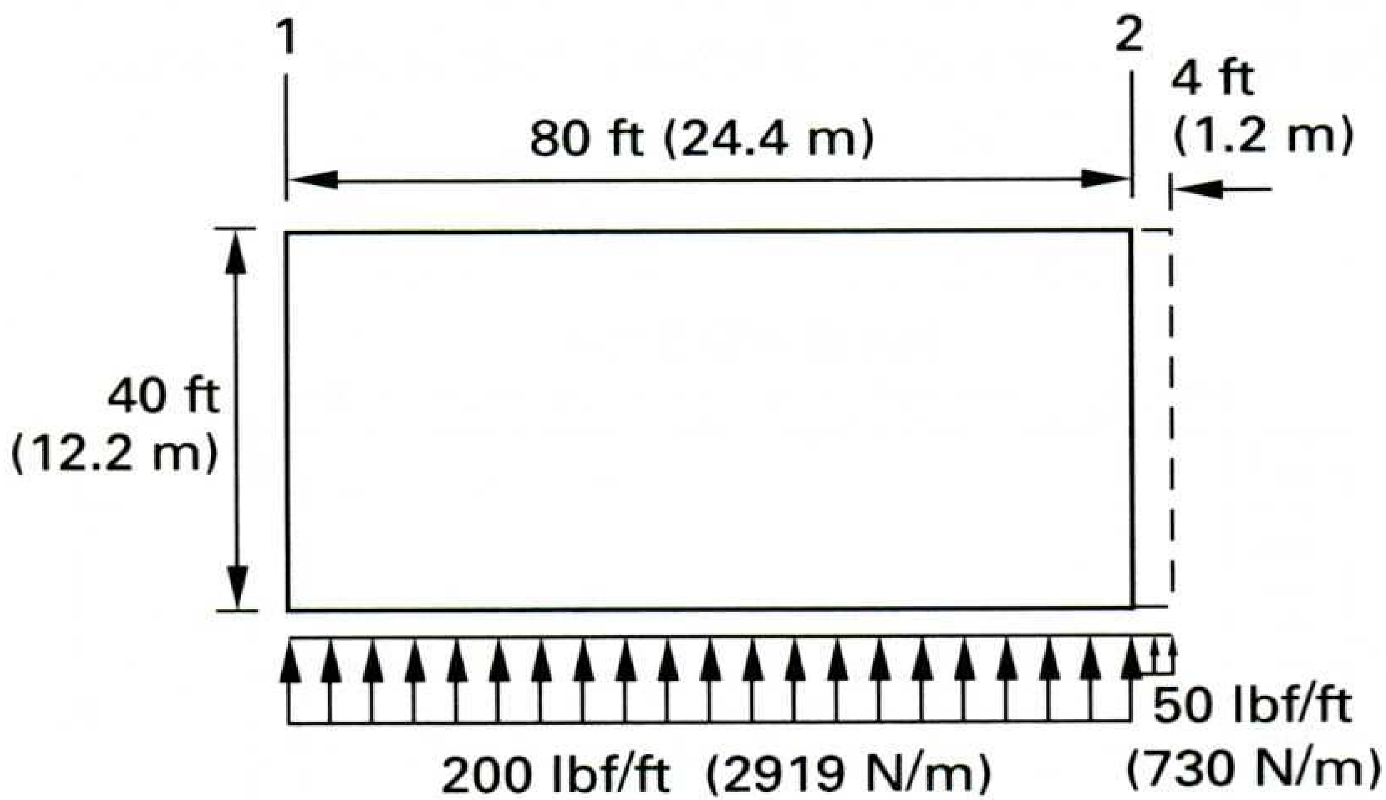
For the north-south direction, determine the roof diaphragm shear force at line 1.

A. 4,000 lbf.

B. 4,200 lbf.

C. 8,000 lbf.

D. 8,200 lbf.



Answer to #13.

C.

