INDEX

1. WALLS

1.1. SW1

1.1.1. Floor 15

Ultimate limit state under normal stresses (ACI 318S-14, 22.4)

The worst case forces to be withstood from the analysis are produced at "Elevation 49.00 (Base)", in the combination of loadcase "1.4·SW+1.4·DL".

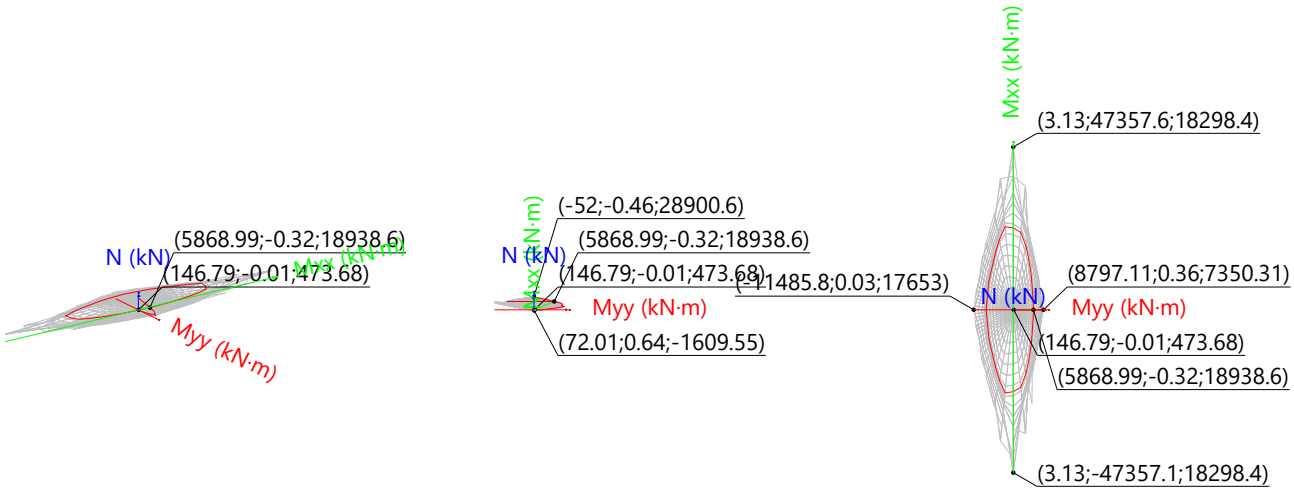
The following criteria must be satisfied:

$$\eta_1 = \sqrt{\frac{P_u^2 + M_{u,x}^2 + M_{u,y}^2}{(\phi \cdot P_n)^2 + (\phi \cdot M_{n,x})^2 + (\phi \cdot M_{n,y})^2}} \leq 1$$

η : ***0.025*** ✓

$$P_u \leq \phi \cdot P_{n,max}$$

473.68 kN ≤ **19745.49 kN** ✓



Capacity volume View N, M View Mx, My

Resistance check of the section (η_1)

P_u,M_u are the first order design forces.

P_u: Design normal force. **P_u** : *473.68* kN

M_u: First order design moment. **$M_{u,x}$** : *-0.01* kN·m

$M_{u,y}$: *146.79* kN·m

$\phi \cdot P_n$,$\phi \cdot M_n$ are the forces that cause the section to fail with the same eccentricities as the worst-case design forces.

ϕ·**P_n**: Ultimate axial resistance. ϕ·**P_n** : *18938.59* kN

ϕ·**M_n**: Bending resistance. ϕ·**$M_{n,x}$** : *-0.32* kN·m

ϕ·**$M_{n,y}$** : *5868.99* kN·m

Instability limit status check

In the x-axis:

It shall be permitted to ignore slenderness effects for compression members that satisfy (Article 6.2.5):

$$\frac{k \cdot l_u}{r} \leq 22$$

1.3 ≤ **22.0** ✓

Where:

kl_u: Effective length. **kl_u** : *3.000* m

r: Radius of gyration of cross section of a compression member. **r** : *237.91* cm

In the y-axis:

It shall be permitted to ignore slenderness effects for compression members that satisfy (Article 6.2.5):

$$\frac{k \cdot l_u}{r} \leq 22$$ **4.5** ≤ **22.0** ✓

Where:

kl$_u$: Effective length. **kl$_u$** : *3.000* m

r: Radius of gyration of cross section of a compression member. **r** : *67.20* cm

Design axial strength check

Factored axial force P_u of compression members shall not be taken greater than $\phi \cdot P_{n,max}$ (Article 22.4.2).

$$\phi \cdot P_{n,max} = 0.80 \cdot \phi \cdot \left[0.85 \cdot f'_c \cdot \left(A_g - A_{st}\right) + f_y \cdot A_{st}\right]$$ **$\phi \cdot P_{n,max}$** : *19745.49* kN

Where:

f'$_c$: Specified compressive strength of concrete. **f'$_c$** : *24.53* MPa

f$_y$: Specified yield strength of reinforcement. **f$_y$** : *420.00* MPa

A$_g$: Gross area of concrete section. **A$_g$** : *17400.00* cm²

A$_{st}$: Total area of nonprestressed longitudinal reinforcement. **A$_{st}$** : *42.58* cm²

Resistance capacity calculation

The calculation of the ultimate resistance capacity of the sections is carried out using the following general hypothesis (Article 22.2.2):

(a) Strength design of members for flexure and axial loads shall be based on satisfaction of applicable conditions of equilibrium and compatibility of strains.

(b) Strain in reinforcement and concrete shall be assumed directly proportional to the distance from the neutral axis.

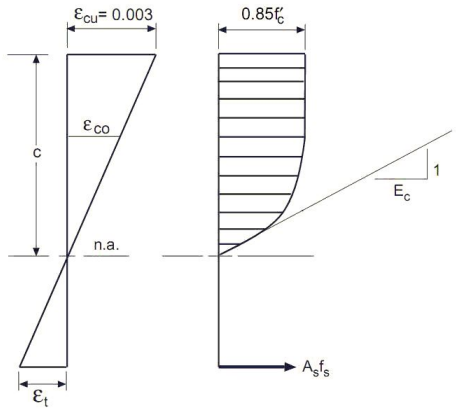
(c) Maximum usable strain at extreme concrete compression fiber shall be assumed equal to 0.003.

(d) Stress in reinforcement below f_y shall be taken as E_s times steel strain. For strains greater than that corresponding to f_y, stress in reinforcement shall be considered independent of strain and equal to f_y.

(e) Tensile strength of concrete shall be neglected in axial and flexural calculations of reinforced concrete.

(f) The relationship between concrete compressive stress distribution and concrete strain shall be assumed to be rectangular, trapezoidal, parabolic, or any other shape that results in prediction of strength in substantial agreement with results of comprehensive tests.

The concrete stress-deformation calculation diagram is of the parabola-rectangle type. The tensile resistance of the concrete is not considered.

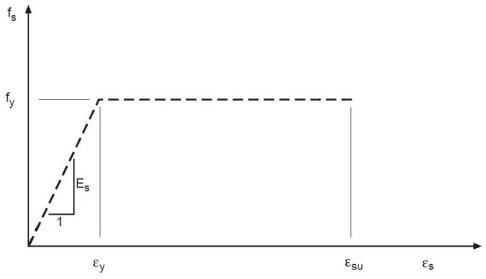


f'c: Specified compressive strength of concrete. **f'c** : *24.53* MPa

εcu: Maximum usable strain at extreme concrete compression fiber. εcu : *0.0030*

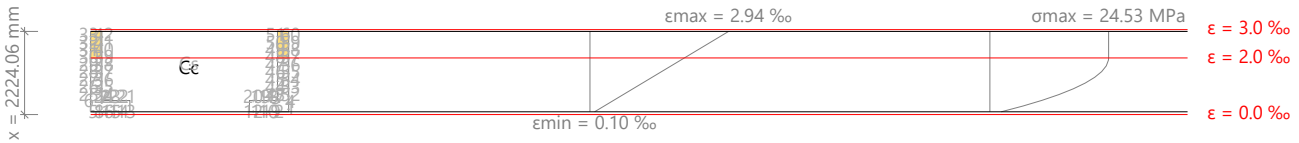
εc0: Strain at reaching the maximum strength. εc0 : *0.0020*

The following stress-deformation calculation diagram of the steel is adopted for the passive reinforcement.



