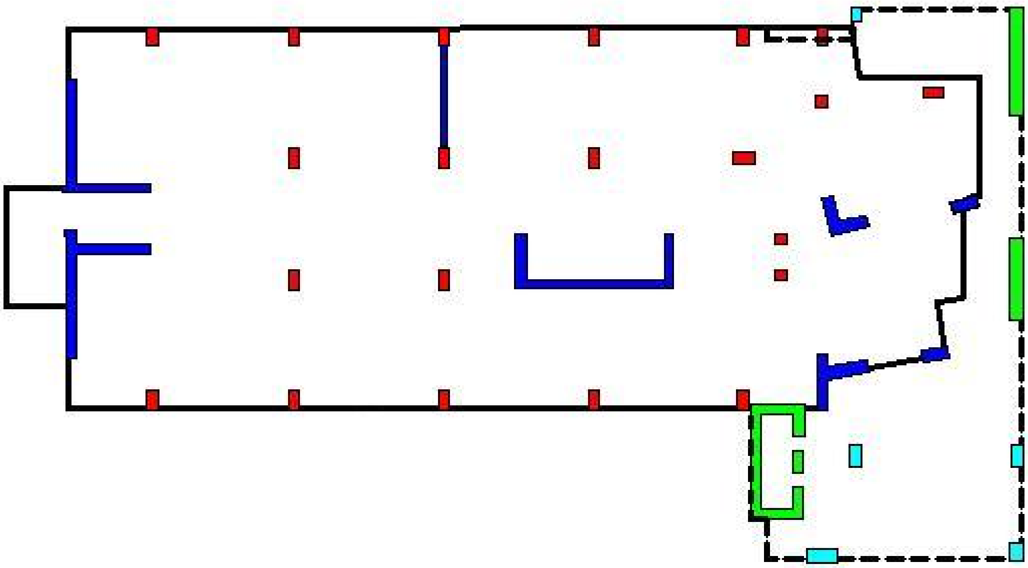
Introduction to Structural System



Simplified Building Schematic for Typical Floor
(Levels 9 through 22):

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

Solid Lines: Tower Perimeter (whole building)
Dashed Line: Garage Addition (Up to 8th Floor)

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 HP12x84 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"x11'-0" and 38 inches thick, with reinforcement in both directions. An exterior pile cap will be 7'-9"x7'-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"x52", and its reinforcement and concrete strength decreases at upper floors. The exterior columns are 16"x36". 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"x9'-0"x3'-0" deep pile caps with (5) HP 12x84 piles. The interior walls will have a 6'-0" wide grade beam with HP12x84 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"x36". 12-inch thick shear walls located throughout the plan will resist the lateral loads on the parking garage.

Governing Codes and Standards

Primary Building Code
BOCA 1996 Building Official and Code Administration with City of Wilmington Amendments

Loads and Serviceability Requirements
American Society of Civil Engineers, "Minimum Design Loads for Buildings and Other Structures" (ASCE 7-02)

Concrete
American Concrete Institute, Building Code Requirements for Reinforced Concrete (ACI318-02)

Masonry
Building Code Requirements for Masonry Structures (ACI530-02/ASCE 5-02)

Structural Steel
American Institute of Steel Construction, Specification for Structural Steel Buildings

Light Steel Framing
American Iron and Steel Institute, Specifications for the Design of Cold-Formed Steel Structural Members, Specification for Structural Steel Buildings
Allowable Stress Design and Plastic Design (AISI CFSD-ASD)

Precast Concrete
Precast/Prestressed Concrete Institute, Design Handbook-Precast and Prestressed Concrete: Code of Standard Practice for Precast/Prestressed Concrete (PCI MNL-120)

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 Structural Loading

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	

<u>Live Load Calculation Results</u>*:* please see Appendix A for detailed calculations

Floor/Level	Primary Usage	Total LL per floor (kips)	(psf)
1	Parking/Residential	1461.35	49.62
2	Parking/Residential	1486.68	49.70
3 to 6	Parking/Residential	1514.48	49.68
7	Parking/Residential	1968.19	49.75
8	Residential/Terrace	2148.59	67.97
9 to 22	Residential	597.11	49.0
23	Penthouse/Mechanical	926.05	99.5
24 to 25	Mechanical	160.5	150
Roof	-----	365.58	30

Live Load Reductions

- "Live loads of 100 psf or less shall be reduced in accordance with the Code established procedure, except at the parking garage levels or roof, where live loads will not be reduced…" (consistent with BOCA 1996 1606.7.2.2). For simplicity, I did not consider these reductions on any level, although levels 8-22 would have been eligible.

