River Tower at Christina Landing

Wilmington, DE

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Structural Thesis Proposal:
Structural and Breadth Redesign Options

Executive Summary

The River Tower is part of the latest phase of redevelopment along the banks of the Christina River in Wilmington, DE. The redevelopment site consists of luxury townhouses, a 22-story apartment building, and will now add the River Tower, a 25-story condominium tower. The River Tower's structural system includes a slab-on-grade structural slab and 8" post-tensioned floor slabs with reinforced concrete columns for gravity load support. The primary lateral system for the tower consists of reinforced concrete shear walls, but the concrete columns also provide lateral resistance.

Previous technical assignments have presented preliminary analysis on the existing post-tensioned slab system and the existing lateral system of reinforced concrete shear walls. Alternate floor systems were also considered, with composite steel framing and hollow core slab planks yielding the most promising results. When compared to the existing system, these alternates would add to the floor-to-floor height by several inches per floor. This would ordinarily be a deciding factor, had the River Tower design team not already received code variance for its building height from the city of Wilmington, DE.

For the educational purposes of this assignment, the composite steel framing system will be further studied despite its increase in assembly cost and floor thickness from the existing conditions. The composite steel framing system would significantly provide a lighter overall building weight and simplify the lateral resistance system. This could potentially open up the current column and architectural layout. Both braced and moment frames will be considered initially, with research and preliminary RAM output becoming deciding factors.

With such a significant change in building material, a complete analysis of the construction management aspects of budget, scheduling, and erection will be considered as a secondary breadth assignment. Finally, with this redesign of steel and the potential change of layout of the interior spaces, the current mechanical system will be analyzed and redesigned accordingly. The fire resistance system will be another key factor in this new analysis, as the new steel framing will also require fire-proofing of some kind. This report finally lists the procedures involved to accomplish these design goals, and provides a tentative timetable for their completion.

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Structural Thesis Proposal:
Breadth Analysis

Executive Summary

The River Tower at Christina Landing is a proposed 25-story condominium tower with a wide parking garage base in the first eight levels of the structure. The existing structural system consists of a post-tensioned concrete flat slab system with reinforced concrete columns. Reinforced concrete shear walls, located primarily around the elevator and stairwell core, provide the primary lateral resistance along with the concrete columns.

The main structural redesign will analyze a composite steel framing system with either moment or braced frames. Both of these steel framing systems will be considered initially, and based on preliminary analysis results and research, the steel system will be appropriately detailed. This steel system offers an opportunity to significantly open the column and architectural layouts, which would in turn affect the requirements of the non-structural building systems.

With a new material and construction method to consider with the proposed structural redesign, constructability must be accounted in a comprehensive building analysis. R.S. Means data was used in Technical Report 2 to assess the potential assembly cost for choosing a composite steel framing system. This research will be expanded upon, with a consideration for the new scheduling and equipment requirements based on a now mostly steel structure. The feasibility for construction of this new system will play a major role in determining the efficiency and suitability of the proposed concrete system.

Likewise, the change from two-way concrete slabs to a composite floor system will significantly alter the mechanical system. The finished ceiling that will hide the new steel floor framing system could be employed to house ductwork and other mechanical equipment. As the floor-to-floor heights and condominium unit layouts are adjusted to the new framing system, the service requirements for the mechanical system may necessitate a resizing or redesign. The fire resistance system will need to be reexamined as well, since there will be no inherent fireproofing in this proposed steel structure.

