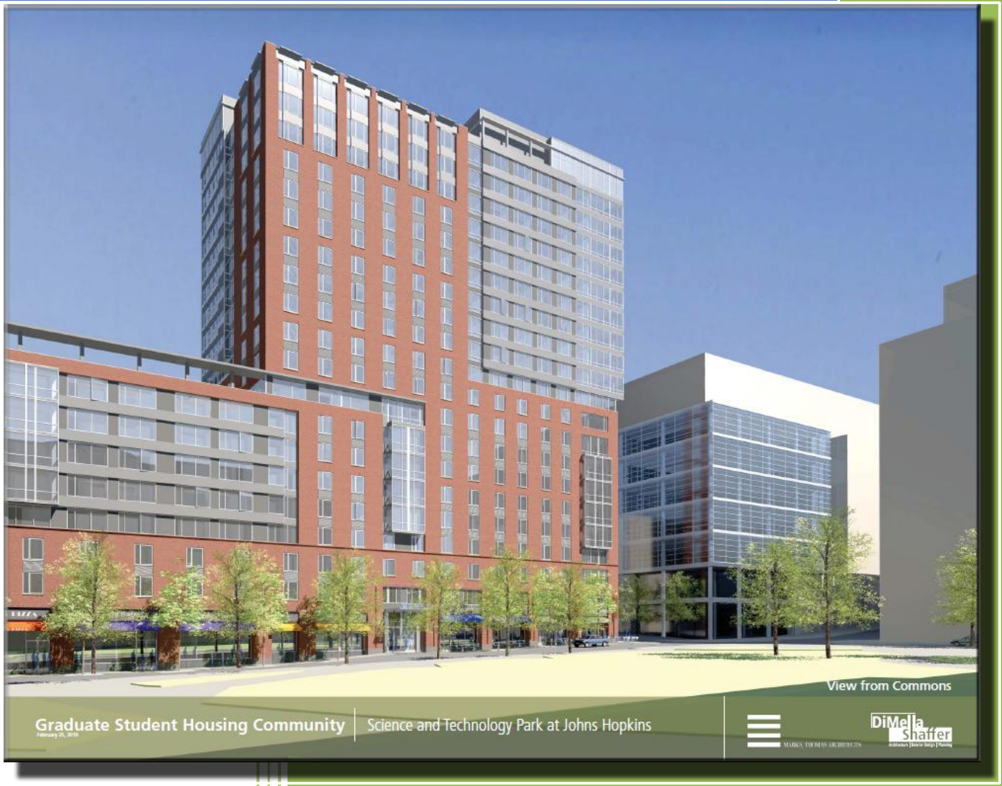
Johns Hopkins Graduate Student Housing

Thesis Proposal



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Baltimore, Maryland

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Table of Contents

Executive Summary -

The goal of this proposal is to identify an area to redesign for the semester as well as to breadth studies. Previous technical reports showed that the Johns Hopkins Graduate Student Housing project is a very efficient structure and also code compliant. Due to interests in seismic activity, a scenario was presented for this proposal that would change the location from Baltimore, to San Francisco, California.

Before moving the site to San Francisco, a steel system for gravity and lateral loads will be designed for Baltimore. At the current location, wind loads will most likely be the controlling case due to the building height (204 feet) and the reduced seismic weight. To resist the lateral loads, an eccentric braced frame will be utilized due to architectural flexibility. An eccentric braced frame will allow for the design to work around openings required for doors and elevator shafts.

Using steel frames in interior and exteriors spaces lead to an architectural breadth. The goal of the redesign is to minimize cost and structural depth similar just like the original design, while maintaining a functional and visually appealing architecture. Any columns or braced frames added will need to be investigated to ensure functionality and pleasing aesthetics. Designing the structure at the current location first will also allow for a construction management breadth study incorporating a schedule and cost comparison between concrete and steel. It is expected that the steel will lead in an expedited schedule saving money during construction, but more expensive material costs.

Once comparisons are made, the site will be changed to San Francisco due to an interest in seismic activity. The lateral system will be designed using a dual system of eccentric braced frames, and moment connections capable of resisting at least 25% of the seismic loads. A dual system is required because many of the lateral systems, such as the existing shear walls, are limited to a maximum height of 160 feet in seismic design category D.

The structure will be analyzed once again considering any additional impacts in schedule and costs. It is expected that costs will increase and create a slightly longer schedule due to larger member sizes and more complicated connections.