fy: Specified yield strength of reinforcement. **fy** : *420.00* MPa

Ultimate force balance of the section, calculated with the same eccentricities as the worst-case design forces:



Bar	Designation	X Coord. (mm)	Y Coord. (mm)	f_s (MPa)	ε
1	1	-767.68	-2605.71	+37.53	+0.000188
2	2	-767.68	-2394.29	+37.53	+0.000188
3	3	-580.06	-2394.29	+87.07	+0.000435
4	4	-603.88	-2605.71	+80.78	+0.000404
5	5	-791.49	2581.90	+31.25	+0.000156
6	6	-580.06	2581.90	+87.08	+0.000435
7	7	-580.06	2394.29	+87.08	+0.000435
8	8	-791.49	2418.10	+31.25	+0.000156
9	9	-791.49	-2300.00	+31.24	+0.000156
10	10	-791.49	-2100.00	+31.24	+0.000156
11	11	-791.49	-1900.00	+31.24	+0.000156
12	12	-791.49	-1700.00	+31.24	+0.000156
13	29	-791.49	1700.00	+31.25	+0.000156
14	30	-791.49	1900.00	+31.25	+0.000156
15	31	-791.49	2100.00	+31.25	+0.000156
16	32	-791.49	2300.00	+31.25	+0.000156
17	33	-580.06	-2300.00	+87.07	+0.000435
18	34	-580.06	-2100.00	+87.07	+0.000435
19	35	-580.06	-1900.00	+87.07	+0.000435
20	36	-580.06	-1700.00	+87.07	+0.000435
21	53	-580.06	1700.00	+87.08	+0.000435
22	54	-580.06	1900.00	+87.08	+0.000435
23	55	-580.06	2100.00	+87.08	+0.000435
24	56	-580.06	2300.00	+87.08	+0.000435
25	57	-418.04	2605.71	+129.86	+0.000649
26	58	-218.04	2605.71	+182.67	+0.000913
27	59	-18.04	2605.71	+235.48	+0.001177
28	60	181.96	2605.71	+288.29	+0.001441
29	61	381.96	2605.71	+341.11	+0.001706
30	62	581.96	2605.71	+393.92	+0.001970
31	63	781.96	2605.71	+420.00	+0.002234
32	64	981.96	2605.71	+420.00	+0.002498
33	65	1181.96	2605.71	+420.00	+0.002762
34	66	-418.04	2394.29	+129.86	+0.000649
35	67	-218.04	2394.29	+182.67	+0.000913
36	68	-18.04	2394.29	+235.48	+0.001177
37	69	181.96	2394.29	+288.29	+0.001441
38	70	381.96	2394.29	+341.11	+0.001706
39	71	581.96	2394.29	+393.92	+0.001970
40	72	781.96	2394.29	+420.00	+0.002234
41	73	981.96	2394.29	+420.00	+0.002498
42	74	1181.96	2394.29	+420.00	+0.002762
43	75	-418.04	-2394.29	+129.86	+0.000649
44	76	-218.04	-2394.29	+182.67	+0.000913
45	77	-18.04	-2394.29	+235.48	+0.001177
46	78	181.96	-2394.29	+288.29	+0.001441
47	79	381.96	-2394.29	+341.10	+0.001705

Bar	Designation	X Coord. (mm)	Y Coord. (mm)	f_s (MPa)	ε
48	80	581.96	-2394.29	+393.91	+0.001970
49	81	781.96	-2394.29	+420.00	+0.002234
50	82	981.96	-2394.29	+420.00	+0.002498
51	83	1181.96	-2394.29	+420.00	+0.002762
52	84	-418.04	-2605.71	+129.85	+0.000649
53	85	-218.04	-2605.71	+182.67	+0.000913
54	86	-18.04	-2605.71	+235.48	+0.001177
55	87	181.96	-2605.71	+288.29	+0.001441
56	88	381.96	-2605.71	+341.10	+0.001705
57	89	581.96	-2605.71	+393.91	+0.001970
58	90	781.96	-2605.71	+420.00	+0.002234
59	91	981.96	-2605.71	+420.00	+0.002498
60	92	1181.96	-2605.71	+420.00	+0.002762

	Resultant (kN)	e.x (mm)	e.y (mm)
Cc	28231.36	306.52	0.02
Cs	904.94	415.19	-1.31
T	0.00	0.00	0.00

$$P_n = C_c + C_s - T$$ **P_n** : *29136.30* kN

$$M_{n,x} = C_c \cdot e_{cc,y} + C_s \cdot e_{cs,y} - T \cdot e_{T,y}$$ **$M_{n,x}$** : *-0.49* kN·m

$$M_{n,y} = C_c \cdot e_{cc,x} + C_s \cdot e_{cs,x} - T \cdot e_{T,x}$$ **$M_{n,y}$** : *9029.21* kN·m

Where:

C_c: Resultant of concrete compressive forces. **C_c** : *28231.36* kN

C_s: Resultant of steel compressive forces. **C_s** : *904.94* kN

T: Resultant of steel tensile forces. **T** : *0.00* kN

e_{cc}: Eccentricity of the concrete compressive forces in the direction of the X and Y axes. **$e_{cc,x}$** : *306.52* mm; **$e_{cc,y}$** : *0.02* mm

e_{cs}: Eccentricity of the steel compressive forces in the direction of the X and Y axes. **$e_{cs,x}$** : *415.19* mm; **$e_{cs,y}$** : *-1.31* mm

e_T: Eccentricity of the steel tensile forces in the direction of the X and Y axes. **e_T** : *0.00* mm

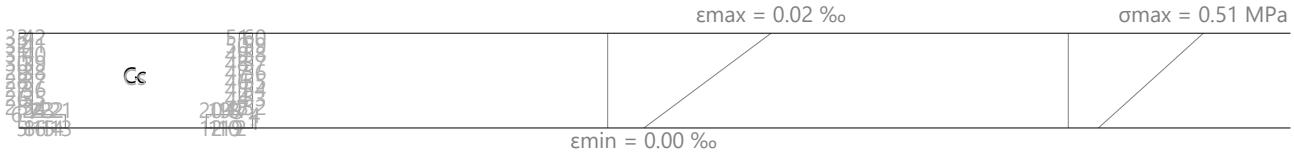
ε_{cmax}: Deformation of the most compressed concrete fibre. ε_{cmax} : *0.0029*

ε_{smax}: Deformation of the steel bar with greatest tension. ε_{smax} : *0.0000*

σ_{cmax}: Stress of the most compressed concrete fibre. σ_{cmax} : *24.53* MPa

σ_{smax}: Stress of the steel bar with greatest tension. σ_{smax} : *0.00* MPa

Worst-case force balance of the section:



Bar	Designation	X Coord. (mm)	Y Coord. (mm)	f_s (MPa)	ε
1	1	-767.68	-2605.71	+1.03	+0.000005
2	2	-767.68	-2394.29	+1.03	+0.000005
3	3	-580.06	-2394.29	+1.31	+0.000007
4	4	-603.88	-2605.71	+1.27	+0.000006
5	5	-791.49	2581.90	+0.99	+0.000005
6	6	-580.06	2581.90	+1.31	+0.000007
7	7	-580.06	2394.29	+1.31	+0.000007
8	8	-791.49	2418.10	+0.99	+0.000005
9	9	-791.49	-2300.00	+0.99	+0.000005
10	10	-791.49	-2100.00	+0.99	+0.000005
11	11	-791.49	-1900.00	+0.99	+0.000005
12	12	-791.49	-1700.00	+0.99	+0.000005
13	29	-791.49	1700.00	+0.99	+0.000005
14	30	-791.49	1900.00	+0.99	+0.000005
15	31	-791.49	2100.00	+0.99	+0.000005
16	32	-791.49	2300.00	+0.99	+0.000005
17	33	-580.06	-2300.00	+1.31	+0.000007
18	34	-580.06	-2100.00	+1.31	+0.000007
19	35	-580.06	-1900.00	+1.31	+0.000007
20	36	-580.06	-1700.00	+1.31	+0.000007
21	53	-580.06	1700.00	+1.31	+0.000007
22	54	-580.06	1900.00	+1.31	+0.000007
23	55	-580.06	2100.00	+1.31	+0.000007
24	56	-580.06	2300.00	+1.31	+0.000007
25	57	-418.04	2605.71	+1.55	+0.000008
26	58	-218.04	2605.71	+1.86	+0.000009
27	59	-18.04	2605.71	+2.16	+0.000011
28	60	181.96	2605.71	+2.46	+0.000012
29	61	381.96	2605.71	+2.76	+0.000014
30	62	581.96	2605.71	+3.06	+0.000015
31	63	781.96	2605.71	+3.36	+0.000017

