Foundation Calculation Report: «1750 OX Residences - 1750 N Oxford Ave. - Eau Claire, WI»

XC structural engineering

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1 Introduction and scope

This report describes the calculation procedure and data considered in order to design the foundation of a new apartment building in Eau Claire, Wisconsin.

The construction consists in a three-story apartment building with a first-floor footprint of about 19,500 square feet, a below-grade parking garage with a footprint of about 27,200 square feet, perimeter retaining walls, a slab-on-grade, and a conventional foundation system.

The first floor system is precast hollow core concrete plank on precast beams and columns. For the upper floors and roof, the system is wood-framed. Retaining walls and slab on grade are comprised of cast in place concrete, except for three reinforced CMU walls next to the garage aisles, that will be demolished during the second phase of construction.

The foundation uses conventional cast in place concrete footings to transfer axial compression and lateral loads to the ground.

2 Building codes

The following building and material codes were used for the design:

- Building code
  - International Building Code, 2018 Edition (IBC 2018) with reference to Minimum Design Loads for Buildings and Other Structures by the American Society of Civil Engineers, 2016 Edition (ASCE 7).
- Material codes
  - Reinforced Concrete: Building Code Requirements for Structural Concrete and Commentary by the American Concrete Institute, 2019 Edition (ACI 318).
  - Masonry: Building Code Requirements and Specification for Masonry Structures and Companion Commentaries, 2013 Edition (ACI 530/530).

3 Loading criteria

A summary of the project-specific loading criteria follows (see appendix A for a detailed list of load values).

3.1 Gravity loading

The gravity loads listed in Table 1 are in addition to the self weight of the structure. The minimum loading requirements were taken from ASCE 7 as well as the loading criteria supplied by the engineer of record. Loads are given in pounds per square foot (psf).

Table 1: **Gravity Loads**

Use	**Live Loading**	**Superimposed Dead Loading**
Parking Garage	40	3
Storage/HVAC	125	28
Stairways, exits	100	28
Level 1 residential	40	28
Level 1 corridors	100	28
Level 1 office, recreational	100	28
Level 1 courtyard (footprint)	150	150
Elevated levels residential	40	28
Elevated levels corridors	40	28
Cornices	60	-
Balconies	40	28
Roof	20	28

In addition to these uniform slab loads, a perimeter dead load of 12 psf was applied to the structure to account for the weight of the cladding system.

3.2 Wind design criteria

Wind loading is in accordance with the IBC and ASCE 7 requirements as shown in Table 2.

Table 2: **Wind Design Criteria**

Parameter	**Value**
Basic Wind Speed, 3-second gust (ultimate)	115 mph
Basic Wind Speed, 3-second gust (nominal)	90 mph
Exposure	B
Occupancy Category	II
Importance Factor (I_w)	1.0
Topographic Factor (K_{zt})	1.0
Enclosure Classification	Enclosed
Mean Roof Height (h)	33’

3.3 Snow loading

Wind loading is in accordance with the ASCE 7 requirements as shown in Table 3.

Table 3: **Snow Design Criteria**

Parameter	**Value**
Ground snow load p_g	60 psf
Terrain category	B
Exposure factor C_e	1.0
Thermal factor C_t	1.0
Occupancy Category	II
Snow load importance factor I_s	1.0
Snow load flat roof	42 psf

4 Seismic design criteria

Seismic loads are in accordance with the IBC requirements as shown in Table 4.

Table 4: **Seismic Design Criteria**

Parameter	**Value**
Building Latitude/Longitude	44^{o}49'01.8"N 91^{o}30'34.8"W
Occupancy Category	II
Importance Factor I_e	1.0
Mapped Spectral Acceleration	S_s = 0.045; S_1 = 0.038
Site Class	B
Site Class Coefficients	F_a = 1.0; F_v = 1.0
Spectral Response Coefficients	S_{DS} = 0.03; S_{D1} = 0.025
Seismic Design Category	A

5 Materials

The material properties used for the design are summarized in Tables 5 and 6.