<u>Dead Load Calculation Results:</u> please see Appendix B for detailed calculations

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

**Please see Appendix B for more clarification on assumptions on roof self weight. In addition to those self weights listed here, there has been an estimation of 20 psf for partition loads where applicable.*

<u>Roof and Snow Loads</u>

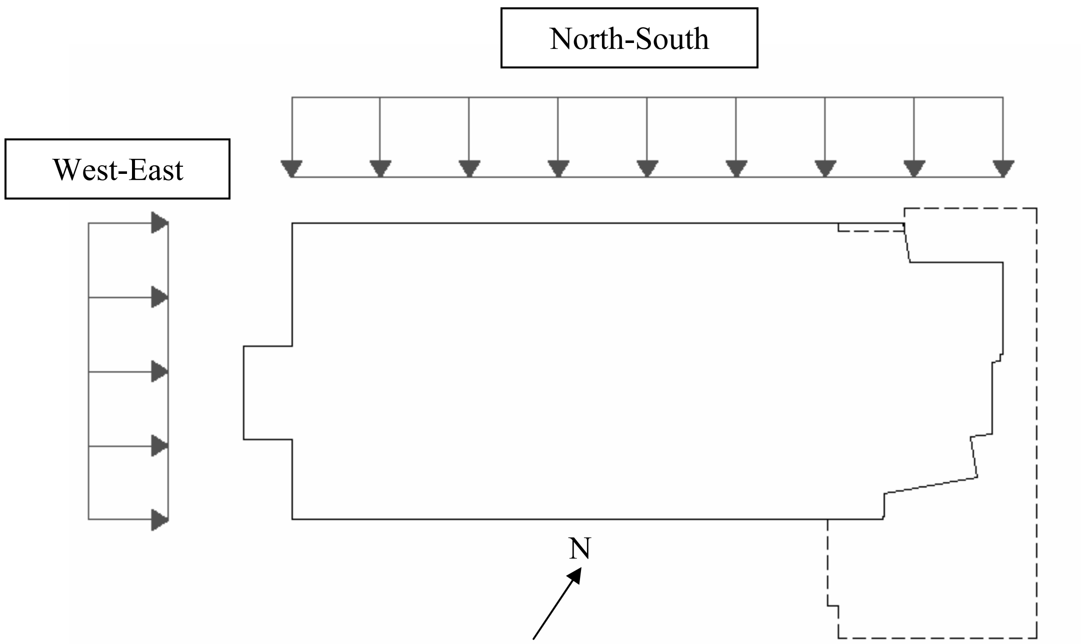
- <u>Minimum Roof Live Load:</u> 30 psf
- <u>Ground Snow Load:</u> 30 psf
- <u>Snow Load Importance Factor:</u> 1.0
- <u>Snow Exposure Factor:</u> 0.7
- <u>Thermal Factor:</u> 1.0
- <u>Flat Roof Snow Load:</u> 14.0 psf (Specified in construction documents as 20 psf minimum)
- *Please consult Appendix C for detailed Snow Load Calculations*

<u>Drift and Deflection Criteria:</u> As provided by O'Donnell & Naccarato, Structural Engineer:

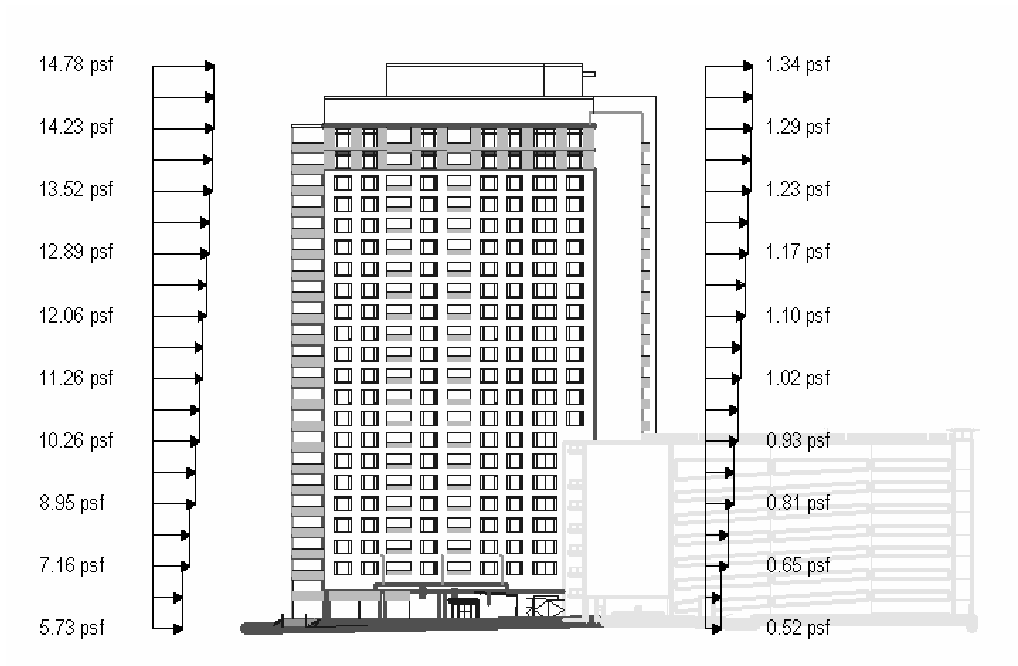
- <u>Lateral wind and seismic loads:</u>
  - Interstitial drift: L/400 *(where L= floor-to-floor height)*
- <u>Vertical gravity and live loads:</u>
  - L/360 under live loads
  - L/240 under total load *(where L= span of member under consideration in both cases)*

