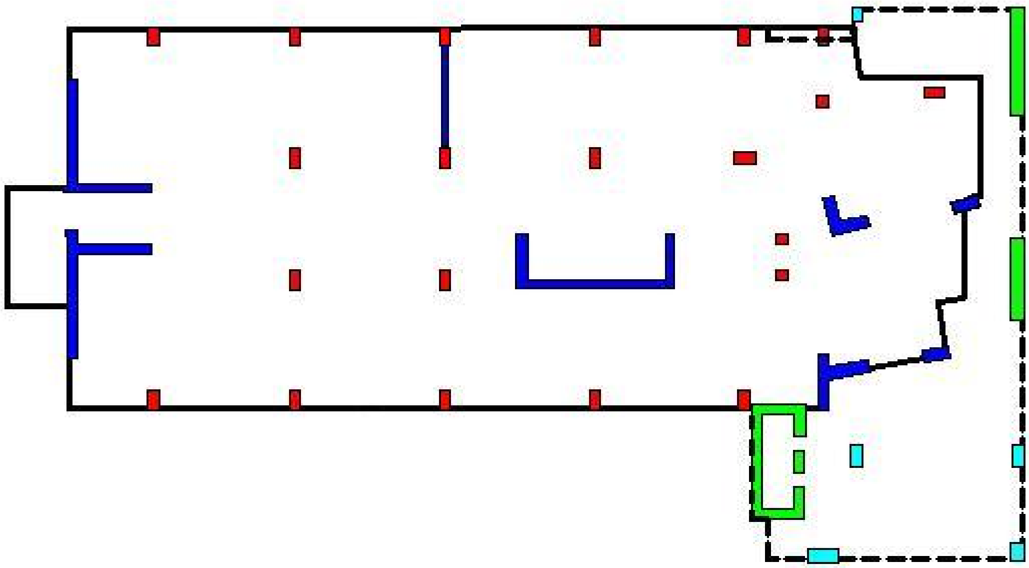
Introduction to the Lateral System



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: Parking Garage Levels
(Foundation Level to Eighth Floor)

The River Tower at Christina Landing uses reinforced concrete shear walls as its lateral resistance. Naturally, the most amount of lateral resistance is provided on the lower levels, where the lateral forces are the greatest. There 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. Included below is the Concrete Shear Wall schedule from drawing sheet S200, provided by O'Donnell & Naccarato, Inc., the structural engineer on the project.

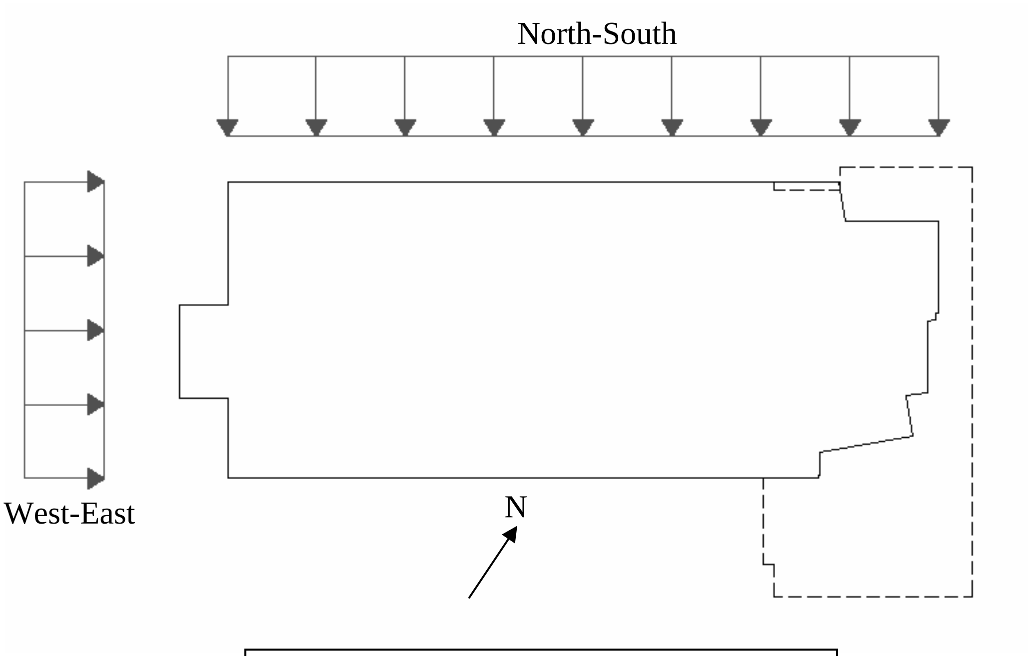
CONCRETE SHEAR WALL SCHEDULE													
LEVEL \ MARK		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12
15TH - ROOF	VERT. STL.	#4 @ 12	#8 @ 8	#6 @ 12	(22) #9	#7 @ 12	#9 @ 12	#9 @ 12	(18) #9	#7 @ 12	-	#9 @ 12	-
	HORIZ. STL.	#4 @ 12	#4 @ 12	#4 @ 14	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	-	#4 @ 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

The parking garage areas are similar to the condominium tower in that reinforced concrete shear walls 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 tee beam system. The roof level uses steel framing as its structural system, with moment connections. For the purposes of simplification, only the condominium tower and parking garage was analyzed in the following lateral analysis, considering each concrete shear wall individually.