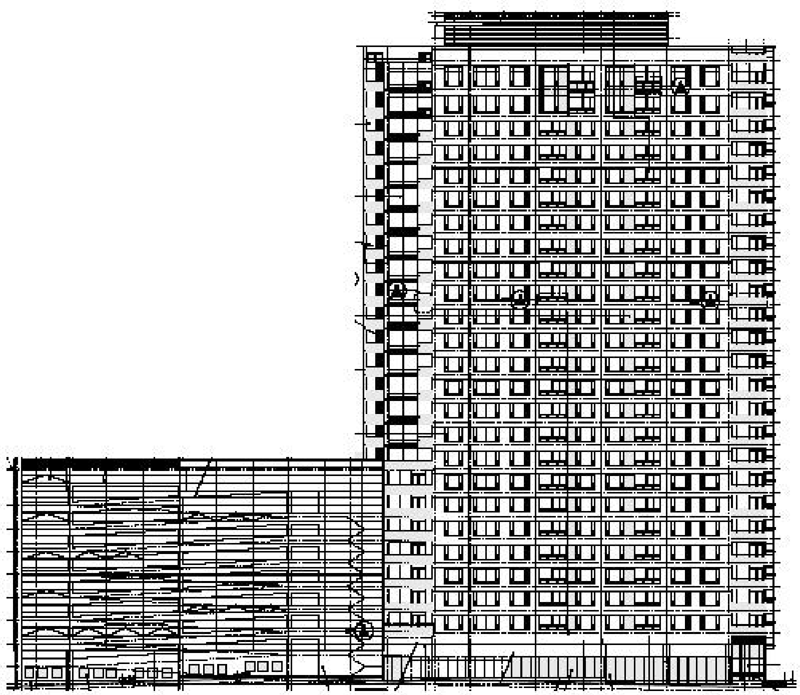
Introduction to the River Tower at Christina Landing

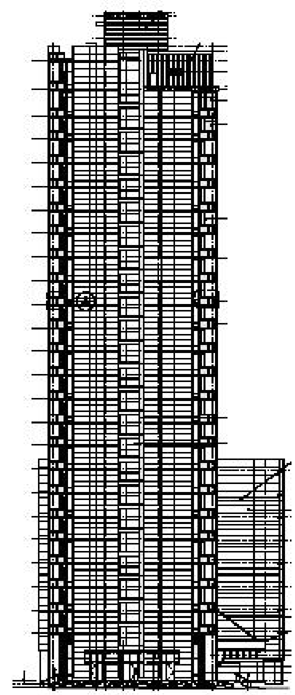
The River Tower is part of the latest phase of redevelopment along the banks of the Christina River in Wilmington, DE. The redevelopment site consists of luxury townhouses, a 22-story apartment building, and will now add the River Tower, a 25-story condominium tower. This tower has since been redesigned for value engineering, and has added two stories to create a 27-story condominium tower. The original 25-story design has been the focus of the preliminary analysis of the first semester assignments.

The first floor of the River Tower contains retail space and various management and mechanical rooms on the south side of the building, with the entrance to the parking garage on the northern side of the floor. The second through seventh floors of the River Tower are comprised of a parking garage on the north side and six units on the southern side. The additional spaces required by the parking garage result in a wider base to the building, as the lowest eight floors have a wider footprint than the remaining seventeen floors. The eighth floor consists of a Great Room, Fitness Center, six luxury units, along with an outdoor terrace containing a rooftop pool, spa, garden, and observation deck. The other floors contain eight units a piece, each with master bedrooms and baths. These luxury units range in size from one- and two-bedroom dwellings, each unit having access to its own terrace. The largest units contain dens and multiple terraces.

Brick-faced pre-cast panels line most of the exterior walls. The entrances on the eastern and southern side of the high rise possess an aluminum glass curtain wall system. The main entrance on the southern side has a canopy with aluminum composite panel system cladding. On the ground floor, a concrete block recessed wall painted black dominates the western elevation, partially obscured by a green-screen fence. An 8" composite aluminum panel reveal lines the building at its uppermost floors. An aluminum storefront glass system is used on the stair towers. Sliding doors open from the units to individual terraces (some penthouses have even two terraces), which are lined with an aluminum perforated railing systems, consistent with the open spaces of the parking garage. Horizontal and vertical metal panel systems hide the rooftop mechanical systems. The rooftop terrace which houses the pool and observation deck is lined with 6" square wood columns with vertical wood infill panels. An expansion joint exists where the edge of the parking garage roof/terrace meets the narrower part of the high rise beginning at the eighth level. The roofing system will be an adhered membrane/roofing flashing system coated with a water proofing sealer.