Table 5: **Concrete properties**

Member	**Nominal f'$_c$**
Footings	3.0 ksi
Basement Walls	4.0 ksi
Foundation frost walls	4.0 ksi
Stair landings and treads	4.0 ksi
Slab on grade	4.0 ksi

Table 6: **Reinforcement properties**

Standard	**Nominal f_y**
All ASTM A615 Grade 60	60 ksi

6 Design and analysis software

The computer software employed for the analysis of the structure is the Finite Element Program called **XC** (see program description at `http://xcengineering.xyz/html_files/software.html`).

7 Load combinations

The load combinations shown in Tables 7 and 8 follow the strength design load combinations listed in IBC, section 1605.

Table 7: **Combinations Ultimate Limit States**

Identifier	**Load Combination**
ULS01:	1.4*D
ULS02_a:	1.2*D + 1.6*Lru + Lpu + 0.5*S
ULS02_b:	1.2*D + 1.6*Lrs + Lps + 0.5*S
ULS03_a:	1.2*D + 1.6*S + 0.5*Lru + Lpu
ULS03_b:	1.2*D + 1.6*S + 0.5*Lrs + Lps
ULS04_b:	1.2*D + 1.6*S + 0.5*W_NS
ULS04_a:	1.2*D + 1.6*S + 0.5*W_WE
ULS05_a:	1.2*D + W_WE + 0.5*Lru + Lpu
ULS05_b:	1.2*D + W_NS + 0.5*Lru + Lpu
ULS05_c:	1.2*D + W_WE + 0.5*Lrs + Lps
ULS05_d:	1.2*D + W_NS + 0.5*Lrs + Lps
ULS06_a:	1.2*D + 0.5*Lru + Lpu + 0.2*S
ULS06_b:	1.2*D + 0.5*Lrs + Lps + 0.2*S
ULS07_a:	0.9*D + W_WE
ULS07_b:	0.9*D + W_NS

Where:

D = dead load
Lru = live load (uniform on rooms)
Lrs = live load (staggered pattern on rooms)
Lpu = live load (uniform on patios)
Lps = live load (staggered pattern on patios)
S = snow load
W_WE = Wind West-East
W_NS = Wind North-South

Table 8: **Combinations Serviceability Limit States**

Identifier	Load Combination
SLS01:	1.0*D
SLS02_a:	1.0*D + 1.0*Lru + Lpu + 0.3*S
SLS02_b:	1.0*D + 1.0*Lrs + Lps + 0.3*S
SLS03_a:	1.0*D + 1.0*S + 0.3*Lru + 0.3*Lpu
SLS03_b:	1.0*D + 1.0*S + 0.3*Lrs + 0.3*Lps
SLS04_a:	1.0*D + W_WE + 1.0*Lru + Lpu
SLS04_b:	1.0*D + W_NS + 1.0*Lru + Lpu
SLS04_c:	1.0*D + W_WE + 1.0*Lrs + Lps
SLS04_d:	1.0*D + W_NS + 1.0*Lrs + Lps
SLS05_a:	1.0*D + W_WE
SLS05_b:	1.0*D + W_NS

Where:

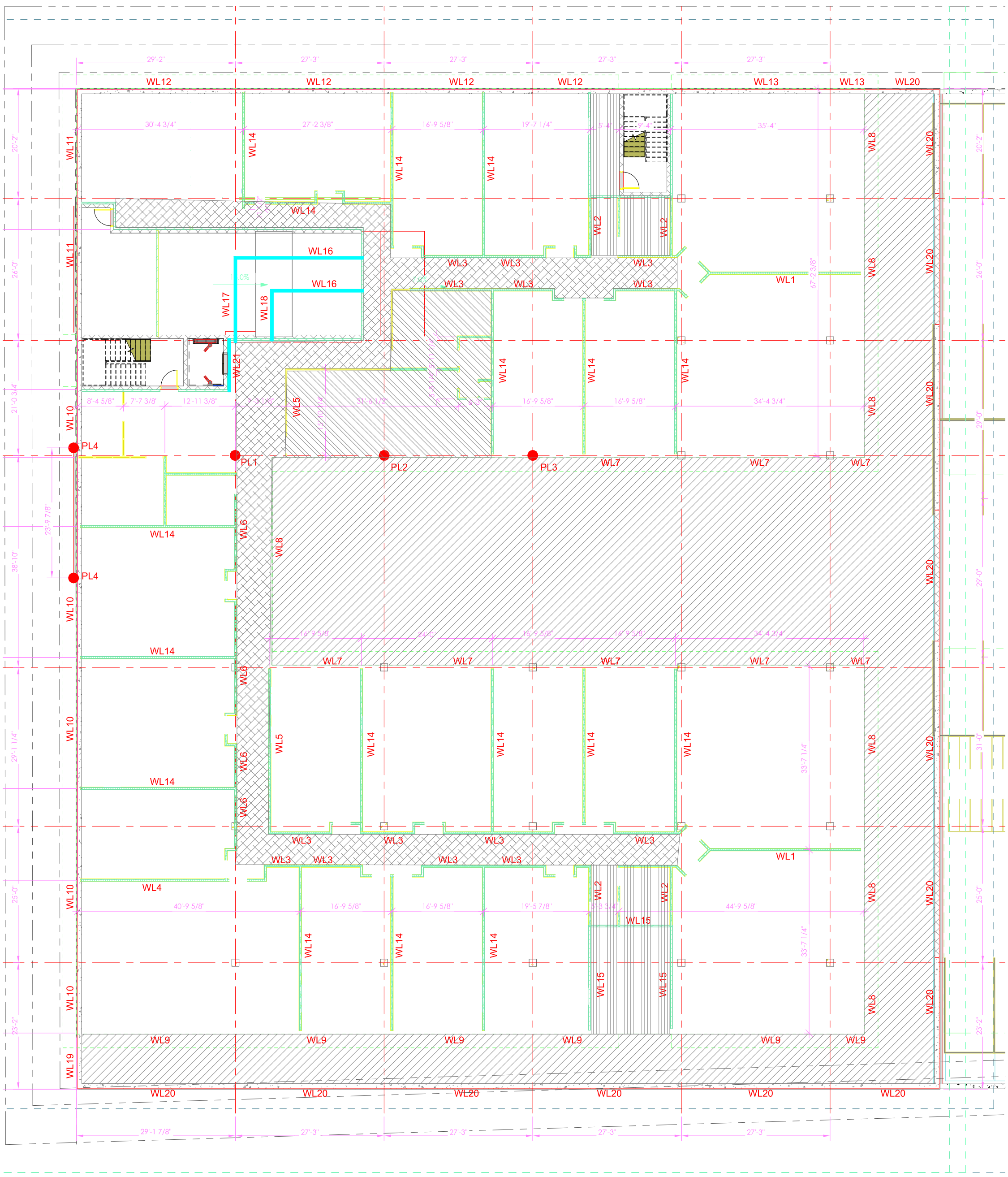
D = dead load
Lru = live load (uniform on rooms)
Lrs = live load (staggered pattern on rooms)
Lpu = live load (uniform on patios)
Lps = live load (staggered pattern on patios)
S = snow load
W_WE = Wind West-East
W_NS = Wind North-South

8 Structural model

A three-dimensional elastic computer model of the substructure is analyzed using XC. The model includes first floor frame and columns (see figure 2). The hollow core planks ar modelled using shell elements, while beams and columns are modelled using frame elements. Loads transmited by 2^{nd}, 3^{rd} floors and roof are applied to the 1^{st}. Load layout is shown in figure 1. See in figures 3 to 10 load distribution for each load case.