The tributary area to line 1 includes everything to the plane halfway between lines 1 and 2. The seismic load from the roof overhang is tributary to line 2.

$$V=\frac{wL}{2}=\frac{\left(200\ lb_f/ft\right)\left(80\ ft\right)}{2}=8{,}000\ lb_f$$

Question #14.

The one-story residential building shown below has a wood structural panel roof diaphragm. This roof has a 4 foot overhang. The seismic load is in the north-south direction. Assume $\rho = 1$.

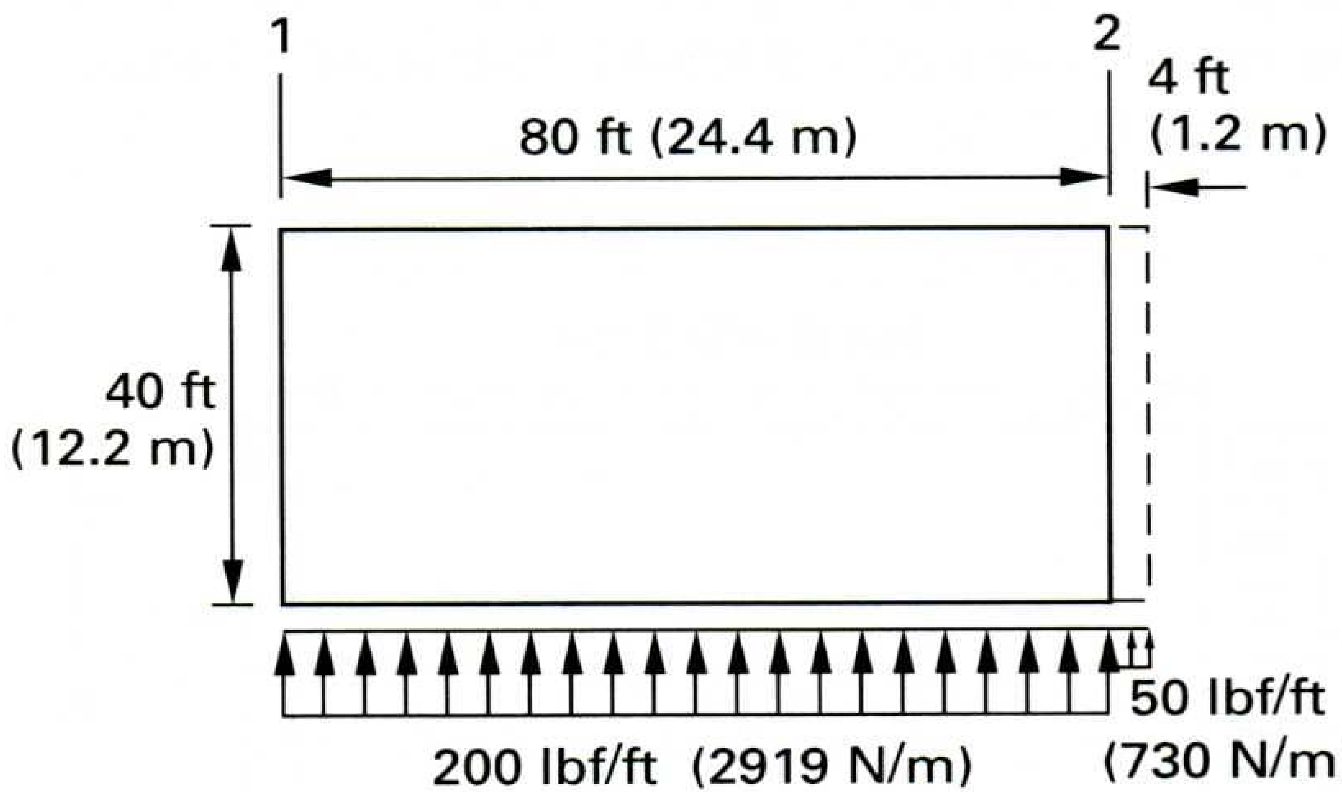
For the north-south direction, determine the roof diaphragm shear force at line 2.