Introduction –

Located just outside the heart of Baltimore, 2 blocks from Johns Hopkins campus, is the site for the new John Hopkins Graduate Student Housing. This housing project is being constructed in the science and technology park of John Hopkins. A developing "neighborhood", the science and technology park is over 277,000 sq. ft. which is planned to host at least five more buildings dedicated to research for John Hopkins University. The site is also directly across from a 3 acre green space. This location is ideal because it places graduate students within walking distance of the schools hospitals, shopping, dining and relaxing.

Figure 1 - Showing glass and brick facade along with curtain wall.

John Hopkins Graduate Student Housing project is a new building constructed with brick and glass facades for a modern look. Upon completion, the building's main function is predominantly for graduate residential use, providing 929 bedrooms over 20 floors. There are efficiencies, 1, 2, and 4 bedroom apartments available. Other features include a fitness room and rooftop terrace. A secondary function of the building is three separate commercial spaces located on the first floor. Retail spaces provide a mixed use floor, creating a welcoming environment and bringing in additional revenue. At the 10th floor, the typical floor size decreases, creating a low roof and a tower for the remaining ten floors. Glass curtain walls on two corners of the building also begin on the 10th floor and extend to the upper roof.

The façade of John Hopkins GSH is composed mainly of red brick and tempered glass with metal cladding. Large storefront windows will be located on the first floor and approximately 6' x 6' windows in the apartments. The curtain wall is to be constructed of glass and metal cladding that can withstand wind loads without damage. There is a mechanical shading system in the windows to assist in the LEED silver certification.

Figure 2 - an overhead showing the green roof and large green area across the street. Courtesy of Marks-Thomas Architects.

John Hopkins GSH is striving to achieve LEED silver certification. Most of the points accumulated to achieve this level come from the sustainable sites category. A total of 20/26 points were picked up in this category due to a number of achievements such as; community connectivity, public transportation access, and storm water design and quality control. Indoor air quality is the next largest category where the building picks up an additional 11 points for the use of low emitting materials throughout construction. Several miscellaneous points are picked up for using local materials and recycling efforts as well. Shading mechanisms are also implemented throughout the design as well as an accessible green roof.

There are three different types of roofs on this project. Above the concrete slab on the green roof is a hot rubberized waterproofing followed by polystyrene insulation, a composite sheet drying system, and finally the shrubbery. The sections of roof containing pavers will be constructed using the same waterproofing, a separation sheet, the insulation and finally pavers placed on a shim system. The remaining portions of the roof will be constructed using a TPO membrane system.

Structural Systems –

Foundations:

A geotechnical report was created based on 7 soil test borings drilled from 80’ to 115’ deep. Four soil types were found during these tests: man placed fill from previous construction 7-13 feet deep, Potomac group deposits of silty sands at 40-75 feet, and competent bedrock at 80-105 feet. Soil tests showed a maximum unconfined compressive strength of 12.37 ksi. The expected compression loads from the structure were 2400k and 1100k for the 20 and 9 floor towers, respectively. The foundation system will also have to support an expected uplift and shear force, respectively, of 1400k per column and 180k per column. Based on pre-existing soils and heavy axial loads it was determined that a shallow foundation system was neither suitable nor economical.

In order to reach the competent bedrock, John Hopkins GSH sits on deep caissons 71-91 feet deep. Caissons range in 36-54” in diameter and are composed of 4000psi concrete. Grade beams, 4000psi, sit on top of the caissons followed by the slab on grade. Slab on grade consists of 3500 psi reinforced with W2.9XW2.9 and rests on 6” of granular fill compacted to at least 95% of maximum dry density based on standard proctor.

