Proposal

West Village Housing Phases III & IV

Towson, Maryland

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Executive Summary

West Village Housing Phases III & IV is located on Emerson Drive in Towson Maryland on Towson University's campus. The project consists of two residential halls which will contain approximately 325,000 gross square feet of apartment-style accommodations for upper level students. The 9 and 11 story residence halls will contain a mix of two and four bedroom apartments. Each with single occupancy rooms and shared bathrooms, kitchens and living areas. Green roofs, penthouses and a basement are also planned to be included. The two buildings have not been named yet.

Structurally, the buildings are composed of 8" thick two-way post-tensioned concrete flat plates supported by reinforced concrete columns. Bays are approximately 27' by 20' with slight variances as the buildings shape changes. They are reinforced with ½" diameter un-bonded tendons in each direction and typical reinforcing, as required. In addition to the floor composition, perimeter steel angles will be provided at each floor level to support the exterior brick veneer with metal frame back up. 12" thick concrete shear walls will effectively resist the forces imposed on the building from all lateral loads. All stair and elevator walls be reinforced concrete shear walls.

Construction of the buildings began simultaneously in September of 2014 to address the continued demand for on-campus housing and are planned to be completed in the summer of 2016. They were designed considering live loads, gravity loads, snow loads, wind loads, seismic loads, and lateral loads. The lateral force resisting system in the building is primarily made up of shear walls that are located around the two stair and elevator towers of the structure located at either ends of the building. The project uses the 2012 Edition of the International Building Code and ASCE 7-10. Design loads were determined based on these codes, additional Baltimore Maryland County Codes and Ordinances, as well as practical engineering judgments.

For purposes of clarity and organization, this report and those following will be based off of the design and construction of the North building shown in Figure 1. Financial figures are being withheld upon request of the owner.

The continuation of this report will cover all of the above elements of this project and more in greater detail.

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1 Introduction

1.1 Purpose and Scope

The objective of this existing conditions report is to evaluate and describe the existing physical conditions of Towson University's, West Village Housing Phases III & IV North building with an emphasis on the structure.

This report will include an overview of the building and its structural components including the typical floor framing, structural slabs, lateral resisting system, foundation system, typical connections and joints, bracing elements and any other structural system elements used. In addition, a further understanding of how the primary structural components work together as a system will be described.

The knowledge documented in this report will be used as reference in future notebook submissions.

1.2 Building Overview

The North building of West Village Housing Phases III & IV is a high-rise residential apartment building located off of Emerson Drive on Towson University's campus. This 9 story building will reach a height of 92' when it is completed in the summer of 2016. The residential units are two and four-bedroom student apartments with shared kitchen, living and bathroom areas. Each main floor contains a quiet study as well as an open lounge area to break up the floor plan which creates a common area for the students. The 1st floor opens up to a lobby with large store front windows to allow light through the building. A large multipurpose room is located on the North West corner with great views and has close proximity to the housing and residents life suite. The HRL suite is purposefully located on the main floor

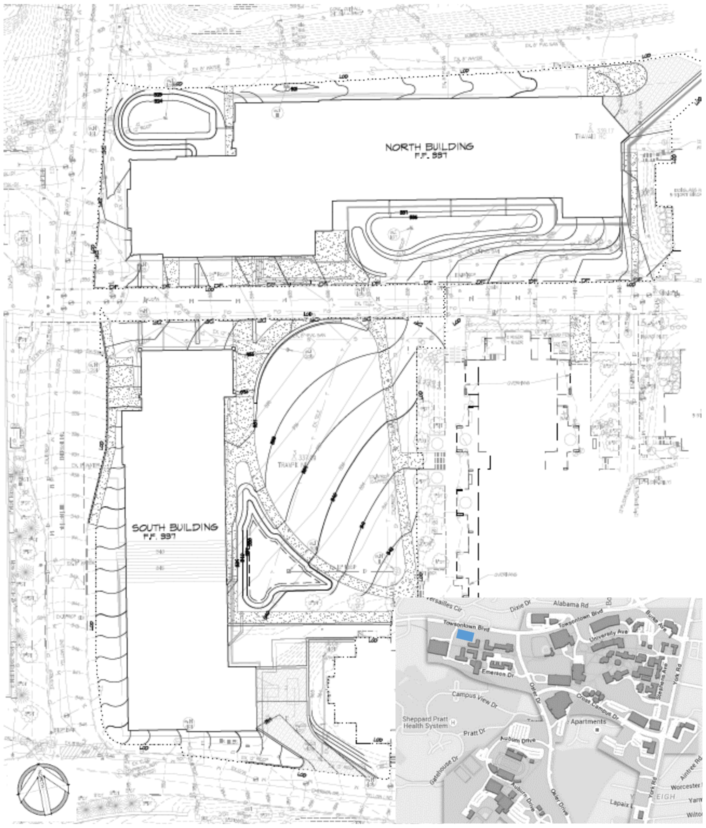


Figure 1: Building Location on Site

for easy access to any student who needs aid but also provides privacy for the resident's life tenants. The building is located in the West Village area of campus, which already contains six residence halls with more than 2,100 student beds; a Commons facility with dining areas, student service space and a 1,500-space parking garage. The educational facilities are located just a short walk east of the project site.

Ayers/Saint/Gross based out of Baltimore, Maryland were the lead architects on the project and worked closely with Towson University Construction Services to develop these apartment buildings on campus. Hope Furrer Associates, the structural engineers on the project, simultaneously worked with the architects to produce an efficient structural system that molded well with the architecture and met the client's needs.

Figure 2: Birds-eye view of north building

The University has contracted with Whiting Turner Contracting Company to provide pre-construction services during the design phases, and to be the Construction Manager at Risk during construction. Similar to most new buildings on Towson University's campus, the two new residence facilities will be built in adherence with sustainable design and construction standards and are expected to achieve LEED Silver certification.

1.3 Structural Systems Overview

West Village Housing's new North building consists of 8" thick two-way post-tensioned concrete flat plates supported by concrete columns. The foundation of the structure is supported by concrete columns and rammed aggregate piers (RAPs) along with spread footings, and foundation walls. Concrete shear walls located on the central axis of the building on both East and West sides are the primary lateral force resisting system and span the entire height of the building. These elements shall be founded on 48" thick mat foundations and shall extend out from the face of the wall. Concrete shear walls shall be assumed at all stair and elevator walls. Roof construction, shall be post-tensioned concrete flat plate similar to the typical floors noted above. In the pages to follow, each component of the structural system will be explained in more detail.

2 Structural Framing System

2.1 Foundation System

A geotechnical study was done by D. W. Kozera, Inc. who was able to provide useful recommendations for the foundation to the design team and structural engineers. Foundation levels are found at nominal structural depths or frost depth, and the encountered soil at footing subgrade are natural soils, newly placed compacted structural fill, or existing fill soils. The existing fill soils were found to be insufficient to support the foundation due to the unknown nature of their locations on site. In order to utilize the conventional spread footings at the North Building, Rammed Aggregate Piers (RAPs) are required.

RAPs are installed by constructing successive layers of densely compacted aggregate in a drilled vertical shaft measuring between 24 and 36 inches in diameter. The aggregate is then tamped making a ramming action which produces lateral prestraining and prestressing in the adjacent soils. Additional lifts of graded aggregate are then successively placed, creating a continuous shaft. The use of traditional shallow spread footing foundations can be then used because of the increase in strength and stiffness due to the compacted aggregate shaft. These piers are designed for an allowable bearing pressure of 5ksf. A simple RAP disturbance zone diagram can be seen in Figure 3.