A. 4,000 lbf.

B. 4,200 lbf.

C. 8,000 lbf.

D. 8,200 lbf.



Answer to #14.

D.

The tributary area to line 2 includes everything to the plane halfway between lines 1 and 2. Problem #13 showed that $V_{roof\ at\ line\ 2}$ = 8,000 lb_f. Therefore,

$$V_{overhang\ at\ line\ 2} = \upsilon b = (50\ lb_f / ft)(4\ ft) = 200\ lb_f$$

$$V_{total} = 8{,}000\ lb_f + 200\ lb_f = 8{,}200\ lb_f$$

Question #15.

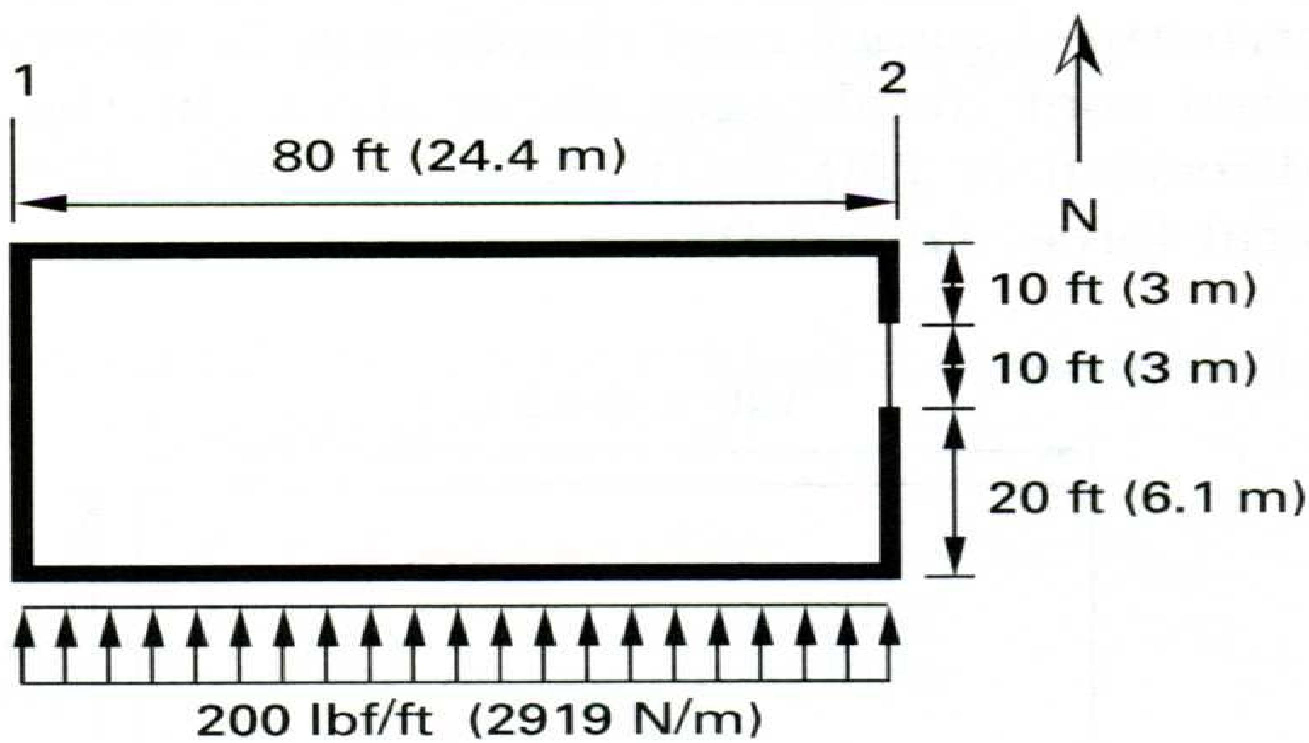
The plan view of a one-story residential building with a height of 14 feet is shown below. This residence is located in a seismic zone 4. The wood structural panel roof diaphragm is well anchored to the shear walls. The plywood shear walls carry a dead load of 16 lb_f/ft^2. The uniform load shown is the seismic force on the diaphragm due to the weight of the roof and the perpendicular walls. The seismic coefficient factor $C_v I / R T = 0.1375$. For the north-south direction, determine the shear wall design shear in the 20 foot shear wall panel along line 2.