Linear loads are expressed in kN/m and surface loads in kN/m^2, where:

1 kN/m =	68.52178 lb/ft
1 kN/m^2 =	20.885434 psf



WALL LOAD SCHEDULE													
MARK	ELEV.	DEAD LOAD Klb/ft	LIVE LOAD Klb/ft	SNOW LOAD Klb/ft	W-E WIND LOAD			N-S WIND LOAD			EARTH PRES.	CHORD LOAD	
					UPLIFT Klb/ft	DOWN LIFT Klb/ft	IN PLANE Klb/ft	UPLIFT Klb/ft	DOWN LIFT Klb/ft	IN PLANE Klb/ft	IN PLANE Klb/ft	DEAD IN PLANE Klb/ft	LIVE IN PLANE Klb/ft
WL1	-0'-4"	1.51	3.35	2.01	0.40	N/A	N/A	0.40	N/A	0.15	N/A	N/A	N/A
WL2	-0'-4"	0.83	0.74	0.44	0.40	N/A	N/A	0.40	N/A	N/A	N/A	N/A	N/A
WL3	-0'-4"	1.12	1.84	1.10	0.40	N/A	N/A	0.40	N/A	0.15	N/A	N/A	N/A
WL4	-0'-4"	1.05	1.57	0.94	0.40	N/A	N/A	0.40	N/A	0.15	N/A	N/A	N/A
WL5	-0'-4"	0.72	0.33	0.20	0.40	N/A	0.39	0.40	N/A	N/A	N/A	N/A	N/A
WL6	-0'-4"	1.11	1.79	1.07	0.40	N/A	0.39	0.40	N/A	N/A	N/A	N/A	N/A
WL7	-0'-4"	1.58	1.67	1.00	1.61	2.39	N/A	N/A	N/A	0.15	N/A	N/A	N/A
WL8	-0'-4"	0.50	N/A	N/A	N/A	N/A	0.39	N/A	1.20	N/A	N/A	N/A	N/A
WL9	-0'-4"	1.73	2.26	1.36	1.86	N/A	N/A	N/A	N/A	0.15	N/A	N/A	N/A
WL10	-0'-4"	1.52	1.46	0.88	N/A	N/A	0.39	1.28	N/A	N/A	2.30	N/A	N/A
WL11	-0'-4"	0.50	N/A	N/A	N/A	N/A	0.39	1.28	N/A	N/A	2.30	N/A	N/A
WL12	-0'-4"	1.55	1.57	0.94	N/A	1.08	N/A	N/A	N/A	0.15	2.30	N/A	N/A
WL13	-0'-4"	1.58	1.67	1.00	N/A	1.08	N/A	N/A	N/A	0.15	2.30	N/A	N/A
WL14	-0'-4"	0.27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WL15	-0'-4"	1.92	1.33	0.44	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WL16	11'-2"	0.95	1.10	1.10	0.40	N/A	N/A	0.40	N/A	0.16	N/A	N/A	N/A
WL17	11'-2"	0.94	1.07	1.07	0.40	N/A	0.39	0.40	N/A	N/A	N/A	N/A	N/A
WL18	11'-2"	0.69	0.20	0.20	0.40	N/A	0.39	0.40	N/A	N/A	N/A	N/A	N/A
WL19	-1'-8"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.30	N/A	N/A
WL20	-1'-8"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.30	N/A	N/A
WL21	-0'-4"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.94	1.76

POINT LOAD SCHEDULE			
MARK	DEAD LOAD Klb	LIVE LOAD Klb	SNOW LOAD Klb
PL1	15.24	25.01	15.01
PL2	30.47	50.02	30.02
PL3	15.24	25.01	15.01
PL4	17.84	17.40	10.50

SUPERIMPOSED UNIFORM LOAD SCHEDULE				
MARK	DEAD LOAD PSF	LIVE LOAD PSF	SNOW LOAD PSF	COMMENTS
	150.00	150.00	42.00	YARDS AND TERRACES PEDESTRIAN
	20.00	100.00	N/A	CORRIDORS FIRST FLOOR
	20.00	100.00	N/A	STAIRS AND EXITS
	20.00	100.00	N/A	STORE FIRST FLOOR
	20.00	40.00	N/A	PRIVATE ROOMS MULTIFAMILY DWELLING

Figure 1: Load layout on first floor.

