# Existing Structural System:
# Post-Tensioned Slab with Concrete Columns and Shear Walls

**Existing Conditions**

*Condominium Tower*

The condominium building will be supported by a deep foundation system that will support the columns, walls, and slabs. The piles will be HP12×84 steel piles driven to 225 tons with a net bearing capacity of 200 tons. These piles will be grouped at columns and transfer load from columns using pile caps. A typical interior pile cap will be 7'-9"×11'-0" and 38 inches thick, with reinforcement in both directions. An exterior pile cap will be 7'-9"×7'-9" with 4 piles and a depth of 32 inches. Concrete grade beams span from column pile cap to pile cap and support the exterior walls of the building. The first floor slab will be a 12 inch thick concrete slab with #7 reinforcement at 12 inches on-center each way, top and bottom.

The condominium building floors will have 8 inch thick post-tensioned concrete slabs. The slabs span between columns spaced at 28'-6" in one direction and 23'-0" in the other direction. A typical interior column is 16"×52", and its reinforcement and concrete strength decreases at upper floors. The exterior columns are 16"×36". Concrete shear walls (varying 12-16 in., depending on location) provide lateral resistance and are located generally around elevators and stair towers and are scattered throughout the plan. The mechanical penthouse roof will be framed by steel beams spaced at 6 ft. on-center with 1 ½" deep, 22 gage roof deck spanning in between these beams. The mechanical area will be enclosed by metal panels with steel stud support. The cooling tower will similarly be enclosed with metal paneling, with a structural channel girt system to support it.

*Parking Garage*

For the parking garage, additional steel piles (80 ton HP12x53) will be added at approximately 20 feet on-center to support the lowest level slab.  The exterior columns will have 9’-0”×9’-0”×3’-0” deep pile caps with (5) HP 12×84 piles.  The interior walls will have a 6’-0” wide grade beam with HP12×84 piles on each side of the wall, spaced 8’-0” on-center.  The slab spanning these piles and columns will be the same as the apartment building slab.

The floor framing of the parking garage will be 34 inch deep pre-topped double tees which span between 45 to 60 feet.  An “L” shaped beam makes up the exterior of the building and support the pre-cast tees.  These L beams will span approximately 48 feet from column to column.  The interior support, including the support of the sloping tees, will be supported by 12 inch thick pre-cast light wall.  The exterior pre-cast columns will be approximately 24”×36”.  12-inch thick shear walls located throughout the plan will resist the lateral loads on the parking garage.  In the northern

*Interface Between Condominium Tower and Parking Garage*

For the first seven floors of the combined, the parking garage adjoins the condominium tower, and is separated by an expansion joint which spans the full depth of the parking garage.  This parking garage was considered a stabile and completely independent entity from the tower in the scope of this report**,** and further research was concentrated on the condominium tower structure and its systems.

**Structural Material Specifications**

*Concrete*

- Foundations (Pile Caps and Grade Beams): 6,000 psi normal weight
- Slab on Grade: 4,000 psi normal weight
- Post Tensioned Slabs and Beams: 5,000 psi normal weight
- Columns: 5,000 and 6,000 psi normal weight
- Precast Garage Panels: 5,000 psi concrete

*Concrete Reinforcing*

- Deformed Reinforcing Bars: ASTM A615 Grade 60
- Welded Wire Fabric: ASTM A185

*Structural Steel*

- Wide Flange Shapes: ASTM A992
- M, S, Channels, Angle Shapes: ASTM A36
- Hollow Structural Steel: ASTM A500 Grade B
- Structural Pipe: ASTM A53 Grade B

**Existing Gravity Loading**

*Live Loads*

| Area Type | Provided Design Values | Table 1606 of BOCA 1996 Code |
|---|---|---|
| Parking Garage | 50 psf | 50 psf (Passenger cars only) |
| Balconies | 60 psf | 60 psf (One- and two-story dwellings that do not exceed 100 sq. ft.) |
| Exit Stairs | 100 psf | 100 psf (Fire Escapes) |
| Tower Floors | 40 psf | 40 psf (Dwelling units and corridors) |
| Partitions | 20 psf (where applicable) | 20 psf minimum (by 1606.2.4 of code) |
| Terrace | 100 psf | 100 psf (Exterior balcony) |
| Mechanical Rooms | 150 psf | |
| Elevator Machine Room | 150 psf | |