A. 200 lb_f/ft

B. 210 lb_f/ft

C. 265 lb_f/ft

D. 280 lb_f/ft



Answer to #15.

D.

The diaphragm force on the parallel walls (shear force along the resisting lines 1 and 2,

$$V = \frac{wL}{2} = \frac{(200\ lb_f / ft)(80\ ft)}{2} = 8{,}000\ lb_f$$

For the shear wall, their shear stress in the parallel walls is due to the diaphragm force plus the inertia force of the parallel wall weights.

$$L_{shearwalls,\,line 2} = 10\ ft + 20\ ft = 30\ ft$$

$$W_{shearwalls,\,line\ 2} = \frac{(30\ ft)(16\ lb_f / ft^2)(14\ ft)}{2} = 3{,}360\ lb_f$$

$$V = \left(\frac{C_v I}{RT}\right) W = (0.1375) W = (0.1375)(3{,}360\ lb_f) = 460\ lb_f$$

$$V = V_{roof} + V_{wall} = 8{,}000\ lb_f + 460\ lb_f = 8{,}460\ lb_f$$

At line 2 for the 20 foot shear wall,

$$\upsilon = \frac{V}{b} = \frac{(8{,}460\ lb_f)}{10\ ft + 20\ ft} = 282\ lb_f / ft$$

Question #16.

What are the maximum dimension ratio based on CBC requirements for horizontal wood structural panel diaphragms?

A. 2½ : 1

B. 3 : 1

C. 3½ : 1

D. 4 : 1

Answer to #16.

D.

CBC Table 23-II-G specifies that the maximum span-to-width ratio for horizontal wood structural panel diaphragms should be 4:1 for all seismic zones.

Question #17.

Based on CBC requirements for vertical wood structural panel diaphragms nailed along their edges, what should be the maximum *dimension ratio* (height-to-width ratio) in a seismic zone 4?

A. 2:1

B. 3:1

C. 3½:1

D. 4:1

<u>Answer to #17.</u>

A.

For structures in seismic zone 4, the CBC Table 23-II-G the maximum diaphragm *<u>dimension ratio</u>* (that is, the height-to-width ratio) for vertical diaphragms (with all the edges nailed) should be 2:1.

Question #18.

