Thesis Proposal

John Jay College Expansion Project

New York, NY

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Structural Option

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Executive Summary

The John Jay College Expansion project is an academic building for the John Jay College of Criminal Justice located in Manhattan. A midrise tower includes classroom, laboratory, and office spaces and reaches a maximum height of approximately 240 feet above 11th avenue. This tower is connected to the existing building by a 5 story "grand cascade".

The project also has a major site restriction: Amtrak tracks cross the South-West corner of the site. This problem was solved by transferring gravity loads over the tracks in two places. Built-up steel transfer girders are used to transfer 5 levels of gravity loads and trusses at the penthouse level of the midrise tower transfer the remaining 9 levels of gravity loads. Perimeter steel plates hang from the trusses at the penthouse level and support the floors below.

This complicated solution to transfer over the trusses calls for a unique and expensive construction method. Therefore, the proposed thesis is intended to simplify the transfer system. Transfer trusses will be moved from the penthouse level and redesigned for the 5th or 6th level. By transferring gravity loads over the Amtrak tracks at the 5th or 6th level, typical steel framing can be used to support all floor levels. This change will also impact the lateral force-resisting systems, which are steel braced frames. In the North-South direction, the transfer trusses act as a coupling beam at the penthouse level between braced frame cores. After studying the behavior of the braced frame core in technical report three, it was found that the coupling behavior was needed to control lateral drift requirements. Therefore, an in-depth lateral analysis will be performed to determine the impact on the lateral system caused by changing the location of the transfer trusses.

Moving the location of the transfer trusses not only impacts the structural system, but it also affects other aspects of the building. An architectural breadth must be implemented to adjust the floor plans to meet functional and aesthetical requirements of exposed steel trusses. A construction breadth must also be studied to determine the necessary changes in the construction methodology to build the new system. To do this, a revised construction schedule will be created and cost differentials will be presented.

Final comparisons between the new and existing structural systems will then be presented based on structural steel weight, cost, incorporation with architecture, and construction time. These criteria will lead to a final recommendation.

Introduction

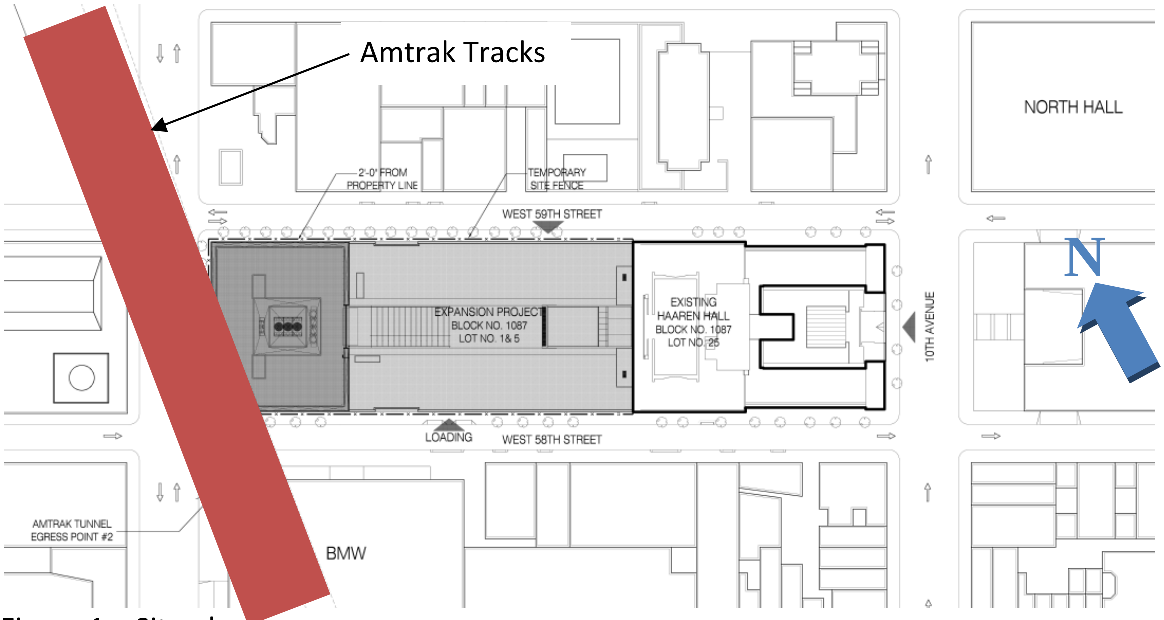


Figure 1 – Site plan

This major expansion project in Manhattan will unify the City University of New York's John Jay College of Criminal Justice into a one block campus that will "demonstrate the transparency of justice". The design includes a mid-rise tower situated on the west side of the site, which will contain classrooms, forensic laboratories, department offices, several student lounge spaces, a "moot" courtroom, a café, and a student bookstore.

A mid-rise structure connects the expansion to Haaren Hall (the existing building) and calls for a multi-level grand cascade, which also serves as a main lounge space for students (see picture 1 below). The connection also contains classrooms, a black box theater, and two cyber cafes. A landscaped roof accommodates outdoor lounge and dining areas, and an outdoor commons.

Picture 1 – Rendering of the Grand Cascade

Amtrak tracks cross the south-west corner of the site, which is beneath the mid-rise tower (see figure 1). This restriction led to a unique structural solution to transfer over the tracks. Floors 1 through 5 are transferred over the tracks using built-up steel transfer girders at the first level and floors 6 through 14 are hanging from perimeter plate hangers supported at the penthouse level by transfer trusses that are one-story tall (see figure 2 and 3 below). These trusses then transfer the loads to the lateral force-resisting system, which is a steel braced frame. This braced frame wraps around a centralized service core located in the 14 story tower. A braced frame is also utilized in the service core of the 5 story cascade.