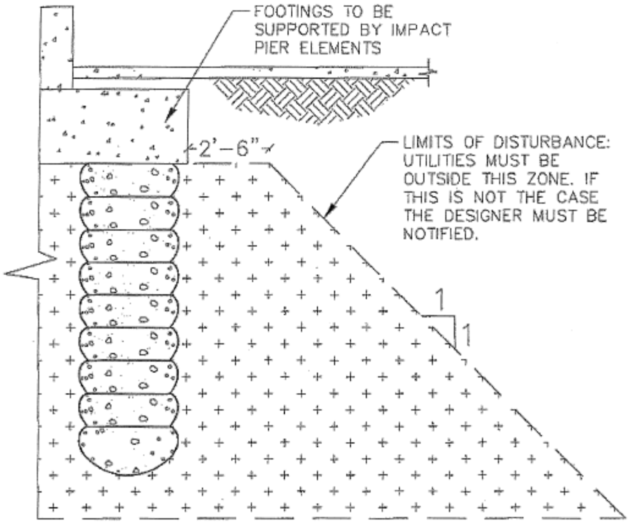


Figure 3: Example of RAP disturbance zone

The RAP ground improvement is typically designed and installed by a qualified contractor, in conjunction with the information provided by the structural engineer. Considerations that affect the design of RAPs include ground water elevations above the RAP tip elevation, soft or loose soils that may collapse during excavation, and the potential for construction debris in the fill soils. RAPs should fully penetrate the existing fill and loose residual soils and extend into dense residual soils. Therefore, RAP shaft lengths ranging from 15 to 30 feet below the finished floor exist for West Village Housing's north building. Once rammed aggregate piers are installed, the compacted/confining zone surrounding the RAPs cannot be disturbed. The disturbance cannot occur after the RAPs are installed regardless of whether the building load is applied yet or not.

The column footings (Figure 4) were recommended to be designed to have a maximum load of 700 kips. All footings are at least 16 inches deep for shear considerations. In addition, they are placed at least 30 inches below final exterior grade for frost protection. At the east end of the North Building, up to 15 feet of the wall is below final exterior grade. Therefore, the perimeter walls were required to resist lateral earth pressure loads. Designs and parameters can be seen in Figure 5. Walls shall be 12" thick reinforced with #5@12" vertical bars on each face and #4@12" horizontal bars on each face and be supported by a continuous wall footing.

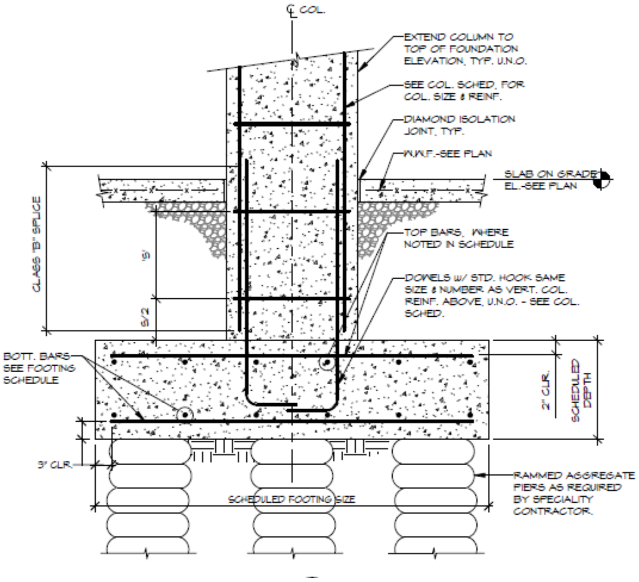


Figure 4: Typical column footing detail

A subgrade drainage system is required because the floor slab of the lower portion of the North building is below the surface of the groundwater table. It is designed to collect groundwater around the perimeter of the building below grade. Figure 6 shows the subgrade drainage detail and dimensions.