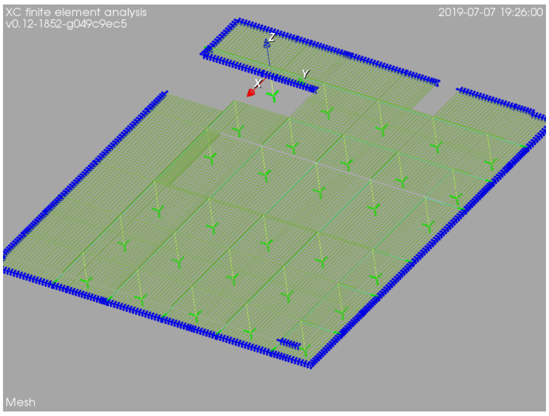


Figure 2: Elastic model, mesh.

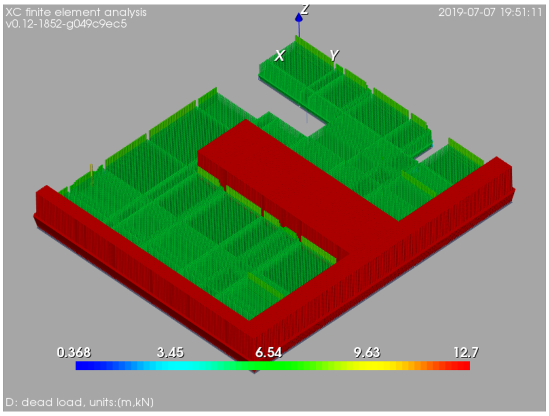


Figure 3: Load case D: dead load (include slab self-weight) [units: kN,m].

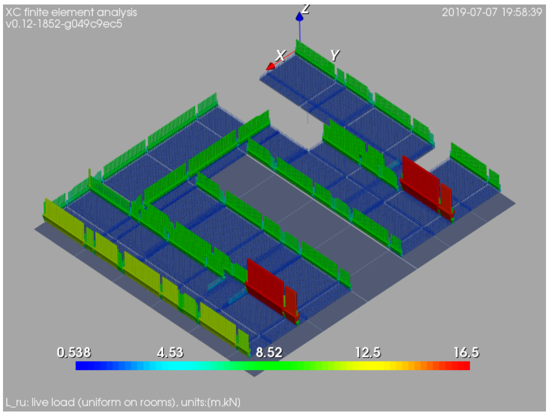


Figure 4: Load case Lru: live load (uniform on rooms) [units: kN,m].

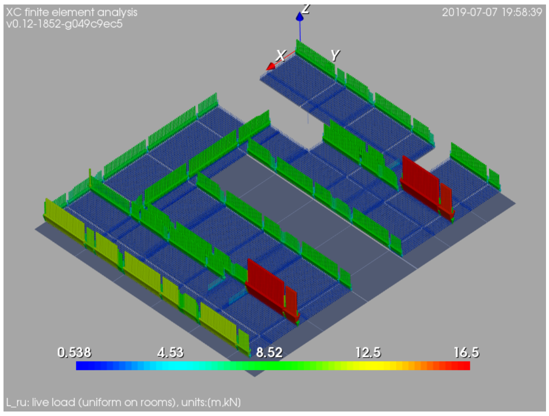


Figure 5: Load case Lrs: live load (staggered pattern on rooms) [units: kN,m].