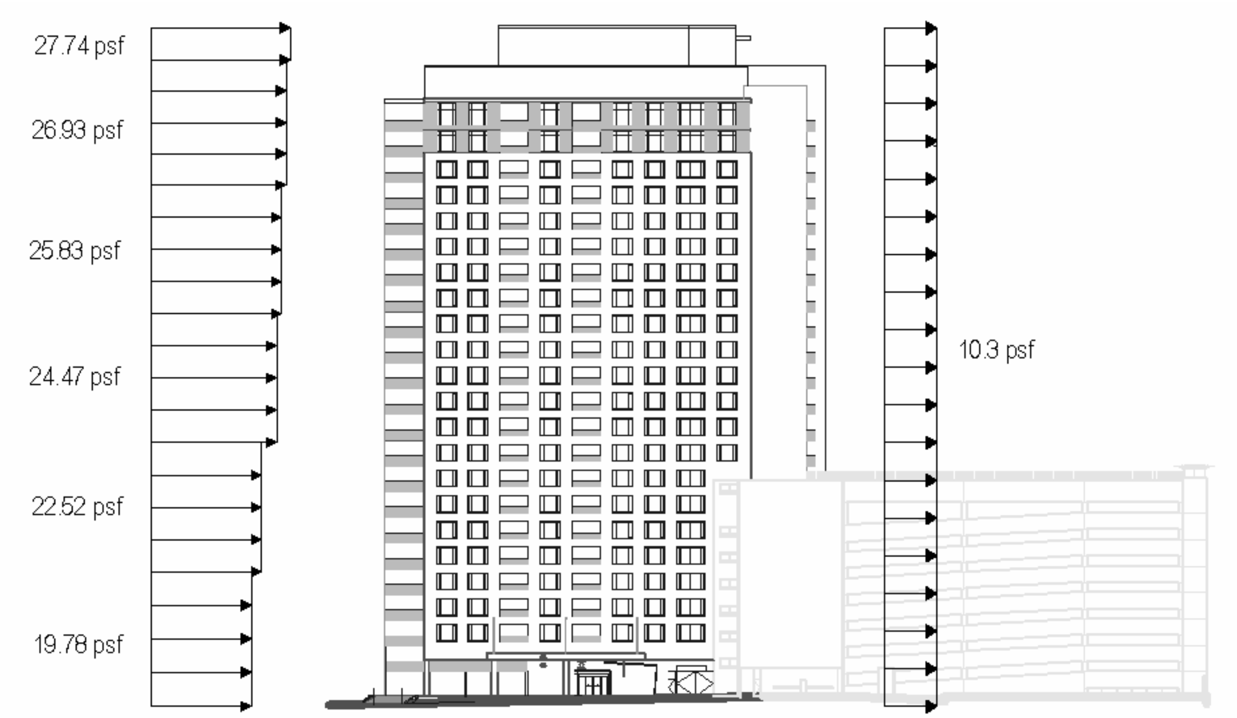
Wind Loading Criteria

- Wind Importance Factor: 1.04
- Wind Exposure: C
- Components and Cladding Loads: vary per code requirements
- Load Diagrams with results provided on next page
- Please consult Appendix B for detailed Wind Load Calculations

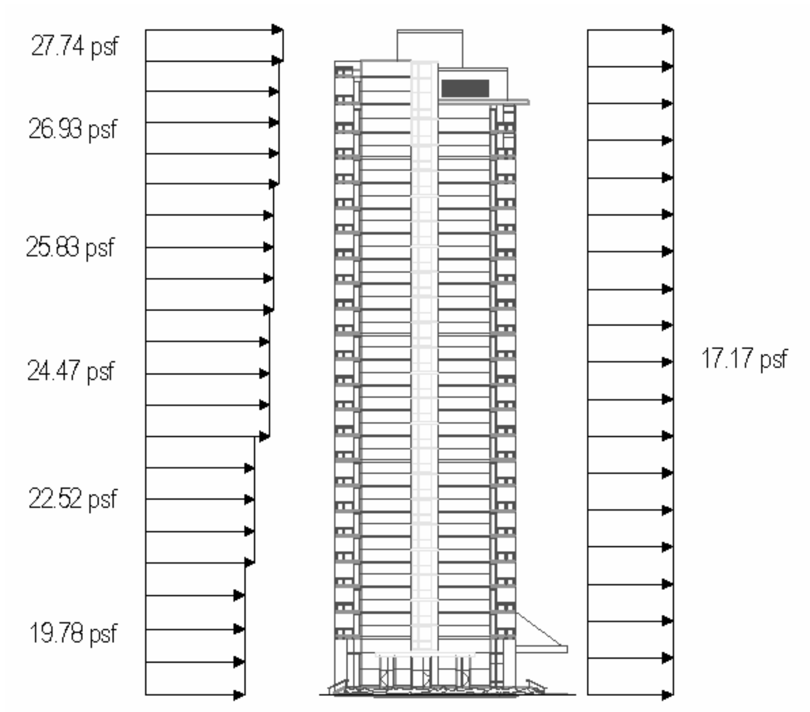


Wind Direction Schematic:
Condominium Tower shown in solid line;
Parking garage floors in dashed line

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 next 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
- *Please see Appendix C for detailed Seismic Load Calculations and results*