Wind Loads

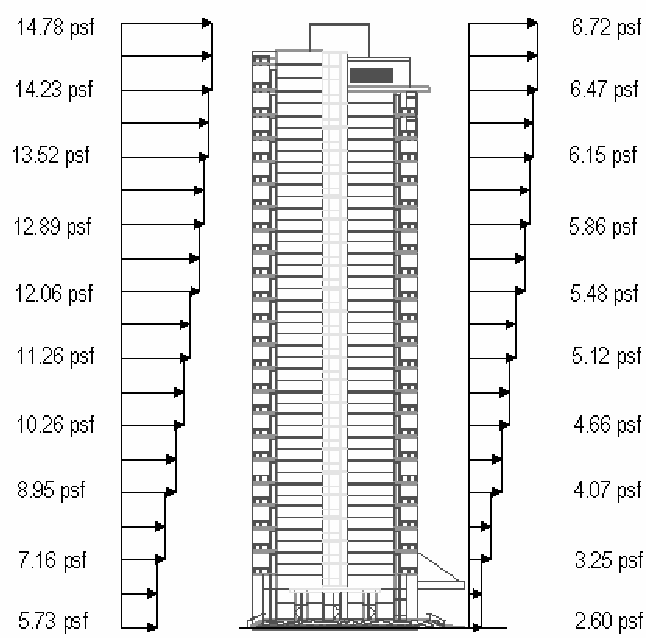
- Basic Wind Speed: 80 mph
- Wind Importance Factor: 1.04
- Wind Exposure: B
- Internal Pressure Coefficient: +/-0.25
- Components and Cladding Loads: vary per code requirements
- *Load Diagrams with results provided on next page*
- *Please consult Appendix D for detailed Wind Load Calculations*



Wind Direction Schematic:
Only tower considered for simplicity;
Parking garage (dashed) not considered



Wind Pressures (psf) in West-East Direction



Wind Pressures (psf) in North-South Direction

Seismic Loads

- 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 iteration
- Response Modification Factor, R = 6
- Site Coefficient, S_4 = 2.0
- Analysis Procedure Used: Equivalent Force Method
- Base Shear = V = 849.73 kips
- *Please see Appendix E for detailed Seismic Load Calculations and results*

Structural Design and Theory

From my own personal discussions with the structural engineers on this project, the Residences at Christina Landing tower, a 23-story apartment building adjacent to this structure, served as the initial inspiration for the River Tower's design. The Residences at Christina Landing was designed structurally by the Kling engineering firm, and in fact was the subject of Ms. Pamela A. Morris' senior thesis project of 2004-2005. This structure, which is in the process of being completed, made use of two-way precast concrete floor slabs.

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.

Preliminary Spot Check and Lateral Analysis

I attempted to perform a spot check analysis on the post-tensioned slab based on my dead and live load calculations. This proved difficult as my knowledge and experience with both post-tensioned and reinforced slabs are severely limited. Because of the post-tensioning in the slab, the Equivalent Frame Method was recommended by ACI. I then tried to check the slab using Ultimate Flexural Strength Analysis, considering a small 12" section of the slab as a beam. However, this over-simplification (and perhaps poor assumptions along the way) has that compressive reinforcement is needed in the interior bay of the tenth floor that I was analyzing, as shown on the following page. Because this does not match the actual design, I reasoned that my assumptions and methods are not applicable in this case. Unfortunately, this particular system has not been part of my curriculum as of yet, so I will further investigate these methods of analysis and their applicability in future reports. Please consult Appendix F for the Spot Check Calculations in greater detail.

The lateral resistance check of the shear walls, also taken from the tenth floor for consistency, appeared to verify the actual design as the reinforcement and deflection of the wall met the minimum criteria of which I was aware. Again, this was a first attempt at such an analysis, and a more proficient method will be used in the future to confirm the legitimacy of the actual designs. My spot check for gravity loading and lateral resistance checks are only preliminary investigations into the analysis, and will be updated in future reports. Please consult Appendix G for the Lateral Resistance Check calculations in greater detail.

<u>Typical Floor Plan:</u>
From Sheet S104
Courtesy of O'Donnell & Naccarato