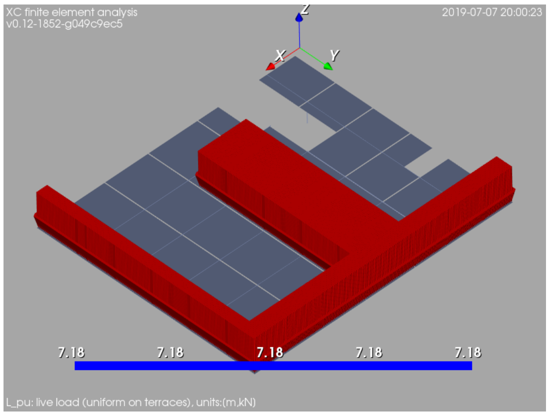


Figure 6: Load case Lpu: live load (uniform on patios) [units: kN,m].

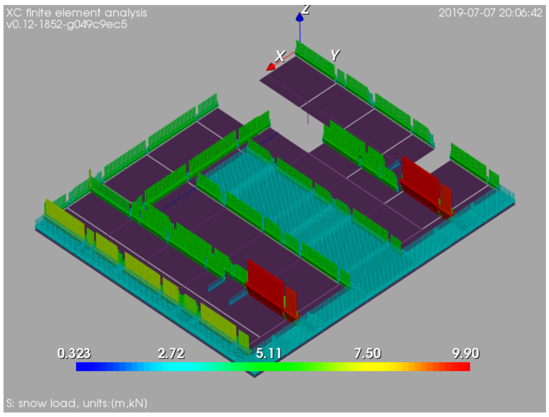


Figure 7: Load case S: snow [units: kN,m].

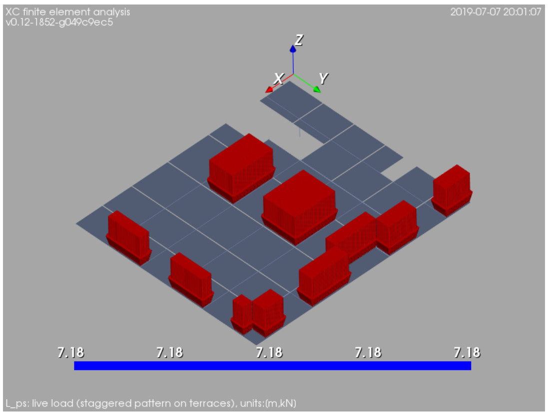


Figure 8: Load case Lps: live load (staggered pattern on patios) [units: kN,m].

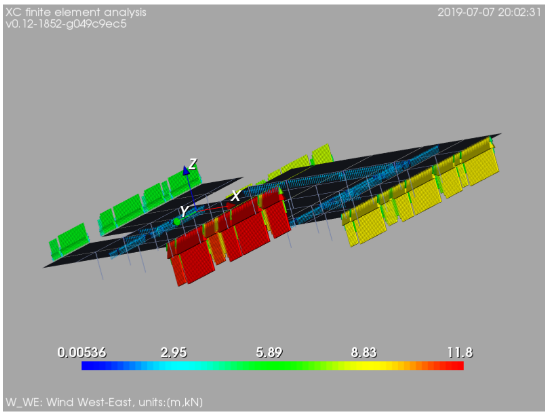


Figure 9: Load case W_WE: wind West-East [units: kN,m].

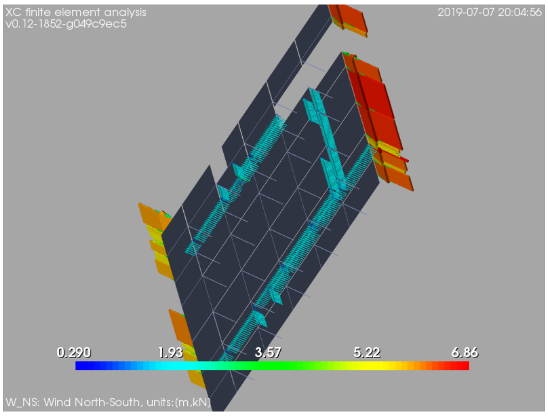


Figure 10: Load case W_NS: wind North-South [units: kN,m].

