

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

XC structural engineering

July 7, 2019

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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).

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 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

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.

## 4 Seismic design criteria

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

## 5 Materials

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

## 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](http://xcengineering.xyz/html_files/software.html)).

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

Table 4: Seismic Design Criteria

Parameter	Value
Building Latitude/Longitude	44°49'01.8"N 91°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

## 7 Load combinations

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

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

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

## 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 $\times$ 102in	3.2 psf = 153 pascal
Fiber cement panels, small scale 9.6in $\times$ 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

#### Sheathing

Roof sheathing	3.5 psf = 167 pascal
Floor sheathing	2.5 psf = 120 pascal
Ceilings	2.5 psf = 120 pascal
Deck composite sleepers (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) + maintenance	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	$p_g = 60.0 \text{ psf} = 2873 \text{ pascal}$	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
<b>Snow load flat roof</b>	$p_f = 0.7 \times C_e \times C_t \times I_s \times p_g = 0.7 \times 1.0 \times 1.0 \times 1.0 \times 60.0 = 42.0 \text{ psf} = 2873 \text{ pascal}$	ASCE 7. Sect. 7.3



## A.4 Wind loads

Alternate all-heights method.

Ultimate design wind speed	$V_{ult} = 115 \frac{\text{miles}}{\text{hour}} = 51 \frac{\text{meters}}{\text{second}}$
Velocity pressure exposure coefficient	$K_z = 0.72$
Topographic factor	$K_{zt} = 1.0$

*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*

*IBC-2018, figure 1609.3(1). Risk category II building*

*ASCE 7, table 27.3.1. Exposure B, height above ground level  $z \approx 33$  feet*

*ASCE 7, sect. 26.8*

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

Description	$C_{net} + \text{Internal pressure}$	$C_{net} - \text{Internal pressure}$
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

*IBC-2018, Table 1609.6.2, enclosed*

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

$P_{net} = 0.00256 \times V^2 \times K_z \times C_{net} \times K_{zt}$		
Description	$P_{net} + \text{Internal pressure}$	$P_{net} - \text{Internal pressure}$
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

*IBC-2018, sect. 1609.6.3*

## A.5 Earthquake loads

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