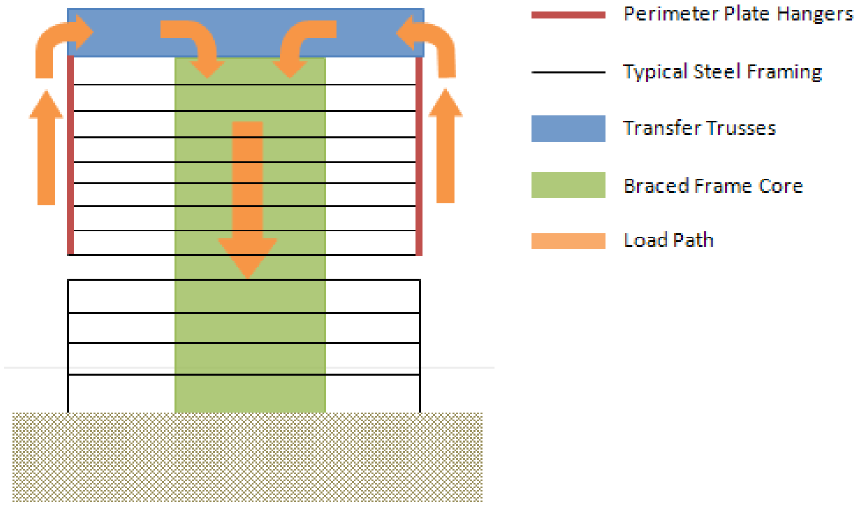


Figure 2 – Schematic diagram of the load path for the 14 story tower

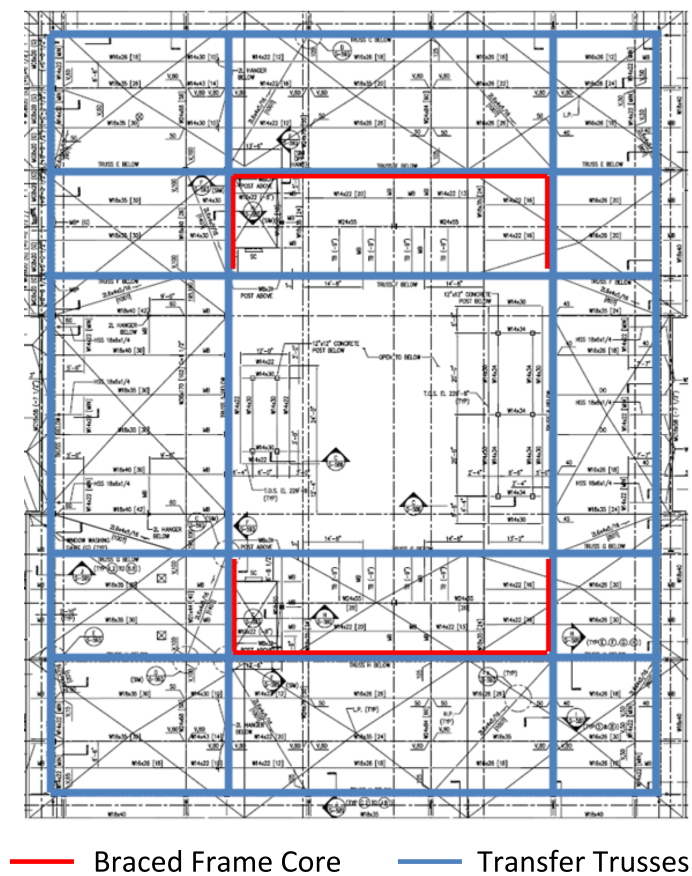


Figure 3 – Roof level framing plan with transfer trusses beneath shown

Existing Composite Steel System

Floor System:

The floor system of the John Jay College Expansion Project is a composite system with the most typical bay size being 30'-0"x 37'-10". 3 ½" light weight concrete and 3" metal decking typically span 12'-2" to W14x22 or W16x26 infill beams. ¾" diameter x 5 ½" long shear studs allow composite action between the floor system and beams. Infill beams span into W-shape girders of varying sizes or two back-to-back MC-shapes. Framing of the cascade, which connects the tower to the existing building (Haaren Hall), consists of W36 girders spanning 68'-4" with infill beams spaced typically at 11'-4" on center. See Appendix A for typical floor framing plans.

Lateral system:

The 14 story tower of the expansion project has a large centralized braced frame core (see Figure 4). This braced frame surrounds the vertical shafts of the building, such as elevator shafts, stairwells, mechanical shafts, and plumbing. Columns of the braced frames are heavy W14 sections and the beams are typically W16 sections. HSS 6x6x3/8 are typically used for diagonal bracing at the 13th level and HSS 8x8x3/8 are used for the diagonal bracing at the 1st level. Reinforced concrete walls span between caissons and concrete piers at the foundation, which support the braced frame.

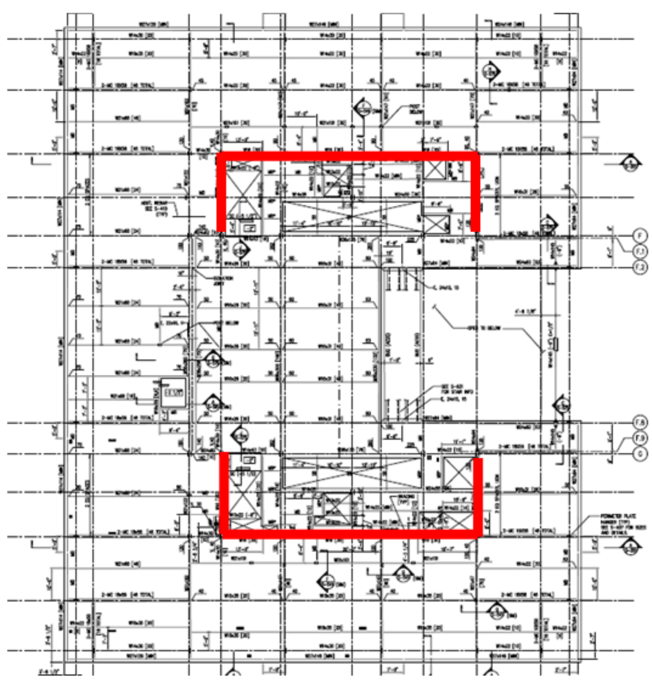


Figure 4 – Location of the Braced Frames in the tower

The lateral system for the 5 story cascade is also a braced frame which encases the building's vertical circulation shafts (see Figure 5). Columns of these braced frames are lighter W14 sections than the 14 story braced frame and the beams are W16x31's and W21x94's. Diagonal braces are typically 2L 6x4's with varying thicknesses.