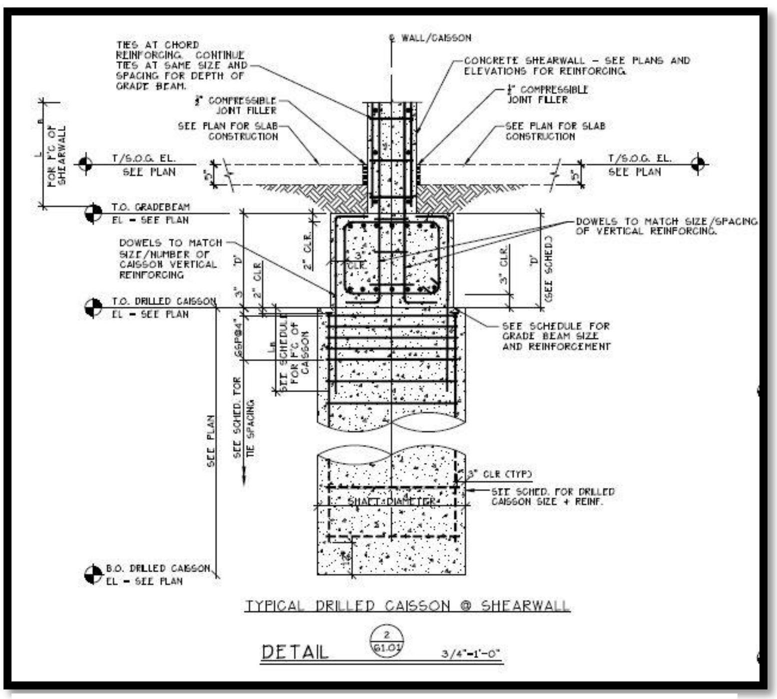


Figure 3 - a detail section of a caisson and column. Courtesy of EDR.

According to the geotechnical report, the water table is approximately 10 feet below the first floor elevation, therefore a sub drainage system was not necessary.

Floor Framing:

Dead and live loads are supported in John Hopkins GSH through a 2-way post-tensioned slab. The slab is typically 8" thick normal weight 5000 psi concrete reinforced with #4 bars at 24" on center along the bottom in both directions. The tendons are low-relaxation composed of a 7-wire strand according to ASTM A-416. Effective post tensioning forces vary throughout the floor, but the interior bands are typically 240k and 260k. This system is typical for every floor except for the 9th which supports a green roof and accessible terrace. Higher loads on this floor require a 10" thick 2 way post tensioned slab reaching a maximum effective strength of 415k. The bottom layer of reinforcing in this area is also increased to #5 bars spaced every 18". One bay on the 9th floor (grid lines 7-8) is constructed with a 10" cast in place slab. Plans of this floor can be found in appendix E.

Mechanical penthouses exist on the 9th and 20th roof constructed with a steel moment frame. Typical sizes for the 9th floor penthouse are W10's and W12's with 1.5" 20 gage "B" metal deck. As for the 20th floor penthouse, the typical beam size is W16x26. Equipment will be supported on concrete pads typically 4" thick. Two air handling units and cooling towers on the roof will require 6" pads.

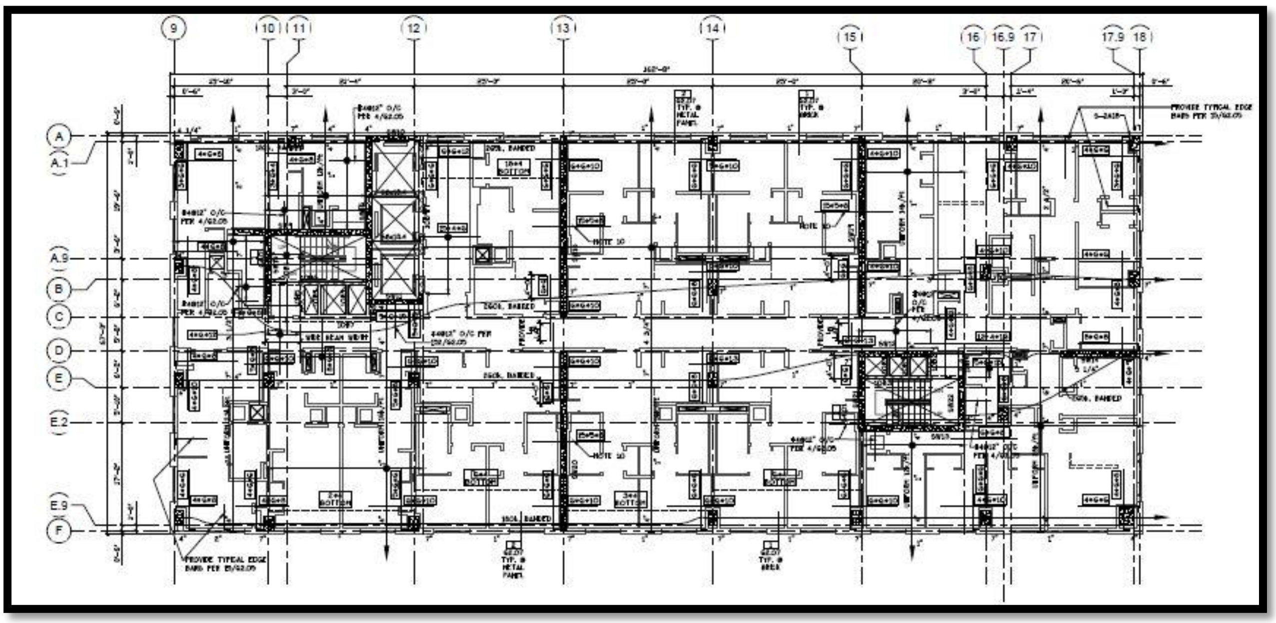


Figure 4 - Typical floor plan of upper tower. Courtesy of EDR.