Bar	Designation	X Coord. (mm)	Y Coord. (mm)	f_s (MPa)	ε
32	64	981.96	2605.71	+3.67	+0.000018
33	65	1181.96	2605.71	+3.97	+0.000020
34	66	-418.04	2394.29	+1.55	+0.000008
35	67	-218.04	2394.29	+1.86	+0.000009
36	68	-18.04	2394.29	+2.16	+0.000011
37	69	181.96	2394.29	+2.46	+0.000012
38	70	381.96	2394.29	+2.76	+0.000014
39	71	581.96	2394.29	+3.06	+0.000015
40	72	781.96	2394.29	+3.36	+0.000017
41	73	981.96	2394.29	+3.67	+0.000018
42	74	1181.96	2394.29	+3.97	+0.000020
43	75	-418.04	-2394.29	+1.55	+0.000008
44	76	-218.04	-2394.29	+1.86	+0.000009
45	77	-18.04	-2394.29	+2.16	+0.000011
46	78	181.96	-2394.29	+2.46	+0.000012
47	79	381.96	-2394.29	+2.76	+0.000014
48	80	581.96	-2394.29	+3.06	+0.000015
49	81	781.96	-2394.29	+3.36	+0.000017
50	82	981.96	-2394.29	+3.67	+0.000018
51	83	1181.96	-2394.29	+3.97	+0.000020
52	84	-418.04	-2605.71	+1.55	+0.000008
53	85	-218.04	-2605.71	+1.86	+0.000009
54	86	-18.04	-2605.71	+2.16	+0.000011
55	87	181.96	-2605.71	+2.46	+0.000012
56	88	381.96	-2605.71	+2.76	+0.000014
57	89	581.96	-2605.71	+3.06	+0.000015
58	90	781.96	-2605.71	+3.36	+0.000017
59	91	981.96	-2605.71	+3.67	+0.000018
60	92	1181.96	-2605.71	+3.97	+0.000020

	Resultant (kN)	e.x (mm)	e.y (mm)
Cc	464.67	310.74	0.00
Cs	9.02	266.63	-0.92
T	0.00	0.00	0.00

$P_u = C_c + C_s - T$ — **P_u** : *473.68* kN

$M_{u,x} = C_c \cdot e_{cc,y} + C_s \cdot e_{cs,y} - T \cdot e_{T,y}$ — **$M_{u,x}$** : *-0.01* kN·m

$M_{u,y} = C_c \cdot e_{cc,x} + C_s \cdot e_{cs,x} - T \cdot e_{T,x}$ — **$M_{u,y}$** : *146.79* kN·m

Where:

C_c: Resultant of concrete compressive forces. — **C_c** : *464.67* kN

C_s: Resultant of steel compressive forces. — **C_s** : *9.02* kN

T: Resultant of steel tensile forces. — **T** : *0.00* kN

e_{cc}: Eccentricity of the concrete compressive forces in the direction of the X and Y axes. — **$e_{cc,x}$** : *310.74* mm; **$e_{cc,y}$** : *0.00* mm

e_{cs}: Eccentricity of the steel compressive forces in the direction of the X and Y axes.	**$e_{cs,x}$** :	*266.63*	mm
	$e_{cs,y}$:	*-0.92*	mm
e_T: Eccentricity of the steel tensile forces in the direction of the X and Y axes.	**e_T** :	*0.00*	mm
ε_{cmax}: Deformation of the most compressed concrete fibre.	ε_{cmax} :	*0.0000*	
ε_{smax}: Deformation of the steel bar with greatest tension.	ε_{smax} :	*0.0000*	
σ_{cmax}: Stress of the most compressed concrete fibre.	σ_{cmax} :	*0.51*	MPa
σ_{smax}: Stress of the steel bar with greatest tension.	σ_{smax} :	*0.00*	MPa

ACI 318M-14, Work section 11

In-plane shear strength (ACI 318S-14, 11.5.4)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 0.84·SW+0.84·DL+0.3·SX+SY (6).

$\phi V_n \geq V_u$ **1690.4 kN ≥ 23.6 kN** ✓

Where:

V_u: Factored shear force at section. **V_u** : *23.6* kN

V_n: Nominal shear strength. **V_n** : *2817.4* kN

$$V_n = V_c + V_s$$

$$V_n \leq 0.83\sqrt{f'_c}hd$$

V_c: Nominal shear strength provided by concrete. **V_c** : *1625.2* kN

$V_c = MIN(V_{c1}, V_{c2})$

$$V_{c1} = 0.27\lambda\sqrt{f'_c}hd + \frac{N_u d}{4l_w}$$

V_{c1} : *1625.2* kN

$$V_{c2} = \left[0.05\lambda\sqrt{f'_c} + \frac{l_w\left(0.1\lambda\sqrt{f'_c} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right]hd$$

V_{c2} : -- kN

Equation shall not apply if (M_u/V_u - $l_w/2$) is negative.

V_s: Nominal shear strength provided by shear reinforcement. **V_s** : *1192.3* kN

$$V_S = \frac{A_v f_{yt} d}{s}$$

N_u: Factored axial force. **N_u** : *103.1* kN

M_u: Factored moment. **M_u** : *-14.5* kN·m

A_v/s: Area of shear reinforcement. **A_v/s** : *7.10* cm²/m

f'$_c$: Specified compressive strength of concrete. **f'$_c$** : *24.53* MPa

$$\sqrt{f'_c} \leq 8.3\text{MPa}$$

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

l_w: Length of wall. **l_w** : *500.0* cm

h: Thickness of wall. **h** : *30.0* cm

d: Distance from extreme compression fiber to centroid of longitudinal tension reinforcement. **d** : *400.0* cm

$$d = 0.8 \cdot l_w$$

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

ϕ: Strength reduction factor. ϕ : *0.60*

Transverse shear (ACI 318S-14, 11.5.4)

The check does not proceed, as there is no shear force.

Minimum transverse reinforcement (ACI 318S-14, 11.6)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$\rho_t \geq \rho_{t,min}$ **0.0024 ≥ 0.0020** ✓

Where:

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : *0.0024*

$\rho_{t,min}$: Minimum ratio. $\rho_{t,min}$: *0.0020*

Bar size	f_y	$\rho_{t,min}$
≤ No.16	≥ 420 MPa	0.0020
	< 420 MPa	0.0025
> No.16	--	0.0025

V_u: Factored shear force at section. **V_u** : *0.0* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *1639.0* kN

d_b: Maximum diameter of the reinforcement. **d_b** : *9.5* mm

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

Minimum longitudinal reinforcement (ACI 318S-14, 11.6)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$\rho_l \geq \rho_{l,min}$ **0.0024 ≥ 0.0012** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : *0.0024*

$\rho_{l,min}$: Minimum ratio. $\rho_{l,min}$: *0.0012*

Bar size	f_y	$\rho_{l,min}$
≤ No.16	≥ 420 MPa	0.0012
	< 420 MPa	0.0015
> No.16	--	0.0015

V_u: Factored shear force at section. **V_u** : *0.0* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *1639.0* kN

d_b: Maximum diameter of the reinforcement. **d_b** : *9.5* mm

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

Minimum spacing of transverse reinforcement (ACI 318S-14, 25.2.2)

Reinforcement in the upper layers shall be placed directly above reinforcement in the bottom layer with a clear spacing between layers of at least 25mm

$s \geq 25mm$ **19 cm ≥ 3 cm** ✓

Minimum spacing of longitudinal reinforcement (ACI 318S-14, 25.2.3)

Clear spacing between bars shall be at least the greatest of:

$s \geq s_{min}$ **19 cm ≥ 4 cm** ✓

Where:

s_{min}: Maximum value of s_1, s_2, s_3

$s_1 = 40mm$ **s_1** : *4* cm

$s_2 = 1.5d_b$ **s_2** : *1* cm

$s_3 = \frac{4}{3} \cdot d_{agg}$ **s_3** : *3* cm

Where:

d_b: Nominal bar diameter. **d_b** : *9.5* mm

d_{agg}: Nominal maximum size of coarse aggregate. **d_{agg}** : *20.0* mm

Maximum spacing of transverse reinforcement (ACI 318S-14, 11.7.3)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$s \leq \min(3h,\ 450\ mm)$ **20 cm ≤ 45 cm** ✓