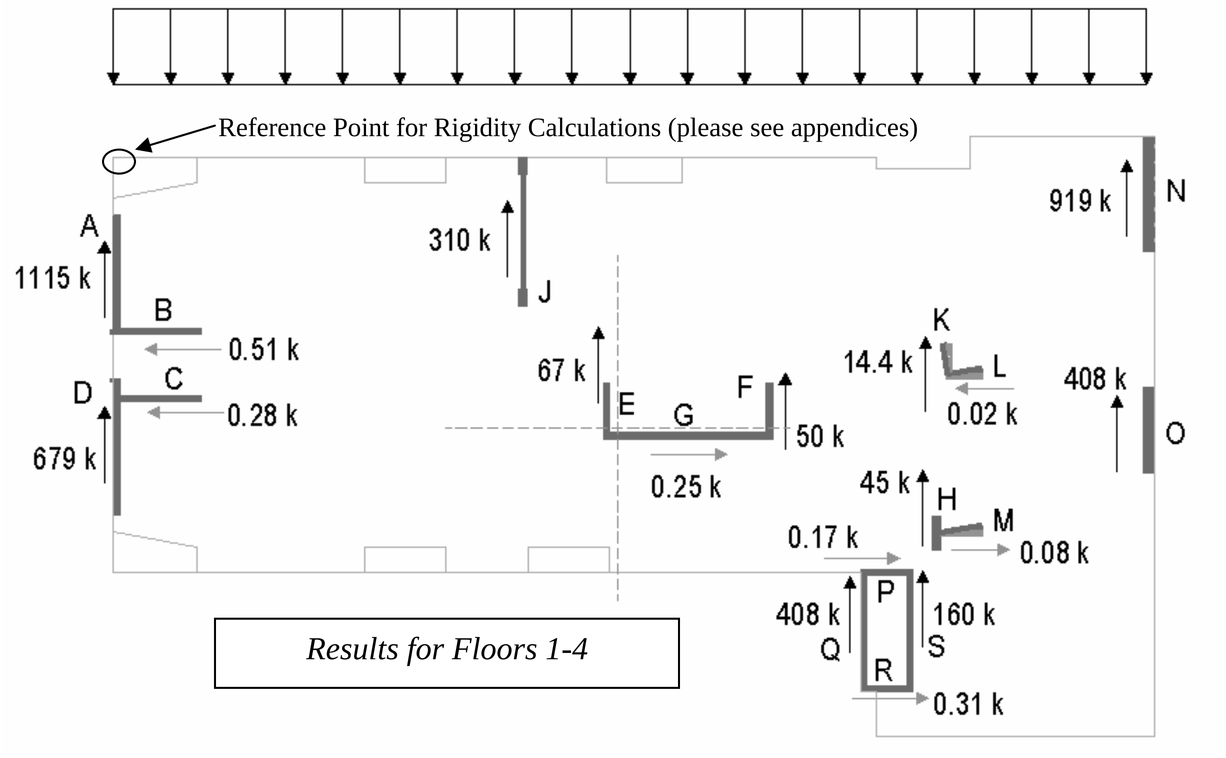
Due to the magnitude of the wind loading, seismic loading was not considered in the lateral resistance calculations. The results of the seismic loading criteria are given in Appendix C for comparative purposes, and also relate to the story drift calculations.

Lateral Resistance Calculations

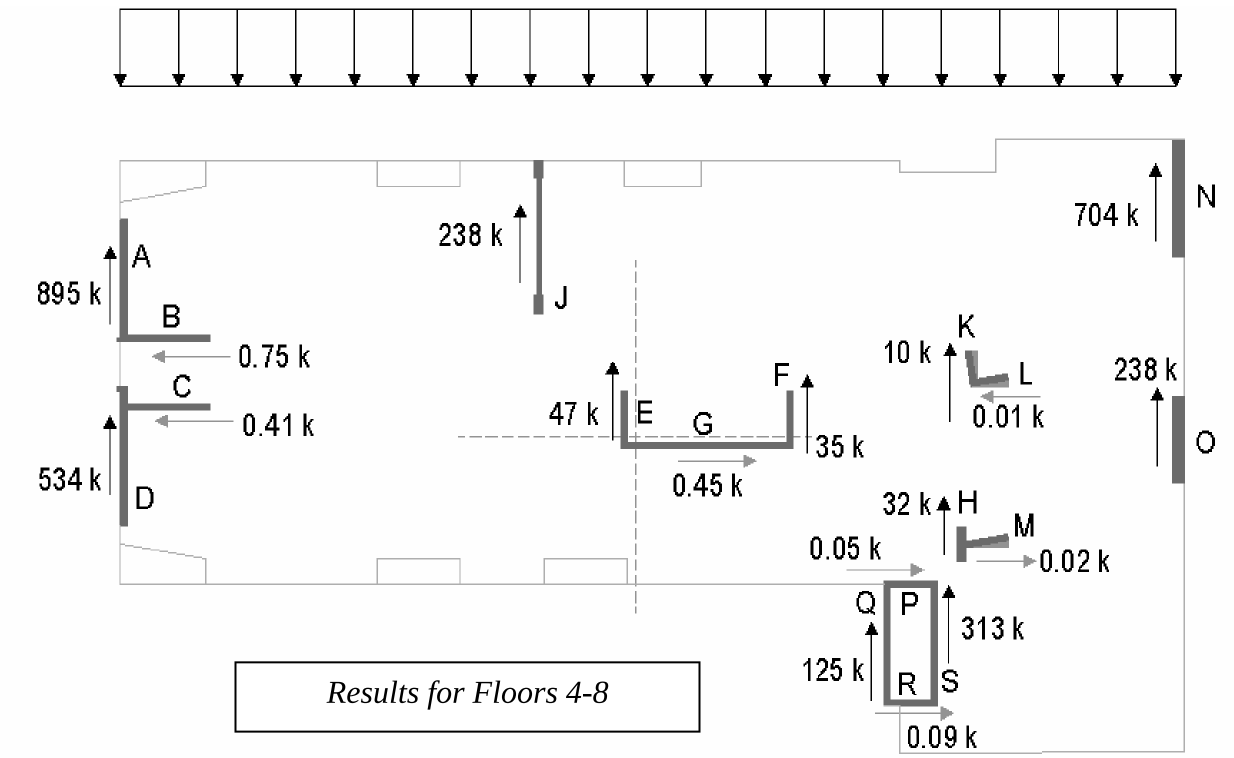
Analyzing the shear wall system for such a tall building can be a complicated task. Therefore, rather than consider each of the 25 floors individually, the building was simplified due to the relatively consistent layout of the shear wall system. The floors were divided into six approximate sections, consisting of 4 floors each. The lone exception concerns the top five floors, and the roof was not considered in this analysis since it does not contain shear walls and relies on steel framing for lateral resistance. The parking garage of the River Tower makes up the lower eight floors of the structure, and the remaining floors consist of the condominium tower, which accounts for the change in building footprint in these diagrams. The wind pressures were averaged for each floor of these generalized six sections of the building. Each shearwall was also considered a separate entity from each other, even though there are mostly combined shapes on the actual floor plan layout. Small openings in the shear walls, shorter sections of shear walls, and other inconsistencies between levels were not included in this analysis as these would not sufficiently affect the distribution of the lateral forces.