*Live Load Calculation Results*

| Floor/Level | Primary Usage | Total LL per floor (kips) | (psf) | With 50% Reduction |
|---|---|---|---|---|
| 1 | Parking/Residential | 1461.35 | 49.62 | 24.81 |
| 2 | Parking/Residential | 1486.68 | 49.70 | 24.85 |
| 3 to 6 | Parking/Residential | 1514.48 | 49.68 | 24.84 |
| 7 | Parking/Residential | 1968.19 | 49.75 | 24.88 |
| 8 | Residential/Terrace | 2148.59 | 67.97 | 33.99 |
| 9 to 22 | Residential | 597.11 | 49.0 | 24.5 |
| 23 | Penthouse/Mechanical | 926.05 | 99.5 | 49.75 |
| 24 to 25 | Mechanical | 160.5 | 150 | 75 |
| Roof | ----- | 365.58 | 30 | 15 |

*Dead Load Calculation Results*

| Self Weights Per Level | | | | | |
|---|---|---|---|---|---|
| **Level** | **Column (k)** | **Slab (k)** | **Shear Wall (k)** | **Total (k)** | **Total (psf)** |
| Roof | N/A | N/A | 374.73 | 400* | 373 |
| 24 to 25 | 20.13 | 104.86 | 374.73 | 499.72 | 467 |
| 23 | 42.73 | 912.09 | 374.73 | 1329.55 | 143 |
| 9 to 22 | 42.73 | 1194.23 | 384.1 | 1621.06 | 133 |
| 8 | 59.01 | 3097.78 | 483.54 | 3640.33 | 115 |
| 7 | 55.96 | 3876.88 | 483.54 | 4416.38 | 112 |
| 3 to 6 | 55.96 | 2987.63 | 483.54 | 3527.13 | 115.7 |
| 2 | 61.99 | 2906.97 | 483.54 | 3452.5 | 116.4 |
| 1 | 58.76 | 2886 | 483.54 | 3428.3 | 116 |
| | | | | 54469.86 | 4234.2 |

*Roof and Snow Loads*

- Minimum Roof Live Load: 30 psf
- Ground Snow Load: 30 psf
- Snow Load Importance Factor: 1.0
- Snow Exposure Factor: 0.7
- Thermal Factor: 1.0
- Flat Roof Snow Load: 14.0 psf (Specified in construction documents as 20 psf minimum)

*Drift and Deflection Criteria:* As provided by O'Donnell & Naccarato, Structural Engineer:

- Lateral wind and seismic loads:
  - Interstitial drift: L/400 *(where L= floor-to-floor height)*
- Vertical gravity and live loads:
  - L/360 under live loads
  - L/240 under total load *(where L= span of member under consideration in both cases)*

**Existing Lateral System**


Simplified Building Schematic: Complete Footprint

*Key:*
- *Tower Columns*
- *Tower Shear Walls*
- *Parking Garage Columns*
- *Parking Garage Shear Walls*
- *Expansion Joint*

*Solid Lines:* Tower Perimeter *(whole building)*
*Dashed Line:* Parking Garage Levels
*(Base to Eighth Floor)*

The River Tower at Christina Landing uses reinforced concrete shear walls as its primary lateral resistance, with help from the large rectangular concrete columns oriented perpendicular to the controlling wind loading in the wide direction. The greatest amount of lateral resistance is provided on the lower levels to account for the largest shear forces. Additional shear walls are located on the lower parking garage levels (the lower eight levels of the building), mostly near elevator and stairwell openings and the eastern walls, as shown in the diagram above. The shear walls located in the condominium tower, which stands the full 25 stories of the building, are relatively consistent in location and size, with occasional openings left for stairwells, elevators, and other architectural features. The thickness of these common stairwells is relatively

consistent, although the concrete strength for the shared parking garage/condominium levels (foundation to eighth floors) of this tower is 6000 psi. From the ninth to 25th floors, the concrete strength for the tower shear walls decreases to 5000 psi. Please consult the included concrete shear wall schedule below for more detailed information.