A Appendix A. Loading criteria

A.1 Dead loads

Materials	
Wood structural panel	36.0 pcf $= 5655 \frac{\text{newton}}{\text{meter}^3}$
Concrete reinforced stone (including gravel)	150.0 pcf $= 23563 \frac{\text{newton}}{\text{meter}^3}$
Steel	489.0 pcf $= 76816 \frac{\text{newton}}{\text{meter}^3}$
Gypsum crete	115.0 pcf $= 18065 \frac{\text{newton}}{\text{meter}^3}$
Gypsum,loose	70.0 pcf $= 10996 \frac{\text{newton}}{\text{meter}^3}$
Earth (not submerged) sand and gravel (wet)	120.0 pcf $= 18850 \frac{\text{newton}}{\text{meter}^3}$
Water	62.4 pcf $= 9802 \frac{\text{newton}}{\text{meter}^3}$
Frame partitions	
Wood or steel studs, $\frac{1}{2}$in gypsum board inside	8 psf = 383 pascal
Wood studs, 2x4 unplastered	4 psf = 192 pascal
Wood studs, 2x4 plastered one side	12 psf = 575 pascal
Wood studs, 2x4 plastered two sides	20 psf = 958 pascal
Movable steel partitions	4 psf = 192 pascal
Frame walls	
Exterior stud wall 2x4 @ 16in, $\frac{5}{8}$ gypsum insulated, $\frac{3}{8}$ in siding	11 psf = 526 pascal
Exterior stud wall 2x6 @ 16in, $\frac{5}{8}$ gypsum insulated, $\frac{3}{8}$ in siding	12 psf = 575 pascal
Exterior stud wall with brick veneer	48 psf = 2298 pascal
CMU wall 8in	60 psf = 9425 pascal
Window, glass, frame and sash	8 psf = 383 pascal
Cladding	
Fiber cement panels, large format 38.4in × 102in	3.2 psf = 153 pascal
Fiber cement panels, small scale 9.6in × 102in	3.2 psf = 153 pascal
Perforated metal panel at exterior HVAC location	
Floor truss	
Single chord @ 24in o.c. spacing	3.2 psf = 153 pascal
Double chord @ 24in o.c. spacing	4.25 psf = 203 pascal
Sheating	
Roof sheating	3.5 psf = 167 pascal
Floor sheating	2.5 psf = 120 pascal
Ceilings	2.5 psf = 120 pascal
Deck composite sleeperes (3in)	9.00 psf = 431 pascal

A.2 Live loads

Occupancy or use	Uniform	Concentrated	Notes
Private rooms and corridors serving them in multifamily dwelling	40.0 psf = 1915 pascal	-	*IBC-2018 Table 1607.1*
Stairs and exits	100.0 psf = 4788 pascal	300 pound = 1334 newton	*IBC-2018 Table 1607.1. Concentrated load on stair treads applied on an area of 2 inches by 2 inches*
Balconies and decks	same as occupancy served	-	*IBC-2018 Table 1607.1*
Garages (passenger vehicles only)	40.0 psf = 1915 pascal	-	*IBC-2018 Table 1607.1*
Cornices	60.0 psf = 2873 pascal	-	*IBC-2018 Table 1607.1*
Elevator machine room and control room grating	-	300 pound = 1334 newton	*IBC-2018 Table 1607.1. Concentrated load applied on an area of 2 inches by 2 inches*
Flat roof (not occupiable) + maintenace	20.0 psf = 958 pascal	300 pound = 1334 newton	*IBC-2018 Table 1607.1*
Yards and terraces, pedestrians	100.0 psf = 4788 pascal	-	*IBC-2018 Table 1607.1*
Sidewalks, vehicular driveways and yards, subject to trucking	250.0 psf = 11970 pascal	8000 pound = 35586 newton	*IBC-2018 Table 1607.1*
Corridors first floor	100.0 psf = 4788 pascal	-	*IBC-2018 Table 1607.1*
Store first floor	100.0 psf = 4788 pascal	-	*IBC-2018 Table 1607.1*