Where:

s: Spacing of transverse bars. **s** : *20* cm

h: Thickness of wall. **h** : *30.0* cm

V_u: Factored shear force at section. **V_u** : *0.0* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *1639.0* kN

Maximum spacing of longitudinal reinforcement (ACI 318S-14, 11.7.2)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$s \leq \min(3h,\ 450\ mm)$ **20 cm ≤ 45 cm** ✓

Where:

s: Spacing of longitudinal bars. **s** : *20* cm

h: Thickness of wall. **h** : *30.0* cm

V_u: Factored shear force at section. **V_u** : *0.0* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *1639.0* kN

Number of layers (ACI 318S-14, 11.7.2.3)

For walls with 'h' greater than 250 mm distributed reinforcement for each direction shall be placed in two layers parallel with wall faces. ✓

h: Thickness of wall. **h** : *30.0* cm

n: Number of layers. **n** : *2*

ACI 318M-14, Work section 18

Distributed web reinforcement ratios (ACI 318S-14, 18.10.2.1)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.083A_{cv}\lambda\sqrt{f'_c}$, shall be satisfied:

$\rho_l \geq 0.0012$ **0.0024 ≥ 0.0012** ✓

$\rho_t \geq 0.0020$ **0.0024 ≥ 0.0020** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : *0.0024*

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : *0.0024*

V_u: Factored shear force at section. **V_u** : *0.0* kN

A_{cv}: Area of concrete section. **A_{cv}** : *1500000.00* mm²

f'_c: Specified compressive strength of concrete. **f'_c** : *24.53* MPa

$\sqrt{f'_c} \leq 8.3\text{MPa}$

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

Maximum reinforcement spacing (ACI 318S-14, 18.10.2.1)

Required:

$s_l \leq 450$ mm **20 cm ≤ 45 cm** ✓

$s_t \leq 450$ mm **20 cm ≤ 45 cm** ✓

s_l: Spacing of longitudinal bars. **s_l** : *20* cm

s_t: Spacing of transverse bars. **s_t** : *20* cm

Number of layers (ACI 318S-14, 18.10.2.2)

At least two curtains of reinforcement shall be used in a wall if $V_u > 0.17A_{cv}\lambda\sqrt{f'_c}$ or $h_w/l_w \geq 2.0$ ✓

n: Number of layers. **n** : *2*

V_u: Factored shear force at section. **V_u** : *0.0* kN

A_{cv}: Area of concrete section. **A_{cv}** : *1500000.00* mm²

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

f'_c: Specified compressive strength of concrete. **f'_c** : *24.53* MPa

h_w: Height of wall. **h_w** : *300.0* cm

l_w: Length of wall. l_w : 500.0 cm

Shear strength (ACI 318S-14, 18.10.4.1)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.26·SW+1.26·DL-0.3·SX-SY (6).

$\phi V_n \geq V_u$ **2008.5 kN ≥ 23.6 kN** ✓

Where:

V_u: Factored shear force at section. V_u : 23.6 kN

V_n: Nominal shear strength. V_n : 3347.4 kN

$$V_n = A_{cv}\left(\alpha_c \lambda \sqrt{f'_c} + \rho_t f_y\right)$$

$$V_n \leq 0.83 A_{cv} \sqrt{f'_c} \quad (18.10.4.4)$$

A_{cv}: Area of concrete section. A_{cv} : 1500000.00 mm²

The coefficient α_c is 0.25 for $h_w/l_w \leq 1.50$, is 0.17 for $h_w/l_w \geq 2.00$, and varies linearly between 0.25 and 0.17 for h_w/l_w between 1.50 and 2.00. α_c : 0.25

h_w: Height of wall. h_w : 300.0 cm

l_w: Length of wall. l_w : 500.0 cm

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : 1.00

f'_c: Specified compressive strength of concrete. f'_c : 24.53 MPa

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : 0.0024

f_y: Specified yield strength of transverse reinforcement. f_y : 420.00 MPa

ϕ: Strength reduction factor. ϕ : 0.60

Longitudinal reinforcement ratio (ACI 318S-14, 18.10.4.3)

If h_w/l_w does not exceed 2.00, reinforcement ratio ρ_l shall be at least the reinforcement ratio ρ_t.

$\rho_l \geq \rho_t$ **0.0024 ≥ 0.0024** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : 0.0024

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : 0.0024

h_w/l_w : 0.60

Edge elements (ACI 318S-14, 18.10.6.1, 18.10.6.5) (Initial)

Special boundary elements

Structural wall shall have special boundary elements at boundaries and edges around openings where the maximum extreme fiber compressive stress, σ, exceeds $0.2f'_c$:

(ACI 318S-14, 18.10.6.3)

P_u (kN)	M_u (kN·m)	Edge elements	Location	σ (MPa)	$0.2f'_c$ (MPa)	Special element required
172.4	0.0	1.4·SW+1.4·DL	Elevation 49.00 (Base)	0.11	4.91	No

Where:

P_u: Factored axial force.
M_u: Factored moment.
σ: Maximum extreme fiber compressive stress.
f'_c: Specified compressive strength of concrete.

Edge elements (ACI 318S-14, 18.10.6.1, 18.10.6.5) (Final)

Special boundary elements

Structural wall shall have special boundary elements at boundaries and edges around openings where the maximum extreme fiber compressive stress, σ, exceeds $0.2f'_c$:

(ACI 318S-14, 18.10.6.3)

P_u (kN)	M_u (kN·m)	Edge elements	Location	σ (MPa)	$0.2f'_c$ (MPa)	Special element required
155.5	14.5	1.26·SW+1.26·DL-0.3·SX-SY (6)	Elevation 49.00 (Base)	0.12	4.91	No

Where:

P_u: Factored axial force.
M_u: Factored moment.
σ: Maximum extreme fiber compressive stress.
f'_c: Specified compressive strength of concrete.

Length of boundary element (ACI 318S-14, 18.10.6.4(a)) (Initial)

No check required

Length of boundary element (ACI 318S-14, 18.10.6.4(a)) (Final)

No check required

Maximum spacing of longitudinal bars laterally supported (ACI 318S-14, 18.10.6.4(e), 18.7.5.2) (Initial)

No check required

Maximum spacing of longitudinal bars laterally supported (ACI 318S-14, 18.10.6.4(e), 18.7.5.2) (Final)

No check required

Width of boundary element (ACI 318S-14, 18.10.6.4(b)) (Initial)

No check required

Width of boundary element (ACI 318S-14, 18.10.6.4(b)) (Final)

No check required

Spacing of transverse reinforcement (ACI 318S-14, 18.10.6.5) (Initial)

No check required

Spacing of transverse reinforcement (ACI 318S-14, 18.10.6.5) (Final)

No check required

Amount of transverse reinforcement of boundary element (ACI 318S-14, 18.10.6.4(f)) (Initial)

No check required

Amount of transverse reinforcement of boundary element (ACI 318S-14, 18.10.6.4(f)) (Final)

No check required

ACI 318M-14, Work section 11

In-plane shear strength (ACI 318S-14, 11.5.4)

The worst case forces to be withstood from the analysis are produced at Elevation 52.00 (Top), in the combination of loadcase 1.26·SW+1.26·DL+0.5·Qa-0.3·SX-SY (6).

$\phi V_n \geq V_u$ **678.9 kN ≥ 20.0 kN** ✓

Where:

V_u: Factored shear force at section. **V_u** : *20.0* kN

V_n: Nominal shear strength. **V_n** : *1131.5* kN

$$V_n = V_c + V_s$$

$$V_n \leq 0.83\sqrt{f'_c}hd$$

V_c: Nominal shear strength provided by concrete. **V_c** : *654.6* kN

$V_c = MIN(V_{c1}, V_{c2})$

$$V_{c1} = 0.27\lambda\sqrt{f'_c}hd + \frac{N_u d}{4l_w}$$ **V_{c1}** : *654.6* kN

$$V_{c2} = \left[0.05\lambda\sqrt{f'_c} + \frac{l_w\left(0.1\lambda\sqrt{f'_c} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right]hd$$ **V_{c2}** : *--* kN

Equation shall not apply if (M_u/V_u - $l_w/2$) is negative.