The parking garage areas are similar to the condominium tower in that reinforced concrete shear walls and thick columns provide the lateral resistance. The main structural system for the parking garage is a light precast concrete wall system with precast columns. The floor system consists of a pre-topped double-tee system, as noted previously.

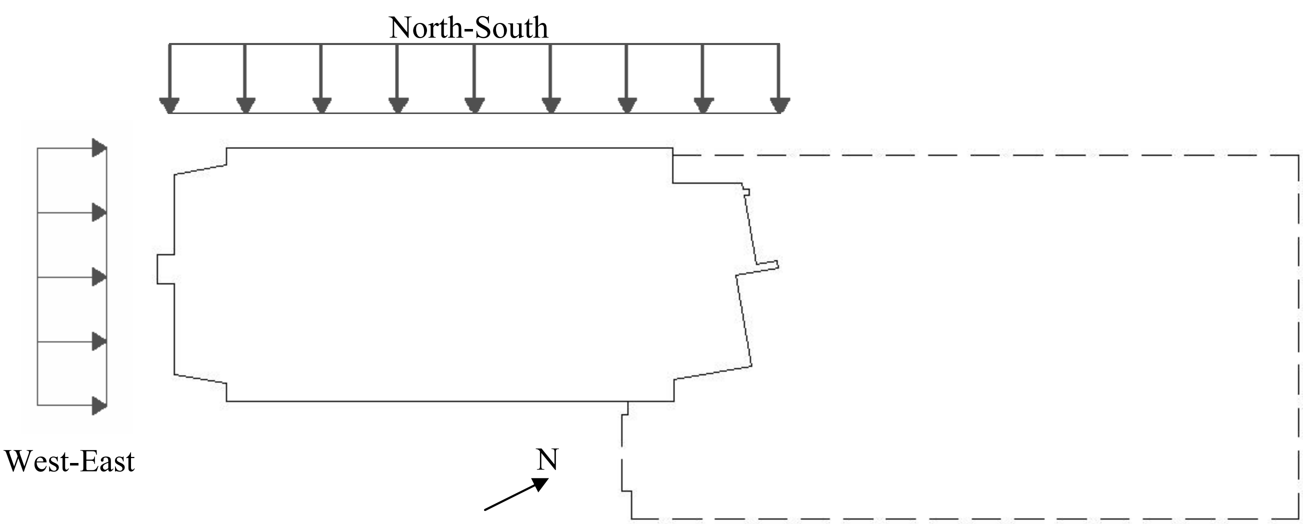
**CONCRETE SHEAR WALL SCHEDULE**

| LEVEL \ MARK | | SW1 | SW2 | SW3 | SW4 | SW5 | SW6 | SW7 | SW8 | SW9 | SW10 | SW11 | SW12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15TH - ROOF | VERT. STL. | #4 @ 12 | #8 @ 8 | #6 @ 12 | (22) #9 | #7 @ 12 | #9 @ 12 | #9 @ 12 | (18) #9 | #7 @ 12 | - | #9 @ 12 | - |
| | HORIZ. STL. | #4 @ 12 | #4 @ 12 | #4 @ 14 | #4 @ 12 | #4 @ 12 | #4 @ 12 | #4 @ 12 | #4 @ 12 | #4 @ 12 | - | #4 @ 12 | - |
| | f'c | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | - | 5000 | - |
| | THICKNESS | 16 | 12 | 9 | 12 | 12 | 12 | 12 | 12 | 12 | - | 12 | - |
| 8TH - 15TH | VERT. STL. | #5 @ 12 | #10 @ 8 | #11 @ 10 | (22) #11 | #9 @ 12 | #11 @ 8 | #11 @ 8 | (18) #11 | #9 @ 12 | - | #11 @ 8 | - |