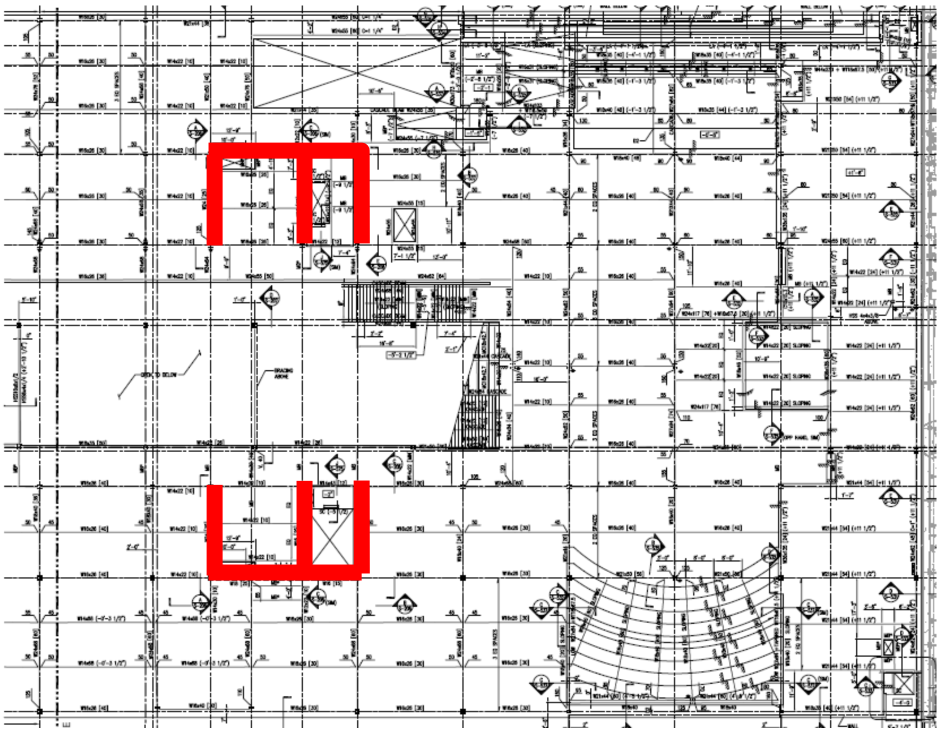


Figure 5 – Location of the Braced Frames in the 5 story cascade

Foundation:

The site of the John Jay College Expansion Project is sloping from the east down to the west, and therefore the foundation system is split into two levels. This caused the designers to use various types of foundation systems to support the structure. The northern half and south-eastern corner of the building is primarily supported on drilled caissons ranging from 18" to 36" in diameter. These caissons are embedded up to 14'-0" into the bedrock below. On the south-western corner of the site, columns are supported by reinforced concrete piers of dimensions ranging from 20"x 20" to 72"x 42". These concrete piers are then supported by individual column footings ranging in sizes of 3'-0"x 3'-0" to 9'-0"x 9'-0" that are bearing on bedrock.

Problem Statement

The present design of the John Jay College Expansion Project calls for a unique solution to transfer gravity loads over the Amtrak tracks beneath the building. Built-up steel transfer girders at the first level are limited to 3’-0” in depth and therefore can only support 5 levels of gravity load. To transfer the additional 9 levels of gravity loads over the train tracks, trusses at the penthouse level transfer loads to the braced frame core. This allows the 6^{th} through 13^{th} levels to be supported by 1 to 2 inch thick steel plate hangers at the perimeter of the building. Level 5 has no perimeter columns or plate hangers (see figure 2 above).

While this solution to transfer gravity loads over the Amtrak tracks offers unique architectural features such as a column-less 5^{th} level, it also creates several difficulties. One major issue with this project is that it is very expensive. Initially the project was estimated around 250 million dollars and now is projected to cost roughly 457 million dollars. Although this is the overall cost of the project, having a complicated structure that is difficult to construct has a significant impact on the project cost. Another area of concern is the columns in the braced frame core. These columns support the gravity loads from their tributary areas, but they also must support the perimeter plate hanger gravity loads transferred from the trusses at the penthouse. If a simplified transfer method is found, a more efficient construction method could be used, which could possibly result in a reduced construction timeline and reduced overall costs.

The John Jay College Expansion Project is also delayed and behind in construction. This is not entirely caused by the complicated structural system, but due to the transfer system being at the penthouse level, temporary columns and bracing must be used to construct each floor supported by plate hangers. Construction must also be closely monitored to ensure the built-up transfer girders at level one are not overstressed because they will be supporting all floors until the transfer trusses are built at the penthouse level.

Proposed Solutions

With the intentions of reducing the structural system cost and reducing delays in construction, a new transfer system will be studied in detail. This new system includes removing the transfer trusses from the penthouse level, and redesigning them to fit on the 5th or 6th levels. These trusses will be partially exposed and will provide a new aesthetic. By moving the trusses to the one of these levels (see figure 6), there is no need to hang the above floors. This will simplify the construction process by eliminating the need for temporary columns and bracing.

After studying the behavior of the braced frames in technical report 3, it was found that the coupling action in the penthouse level caused by the transfer trusses was used to reduce the drift in the North-South direction. By moving the transfer trusses to the 5th or 6th level, the coupling action would be removed from the top of the braced frames and lateral drifts would change. Therefore, members of the existing braced frames will also need to be resized for drift in the North-South direction by performing a detailed lateral analysis using ETABS (see figure 7 below for coupling diagram). The new system of trusses, perimeter columns, and resized braced frames will be analyzed and compared to the existing system based on weight, cost, drift, and feasibility.