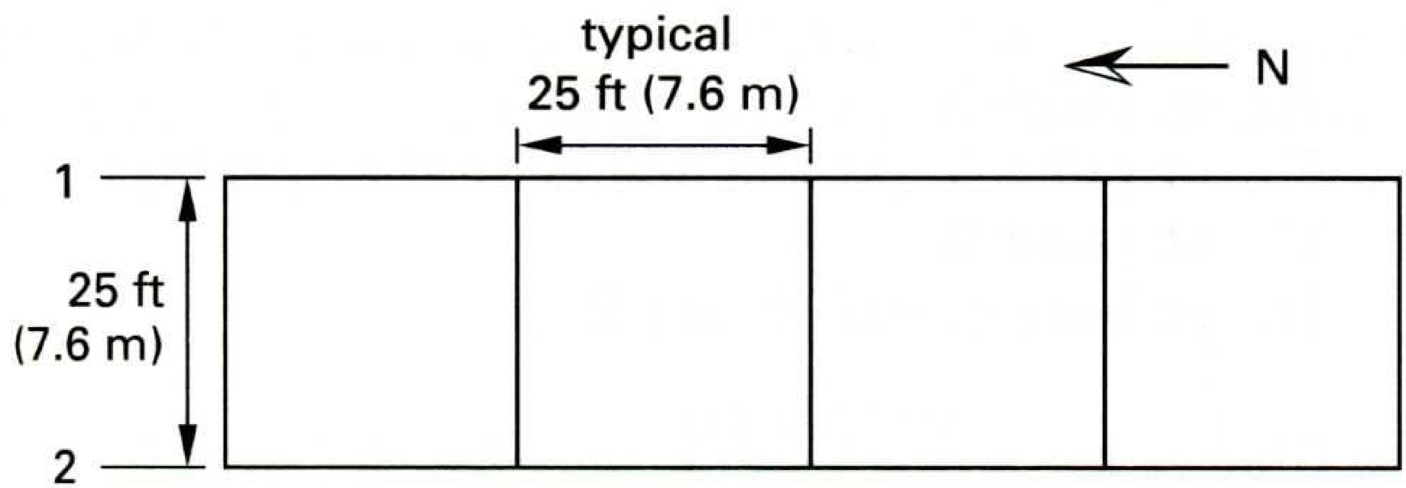
A wood structure building has four equal sections, as shown in the plan view below. It has a wood structural panel roof diaphragm (with $D = 20\ lb_f/ft^2$) and a wood structural panel shear walls (with $D = 25\ lb_f/ft^2$). The walls have a height of 16 feet. This structure conforms to the CBC Section 1629.8.2 requirements of the simplified static lateral-force procedure. The near source factor $N_a = 1.0$. For the north-south direction in seismic zone 4 and a soil profile S_C, what should the roof diaphragm shear force be along line 1? Assume $\rho = 1$.

A. 4,800 lb_f

B. 6,200 lb_f

C. 8,180 lb_f

D. 16,360 lb_f



Answer to #18.

C.

With the problem data, CBC Table 16-I specifies $Z = 0.4$, and CBC Table 16-N states that $R = 5.5$. Also, CBC Table 16-Q, gives $C_a = 0.4\ N_a = (0.4)(1.0) = 0.4$.

Based on CBC Section 1630.2.3, Formula 30-11,

$$W_{roof} = (4)(25\ ft)(25\ ft)(20\ lb_f/ft^2) = 50{,}000\ lb_f$$

$$W_{walls} = (5\ walls)\left(\frac{16\ ft}{2}\right)(25\ ft)(25\ lb_f/ft^2) = 25{,}000\ lb_f$$

$$W_{total} = 50{,}000\ lb_f + 25{,}000\ lb_f = 75{,}000\ lb_f$$

$$V = \left(\frac{3.0C_a}{R}\right)W = \left(\frac{(3.0)(0.4)}{5.5}\right)W = (0.2182)W = (0.2182)(75{,}000\ lb_f) = 16{,}365\ lb_f$$

$$V_{shear\ at\ line\ 1} = \frac{16{,}365\ lb_f}{2} = 8{,}180\ lb_f$$

Question #19.