| | HORIZ. STL. | #4 @ 12 | #4 @ 12 | #4 @ 14 | #4 @ 12 | #4 @ 12 | #4 @ 12 | #4 @ 12 | #4 @ 12 | #4 @ 12 | - | #4 @ 12 | - |
| | f'c | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | 5000 | - | 5000 | - |
| | THICKNESS | 16 | 12 | 9 | 12 | 12 | 12 | 12 | 12 | 12 | - | 12 | - |
| FND. - 8TH | VERT. STL. | SEE DETAIL SW1/S200 | #10 @ 8 | #11 @ 11 | (22) #11 | #9 @ 12 | #11 @ 8 | #11 @ 8 | (18) #11 | #9 @ 12 | #14 @ 13 | #11 @ 8 | #14 @ 13 |
| | HORIZ. STL. | | #4 @ 12 | #4 @ 14 | #4 @ 12 | #4 @ 12 | #4 @ 10 | #4 @ 10 | #4 @ 12 | #4 @ 12 | #5 @ 10 | #4 @ 12 | #5 @ 10 |
| | f'c | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 5000 | 6000 | 5000 |
| | THICKNESS | 16 | 12 | 9 | 12 | 12 | 12 | 12 | 12 | 12 | 24 | 12 | 24 |

*Concrete Shear Wall Schedule from Sheet S200, Courtesy of O'Donnell & Naccarato*

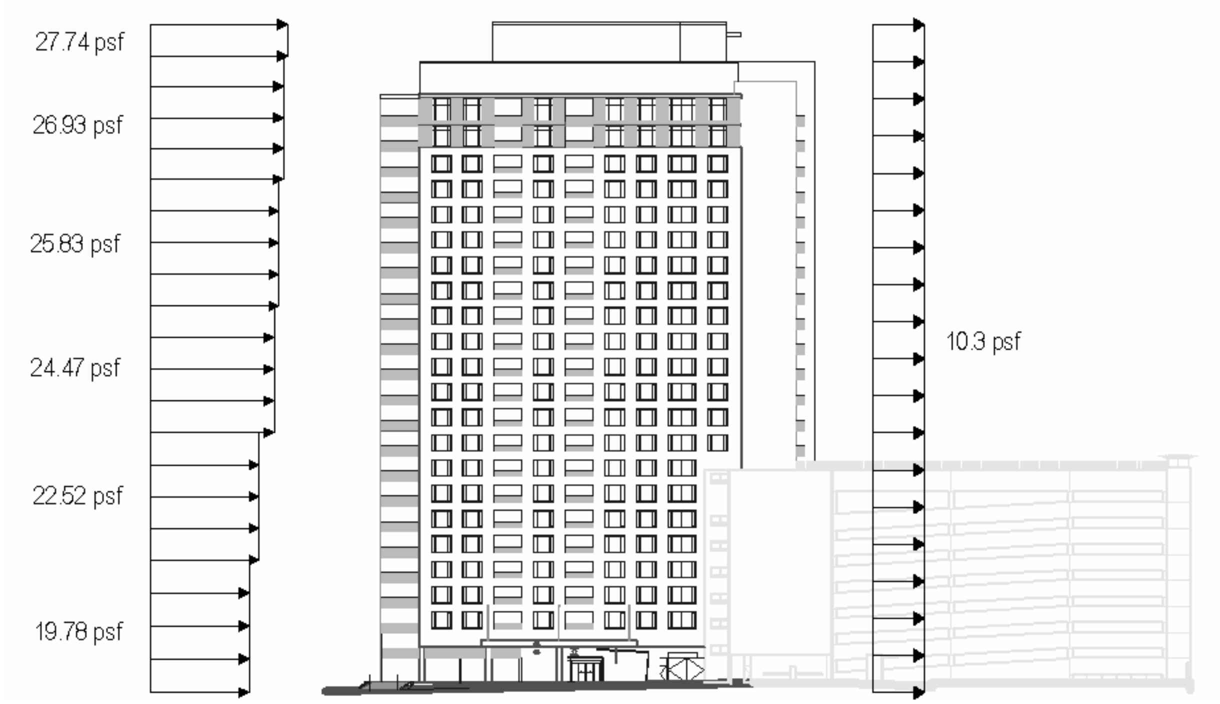
*Wind Loading Criteria*

- Wind Importance Factor: 1.04
- Wind Exposure: C
- Components and Cladding Loads: vary per code requirements
- Load Diagrams with results provided on next page