Breadth Studies

The structural system is not the only aspect of the John Jay College Expansion Project affected by redesigning the transfer system. Due to the change in location of the transfer trusses the steel erection sequence will be altered, and therefore a construction management breadth will be studied. This study will consist of creating and comparing a new construction schedule for erecting the structure to the existing schedule. Cost comparisons will also be made between the proposed structural system and the existing system.

Another area of study that will be necessary to implement the proposed structural system into the building will be an architectural breadth. The current 5th floor is used as a cafeteria with kitchen, student dining areas, and faculty dining areas. This space is primarily open, so the floor plan will need to be reconfigured in plan view and three-dimensionally to incorporate the proposed trusses. Fireproofing methods of the exposed steel trusses will also be investigated. See appendix B for the existing 5th level floor plan and figure 6 below for a building section of the proposed location change of the trusses. The 6th floor primarily contains chemistry and physics laboratories. If the trusses are found adequate for this level, the floor plan will be arranged so that the trusses are mostly within the partitions. By transferring loads at the 6th level, the 5th floor will remain column-less, which was an attractive option to the architect. Appendix B contains the existing 6th floor plan. Selecting the 5th or 6th floor to transfer loads will depend on which floor plan can successfully accommodate the trusses without having a negative impact on the architecture.

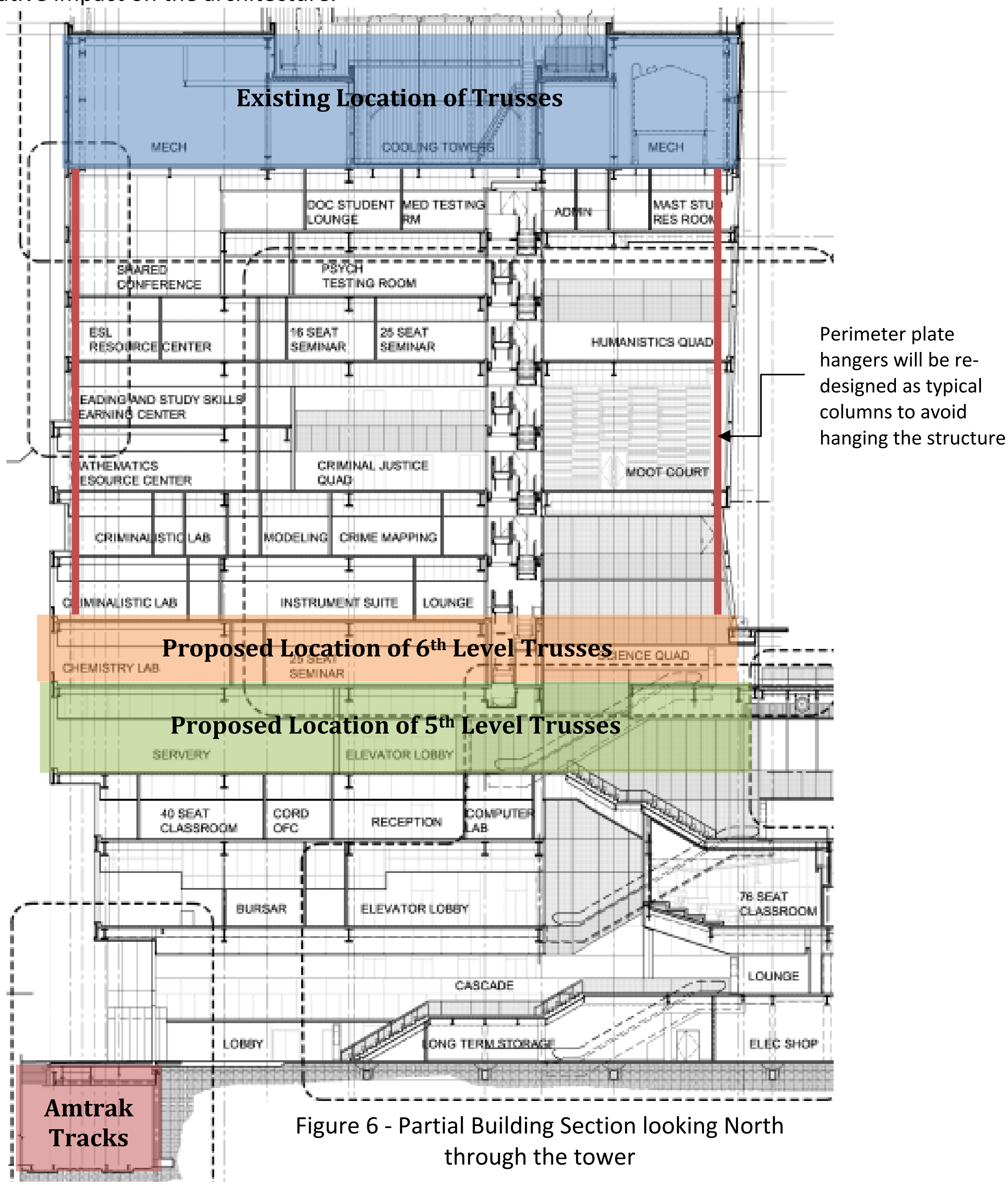


Figure 6 - Partial Building Section looking North through the tower

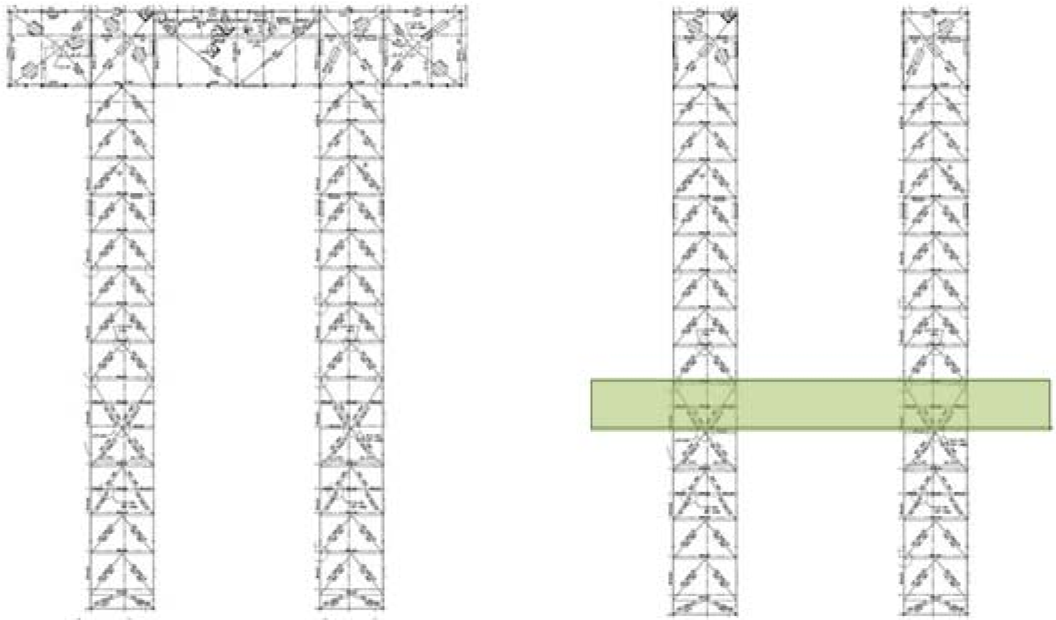


Figure 7 – The left image displays the existing North-South Braced Frames where the transfer truss at the penthouse level acts as a coupling beam and controls drift. The image to the right shows the new location of the transfer trusses, which will impact lateral drifts in the North-South direction of the braced frames.

Solution Methods

To determine the most efficient method of transferring gravity loads over the Amtrak tracks, several schematic designs for trusses will be analyzed. Truss configurations will be determined by simultaneously sketching truss layouts with revised 5th and 6th level floor plans. An ETABS model will be used to analyze each possibility by applying lateral and gravity loads from ASCE 7 – 05. Perimeter columns, transfer trusses, and braced frames will be designed using the 13th Edition of the Steel Construction Manual by the American Institute of Steel Construction. All designs will be performed using LRFD. Preliminary sizes will be input into ETABS and will be determined if they are adequate by using the design/check option. Final comparisons between the proposed solution and the existing solution will determine which method of transferring loads over the Amtrak tracks is the most efficient.