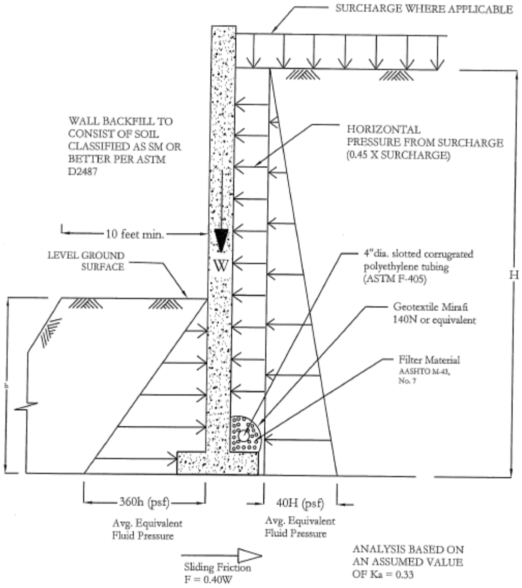


Figure 5: Lateral earth pressure diagram for cantilevered walls

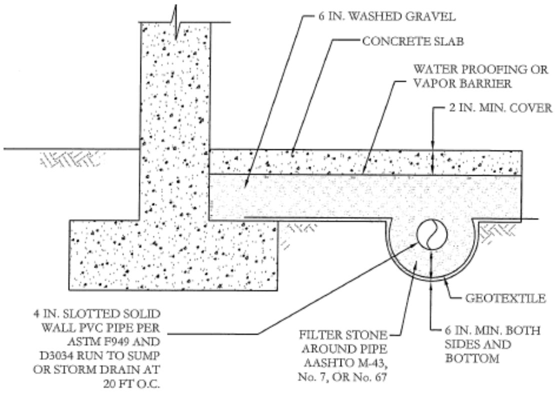


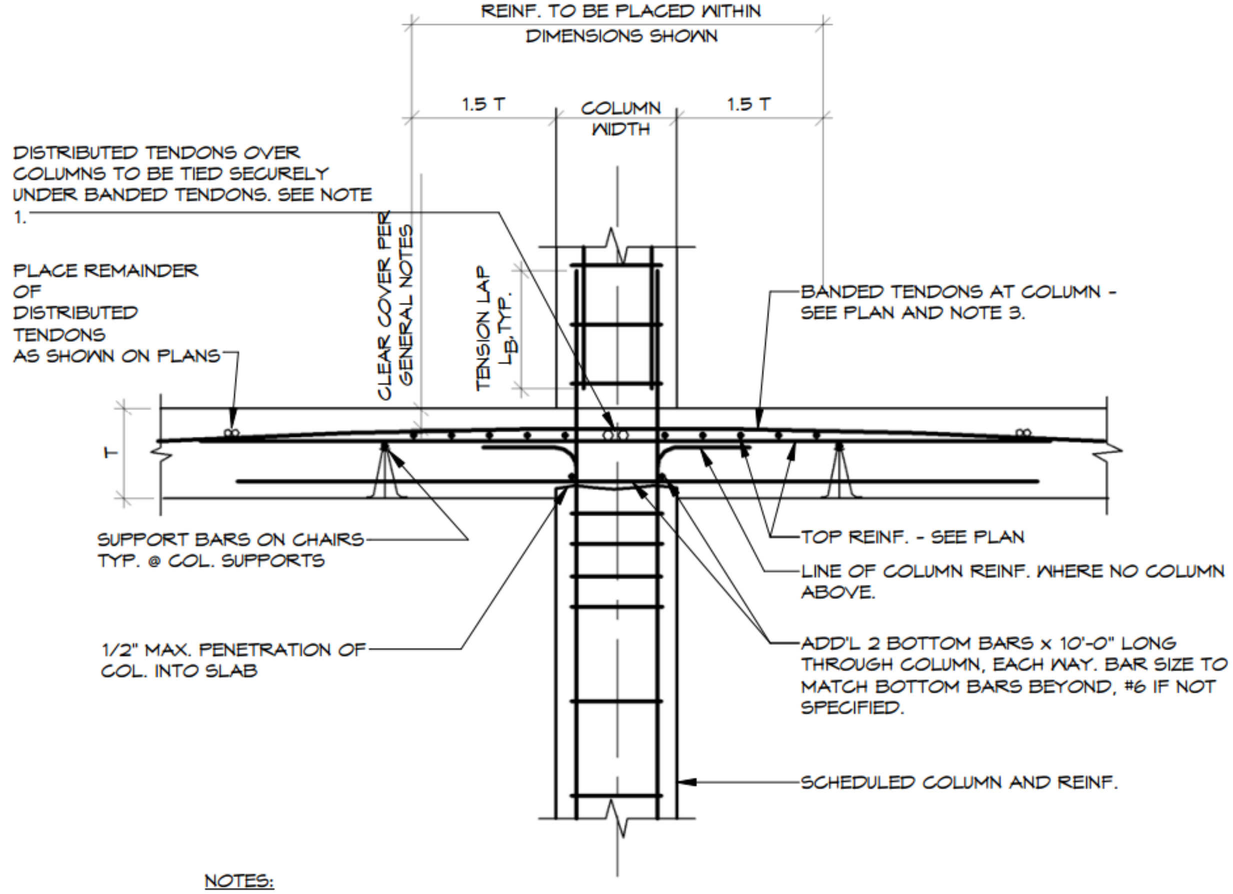
Figure 6: Typical sub drainage detail

2.2 Gravity System

The gravity system is comprised of the floor system and vertical columns in order to take the load to the foundation. The 3 sections below provide further detail.

2.2.1 Floor System

As previously mentioned, West Village Housing North Building is a concrete structure utilizing 8" thick two-way post-tensioned concrete flat plate supported by concrete columns. The slab is reinforced with ½" diameter un-bonded tendons in each direction and typical grade 60 reinforcement, as required, in other locations. The average pre-stress force in the slab shall be 18 kips/ft in each direction and the average weight of mild reinforcement shall be 2.5 lb/s.f. For the majority of the building, banded tendons run along the long axis of the building with uniform tendons running perpendicular. A painted textured finish with a UL 2-hour fire rated assembly is applied to the underside of the concrete. Below is a section showing reinforcement locations for a slab-column connection.



NOTES:

1. A MINIMUM OF TWO TENDONS SHALL BE PLACED IN EACH DIRECTION DIRECTLY OVER COLUMN.
2. WHERE BANDED TENDONS AND TOP REINFORCEMENT ARE IN SAME PLANE OVER TOP OF COLUMN, BANDED TENDONS TAKE PRIORITY.

Figure 5: Typical column-slab connection

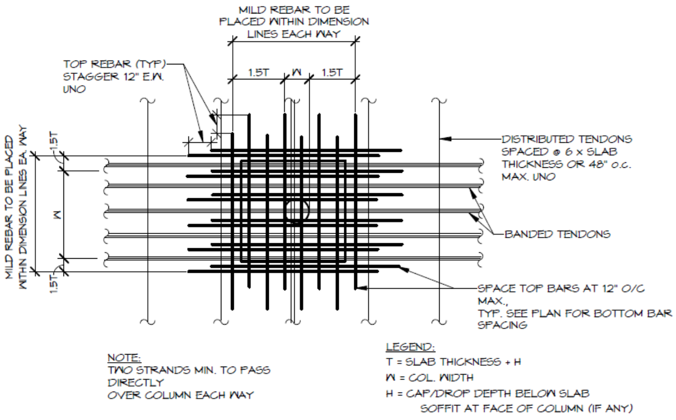
Concrete columns are another main aspect of the gravity system. As shown on the following figures, all the buildings columns have a 26" diameter and reinforced as follows:

Floors 1-4:
8#10 vertical bars with #3 ties at 18" o.c.

Floors 6 and up:
8#9 vertical bars with #3 ties at 18" o.c.

All column splices are Class B lap splices.

Figure 8 shows the complexity that goes into the construction of a typical column. Banded tendons must be aligned correct to line up with column lines.



NOTE:
TWO STRANDS MIN. TO PASS DIRECTLY
OVER COLUMN EACH WAY

LEGEND:
T = SLAB THICKNESS + H
W = COL. WIDTH
H = CAP/DROP DEPTH BELOW SLAB SOFFIT AT FACE OF COLUMN (IF ANY)

Figure 6: Top reinforcement at interior columns

2.2.2 Typical Bay

Due to the unique shape of the building and architecturally driven exterior, there are not "typical" bays. Multiple grid lines and non-symmetrical column spacing adds to the diverse bay layouts. Dimensions may vary per bay but the floor system described above is common between all of them. Figures 9 and 10, show the locations of the post-tensioned cables on the typical residence hall framing plan. The banded tendons running parallel to the long axis vary in force from 200 kip to 325 kip while the distributed tendons have a typical strength of 17 kip/ft. There locations were guided by the layout of the hallway and adjacent apartments in the East-West direction. The South West part of the building has tendons that swap grid lines in order to connect all column lines as shown below.

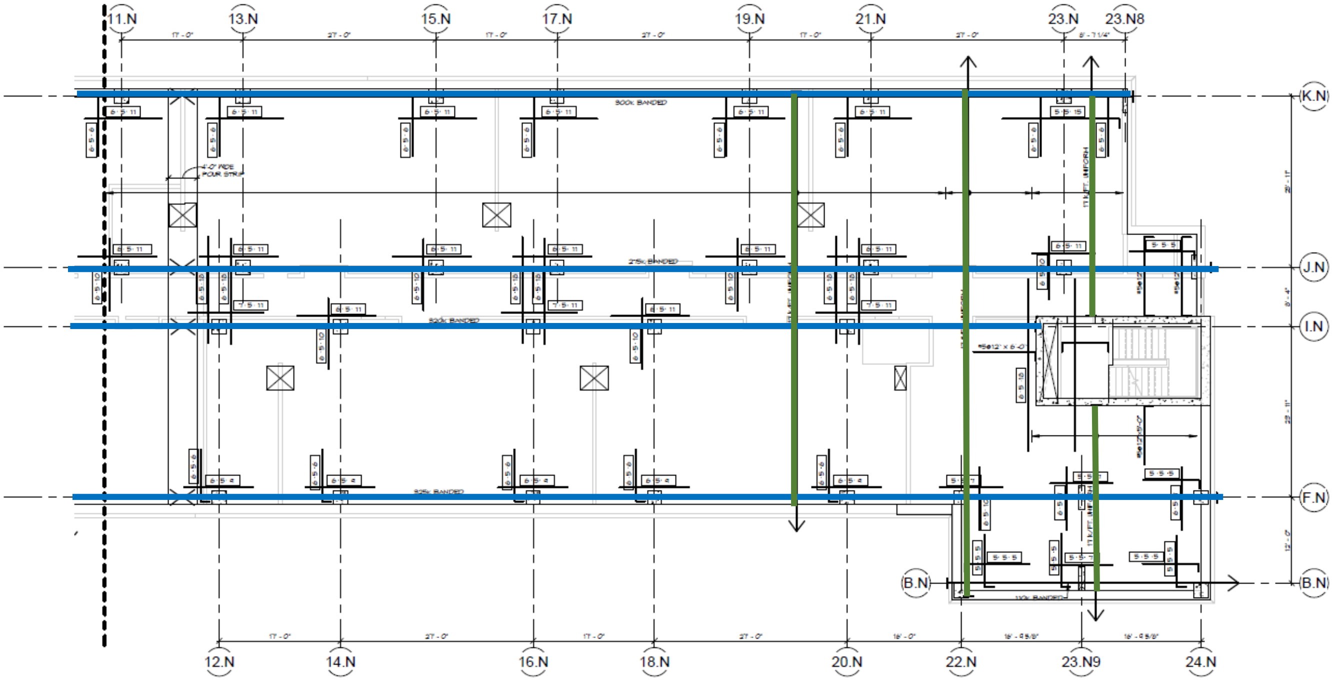
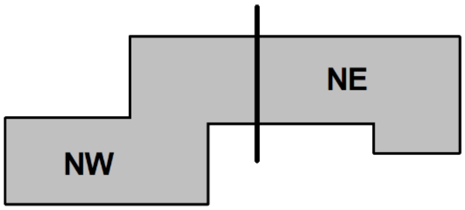