On the next page, net results of the distribution by rigidity method of the shear walls, shown for each of the six groups of floors. These values are the total shear forces on the wall, both concentric and eccentric forces combined with respect to their directions. For more detailed calculations and explanations, please consult Appendices D and E for each respective wind direction. The center of rigidity for each system is shown. In the instance of walls K and L, which were rotated 10 degrees from the normal plane; this rotation was neglected for this report since the shear walls in question were very short in length. Both the actual placement and the generalized arrangement used for analysis are both shown in the following diagrams.

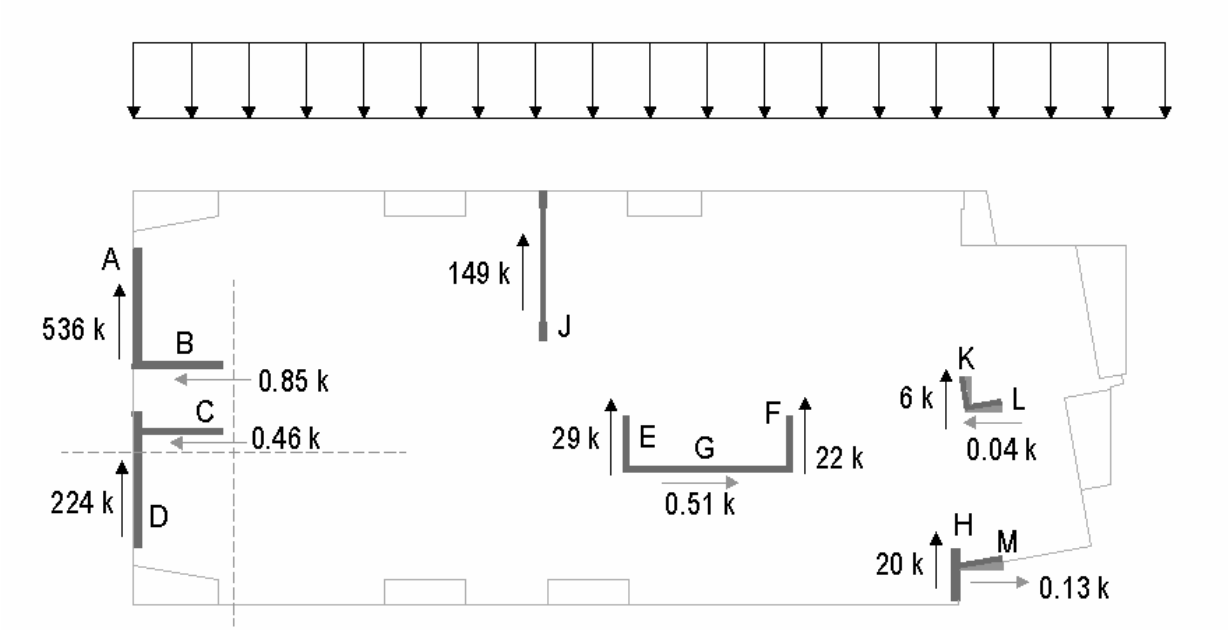
Results for the North-South Wind Direction