By modifying the floor plan of the 5th or 6th levels, all changes must still comply with the governing code. Therefore, IBC 2006 will be used to ensure that all modifications will meet code requirements. Computer programs Autodesk Revit will be used to reconstruct the floor plans and to ensure the transfer trusses meet functional and aesthetical requirements.

To determine which structural system is the most efficient in terms of cost and feasibility, a detailed estimate and schedule must be created for the new system and be directly compared to the existing system. RS Means will be used to estimate the cost of implementing this change to the structural system and Microsoft project will be used to modify the existing construction schedule.

Tasks and Tools

I. Relocation and Design of Transfer Trusses

1. Task 1: Determine schematic location and configuration of Transfer System
   a. Sketch possible location of trusses in plan
   b. Sketch possible floor plan orientations
   c. Sketch elevation views of trusses
   d. Coordinate trusses with architecture in 3 Dimensions
   e. Finalize all transfer options and select floor which will incorporate trusses
2. Task 2: Analyze and Design Transfer Systems and Perimeter Columns for Gravity Loads
   a. Determine gravity loads and perform load takedowns for individual columns
   b. Create ETABS model for possible transfer options
   c. Establish trial member sizes
   d. Finalize all member sizes
   e. Compare all possible transfer options

II. Impact on Lateral System

1. Task 3: Create ETABS Model for Lateral Analysis
   a. Build 3-D model using finalized transfer options
2. Task 4: Perform In-Depth Lateral Analysis
   a. Input gravity and lateral loads and input combinations of load cases
3. Task 5: Evaluate Lateral Force-Resistant System
   a. Compare lateral drifts to code drift limitations
   b. Evaluate design and re-size braced frame members to reduce drift if needed
   c. Compare new and existing lateral systems

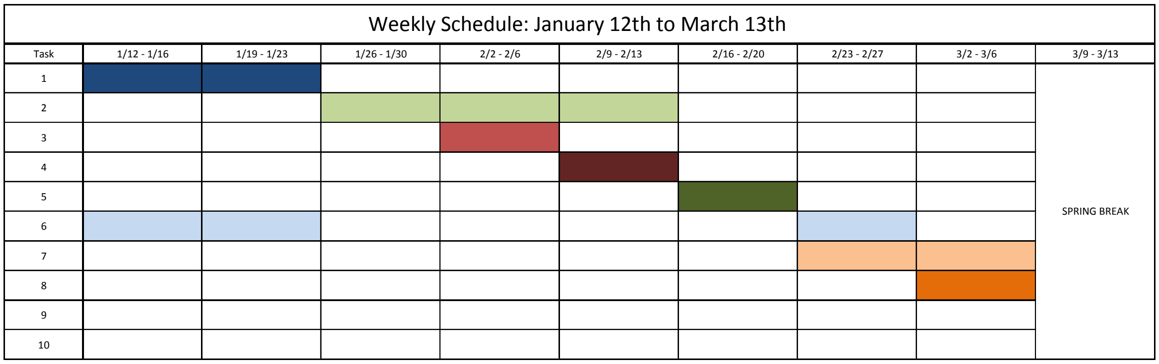
III. Breadth Studies

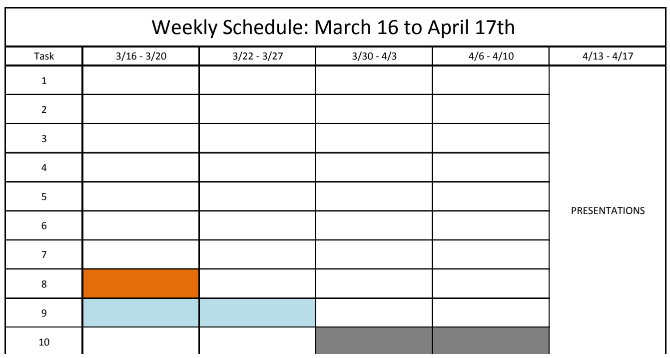
1. Task 6: Architecture
   a. Study requirements for exposed steel members
   b. Ensure trusses meet functional and aesthetic requirements
   c. Finalize floor plan for chosen truss configuration
2. Task 7: Construction Management Impacts - Schedule
   a. Study existing structural system erection schedule
   b. Create construction schedule for the new structural system
   c. Compare schedule of new structural system to the existing
3. Task 8: Construction Management Impacts – Cost
   a. Study existing structural system costs
   b. Estimate cost for the new structural system
   c. Compare costs of new structural system to the existing