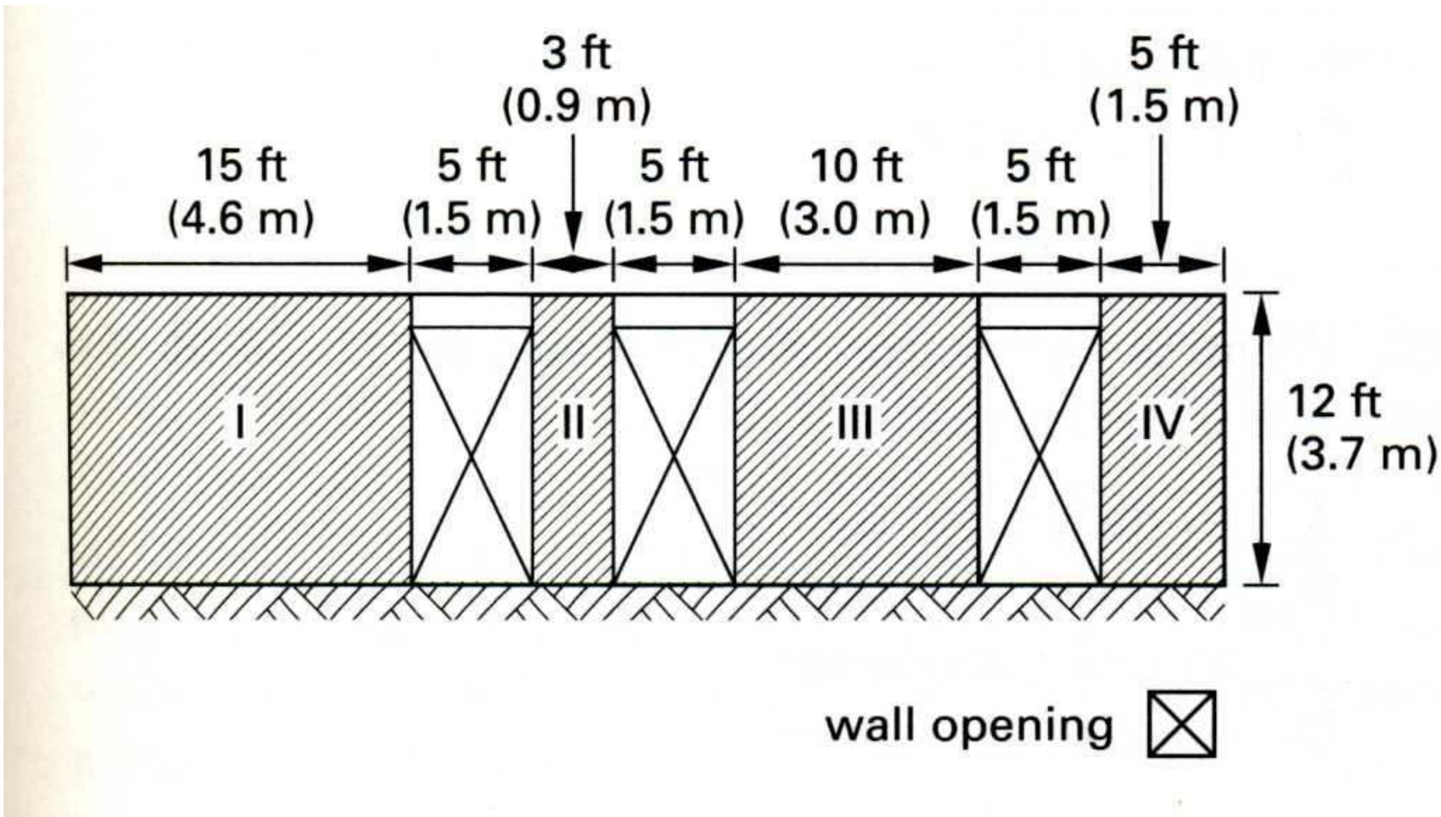
The wood shear wall shown below is part of a one-story building in a seismic zone 4, with a plywood-sheathed roof. The shear wall panels are wood structural and nailed at their edges. Based on the figure, which panels comply with the CBC Maximum Diaphragm Dimension Ratio requirements?

A. I and III

B. II and IV

C. I, II and IV

D. I, III and IV



<u>Answer to #19.</u>

A.

For wood structural shear wall panels that are nailed at their edges, as per CBC Chapter 23, Table 23-II-G, the maximum diaphragm dimension ratios for a vertical diaphragm in a seismic zone 4 should be 2:1. Therefore, check the height-to-width ratios of all the panels,

For panel I,

$$\frac{12}{15} = 0.8 \quad \text{which is less than 2:1}$$

For panel II,

$$\frac{12}{3} = 4.0 \quad \text{which is greater than 2:1}$$

For panel III,

$$\frac{12}{10} = 1.2 \quad \text{which is less than 2:1}$$

For panel IV,

$$\frac{12}{5} = 2.4 \quad \text{which is greater than 2:1}$$

Therefore, panels I and III are in compliance with the CBCMaximum Diaphragm Dimension Ratio requirements.