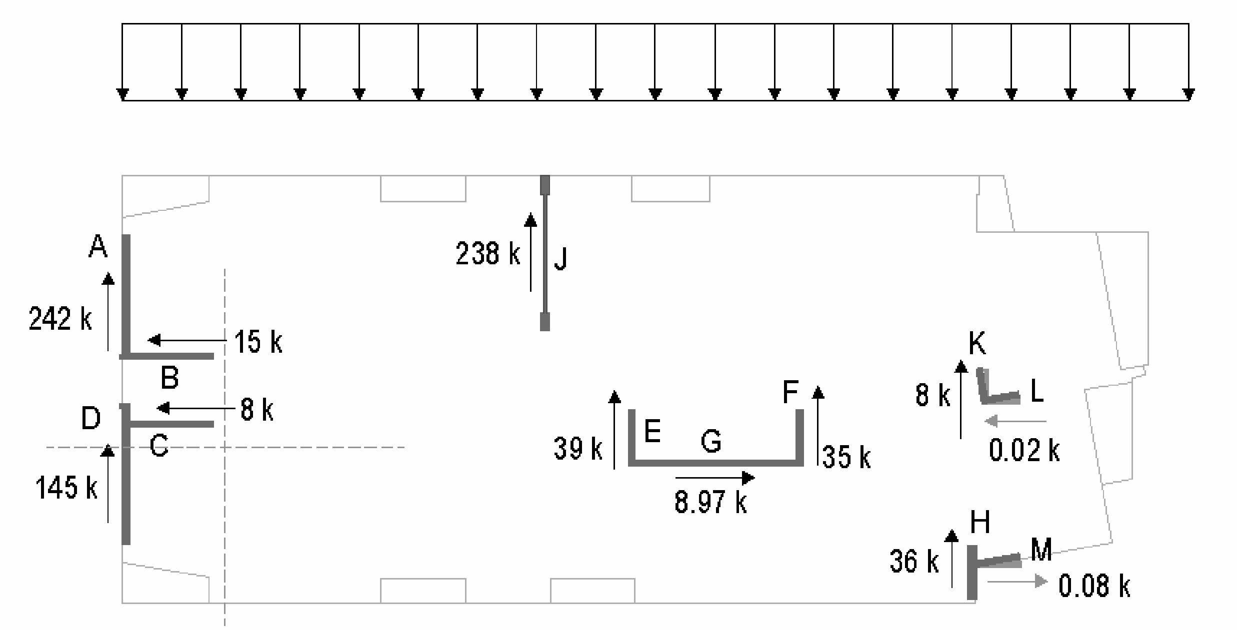
Results for Floors 1-4



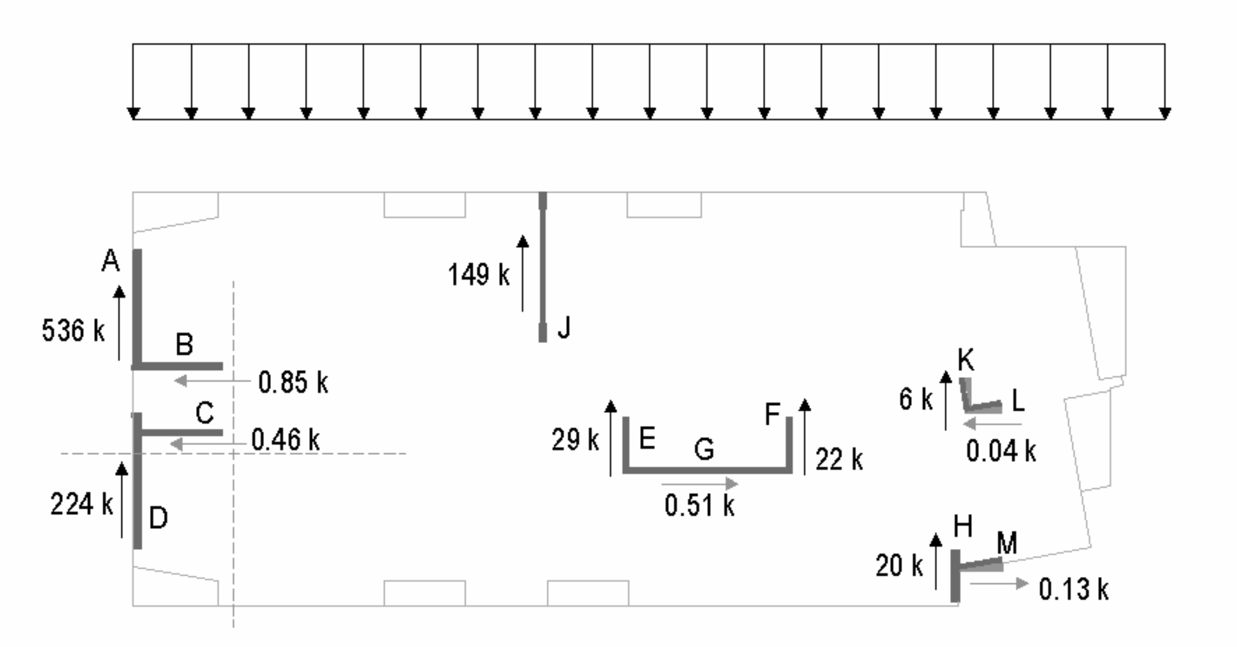
Results for Floors 4-8



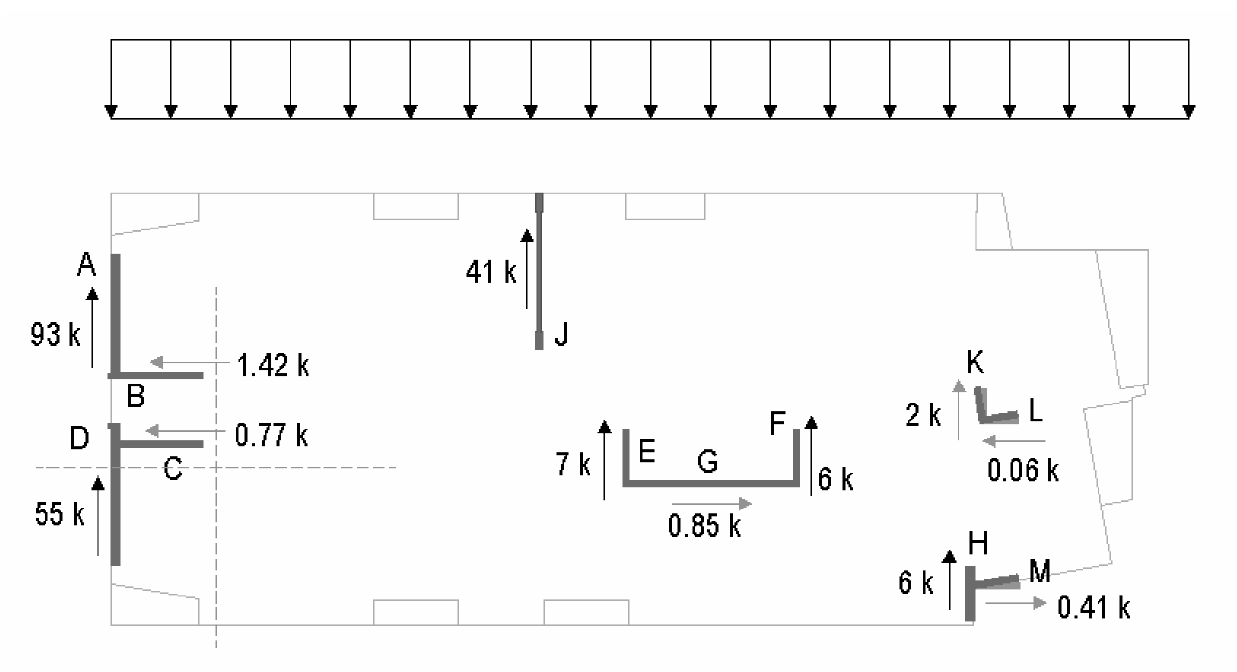
Results for Floors 9-12



Results for Floors 13-16

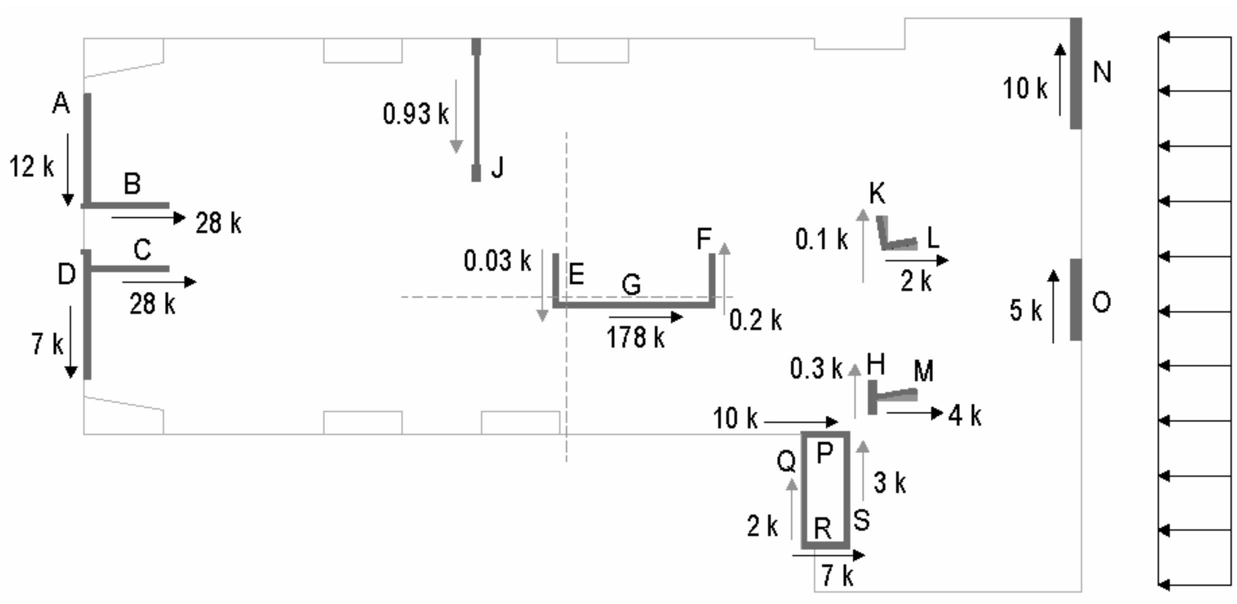


Results for Floors 17-20

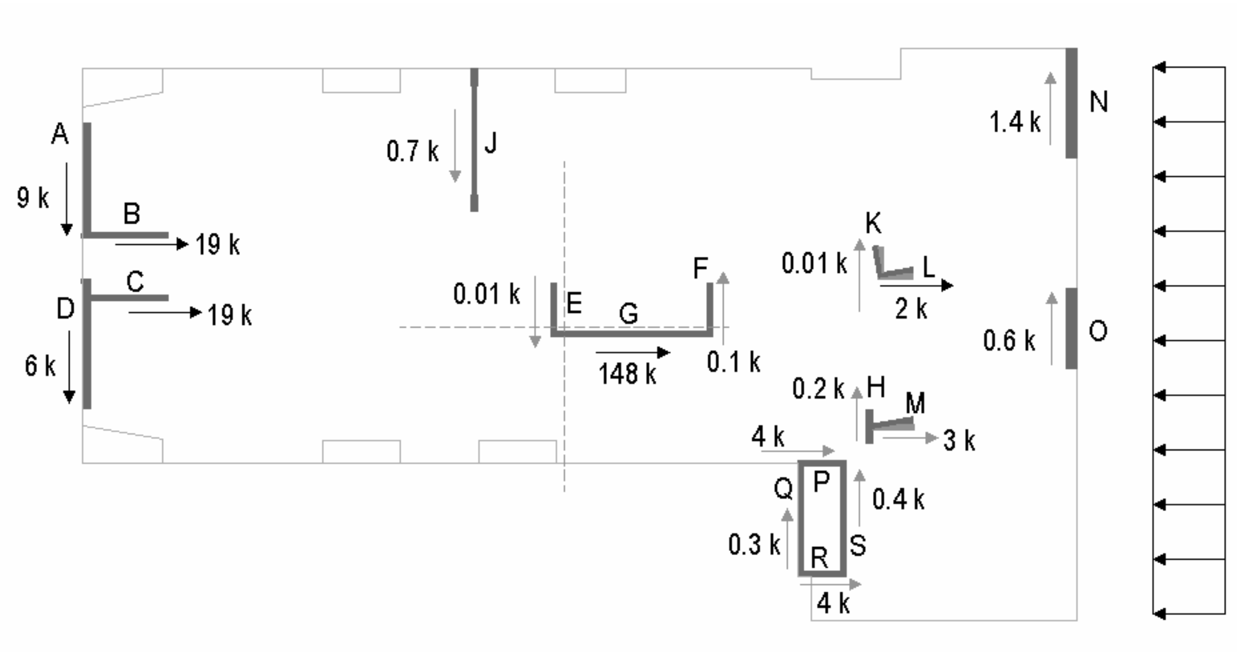


Results for Floors 21-25

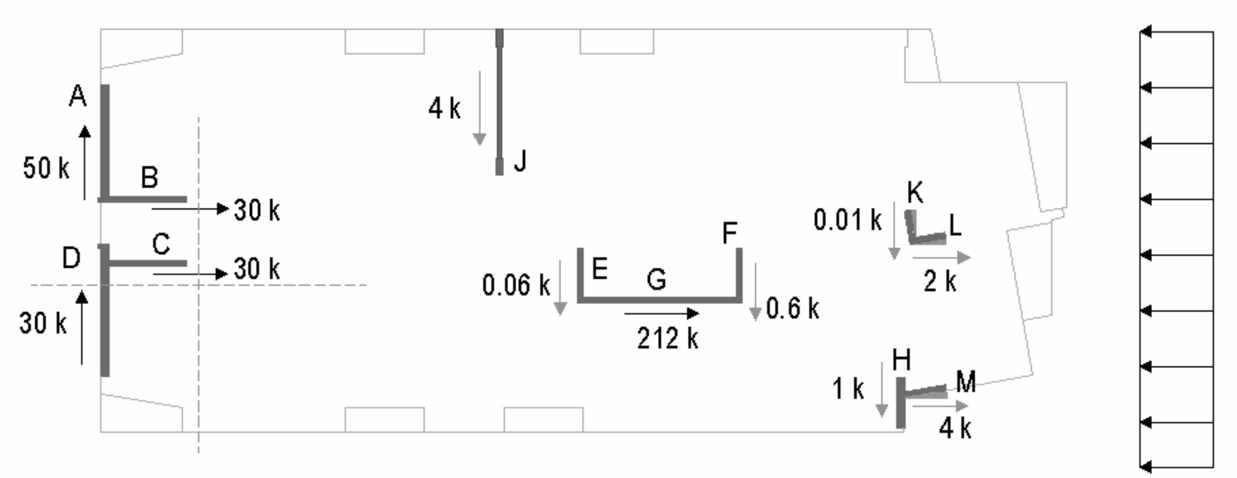
Results for West-East Wind Direction



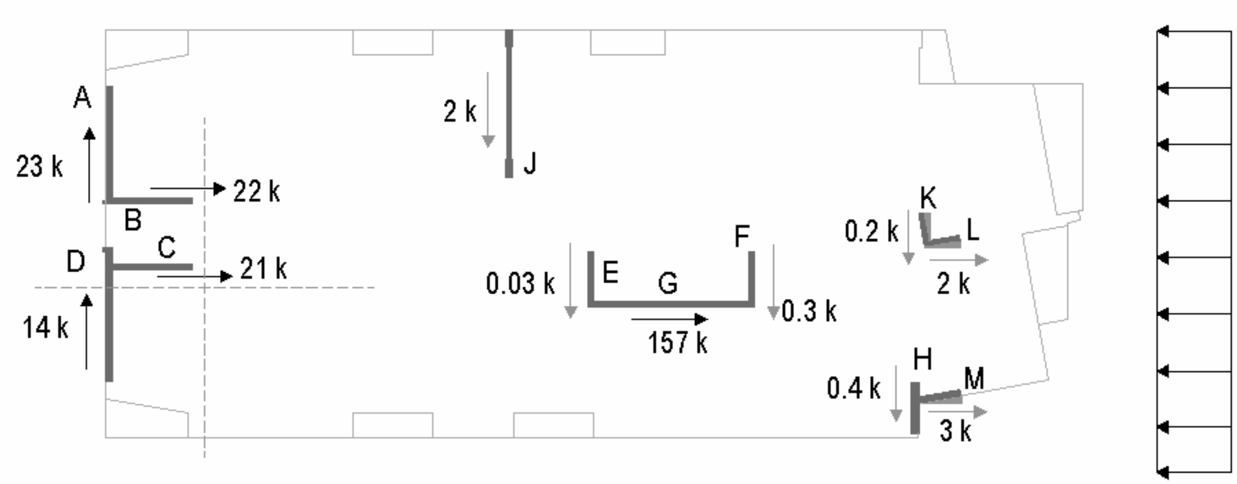
Results for Floors 1-4



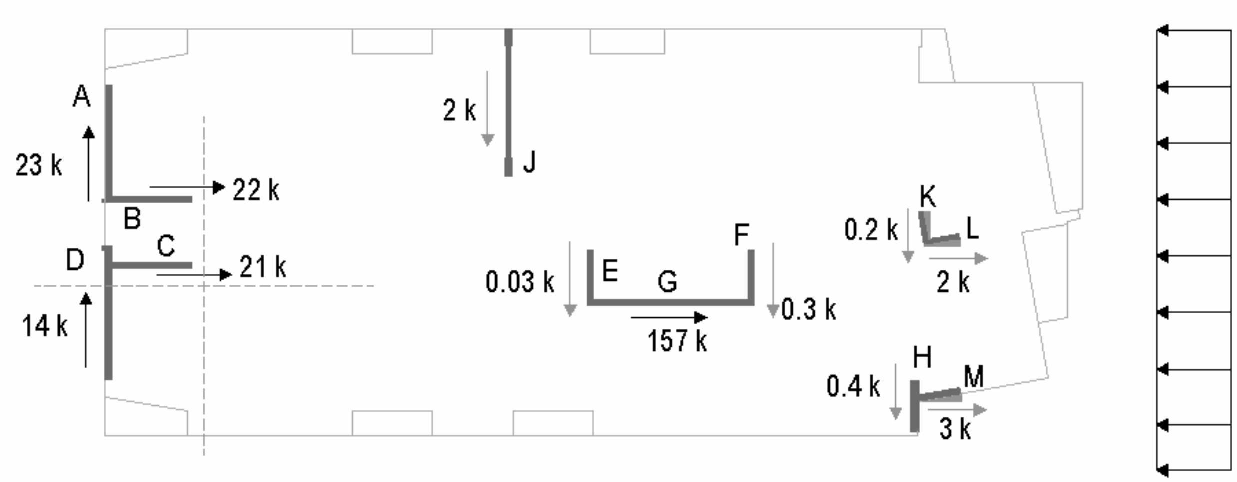
Results for Floors 5-8



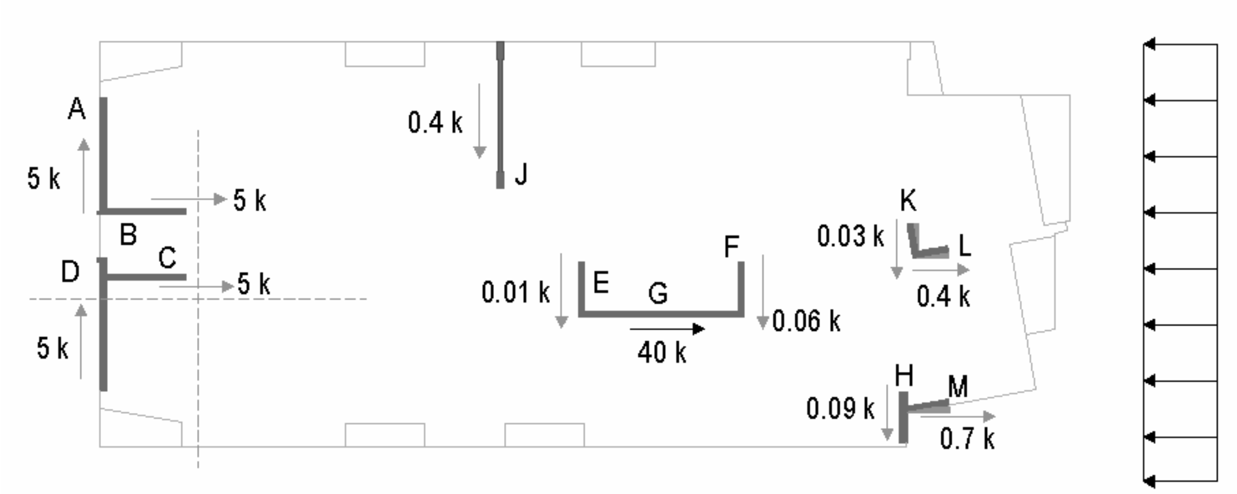
Results for Floors 9-12



Results for Floors 13-16



Results for Floors 17-20



Results for Floors 20-25

Strength Check

The reinforced concrete columns were judged to be only gravity load-carrying, and likewise, gravity loads were not considered in this shear wall analysis. To approximate the legitimacy of the reinforcement chosen for these reinforced concrete shear walls, these walls were likened to a very thin, deep beam cantilevered from the base of the building, spanning the full height of the building. This approximate