Floor/ Level	Residential Spaces		Parking Garage/ Other Use		Total Floor SF (*: Estimated)
	SF	% of SF	SF	% of SF	
1	11105	37.71	18344	62.29	29449
2	9812	33.08	19851	66.92	29663
3 to 6	9812	32.19	20674	67.81	30486
7	9812	24.80	29748	75.20	39560
8	19851	62.80	11759	37.20	31610
9 to 22	12186	100.00	0	0.00	12186
23	5724	61.50	3583	38.50	9307
24 to 25	0	0.00	1070	100.00	1070*
Roof	0	0.00	12186	100.00	12186*





West and South Elevations of the River Tower at Christina Landing

Provided by O'Donnell & Naccarato, Inc., Structural Engineers

Structural System Summary

Condominium Building Structural System

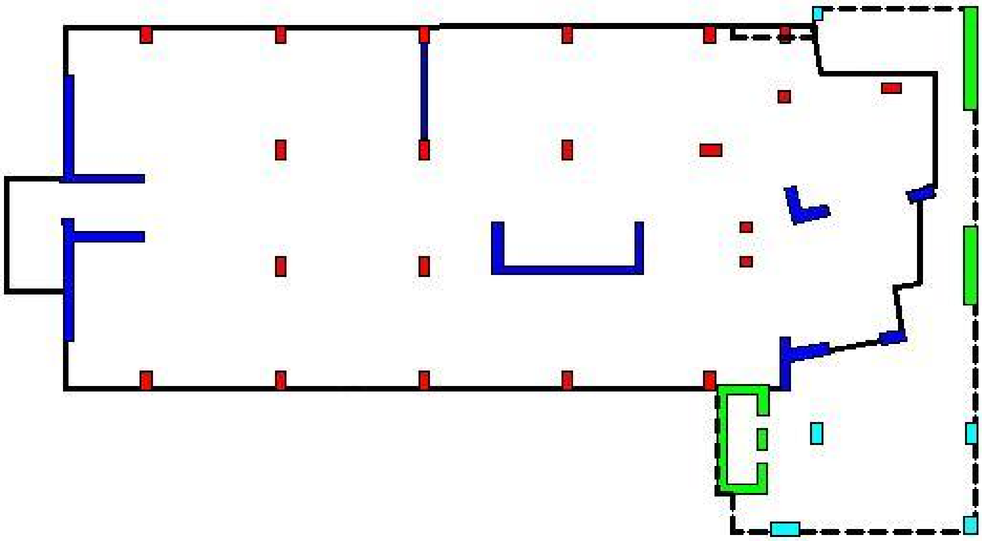
The condominium building will be supported by a deep foundation system that will support the columns, walls, and slabs. The piles will be HP12×84 steel piles driven to 225 tons with a net bearing capacity of 200 tons. These piles will be grouped at columns and transfer load from columns using pile caps. 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 will span from column pile cap to pile cap and support the exterior walls of the building. The first floor structural 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 will span between columns spaced at 28’-6” in one direction and 23’-0” in the other direction. A typical interior column will be 16”×52”, and its reinforcement and concrete strength will decrease at upper floors. The typical 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 six feet 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 support system.

Parking Garage Structural System

For the parking garage, additional steel piles (80 ton HP12×53) 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.