IV. Comparisons and Presentation

1. Task 9: Final Comparisons
2. Task 10: Presentation

Schedule





Task 1: Determine schematic location and configuration of Transfer System
Task 2: Analyze and Design Transfer Systems and Perimeter Columns (Gravity Loads)
Task 3: Create ETABS Model for Lateral Analysis
Task 4: Perform Lateral Analysis - Input Lateral Loads and Load Cases
Task 5: Evaluate Design for Drift due to Lateral Loads and make appropriate improvements
Task 6: Architecture
Task 7: Construction Management Schedule Impacts
Task 8: Construction Management Cost Impacts
Task 9: Final Comparisons
Task 10: Presentation

Conclusions

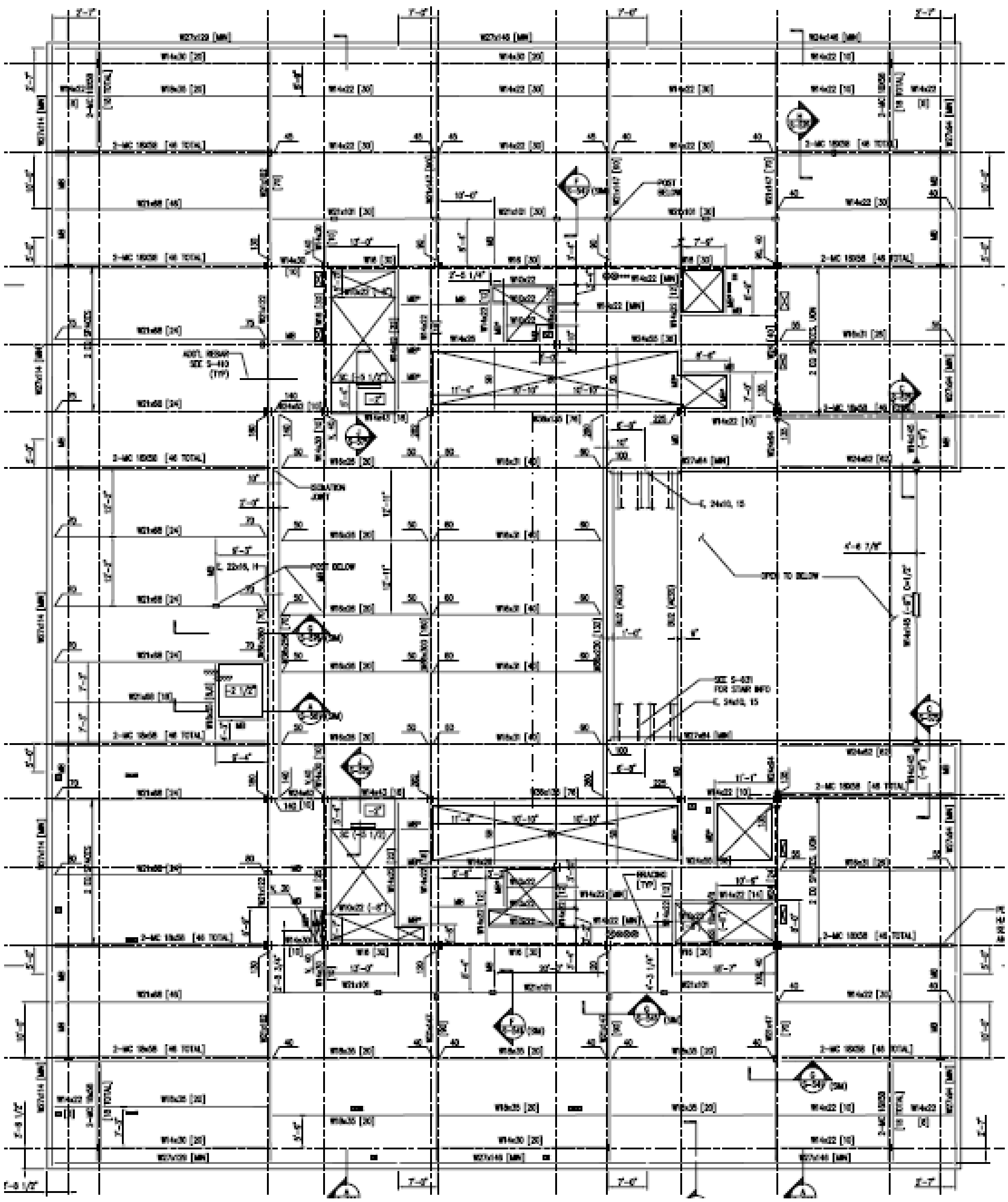
Due to the complicated existing structural system design of the John Jay College Expansion Project, several constructability issues make the project extremely expensive. In an attempt to simplify the structural system, the trusses which transfer gravity loads over the Amtrak tracks beneath the building to the braced frame core will be moved from the penthouse level and redesigned to fit the 5^{th} or 6^{th} level. Therefore, instead of hanging levels 6 through 14, typical steel framing can be used to support each floor. To allow the trusses to be moved to one of these levels, an architectural breadth will be studied in which the floor plans will be reconstructed and the partially exposed transfer trusses will be detailed to meet code, functional, and aesthetical requirements.

By changing the location of the transfer trusses from the penthouse level to the 5^{th} or 6^{th} level, several other aspects of the project are affected. The North-South braced frames of the 14 story tower use the trusses at the penthouse level as a large coupling beam which helps control drift due to lateral forces in the North-South direction. As a result of moving the coupling action from the penthouse level to a lower level, a detailed lateral analysis will be performed to determine building and story drifts. Braced frame member sizes will be increased or decreased to control lateral drifts as according.