analysis provides a credible solution for hand calculations. In future reports, this system will be more accurately modeled using computer software, most likely *ETABS*.

Based on this initial strength check of the most critical shear walls for each wind direction, it appears that the axial loading needs to be considered when analyzing these shear walls as cantilevered deep beams. In the most extreme shear cases, such as Wall A and D in the N-S wind case, shear strength checks did not pass. This area of study will be covered in more detail in future reports. Please consult Appendix F for more detailed calculations and information.

Drift and Story Drift Check

The River Tower meets BOCA 1996 restrictions on story drift in all of its floors, even in this generalized analysis. The shear wall drift values, based on the height of the walls, yielded small values (less than one inch) in most cases, except for the extreme shear cases. Because of the basic concrete nature of the entire building, essentially a very tall and wide shear wall, the actual story drift was approximated using the deflection criteria for shear walls. This approximation yielded values much smaller than that of the allowable drift, ensuring its legitimacy. Please consult Appendix G for more detailed calculations and information.

Overturning Effects

Because the River Tower contains mostly 25 floors of concrete slabs, shear walls, and columns, its significant weight counteracts any possible overturning effect of the wind. Appendix H provides calculations to support this claim. The maximum overturning moment caused by lateral loads, caused by the controlling case, the N-S wind loading, is 295172.2 kip-ft. This moment distributed over the span in the North-South direction still does not compare to an overall building weight of 54470 kips, so overturning effects are sufficiently accounted for in this design and its foundation. Please consult Appendix H for more detailed calculations and information.

Conclusion

As expected, the North-South directed wind loading was the controlling lateral loading case. Wilmington, Delaware, does not lie near any major seismic fault lines, so its earthquake loads will not control over wind. Distribution by rigidity yielded predictable results as well, since most of the lateral loads were distributed to the longest shear walls in each respective direction. Strength checks of these critical members were not able to fully account for these distributed shears, which indicates that more than just the shear walls might be needed for lateral resistance, especially for flexural strength of the wall. The generalization of the building into basically a six floor structure rather than its actual 25 stories has resulted in larger shears distributed to the lower floors than in reality as well.

Some factors not considered in the scope of this analysis are the lateral resistance of the columns, which due to their orientation may in fact provide additional stiffness. The post-tensioned concrete flat plate system at each floor also provides lateral stiffness for the River Tower. Finally, the self weight and other gravity loading of the structure provide enough axial force on the shear walls to stiffen each shear wall through compression. These combined effects, from floor-to-floor rather than specific groups of floors, will be more accurately accounted for in future reports, with the aid of computer software analysis.