V_s: Nominal shear strength provided by shear reinforcement. **V_s** : *476.9* kN

$$V_S = \frac{A_v f_{yt} d}{s}$$

N_u: Factored axial force. **N_u** : *64.0* kN

M_u: Factored moment. **M_u** : *13.4* kN·m

A_v/s: Area of shear reinforcement. **A_v/s** : *7.10* cm²/m

f'_c: Specified compressive strength of concrete. **f'_c** : *24.53* MPa

$\sqrt{f'_c} \leq 8.3MPa$

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

l_w: Length of wall. **l_w** : *200.0* cm

h: Thickness of wall. **h** : *30.0* cm

d: Distance from extreme compression fiber to centroid of longitudinal tension reinforcement. **d** : *160.0* cm

$d = 0.8 \cdot l_w$

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

ϕ: Strength reduction factor. ϕ : *0.60*

Transverse shear (ACI 318S-14, 11.5.4)

The check does not proceed, as there is no shear force.

Minimum transverse reinforcement (ACI 318S-14, 11.6)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$\rho_t \geq \rho_{t,min}$ **0.0024 ≥ 0.0020** ✓

Where:

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : *0.0024*

$\rho_{t,min}$: Minimum ratio. $\rho_{t,min}$: *0.0020*

Bar size	f_y	$\rho_{t,min}$
≤ No.16	≥ 420 MPa	0.0020
	< 420 MPa	0.0025
> No.16	--	0.0025

V_u: Factored shear force at section. **V_u** : *9.6* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *405.5* kN

d_b: Maximum diameter of the reinforcement. **d_b** : *9.5* mm

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

Minimum longitudinal reinforcement (ACI 318S-14, 11.6)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$\rho_l \geq \rho_{l,min}$ **0.0024 ≥ 0.0012** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : *0.0024*

$\rho_{l,min}$: Minimum ratio. $\rho_{l,min}$: *0.0012*

Bar size	f_y	$\rho_{l,min}$
≤ No.16	≥ 420 MPa	0.0012
	< 420 MPa	0.0015
> No.16	--	0.0015

V_u: Factored shear force at section. **V_u** : *9.6* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *405.5* kN

d_b: Maximum diameter of the reinforcement. **d_b** : *9.5* mm

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

Minimum spacing of transverse reinforcement (ACI 318S-14, 25.2.2)

Reinforcement in the upper layers shall be placed directly above reinforcement in the bottom layer with a clear spacing between layers of at least 25mm

$s \geq 25mm$ **19 cm ≥ 3 cm** ✓

Minimum spacing of longitudinal reinforcement (ACI 318S-14, 25.2.3)

Clear spacing between bars shall be at least the greatest of:

$s \geq s_{min}$ **19 cm ≥ 4 cm** ✓

Where:

s_{min}: Maximum value of s_1, s_2, s_3

$s_1 = 40mm$ **s_1** : *4* cm

$s_2 = 1.5d_b$ **s_2** : *1* cm

$s_3 = \frac{4}{3} \cdot d_{agg}$ **s_3** : *3* cm

Where:

d_b: Nominal bar diameter. **d_b** : *9.5* mm

d_{agg}: Nominal maximum size of coarse aggregate. **d_{agg}** : *20.0* mm

Maximum spacing of transverse reinforcement (ACI 318S-14, 11.7.3)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$s \leq \min(3h,\ 450\ mm)$ **20 cm ≤ 45 cm** ✓

Where:

s: Spacing of transverse bars. **s** : *20* cm

h: Thickness of wall. **h** : *30.0* cm

V_u: Factored shear force at section. **V_u** : *9.6* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *405.5* kN

Maximum spacing of longitudinal reinforcement (ACI 318S-14, 11.7.2)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$s \leq \min(3h,\ 450\ mm)$ **20 cm ≤ 45 cm** ✓

Where:

s: Spacing of longitudinal bars. **s** : *20* cm

h: Thickness of wall. **h** : *30.0* cm

V_u: Factored shear force at section. **V_u** : *9.6* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *405.5* kN

Number of layers (ACI 318S-14, 11.7.2.3)

For walls with 'h' greater than 250 mm distributed reinforcement for each direction shall be placed in two layers parallel with wall faces. ✓

h: Thickness of wall. **h** : *30.0* cm

n: Number of layers. **n** : *2*

ACI 318M-14, Work section 18

Distributed web reinforcement ratios (ACI 318S-14, 18.10.2.1)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.083A_{cv}\lambda\sqrt{f'_c}$, shall be satisfied:

$\rho_l \geq 0.0012$ **0.0024 ≥ 0.0012** ✓

$\rho_t \geq 0.0020$ **0.0024 ≥ 0.0020** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : *0.0024*

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : *0.0024*

V_u: Factored shear force at section. **V_u** : *9.6* kN

A_{cv}: Area of concrete section. **A_{cv}** : *600000.00* mm²

f'_c: Specified compressive strength of concrete. **f'_c** : *24.53* MPa

$\sqrt{f'_c} \leq 8.3\text{MPa}$

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

Maximum reinforcement spacing (ACI 318S-14, 18.10.2.1)

Required:

$s_l \leq 450$ mm **20 cm ≤ 45 cm** ✓

$s_t \leq 450$ mm **20 cm ≤ 45 cm** ✓

s_l: Spacing of longitudinal bars. **s_l** : *20* cm

s_t: Spacing of transverse bars. **s_t** : *20* cm

Number of layers (ACI 318S-14, 18.10.2.2)

At least two curtains of reinforcement shall be used in a wall if $V_u > 0.17A_{cv}\lambda\sqrt{f'_c}$ or $h_w/l_w \geq 2.0$ ✓

n: Number of layers. **n** : *2*

V_u: Factored shear force at section. **V_u** : *9.6* kN

A_{cv}: Area of concrete section. **A_{cv}** : *600000.00* mm²

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

f'_c: Specified compressive strength of concrete. **f'_c** : *24.53* MPa

h_w: Height of wall. **h_w** : *300.0* cm

l_w: Length of wall. l_w : 200.0 cm

Shear strength (ACI 318S-14, 18.10.4.1)

The worst case forces to be withstood from the analysis are produced at Elevation 52.00 (Top), in the combination of loadcase 1.26·SW+1.26·DL+0.5·Qa-0.3·SX-SY (6).

$\phi V_n \geq V_u$ **803.4 kN ≥ 20.0 kN** ✓

Where:

V_u: Factored shear force at section. V_u : 20.0 kN

V_n: Nominal shear strength. V_n : 1339.0 kN

$$V_n = A_{cv}\left(\alpha_c \lambda \sqrt{f'_c} + \rho_t f_y\right)$$

$$V_n \leq 0.83 A_{cv} \sqrt{f'_c} \quad (18.10.4.4)$$

A_{cv}: Area of concrete section. A_{cv} : 600000.00 mm²

The coefficient α_c is 0.25 for $h_w/l_w \leq 1.50$, is 0.17 for $h_w/l_w \geq 2.00$, and varies linearly between 0.25 and 0.17 for h_w/l_w between 1.50 and 2.00. α_c : 0.25

h_w: Height of wall. h_w : 300.0 cm

l_w: Length of wall. l_w : 200.0 cm

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : 1.00

f'_c: Specified compressive strength of concrete. f'_c : 24.53 MPa

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : 0.0024

f_y: Specified yield strength of transverse reinforcement. f_y : 420.00 MPa

ϕ: Strength reduction factor. ϕ : 0.60

Longitudinal reinforcement ratio (ACI 318S-14, 18.10.4.3)

If h_w/l_w does not exceed 2.00, reinforcement ratio ρ_l shall be at least the reinforcement ratio ρ_t.

$\rho_l \geq \rho_t$ **0.0024 ≥ 0.0024** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : 0.0024

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : 0.0024

h_w/l_w : 1.50

Edge elements (ACI 318S-14, 18.10.6.1, 18.10.6.5) (Initial)

Special boundary elements

Structural wall shall have special boundary elements at boundaries and edges around openings where the maximum extreme fiber compressive stress, σ, exceeds $0.2f'_c$:

(ACI 318S-14, 18.10.6.3)

P_u (kN)	M_u (kN·m)	Edge elements	Location	σ (MPa)	$0.2f'_c$ (MPa)	Special element required
142.5	24.4	1.26·SW+1.26·DL-0.3·SX-SY (6)	Elevation 49.00 (Base)	0.12	4.91	No

Where:

P_u: Factored axial force.
M_u: Factored moment.
σ: Maximum extreme fiber compressive stress.
f'_c: Specified compressive strength of concrete.