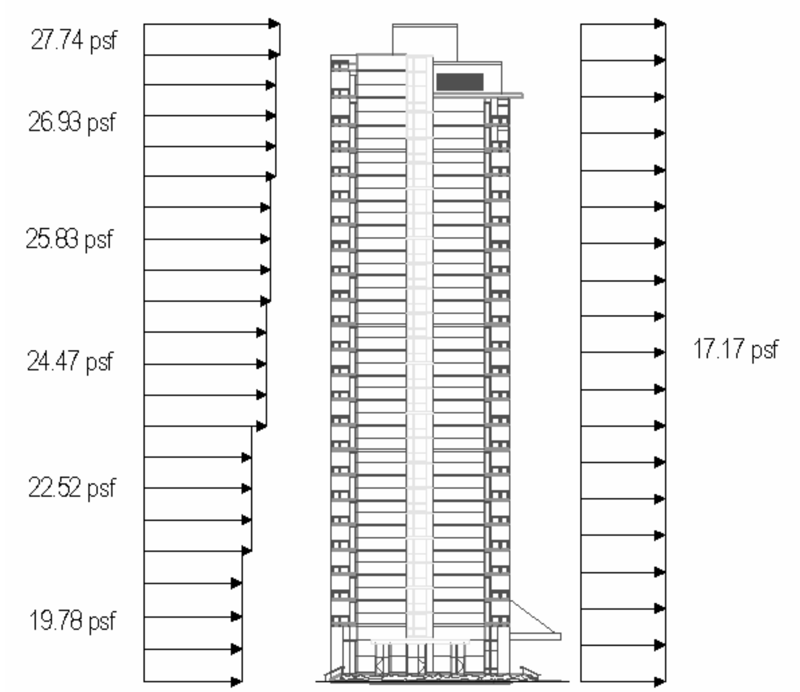



Wind Direction Schematic:
*Condominium Tower shown in solid line*
*Parking garage shown in dashed line*

When compared to the seismic loading results, the wind loading controlled as the primary source of lateral loading. This is to be expected, as the site of the building is in Wilmington, DE and along the riverfront. This riverfront location provides the reasoning behind the choosing of Wind Exposure category "C," which differs from the information on the project's Structural Narrative. This, however, provides larger loads and therefore, a more conservative analysis of the lateral system. Diagrams of the wind pressures in both major directions of the building are provided on the following page.




Wind Pressures (psf) in West-East Direction




Wind Pressures (psf) in North-South Direction

*Seismic Loading Criteria*

- Seismic Importance Factor: 1.0
- $A_v$ (Velocity related acceleration coefficient) = 0.075
- $A_a$ (Peak acceleration coefficient) = 0.05
- Seismic Design Category: B
- Basic Seismic Force Resisting System: Dual system with shear wall and intermediate concrete frame
- Response Modification Factor, R = 6
- Site Coefficient, $S_4$ = 2.0
- Analysis Procedure Used: Equivalent Force Method
- Base Shear = V = 849.73 kips

**Structural Design and Theory**

The riverfront location of the River Tower necessitated the use of piles as foundation support, as a spread foundation would not be sufficient in construction so close to the riverbed. The shear walls provide the lateral resistance for the structure, while the flat plate post-tensioned slabs distribute the gravity loads. Part of the reason for the choosing of a post-tensioned flat plate slab, as opposed to another type of two-way or a reinforced slab, is its improved resistance to punching shear. Whereas a reinforced flat plate system would most likely require drop panels or column capitals to provide this necessary shear resistance, the post-tensioning element provides this benefit without additional slab depth. This allows for speedier construction, and ultimately more cost- and space-efficient structures.