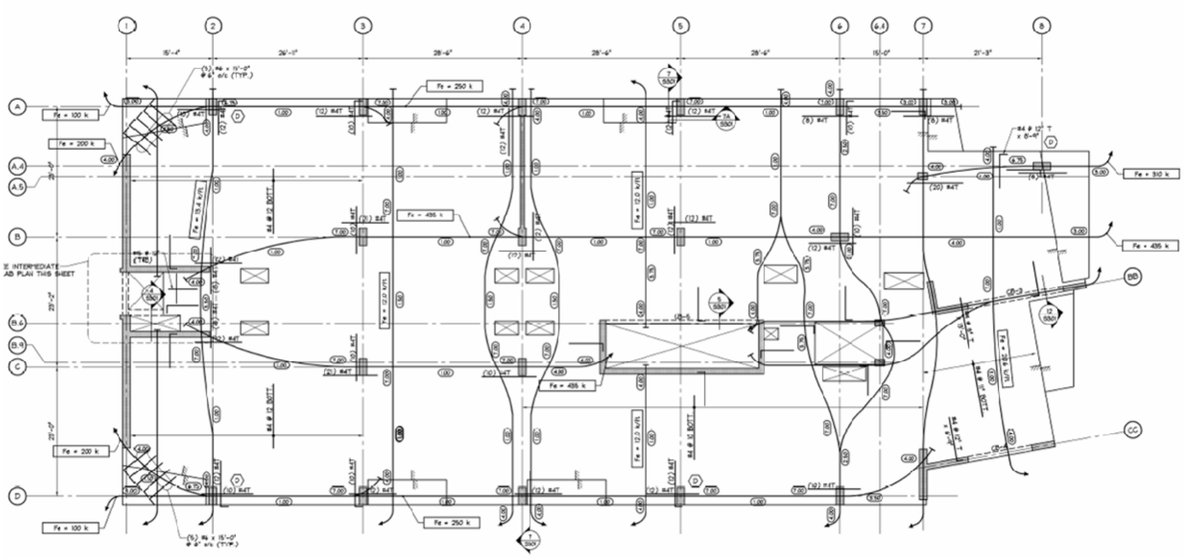
The floor framing of the parking garage will be 34 inch deep pre-topped tees which span between 45 to 60 feet. An “L” shaped beam will comprise the exterior of the building and support the pre-cast tees. These L beams will span approximately 48 feet from column to column. The interior support, including 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 but concentrated at the stair and elevator cores will resist the lateral loads on the parking garage.



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)



Typical Floor of River Tower Condominium Tower

Provided by O'Donnell & Naccarato, Inc., Structural Engineers

Problem Statement

The River Tower's current structural system of post-tensioned concrete slabs provides minimal floor-to-floor height requirements, minimizing the overall height of the building. This is crucial to reduce the overturning capacity of the structure, which is also aided by the overall building weight provided by the concrete slabs, columns, and shear walls.

In Technical Report 2, an analysis of alternate floor systems for the River Tower confirmed the adequacy of the current post-tensioned concrete floor slab system. This system provides an efficient balance of minimal floor-to-floor height, system dead weight, and assembly installation cost. A significant reduction of system weight can be achieved using a composite steel framing system. However, this system would add to the floor-to-floor height and system cost. For the educational purposes of this assignment, composite steel framing will be considered as a possible redesign for the River Tower.

A composite structural system could present some interesting opportunities for more architectural flexibility. In Technical Report 2, the existing column layout was kept for comparative purposes. During the redesign process, the spans between these columns can be adjusted and perhaps lengthened to open the typical floor plan. Both moment frames and braced frames will be considered in this redesign for the unique benefits for which they provide. Moment frames would allow for unobstructed paneling, an architectural benefit. However, this system resists lateral loading through bending, a very inefficient method that would result in relatively larger column sizes. Moment framing would also require many difficult and complicated connections to ensure this lateral resistance. Braced frames, in contrast, would provide stiffer resistance against lateral loads through axial loading through its braced members. A staggered truss lateral system could be used where architects already have shared party walls between condominium units, and in the process, minimize the use of columns per floor. This could open up the architectural floor plans considerably and allow for more flexible and unique condominium unit features. Overturning capacity for this lighter proposed structure will still be counteracted by the concrete systems of the parking garage located at the lower eight levels of the River Tower. The parking garage areas were not considered in the scope of this redesign project.