Edge elements (ACI 318S-14, 18.10.6.1, 18.10.6.5) (Final)

Special boundary elements

Structural wall shall have special boundary elements at boundaries and edges around openings where the maximum extreme fiber compressive stress, σ, exceeds $0.2f'_c$:

(ACI 318S-14, 18.10.6.3)

P_u (kN)	M_u (kN·m)	Edge elements	Location	σ (MPa)	$0.2f'_c$ (MPa)	Special element required
142.0	31.3	1.2·SW+1.2·DL+1.6·Qa	Elevation 49.00 (Base)	0.39	4.91	No

Where:

P_u: Factored axial force.
M_u: Factored moment.
σ: Maximum extreme fiber compressive stress.
f'_c: Specified compressive strength of concrete.

Length of boundary element (ACI 318S-14, 18.10.6.4(a)) (Initial)

No check required

Length of boundary element (ACI 318S-14, 18.10.6.4(a)) (Final)

No check required

Maximum spacing of longitudinal bars laterally supported (ACI 318S-14, 18.10.6.4(e), 18.7.5.2) (Initial)

No check required

Maximum spacing of longitudinal bars laterally supported (ACI 318S-14, 18.10.6.4(e), 18.7.5.2) (Final)

No check required

Width of boundary element (ACI 318S-14, 18.10.6.4(b)) (Initial)

No check required

Width of boundary element (ACI 318S-14, 18.10.6.4(b)) (Final)

No check required

Spacing of transverse reinforcement (ACI 318S-14, 18.10.6.5) (Initial)

No check required

Spacing of transverse reinforcement (ACI 318S-14, 18.10.6.5) (Final)

No check required

Amount of transverse reinforcement of boundary element (ACI 318S-14, 18.10.6.4(f)) (Initial)

No check required

Amount of transverse reinforcement of boundary element (ACI 318S-14, 18.10.6.4(f)) (Final)

No check required

ACI 318M-14, Work section 11

In-plane shear strength (ACI 318S-14, 11.5.4)

The worst case forces to be withstood from the analysis are produced at Elevation 52.00 (Top), in the combination of loadcase 1.26·SW+1.26·DL+0.5·Qa+0.3·SX+SY (4).

$\phi V_n \geq V_u$ **678.9 kN ≥ 19.8 kN** ✓

Where:

V_u: Factored shear force at section. **V_u** : *19.8* kN

V_n: Nominal shear strength. **V_n** : *1131.6* kN

$$V_n = V_c + V_s$$

$$V_n \leq 0.83\sqrt{f'_c}hd$$

V_c: Nominal shear strength provided by concrete. **V_c** : *654.7* kN

V_c = MIN(V_{c1}, V_{c2})

$$V_{c1} = 0.27\lambda\sqrt{f'_c}hd + \frac{N_u d}{4l_w}$$ **V_{c1}** : *654.7* kN

$$V_{c2} = \left[0.05\lambda\sqrt{f'_c} + \frac{l_w\left(0.1\lambda\sqrt{f'_c} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right]hd$$ **V_{c2}** : *--* kN

Equation shall not apply if (M_u/V_u - $l_w/2$) is negative.

V_s: Nominal shear strength provided by shear reinforcement. **V_s** : *476.9* kN

$$V_S = \frac{A_v f_{yt} d}{s}$$

N_u: Factored axial force. **N_u** : *64.2* kN

M_u: Factored moment. **M_u** : *13.4* kN·m

A_v/s: Area of shear reinforcement. **A_v/s** : *7.10* cm²/m

f'_c: Specified compressive strength of concrete. **f'_c** : *24.53* MPa

$$\sqrt{f'_c} \leq 8.3\text{MPa}$$

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

l_w: Length of wall. **l_w** : *200.0* cm

h: Thickness of wall. **h** : *30.0* cm

d: Distance from extreme compression fiber to centroid of longitudinal tension reinforcement. **d** : *160.0* cm

$$d = 0.8 \cdot l_w$$

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

ϕ: Strength reduction factor. ϕ : *0.60*

Transverse shear (ACI 318S-14, 11.5.4)

The check does not proceed, as there is no shear force.

Minimum transverse reinforcement (ACI 318S-14, 11.6)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$\rho_t \geq \rho_{t,min}$ **0.0024 ≥ 0.0020** ✓

Where:

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : *0.0024*

$\rho_{t,min}$: Minimum ratio. $\rho_{t,min}$: *0.0020*

Bar size	f_y	$\rho_{t,min}$
≤ No.16	≥ 420 MPa	0.0020
	< 420 MPa	0.0025
> No.16	--	0.0025

V_u: Factored shear force at section. **V_u** : *9.6* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *404.8* kN

d_b: Maximum diameter of the reinforcement. **d_b** : *9.5* mm

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

Minimum longitudinal reinforcement (ACI 318S-14, 11.6)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$\rho_l \geq \rho_{l,min}$ **0.0024 ≥ 0.0012** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : *0.0024*

$\rho_{l,min}$: Minimum ratio. $\rho_{l,min}$: *0.0012*

Bar size	f_y	$\rho_{l,min}$
≤ No.16	≥ 420 MPa	0.0012
	< 420 MPa	0.0015
> No.16	--	0.0015

V_u: Factored shear force at section. **V_u** : *9.6* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *404.8* kN

d_b: Maximum diameter of the reinforcement. **d_b** : *9.5* mm

f_y: Specified yield strength of transverse reinforcement. **f_y** : *420.00* MPa

Minimum spacing of transverse reinforcement (ACI 318S-14, 25.2.2)

Reinforcement in the upper layers shall be placed directly above reinforcement in the bottom layer with a clear spacing between layers of at least 25mm

$s \geq 25mm$ **19 cm ≥ 3 cm** ✓

Minimum spacing of longitudinal reinforcement (ACI 318S-14, 25.2.3)

Clear spacing between bars shall be at least the greatest of:

$s \geq s_{min}$ **19 cm ≥ 4 cm** ✓

Where:

s_{min}: Maximum value of s_1, s_2, s_3

$s_1 = 40mm$ **s_1** : *4* cm

$s_2 = 1.5d_b$ **s_2** : *1* cm

$s_3 = \frac{4}{3} \cdot d_{agg}$ **s_3** : *3* cm

Where:

d_b: Nominal bar diameter. **d_b** : *9.5* mm

d_{agg}: Nominal maximum size of coarse aggregate. **d_{agg}** : *20.0* mm

Maximum spacing of transverse reinforcement (ACI 318S-14, 11.7.3)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$s \leq \min(3h,\ 450\ mm)$ **20 cm ≤ 45 cm** ✓

Where:

s: Spacing of transverse bars. **s** : *20* cm

h: Thickness of wall. **h** : *30.0* cm

V_u: Factored shear force at section. **V_u** : *9.6* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *404.8* kN

Maximum spacing of longitudinal reinforcement (ACI 318S-14, 11.7.2)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.5 \cdot \phi V_c$, shall be satisfied:

$s \leq \min(3h,\ 450\ mm)$ **20 cm ≤ 45 cm** ✓

Where:

s: Spacing of longitudinal bars. **s** : *20* cm

h: Thickness of wall. **h** : *30.0* cm

V_u: Factored shear force at section. **V_u** : *9.6* kN

V_c: Nominal shear strength provided by concrete. **V_c** : *404.8* kN

Number of layers (ACI 318S-14, 11.7.2.3)

For walls with 'h' greater than 250 mm distributed reinforcement for each direction shall be placed in two layers parallel with wall faces. ✓

h: Thickness of wall. **h** : *30.0* cm

n: Number of layers. **n** : *2*

ACI 318M-14, Work section 18

Distributed web reinforcement ratios (ACI 318S-14, 18.10.2.1)

The worst case forces to be withstood from the analysis are produced at Elevation 49.00 (Base), in the combination of loadcase 1.4·SW+1.4·DL.