Figure 7: Typical Framing for East half of North residence hall

━ = Banded Tendons ━ = Uniformly Distributed Tendons



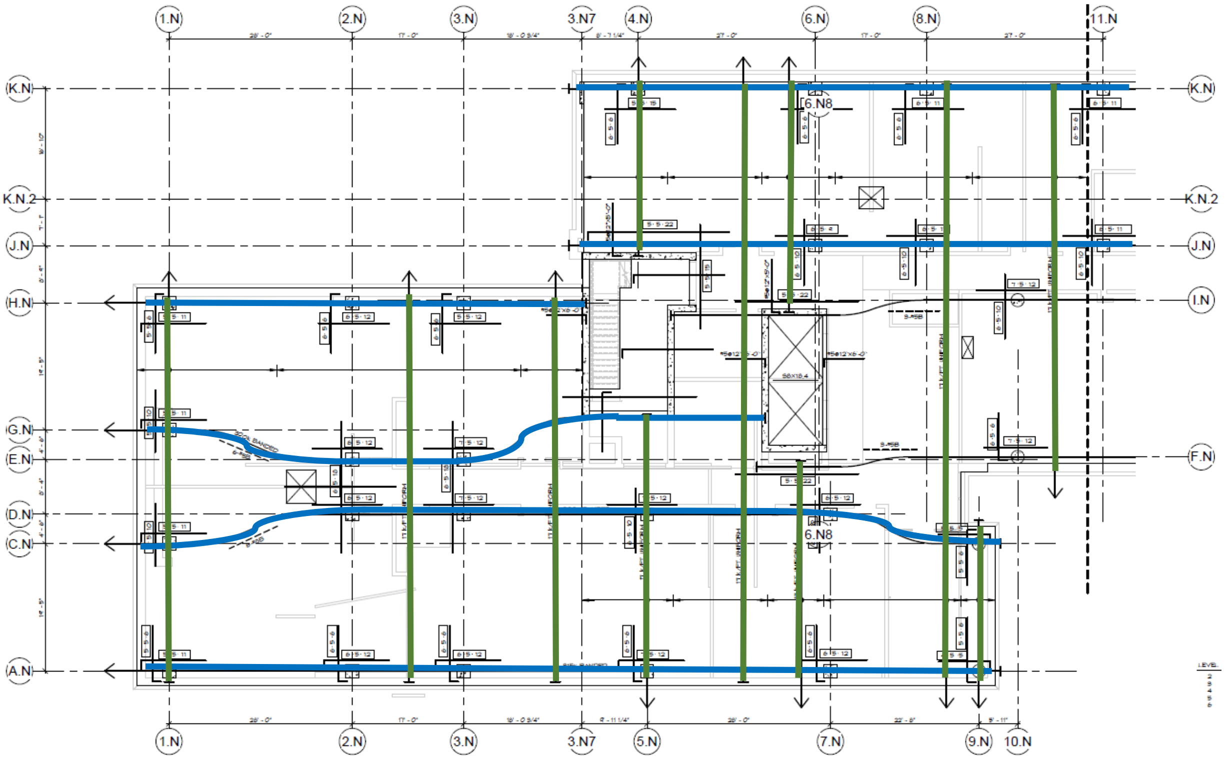


Figure 8: Typical framing for West half of North residence hall

2.2.3 Roof framing

Typical roof construction should be post-tensioned concrete flat plate similar to the typical floors noted above. As shown below, the slab is topped with a typical insulating concrete system. A green roof is also located on the South West portion of the building. It is comprised of hot fluid applied rubberized asphalt membrane that is fully adhered to the concrete deck, insulation, drainage retention mat and other planting materials noted in Figure 12.