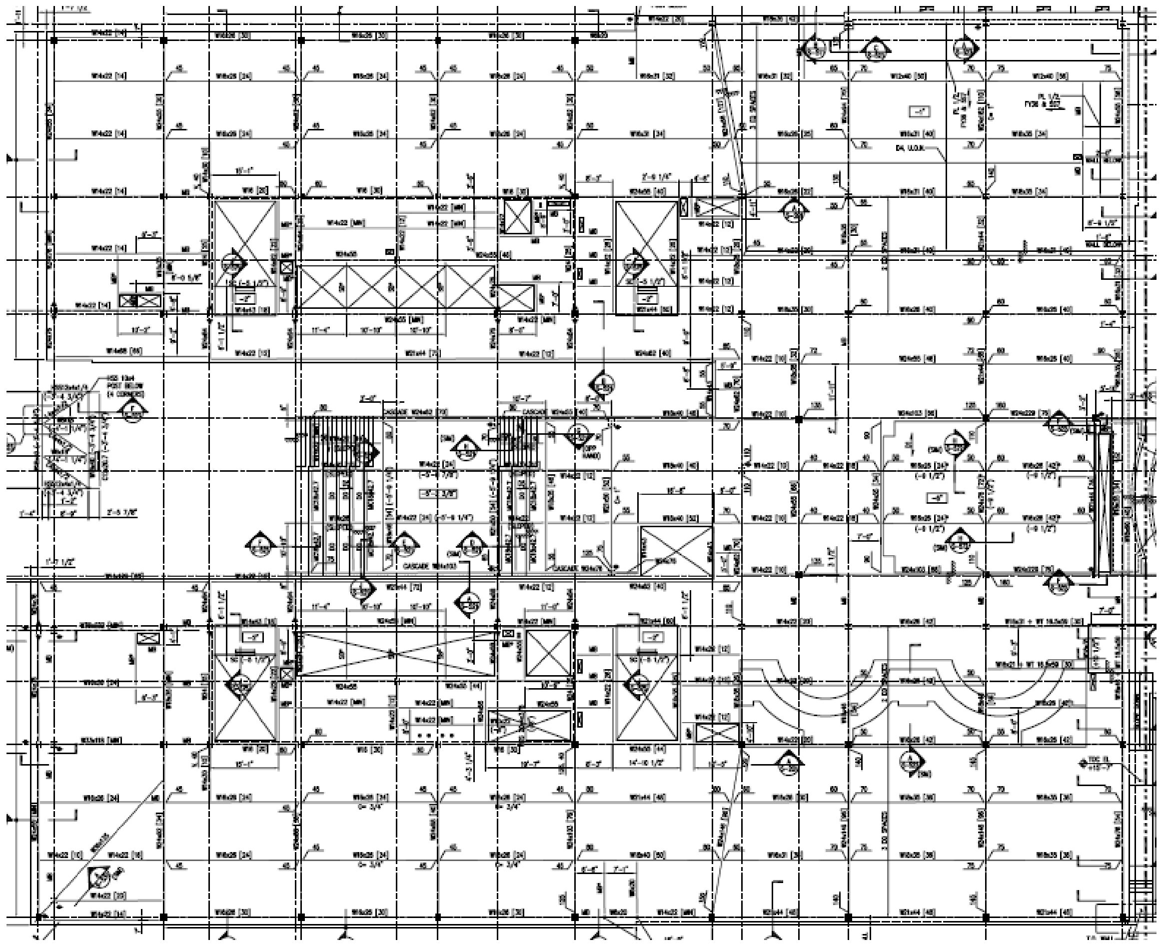
Another aspect which will be significantly impacted by changing the location of the transfer system is the construction schedule. By using typical steel framing for levels 6 through 12, rather than hanging these floors, there is no need for temporary columns and bracing. This idea, along with an easier structure to erect, will reduce construction costs and time and will be studied in detail for the remainder of this project.

After completion of studying the proposed structural system, as well as the architectural and construction impacts, a final comparison and recommendation will be given.