If in-plane $V_u \leq 0.083A_{cv}\lambda\sqrt{f'_c}$, shall be satisfied:

$\rho_l \geq 0.0012$ **0.0024 ≥ 0.0012** ✓

$\rho_t \geq 0.0020$ **0.0024 ≥ 0.0020** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : *0.0024*

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : *0.0024*

V_u: Factored shear force at section. **V_u** : *9.6* kN

A_{cv}: Area of concrete section. **A_{cv}** : *600000.00* mm²

f'_c: Specified compressive strength of concrete. **f'_c** : *24.53* MPa

$\sqrt{f'_c} \leq 8.3\text{MPa}$

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

Maximum reinforcement spacing (ACI 318S-14, 18.10.2.1)

Required:

$s_l \leq 450$ mm **20 cm ≤ 45 cm** ✓

$s_t \leq 450$ mm **20 cm ≤ 45 cm** ✓

s_l: Spacing of longitudinal bars. **s_l** : *20* cm

s_t: Spacing of transverse bars. **s_t** : *20* cm

Number of layers (ACI 318S-14, 18.10.2.2)

At least two curtains of reinforcement shall be used in a wall if $V_u > 0.17A_{cv}\lambda\sqrt{f'_c}$ or $h_w/l_w \geq 2.0$ ✓

n: Number of layers. **n** : *2*

V_u: Factored shear force at section. **V_u** : *9.6* kN

A_{cv}: Area of concrete section. **A_{cv}** : *600000.00* mm²

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1.00*

f'_c: Specified compressive strength of concrete. **f'_c** : *24.53* MPa

h_w: Height of wall. **h_w** : *300.0* cm

l_w: Length of wall. l_w : 200.0 cm

Shear strength (ACI 318S-14, 18.10.4.1)

The worst case forces to be withstood from the analysis are produced at Elevation 52.00 (Top), in the combination of loadcase 1.26·SW+1.26·DL+0.5·Qa+0.3·SX+SY (4).

$\phi V_n \geq V_u$ **803.4 kN ≥ 19.8 kN** ✓

Where:

V_u: Factored shear force at section. V_u : 19.8 kN

V_n: Nominal shear strength. V_n : 1339.0 kN

$$V_n = A_{cv}\left(\alpha_c \lambda \sqrt{f'_c} + \rho_t f_y\right)$$

$$V_n \leq 0.83 A_{cv} \sqrt{f'_c} \quad (18.10.4.4)$$

A_{cv}: Area of concrete section. A_{cv} : 600000.00 mm²

The coefficient α_c is 0.25 for $h_w/l_w \leq 1.50$, is 0.17 for $h_w/l_w \geq 2.00$, and varies linearly between 0.25 and 0.17 for h_w/l_w between 1.50 and 2.00. α_c : 0.25

h_w: Height of wall. h_w : 300.0 cm

l_w: Length of wall. l_w : 200.0 cm

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : 1.00

f'_c: Specified compressive strength of concrete. f'_c : 24.53 MPa

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : 0.0024

f_y: Specified yield strength of transverse reinforcement. f_y : 420.00 MPa

ϕ: Strength reduction factor. ϕ : 0.60

Longitudinal reinforcement ratio (ACI 318S-14, 18.10.4.3)

If h_w/l_w does not exceed 2.00, reinforcement ratio ρ_l shall be at least the reinforcement ratio ρ_t.

$\rho_l \geq \rho_t$ **0.0024 ≥ 0.0024** ✓

Where:

ρ_l: Ratio of area of distributed longitudinal reinforcement to gross concrete area perpendicular to that reinforcement. ρ_l : 0.0024

ρ_t: Ratio of area of distributed transverse reinforcement to gross concrete area perpendicular to that reinforcement. ρ_t : 0.0024

h_w/l_w : 1.50

Edge elements (ACI 318S-14, 18.10.6.1, 18.10.6.5) (Initial)

Special boundary elements

Structural wall shall have special boundary elements at boundaries and edges around openings where the maximum extreme fiber compressive stress, σ, exceeds $0.2f'_c$:

(ACI 318S-14, 18.10.6.3)

P_u (kN)	M_u (kN·m)	Edge elements	Location	σ (MPa)	$0.2f'_c$ (MPa)	Special element required
150.7	27.2	1.4·SW+1.4·DL	Elevation 49.00 (Base)	0.11	4.91	No

Where:

P_u: Factored axial force.
M_u: Factored moment.
σ: Maximum extreme fiber compressive stress.
f'_c: Specified compressive strength of concrete.

Edge elements (ACI 318S-14, 18.10.6.1, 18.10.6.5) (Final)

Special boundary elements

Structural wall shall have special boundary elements at boundaries and edges around openings where the maximum extreme fiber compressive stress, σ, exceeds $0.2f'_c$:

(ACI 318S-14, 18.10.6.3)

P_u (kN)	M_u (kN·m)	Edge elements	Location	σ (MPa)	$0.2f'_c$ (MPa)	Special element required
142.0	31.3	1.2·SW+1.2·DL+1.6·Qa	Elevation 49.00 (Base)	0.39	4.91	No

Where:

P_u: Factored axial force.
M_u: Factored moment.
σ: Maximum extreme fiber compressive stress.
f'_c: Specified compressive strength of concrete.

Length of boundary element (ACI 318S-14, 18.10.6.4(a)) (Initial)

No check required

Length of boundary element (ACI 318S-14, 18.10.6.4(a)) (Final)

No check required

Maximum spacing of longitudinal bars laterally supported (ACI 318S-14, 18.10.6.4(e), 18.7.5.2) (Initial)

No check required

Maximum spacing of longitudinal bars laterally supported (ACI 318S-14, 18.10.6.4(e), 18.7.5.2) (Final)

No check required

Width of boundary element (ACI 318S-14, 18.10.6.4(b)) (Initial)

No check required

Width of boundary element (ACI 318S-14, 18.10.6.4(b)) (Final)

No check required

Spacing of transverse reinforcement (ACI 318S-14, 18.10.6.5) (Initial)

No check required

Spacing of transverse reinforcement (ACI 318S-14, 18.10.6.5) (Final)

No check required

Amount of transverse reinforcement of boundary element (ACI 318S-14, 18.10.6.4(f)) (Initial)

No check required

Amount of transverse reinforcement of boundary element (ACI 318S-14, 18.10.6.4(f)) (Final)

No check required

2. COUPLING BEAMS

2.1. Floor 1

2.1.1. SW1 - SW3

Coupling beam: SW1 - SW3

Requirement to place diagonal reinforcement (ACI 318S-14, 18.10.7.1, 18.10.7.2)

Diagonally reinforced coupling beams are restricted to beams having aspect ratio L/h < 4

$(\ell_n/h) < 4$ **1.1 < 4.0** ✓

Ultimate limit state for shear (ACI 318S-14, 18.10.7.4 (a))

Coupling beams reinforced with two intersecting groups of diagonally placed bars symmetrical about the midspan shall satisfy

$V_u \le \phi \cdot V_n$ **211.0 kN ≤ 227.6 kN** ✓

Where:

$V_n = 2 \cdot A_{vd} \cdot f_y \cdot \sin\alpha \le 0.83\sqrt{f'_c} A_{cw}$

A_{vd}: Total area of reinforcement in each group of diagonal bars.	A_{vd} :	*516.13*	mm²
α: Angle between the diagonal bars and the longitudinal axis of the coupling beam.	α :	*38.14*	
f_y: Specified yield strength for reinforcement.	f_y :	*420.00*	MPa
V_u: Factored shear force at section.	V_u :	*211.0*	kN
A_{cw}: Area of concrete section of a coupling beam resisting shear.	A_{cw} :	*403713.75*	mm²
f'_c: Specified compressive strength of concrete.	f'_c :	*25.00*	MPa
Φ: Strength reduction factor.	Φ :	*0.85*	

Layout of the longitudinal reinforcement at lateral faces (ACI 318S-14, 9.7.2.3)

For beams with h exceeding 900 mm, longitudinal skin reinforcement shall be uniformly distributed on both side faces of the beam ✓

Maximum spacing of the longitudinal reinforcement in lateral faces (ACI 318S-14, 9.7.2.3)

The spacing of skin reinforcement shall not exceed 's', where c_c is the clear cover from the skin reinforcement to the side face

$s \le MIN\left(380\left(\frac{280}{f_s}\right) - 2.5c_c, 300\left(\frac{280}{f_s}\right)\right)$ **22 cm ≤ 28 cm** ✓

Where:

$f_s = \frac{2}{3} f_y$

s: Skin reinforcement spacing	**s** :	*22*	cm
c_c: Clear cover from the skin reinforcement to the side face	**c_c** :	*4.0*	cm

Minimum spacing of the longitudinal reinforcement in lateral faces (ACI 318S-14, 25.2.2)

Reinforcement in the upper layers shall be placed directly above reinforcement in the bottom layer with a clear spacing between layers of at least 25mm

$s \geq 25mm$ **21 cm ≥ 3 cm** ✓

Ratio of the longitudinal reinforcement in lateral faces (ACI 318S-14, 18.10.7.4 (c))