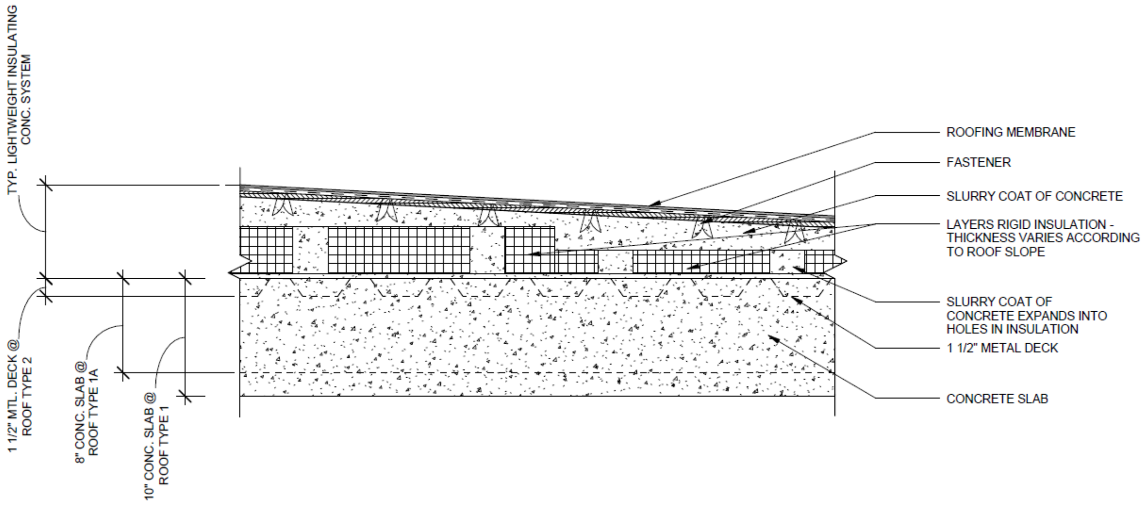


Figure 9: Lightweight insulating concrete roof detail

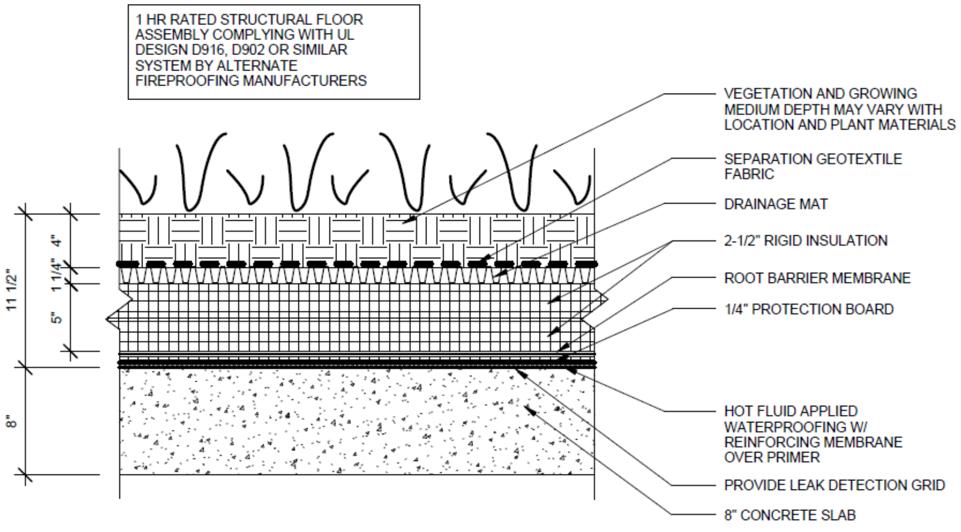
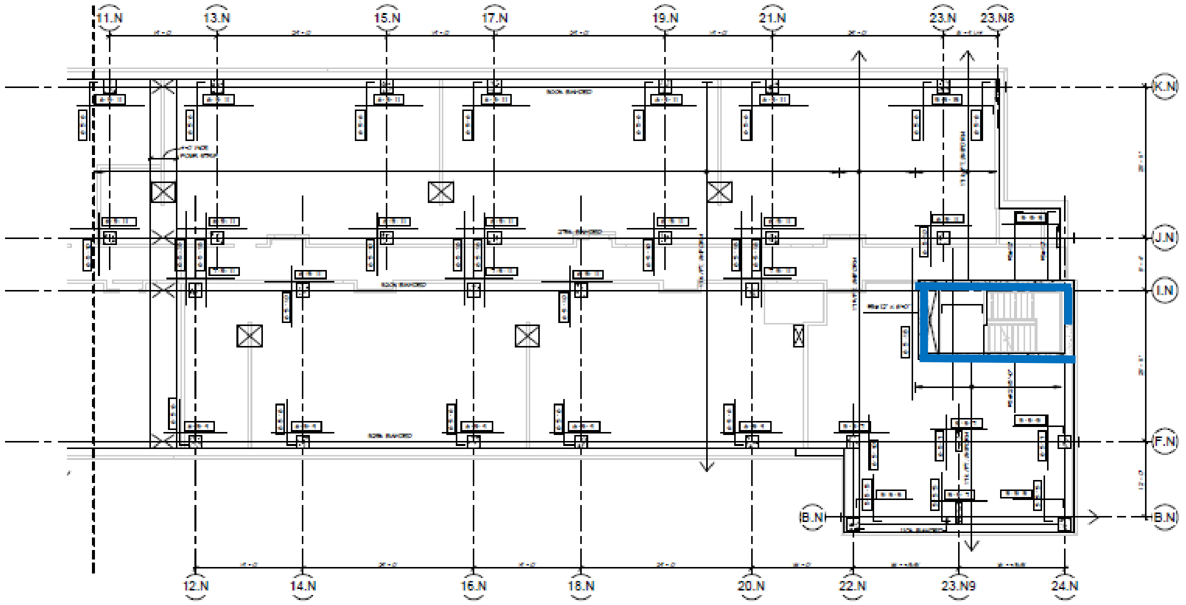
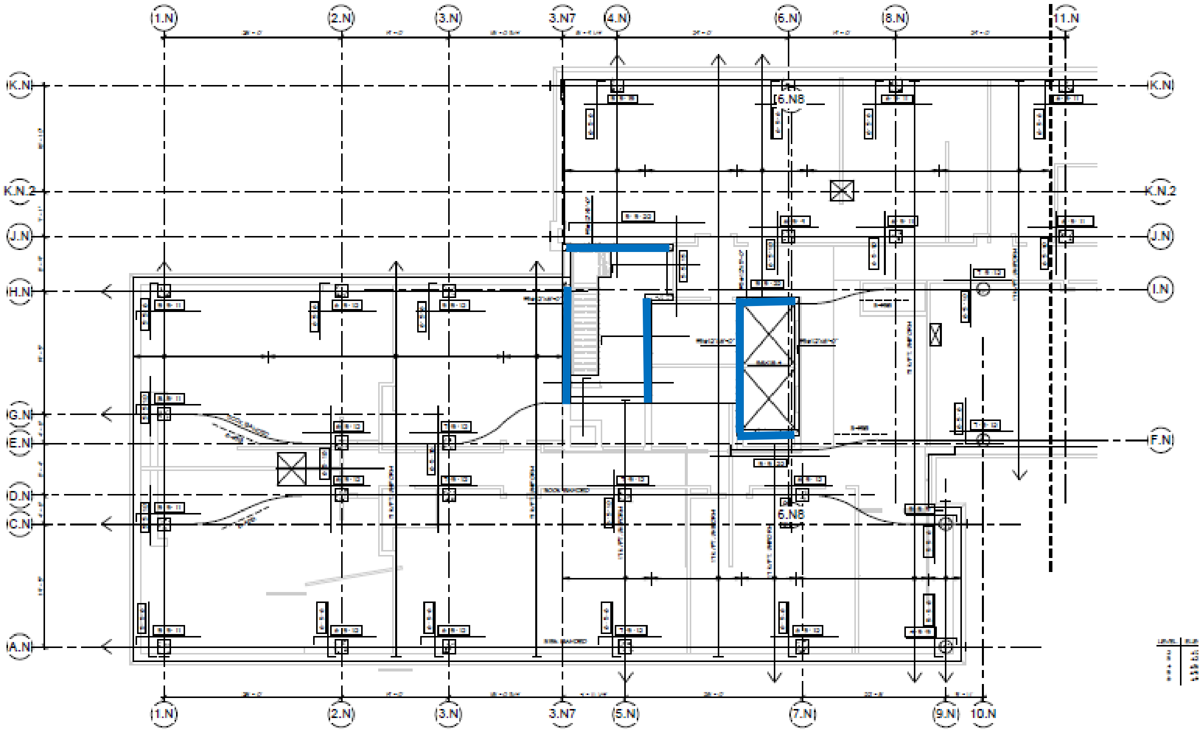


Figure 10: Green roof detail

2.3 Lateral system

The lateral force resisting system (LFRS) of West Village Housing North Building consists of 10 regular concrete shear walls that are 12" thick. They are located at the East and West ends of the building to effectively resist the forces imposed on the building due to the wind and seismic loads. All stair and elevator walls are concrete shear walls with an average weight of reinforcing of 7 lb/s.f.





The reinforcement in each wall consisted of #5 bars at 12” O.C. both vertically and horizontally. In industry this is common reinforcement for shear walls and is uniformly applied to all the shear walls in the building regardless of height or location. Below is Figure 13, showing elevations of two shear walls located on the west side of the building.