Problem Solution

This steel redesign will be based on the LRFD method of design. In order to properly and quickly verify the efficiency and suitability of the two aforementioned systems, RAM computer software will be used to size initial members and spans. Gravity and lateral loads will be computed based upon the original building code used in the actual design, BOCA 1996. As a starting point, the original typical bay sizes will be analyzed using RAM, and will altered to the proposed specifications for comparative purposes. Hand calculations for the gravity and lateral loading (both wind and seismic) from previous assignments will be used to verify the RAM outputs. Hand checks for member sizes will also ensure the correctness of the computer software

tools. The significant height and unique footprint of the River Tower necessitate use of computer software for analysis. The relative ease of performing multiple iterations with RAM or similar structural analysis software will help present the most efficient solution. RAM software will also allow for a three-dimensional analysis of the lateral loading, which can account for the irregularity of the River Tower footprint.

Breadth Studies

With a new material and construction method to consider with the proposed structural redesign, constructability must be accounted in a comprehensive building analysis. R.S. Means data was used in Technical Report 2 to assess the potential assembly cost for choosing a composite steel framing system. This research will be expanded upon, with a consideration for the new scheduling and equipment requirements based on a now mostly steel structure. The feasibility for construction of this new system will play a major role in determining its efficiency and suitability for the River Tower.

Likewise, the change from two-way concrete slabs to a composite floor system would require adjustments to the mechanical system. The finished ceiling that will hide the new steel floor framing system could be employed to house ductwork and other mechanical equipment. As the floor-to-floor heights and condominium unit layouts are adjusted to the new framing system, the service requirements for the mechanical system may necessitate a resizing or redesign. The switch to a mostly steel building will require a fresh analysis of the fire resistance in the structure as well, as the inherent fire proofing of a primarily concrete structure would be lost.

Tasks and Tools

The initial stage of redesign will involve the verification of the lateral loading calculations used in previous technical reports, based on the regulations of the BOCA 1996 building code. Research into various forms of lateral resistance in steel framing, especially the possibility of a staggered truss system, will begin as well. The next step will involve the construction of a two- and three-dimensional model for the River Tower using RAM software or a similar structural analysis program. Initially, the original column layout and gravity load estimates from the post-tensioned flat plate system will be used. Once a proper model has been completed, this layout will be adjusted and compared to the variety of alternate systems found by research. When potential systems are identified through these repetitions of structural analysis, cost data and constructability factors will verify a feasible structural system. With this system finalized, typical connections will be detailed and factored into an ultimate design decision. Finally, after confirmation of the details of this new structural framing system, the current mechanical and fire resistance systems will be analyzed and redesigned accordingly. A tentative schedule of these tasks follows and will be adjusted accordingly as the semester progresses.

Tentative Timetable for the Spring Semester

Week of	Tasks
JANUARY	
8	• Verify lateral loading calculations from BOCA 1996 • Begin creation of 2-D model of existing conditions using RAM software
15	
22	• Research new lateral system and connection alternatives • Complete 2-D and 3-D modeling of structure
29	
FEBRUARY	
5	• Begin alterations and comparison between different column layouts and span dimensions, braced frame versus moment connections, etc.
12	
19	• Breadth Analysis: Cost analysis and constructability
26	• Finalize structural system based on cost analysis and structural performance criteria
MARCH	
5	-- SPRING BREAK --
12	• Breadth Analysis: Examine the suitability of existing mechanical and fire protection system and redesign accordingly
19	
26	• Review and organize material for report and presentation
APRIL	
2	• Final Report due on April 5, 2006 • Finish PowerPoint presentation and rehearse
9	• First Round of Presentations
16	• Adjust and revise presentation
28	• Jury Presentation