Additional longitudinal and transverse reinforcement shall be distributed around the beam perimeter with total area in each direction of at least $0.002 \cdot b_w \cdot s$

$A_s \geq 0.002 \cdot b_w \cdot s$ **141.94 mm² ≥ 129.14 mm²** ✓

Where:

A_s: Longitudinal reinforcement total area **A_s** : *141.94* mm²

b_w: Web width of the coupling beam **b_w** : *30.0* cm

s: Maximum spacing of longitudinal reinforcement **s** : *22* cm

Maximum spacing of the longitudinal reinforcement in lateral faces (ACI 318S-14, 18.10.7.4 (c))

Additional longitudinal and transverse reinforcement shall be distributed around the beam perimeter with spacing not exceeding 300mm

$s \leq 300mm$ **22 cm ≤ 30 cm** ✓

s: Maximum spacing of longitudinal reinforcement **s** : *22* cm

Stirrup spacing (ACI 318S-14, 18.10.7.4 (c))

Additional longitudinal and transverse reinforcement shall be distributed around the beam perimeter with spacing not exceeding 300mm

$s \leq 300mm$ **23 cm ≤ 30 cm** ✓

s: Transverse reinforcement spacing **s** : *23* cm

Ratio of transverse reinforcement (ACI 318S-14, 18.10.7.4 (c))

Additional longitudinal and transverse reinforcement shall be distributed around the beam perimeter with total area in each direction of at least $0.002 \cdot b_w \cdot s$

$A_s \geq 0.002 \cdot b_w \cdot s$ **141.94 mm² ≥ 138.00 mm²** ✓

Where:

A_s: Transverse reinforcement total area **A_s** : *141.94* mm²

b_w: Web width of the coupling beam **b_w** : *30.0* cm

s: Transverse reinforcement spacing **s** : *23* cm

Minimum spacing of the longitudinal reinforcement of the diagonal element (ACI 318S-14, 25.2.1)

For parallel reinforcement in a horizontal layer, clear spacing shall be at least the greatest of

$s \geq s_{min}$ **5 cm ≥ 3 cm** ✓

Where:

s_{min}: Maximum value of s_1, s_2, s_3

$s_1 = d_b$ **s_1** : *1* cm

$s_2 = 25mm$ **s_2** : *3* cm

$s_3 = \frac{4}{3} \cdot d_{agg}$ **s_3** : *3* cm

Where:

d_b: Nominal bar diameter. **d_b** : *12.7* mm

d_{agg}: Nominal maximum size of coarse aggregate. **d_{agg}** : *20.0* mm

Distance between longitudinal reinforcement layers of the diagonal element (ACI 318S-14, 25.2.2)

Reinforcement in the upper layers shall be placed directly above reinforcement in the bottom layer with a clear spacing between layers of at least 25mm

$s \geq 25mm$ **7 cm ≥ 3 cm** ✓

Layout of the longitudinal reinforcement of the diagonal element (ACI 318S-14, 18.10.7.4 (b))

Each group of diagonal bars shall consist of a minimum of four bars provided in two or more layers

$n \geq 4$ **4 ≥ 4** ✓

n: Number of longitudinal bars of the diagonal reinforcement **n** : *4*

Length of the diagonal element that is embedded in the wall (ACI 318S-14, 18.10.7.4 (b))

The diagonal bars shall be embedded into the wall at least 1.25 times the development length for f_y in tension

$l_{dw} \geq 1.25 \cdot l_d$ **63.5 cm ≥ 63.5 cm** ✓

l_{dw}: Length of diagonal reinforcement embedded into the wall **l_{dw}** : *63.5* cm

l_d: Development length. **l_d** : *50.8* cm

$$l_d = \left(\frac{f_y \Psi_t \Psi_e}{2.1 \lambda \sqrt{f'_c}} \right) d_b \geq 300mm$$

Where:

f_y: Specified yield strength for reinforcement. **f_y** : *420.00* MPa

f'_c: Specified compressive strength of concrete. **f'_c** : *25.00* MPa

d'_b: Nominal bar diameter. **d'_b** : *12.7* mm

Ψ_t: Factor used to modify development length for casting location in tension. Ψ_t : *1*

Ψ_e: Factor used to modify development length based on reinforcement coating. Ψ_e : *1*

λ: Modification factor to reflect the reduced mechanical properties of lightweight concrete relative to normalweight concrete of the same compressive strength. λ : *1*

Dimensions of the transverse reinforcement of the diagonal element (ACI 318S-14, 18.10.7.4 (c))

Each group of diagonal bars shall be enclosed by rectilinear transverse reinforcement having out-to-out dimensions of at least $b_w/2$ in the direction parallel to b_w and $b_w/5$ along the other sides

$b_{diag} \geq b_w / 2$ **15.0 cm ≥ 15.0 cm** ✓

$h_{diag} \geq b_w / 5$ **12.0 cm ≥ 6.0 cm** ✓

Where:

b_{diag}: Out-to-out dimension of the transverse reinforcement, parallel to b_w — **b_{diag}** : *15.0* cm

h_{diag}: Out-to-out dimension of the transverse reinforcement, not parallel to b_w — **h_{diag}** : *12.0* cm

b_w: Web width of the coupling beam — **b_w** : *30.0* cm

Volumetric ratio of the transverse reinforcement of the diagonal element (ACI 318S-14, 18.10.7.4 (c))

The transverse reinforcement shall be in accordance with A_{sh} not less than $A_{sh,min}$

In the X-axis:

$A_{sh} \geq A_{sh,min}$ **258.06 mm² ≥ 250.00 mm²** ✓

In the Y-axis:

$A_{sh} \geq A_{sh,min}$ **258.06 mm² ≥ 200.00 mm²** ✓

Where:

$A_{sh,min}$: Maximum value of A_1, A_2

$$A_1 = 0.3\frac{s \cdot b_c \cdot f'_c}{f_{yt}}\left[\left(\frac{A_g}{A_{ch}} - 1\right)\right]$$

A_{1x} : *250.00* mm²

A_{1y} : *200.00* mm²

$$A_2 = 0.09\frac{s \cdot b_c \cdot f'_c}{f_{yt}}$$

A_{2x} : *48.21* mm²

A_{2y} : *38.57* mm²

Where:

s: Center-to-center spacing of transverse reinforcement. — **s** : *6* cm

b_c: Cross-sectional dimension of member core measured to the outside edges of the transverse reinforcement composing area A_{sh}. — **b_{cx}** : *15.0* cm; **b_{cy}** : *12.0* cm

f_y: Specified yield strength for reinforcement. — **f_y** : *420.00* MPa

f'_c: Specified compressive strength of concrete. — **f'_c** : *25.00* MPa

A_g: Gross area of concrete section. — **A_g** : *46000.00* mm²

A_{ch}: Cross-sectional area measured to the outside edges of transverse reinforcement. — **A_{ch}** : *18000.00* mm²

A_{sh}: Total cross-sectional area of transverse reinforcement, including crossties, within spacing s and perpendicular to dimension, b_c.

Spacing of the transverse reinforcement of the diagonal element (ACI 318S-14, 18.10.7.4 (c))

The spacing of the transverse reinforcement, measured parallel to the diagonal bars, shall satisfy

$s_0 \leq s_{0,max}$ **6 cm ≤ 8 cm** ✓

Where:

$s_{0,max}$: Minimum of s_{01} and s_{02}

$s_{01} = 6 \cdot d_b$ — **s_{01}** : *8* cm

$$s_{02} = 100 + \left(\frac{350 - h_x}{3}\right) \rightarrow \begin{cases} s_{02} \geq 100\text{mm} \\ s_{02} \leq 150\text{mm} \end{cases}$$

s_{02} : *14* cm

Where:

d_b: Diameter of the smallest diagonal bar **d_b** : *12.7* mm

h_x: Maximum center-to-center spacing of longitudinal bars laterally supported by corners of crossties or hoop legs. **h_x** : *22* cm

Spacing of the crossties and hooks of the diagonal element (ACI 318S-14, 18.10.7.4 (c))

The transverse reinforcement shall have spacing of crossties or legs of hoops measured perpendicular to the diagonal bars not exceeding 350 mm

$h_x \leq 350mm$ **22 cm ≤ 35 cm** ✓

h_x: Maximum center-to-center spacing of longitudinal bars laterally supported by corners of crossties or hoop legs. **h_x** : *22* cm