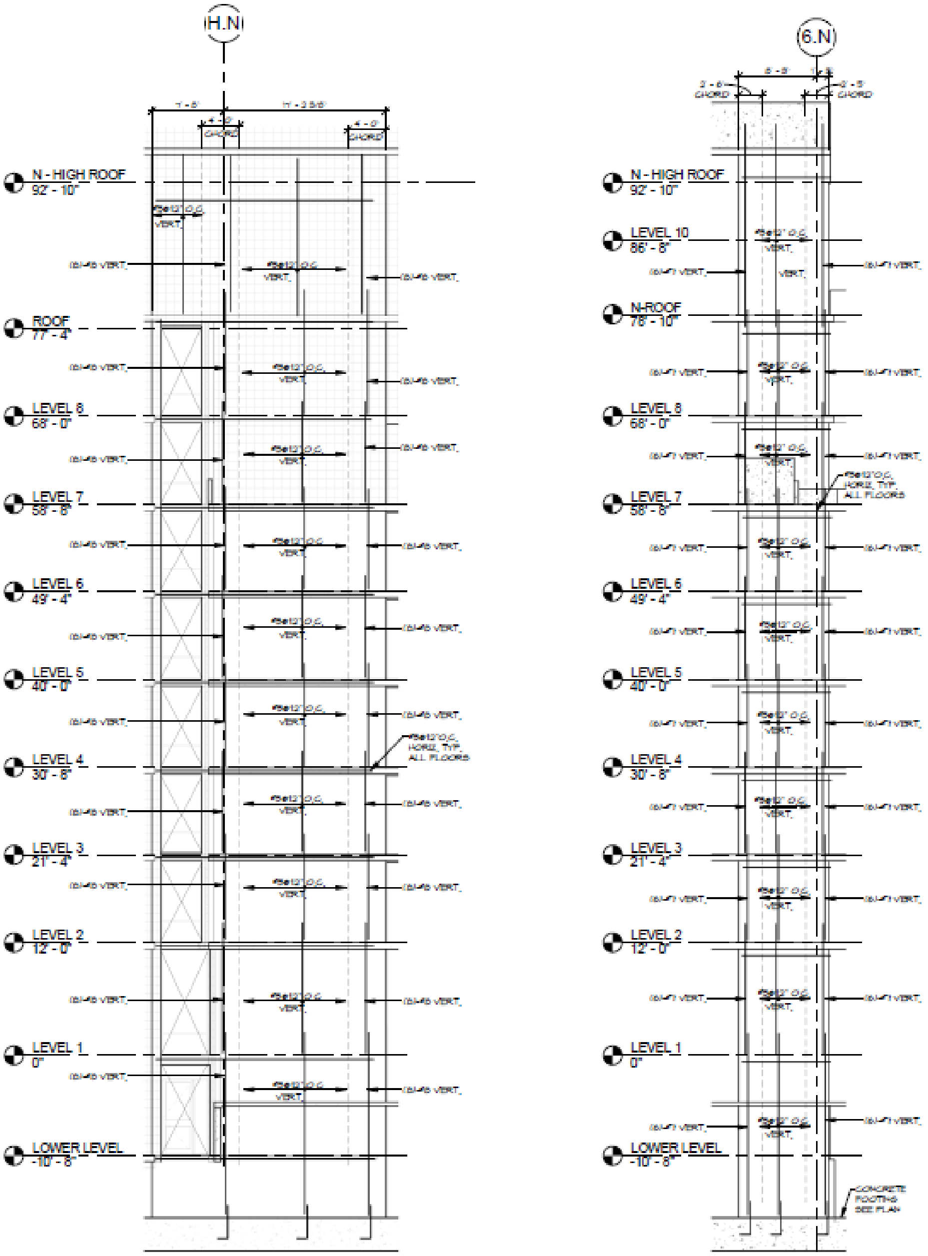


Figure 11: Shear wall elevations on west side of building

2.4 Joint Details

The figures on the right show some of the typical construction joint placements for the concrete slabs. The placement of a contraction joint seen in Figure 14 of is to control cracking for good overall structural behavior. The reinforcement holds random cracks tightly, keeping them small. Contraction joints are located on column centerlines with intermediate joints located between column lines, as required, to provide a maximum distance between joints of 15'. Construction joints (Figure 15 and 16) shall be placed in the slab where the contractors concreting operations are to conclude or be interrupted. This means that every time a concrete slab is finished pouring a construction joint is place to separate it from the next adjacent slab that still needs to be poured.

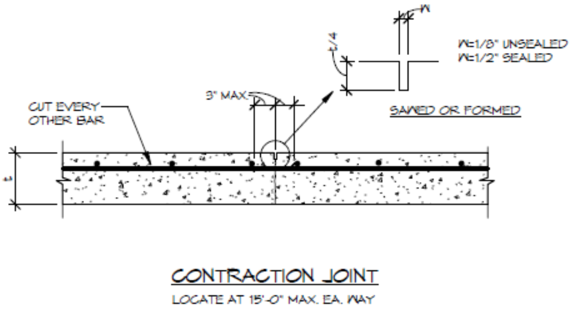


Figure 12: Typical contraction joint used to control random cracking in the floor slab

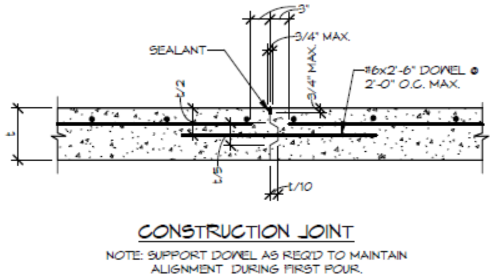


Figure 13: Typical construction joint

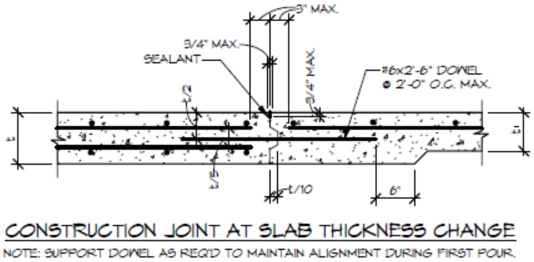


Figure 14: Typical joint when the slab alters its size at the exterior of the building

Joints at the exterior walls require sealants due to moisture. Silicone sealant is applied at exterior non-traffic joints and multi-component urethane is applied as traffic sealants. The joints that are between systems are faced with sheet membrane tape between cladding materials and at all penetrations to seal the air barrier.

3 Design Codes, Standards and References

The following is a list of some of the structural codes used on this project. These codes will be used and referenced in all future reports and design work for this thesis.

International Code Council

- International Building Code, 2012 Edition
- International Building Code, 2006 Edition
  - Used for drift and sliding snow loads only

American Society of Civil Engineers

- ASCE 7-10: Minimum Design Loads for Building and Other Structures

American Concrete Institute

- ACI 318-11: Building Code Requirements for Structural Concrete

Post Tensioning Institute

- Post Tensioning Manual, 6th Edition

American Institute of Steel Construction

- Steel Construction Manual, 14th Edition, 2010

Structural Welding Code

- Steel ANSI/AWS D1.1-10:2010

Towson University Construction Services (owner)

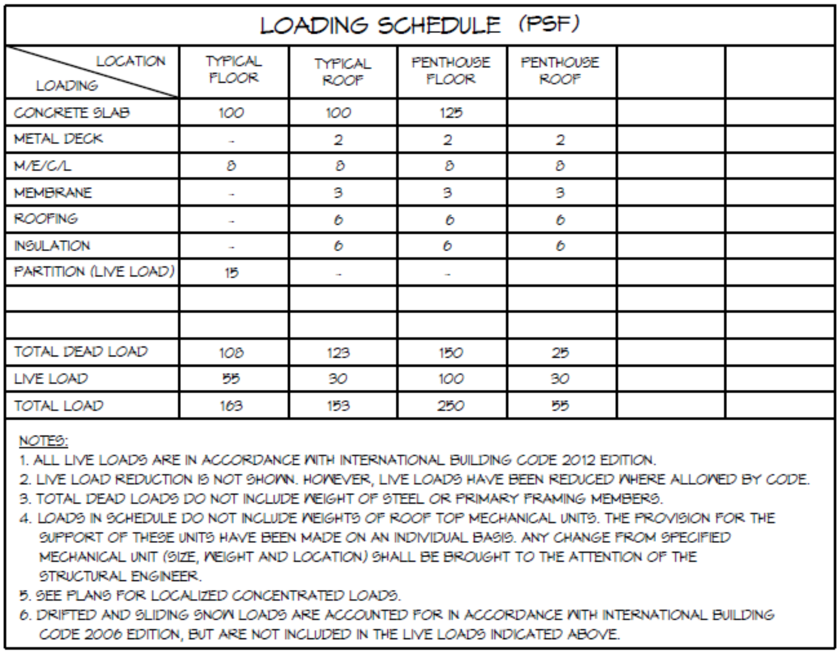
- Architectural drawings for project
- Geotechnical reports

Hope Furrer Associates (structural engineer)

- Structural drawings and details for project

4 Determination of Design Loads

This projects design live loads, wind loads and seismic loads are in accordance with IBC 2012 and ASCE 7-10. Through standard practice over many years, engineers have accumulated standard live and dead loads that can be found in both building codes. Some typical loads used on this project are shown below. The below information does not cover all loads applied to West Village Housing's North building. It should however, provide a basis for typical loads seen in industry that apply to this building in particular. They are based on industry standards as well as engineering judgment from Hope Furrer Associates, the structural engineer on the project.