A.3 Snow loads

Ground snow load	$p_g = 60.0$ psf = 2873 pascal	*ASCE 7. Figure 7.1*
Exposure factor	$C_e = 1.0$	*ASCE 7. Table 7-2. Terrain category B, roof partially exposed*
Thermal factor	$C_t = 1.0$	*ASCE 7. Table 7-3.*
Snow load importance factor	$I_s = 1.0$	*ASCE 7. Table 7-4. Structure risk category II*
Snow load flat roof	$p_f = 0.7 \times C_e \times C_t \times I_s \times p_g = 0.7 \times 1.0 \times 1.0 \times 1.0 \times 60.0 = 42.0$ psf = 2873 pascal	*ASCE 7. Sect. 7.3*

A.4 Wind loads

Alternate all-heights method.		*IBC-2018, sect. 1609.6. Regularly shaped building, less than 75 feet in height, not sensitive to dynamic effects, not channeling effects or buffeting, simple diaphragm building*
Ultimate design wind speed	$V_{ult} = 115 \frac{\text{miles}}{\text{hour}} = 51 \frac{\text{meters}}{\text{second}}$	*IBC-2018, figure 1609.3(1). Risk category II building*
Velocity pressure exposure coefficient	$K_z = 0.72$	*ASCE 7, table 27.3.1. Exposure B, height above ground level $z \approx$ 33 feet*
Topographic factor	$K_{zt} = 1.0$	*ASCE 7, sect. 26.8*

Net pressure coefficients C_{net}. Main windforce-resisting frames and systems

IBC-2018, Table 1609.6.2, enclosed

Description	C_{net} + Internal pressure	C_{net} - Internal presure
Windward wall	0.43	0.73
Leeward wall	-0.51	-0.21
Sidewall	-0.66	-0.35
Parapet windward wall	1.28	
Parapet leeward wall	-0.85	
Flat roof	-1.09	-0.79

Design wind pressures P_{net}. Main windforce-resisting frames and systems

IBC-2018, sect. 1609.6.3

$P_{net} = 0.00256 \times V^2 \times K_z \times C_{net} \times K_{zt}$

Description	P_{net} + Internal pressure	P_{net} - Internal presure
Windward wall	10.5 psf = 501 pascal	17.8 psf = 852 pascal
Leeward wall	-12.4 psf = -595 pascal	-5.1 psf = -245 pascal
Sidewall	-16.1 psf = -770 pascal	-8.5 psf = -409 pascal
Parapet windward wall	31.2 psf = 1494 pascal	
Parapet leeward wall	-20.7 psf = -992 pascal	
Flat roof	-26.6 psf = -1272 pascal	-19.3 psf = -992 pascal

A.5 Earthquake loads

Parameter 0.2-second spectral response acceleration	$S_s = 0.045$	*IBC-2018, figure 1613.3.1(1). Site class B*
Parameter 1-second spectral response acceleration	$S_1 = 0.038$	*IBC-2018, figure 1613.3.1(2). Site class B*
Seismic design category	$S_1 \leq 0.04$ *and* $S_s \leq 0.15 \rightarrow$ SDS A	*IBC-2018, sect. 1613.3.1*
Site coefficients	$F_a = 1.0$, $F_v = 1.0$	*IBC-2018, tables 1613.3.3(1) and 1613.3.3(2). Site class B*
Maximum considered earthquake spectral response acceleration for short periods	$S_{MS} = F_a \cdot S_s = 0.045$	*IBC-2018, sect. 163.3.3*
	$S_{M1} = F_a \cdot S_1 = 0.038$	*IBC-2018, sect. 163.3.3*
Design spectral response acceleration parameters	$S_{DS} = \frac{2}{3} S_{MS} = 0.03$	*IBC-2018, sect. 163.3.4*
	$S_{D1} = \frac{2}{3} S_{M1} = 0.025$	*IBC-2018, sect. 163.3.4*