Appendix A – Typical Framing Plans

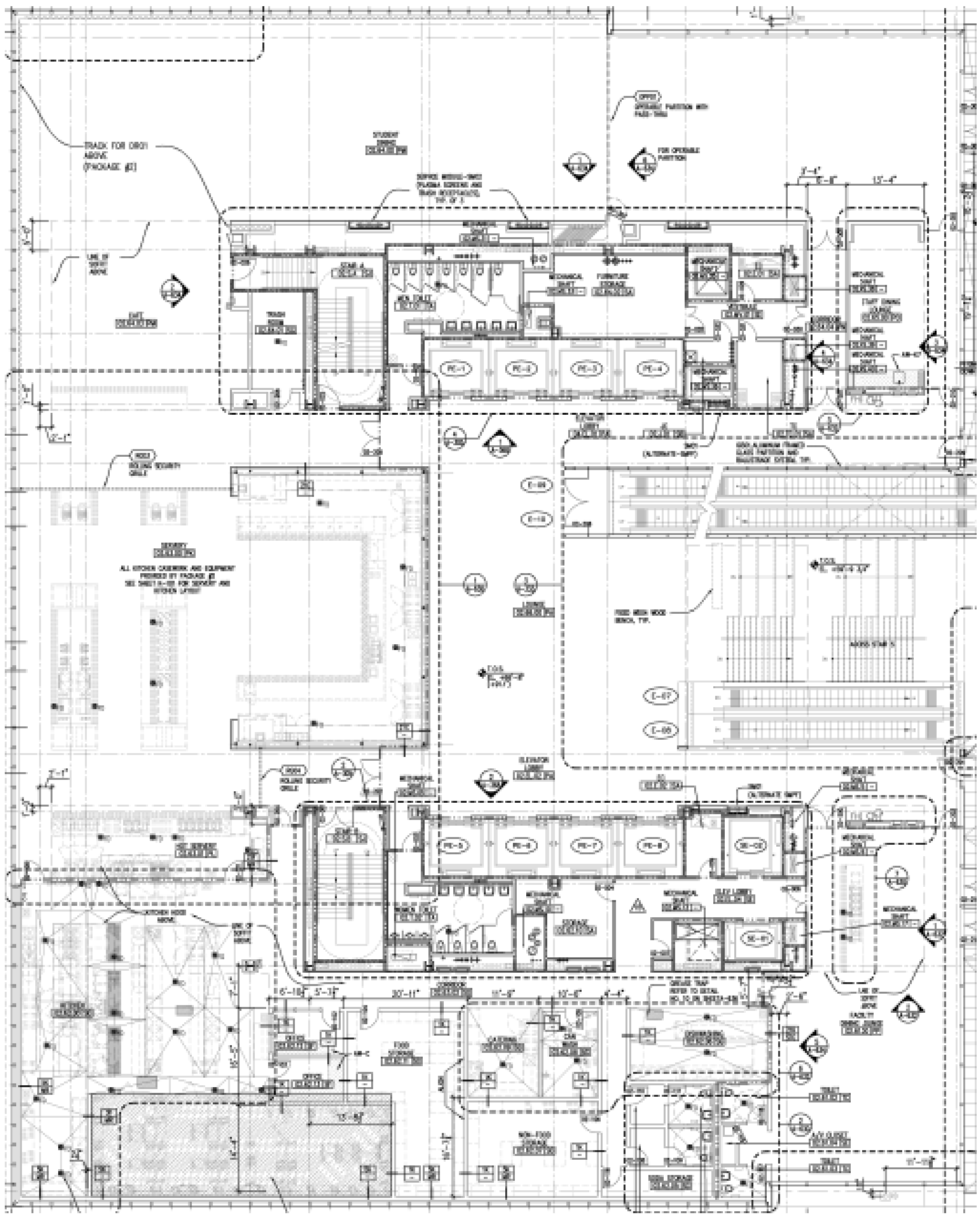


Typical Tower Framing Plan

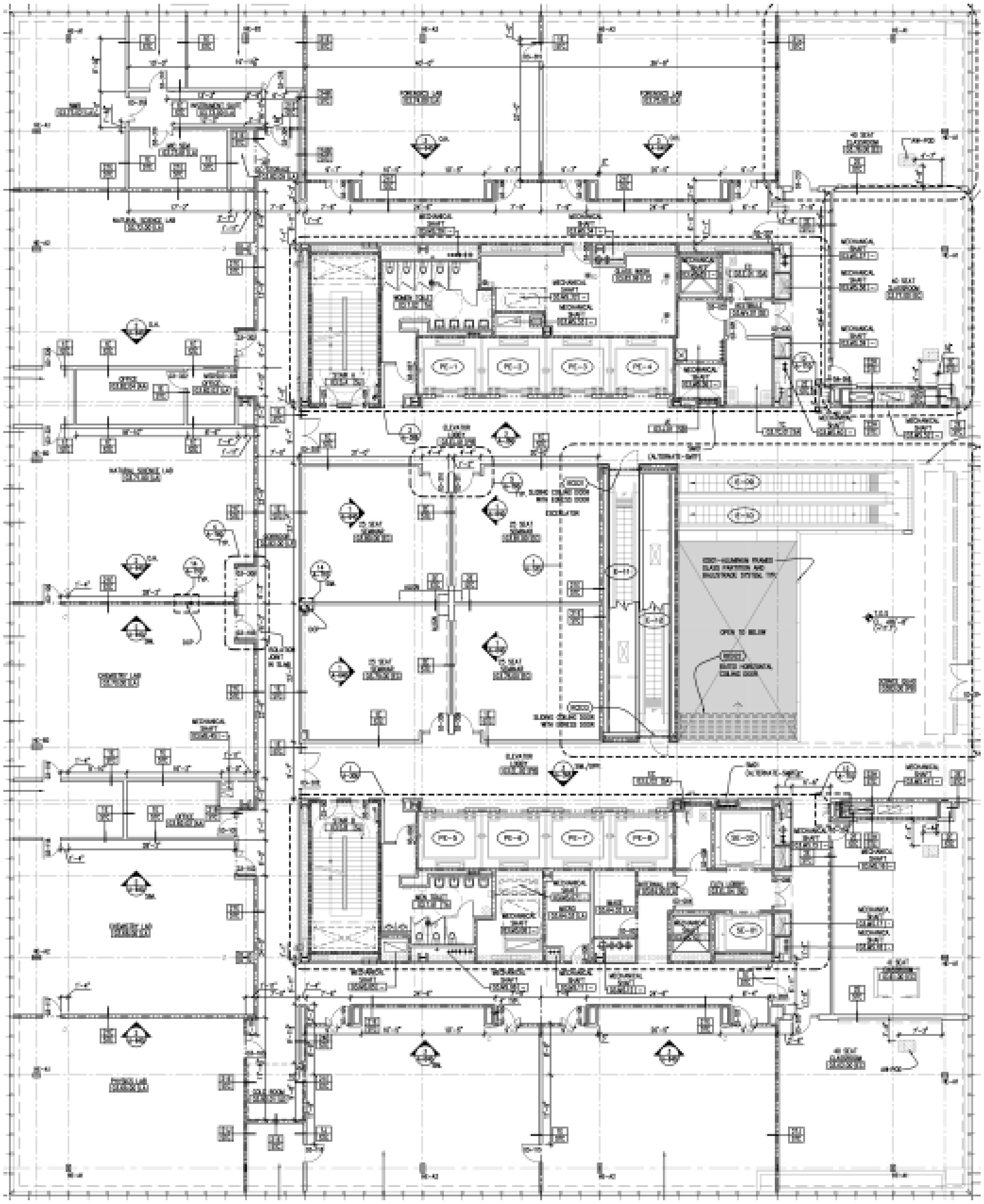


Typical Cascade Area Framing Plan

Appendix B – Architectural Plans



Fifth Floor – Partial Floor Plan



Sixth Floor – Partial Floor Plan