LOADING SCHEDULE (PSF)

LOCATION LOADING	TYPICAL FLOOR	TYPICAL ROOF	PENTHOUSE FLOOR	PENTHOUSE ROOF		
CONCRETE SLAB	100	100	125			
METAL DECK	-	2	2	2		
M/E/C/L	8	8	8	8		
MEMBRANE	-	3	3	3		
ROOFING	-	6	6	6		
INSULATION	-	6	6	6		
PARTITION (LIVE LOAD)	15	-	-			
TOTAL DEAD LOAD	108	123	150	25		
LIVE LOAD	55	30	100	30		
TOTAL LOAD	163	153	250	55		

NOTES:

1. ALL LIVE LOADS ARE IN ACCORDANCE WITH INTERNATIONAL BUILDING CODE 2012 EDITION.
2. LIVE LOAD REDUCTION IS NOT SHOWN. HOWEVER, LIVE LOADS HAVE BEEN REDUCED WHERE ALLOWED BY CODE.
3. TOTAL DEAD LOADS DO NOT INCLUDE WEIGHT OF STEEL OR PRIMARY FRAMING MEMBERS.
4. LOADS IN SCHEDULE DO NOT INCLUDE WEIGHTS OF ROOF TOP MECHANICAL UNITS. THE PROVISION FOR THE SUPPORT OF THESE UNITS HAVE BEEN MADE ON AN INDIVIDUAL BASIS. ANY CHANGE FROM SPECIFIED MECHANICAL UNIT (SIZE, WEIGHT AND LOCATION) SHALL BE BROUGHT TO THE ATTENTION OF THE STRUCTURAL ENGINEER.
5. SEE PLANS FOR LOCALIZED CONCENTRATED LOADS.
6. DRIFTED AND SLIDING SNOW LOADS ARE ACCOUNTED FOR IN ACCORDANCE WITH INTERNATIONAL BUILDING CODE 2006 EDITION, BUT ARE NOT INCLUDED IN THE LIVE LOADS INDICATED ABOVE.

Figure 15: Loading schedule

The structural dead loads include the load from slab, concrete topping and finishing, columns and beams. In addition, superimposed dead loads are applied to certain areas such as mechanical rooms for MEP units, roofing systems accounting for additional roofing materials and any rooftop concrete pavers that may be present.

Structural live loads vary upon occupancy and the use of the space. The loads used in this design can be found in ASCE 7-10.

Soil Loads for the building were calculated using the geotechnical report provided by Kozera D. W and will be detailed in further reports.

Snow Loads were determined from ground snow load maps in ASCE 7-10. Snow drift was calculated using the procedures given in the code.

4.1 Load Paths

The combination of dead and live loads results in a total gravity load that is applied to the building. The concrete floor slabs will resist these loads at every floor where load is applied or carried through the building. Each bay is defined or bound by either concrete columns or shear walls. These elements will take the load from the slab directly down to the base of the building into the foundations that they rest on. Through complex soil properties and engineered gravel the load is dispersed into the ground.

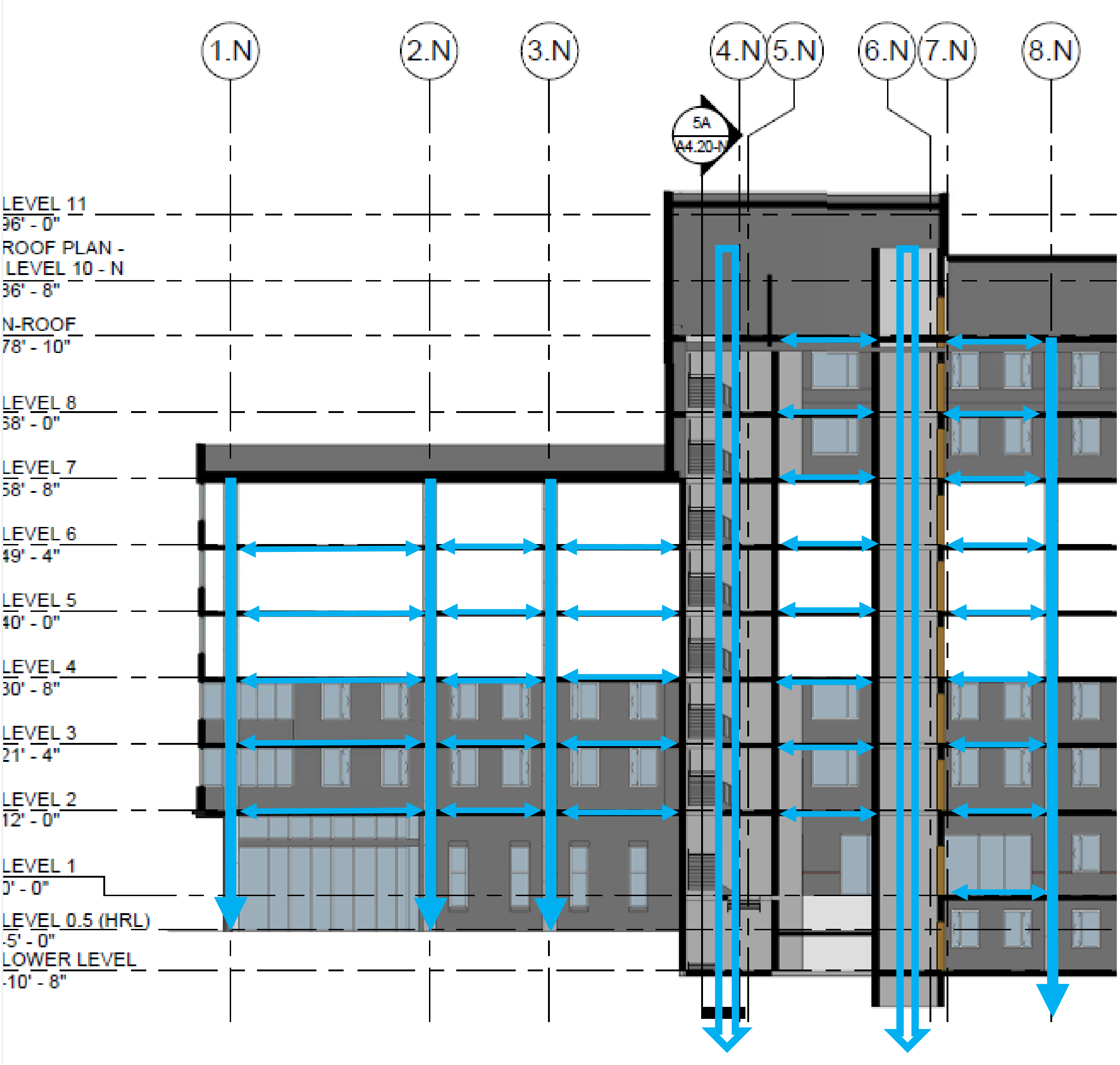


Figure 16: Longitudinal section through north building showing gravity load path

Lateral Loads are sometimes considered more complicated because they are more variable and abnormal than typical gravity loads. Wind forces are applied to the exterior façade of the building as a positive or negative pressure. Connections from the exterior façade to the main structure will transfer the load to the slab creating a horizontal force. In structural engineering, it is common knowledge that load follows stiffness. West Village Housing Building North can be considered a rigid diaphragm because it is comprised of concrete. Therefore, the load will be distributed to the LFRS elements based on their stiffness. Generally, the stiffer the shear wall is the more lateral load it will attract. After the load is distributed to the shear walls, it is then carried down to the foundations.

Earthquake shaking generates inertia forces that are considered seismic loads. These loads or lateral accelerations are applied anywhere there is mass in the building. Typically the higher the building the greater the seismic loads because of the greater amount of mass that is accumulated. The slab-frame connections previously mentioned in the report attracts the shear from these loads and distributed them to the reinforced concrete shear walls. When seismic loads are controlling, foundation design is more crucial to the project. This is because these forces are dependent on the mass of the building so the foundations have to be carefully designed to support the entirety of the load.

5 Structural Design Alternative

The north building of West Village Housing Phases III & IV consists of a reinforced concrete flat plate post tensioned system as well as reinforced concrete shear walls. Previous reports and notebook submissions, have determined that the structure is acceptable for both strength and serviceability requirements.

A new theoretical scenario has been proposed in which the architect and owner prefer the use of a new system rather than post tensioned concrete. This system would utilize precast concrete planks and steel joists for the floors as well as light weight metal gauge bearing walls. The redesign must consider the floor heights as well as the bay sizes when evaluating the appropriate redesign. A detailed schedule will have to be determined as a new design and new materials would adjust the current construction schedule. In addition, an acoustical analysis should be performed to ensure the comfort of the occupants would not get worse due to the structural changes.

5.1 Design Proposal

The proposed solution for the design is a pre cast concrete system with steel joists and bearing walls used for the gravity system with the use of shear walls for the lateral system. In order to maintain the current stair/elevator towers, the shear wall configuration of the building will remain the same as it has been proven to function as an efficient lateral system. RAM will be used to analyze the gravity system while ETABS and SAP 2000 will be used to analyze the lateral system in concurrence with hand spot checks.

Multiple factors based the decision to explore this new system. Pre cast concrete planks are an efficient way to construct long buildings of equally spaced bays with simple geometry. This can reduce the schedule for construction, simultaneously reducing the project cost. In addition, the use of light weight metal gauge bearing walls could reduce the overall building mass and effect of seismic loads on the building. To simplify the layout, the current column grid will have to be adjusted which could help reduce the amount of columns.

A buildings structure can affect many aspects of the project. One issue that is common in residential halls is high noise levels being heard from room to room. Another, is the simple deadline of the project and when people can occupy the building. These two factors were chosen to be evaluated further. In order to facilitate this design proposal, two breadth areas (acoustics and construction management) will be covered, in addition to the depth, to enhance the design and scope of work for the building.

5.2 Construction Management Breadth

The alternate system will have an effect on both the cost and critical path schedule of the project. A critical path comparison will be conducted for the new system in hopes that the overall project schedule will be shortened. The current systems cost is not to be revealed because of the request of the owner. However, calculating if the new system will reduce overall cost can be determined. This cost and schedule data will be used to determine the feasibility of the alternate system.

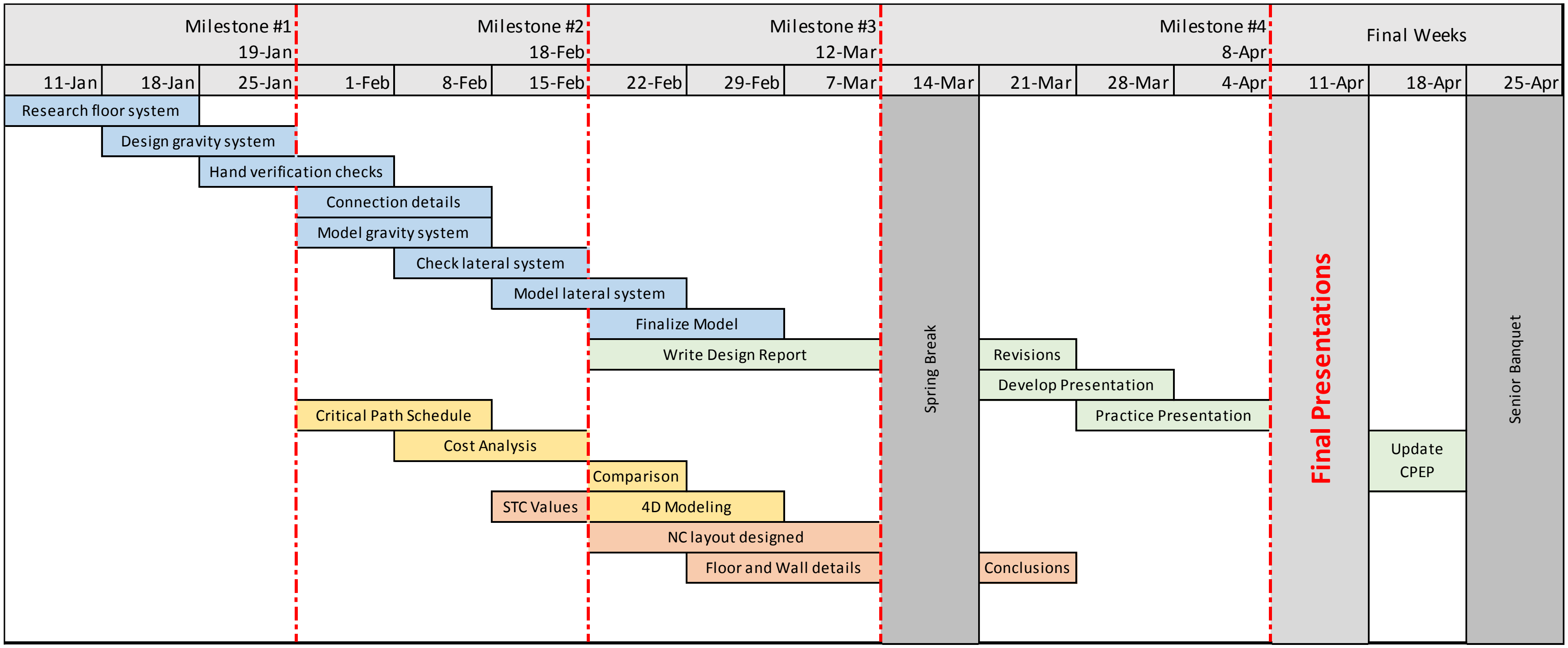
5.3 Acoustics Breadth

Sound transmission through walls and floors are a big factor for the comfort of occupants especially in residence halls. The architects and owners on this project would like to maintain or even reduce their current sound transmission criterion (STC) values. Changing the structure of the building will alter the amount of noise that is heard within the building. An acoustical analysis of a typical floor in the building will be performed for the current design as well as the proposed design to ensure that the STC values do not exceed the limits. In addition, other ways of reducing the noise transmission between rooms will be investigated.

5.4 Tasks and Tools

1. Research phase
    a. Obtain project scheduling information
    b. Research acoustical strategies in residence halls
    c. Develop adjusted column grid and beam layout
2. Design proposed system
    a. Design gravity system
        i. Calculate new structural loads
        ii. Design beams and columns
        iii. Create new 3D model in RAM to check member sizes
    b. Hand calculate strength and serviceability checks
    c. Develop standard detailing for new floor/wall connections
3. Check lateral system
    a. Calculate new building mass
    b. Adjust seismic loads in RAM model
        i. Create additional ETABs model to finalize lateral system
    c. Perform hand calculations for strength and serviceability checks
    d. Research alternative lateral systems if needed
4. Construction management breadth
    a. Develop a critical path schedule comparison for proposed system
    b. Obtain and highlight critical path schedule for existing system
    c. Calculate overall costs of new system
        i. Determine total amount of materials required (steel/concrete)
    d. Draw conclusions in terms of feasibility
5. Acoustic breadth
    a. Determine material STC values
    b. Calculate typical sound transmission between walls and floors
    c. Design floor plan layout showing noise levels
    d. Draw conclusions of improvement opportunities
6. Course documents
    a. Create final report outline
    b. Create presentation outline
    c. Finalize report and presentation
    d. Regularly update CPEP website

5.5 Work Schedule



Legend	
🟦	Structural Depth
🟨	Construction Breadth
🟧	Acoustics Breadth
🟩	Reports/Presentations

Milestone Activity Summary	
Milestone #1: initial research as well as gravity system design is complete	**Milestone #2**: Connection detail and lateral system is finalized and checked
Milestone #3: All modeling is finalized and the construction breadth is completed	**Milestone #4**: Report and presention are put together and revised

6 Conclusion

Next semester’s work will include a redesign of West Village Housing Phases III & IV North building’s structural system. The system will include precast concrete floors and light gauge metal bearing walls. The lateral system will remain the same as reinforced concrete shear walls. The breadth topics will cover construction management and acoustical disciplines. Included in the construction management breadth is a cost and schedule analysis of both the existing and alternate systems. The acoustical breadth will evaluate the changes to the walls and floors to determine if they are better sound barriers. The hopes of these two breadths is to find ways to improve or shorten the project schedule. In addition, residence halls can be loud for occupants which is why acoustical improvements will be part of the proposal.

Further study and design will be require the use of advanced modeling techniques, in-depth research, professional development and engineering ingenuity.