The loads will flow through the slab and reinforcement to the columns eventually making their way down to the foundation. To tie the slab and framing system into the columns, two tendons pass through the columns in each direction. To further tie the systems together, bottom bars have hooked bars at discontinuous edges. Dovetail inserts are installed every 2' on center to tie the brick façade in with the superstructure. Columns are typically 30"x20" and composed of 4ksi strength in the northern tower (9 floors), while columns in the southern tower vary from 8ksi at the bottom, and 4 ksi at the top.

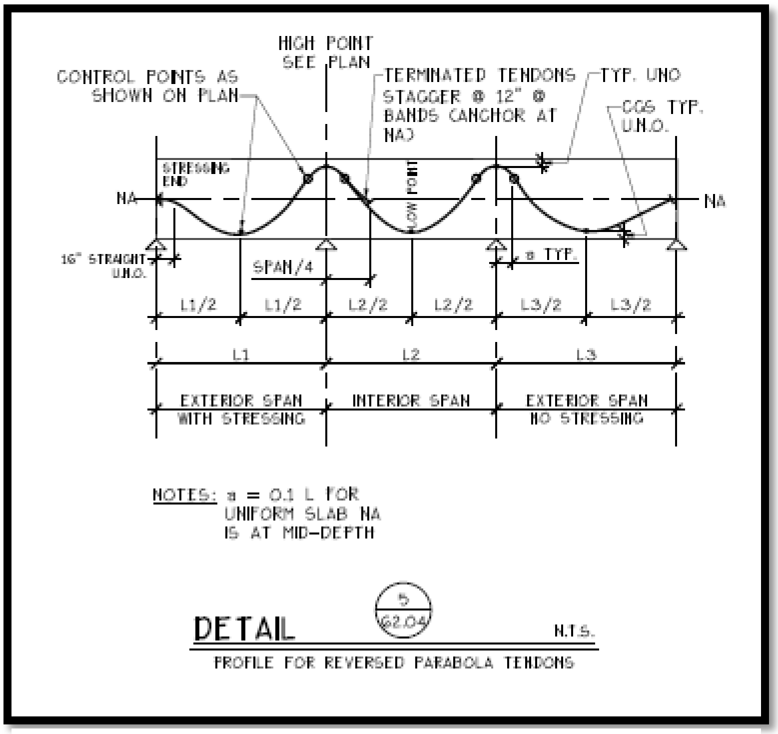


Figure 5- Typical detail for post tensioned tendon profile. Courtesy of EDR.

Lateral System:

John Hopkins GSH is supported laterally through a cast in place reinforced concrete shear wall system. All of the shear walls are 12" thick and located throughout the building and around stairwells and elevator shafts. Shear walls in the 9 floor tower are poured with 4000psi strength concrete while shear walls in the 20 floor tower vary in three locations. From the foundation to 7th floor, 8ksi concrete is used, 6ksi from 7th to below 14th floor, and 4ksi for walls above the 14th floor. The shear walls are tied into the foundation system through bent vertical bars 1' deep into the grade beam as shown in figure 6. Shear walls are shown below in the figure with N-S walls highlighted in blue and E-W walls red. Walls in the center of the building will support lateral stresses directly, while those on the end support the torsion effects caused by eccentric loads.

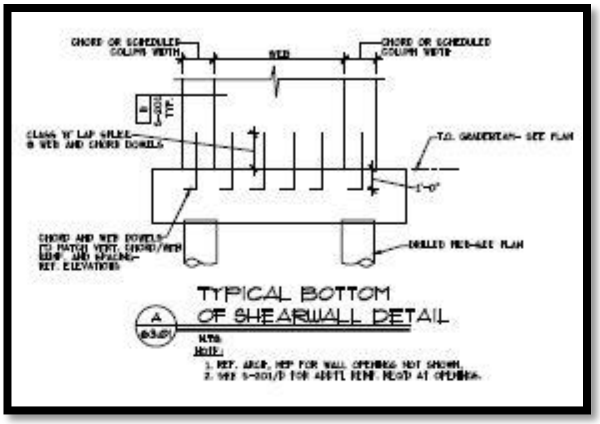


Figure 6 - detail tying shear wall into foundation. Courtesy of EDR.

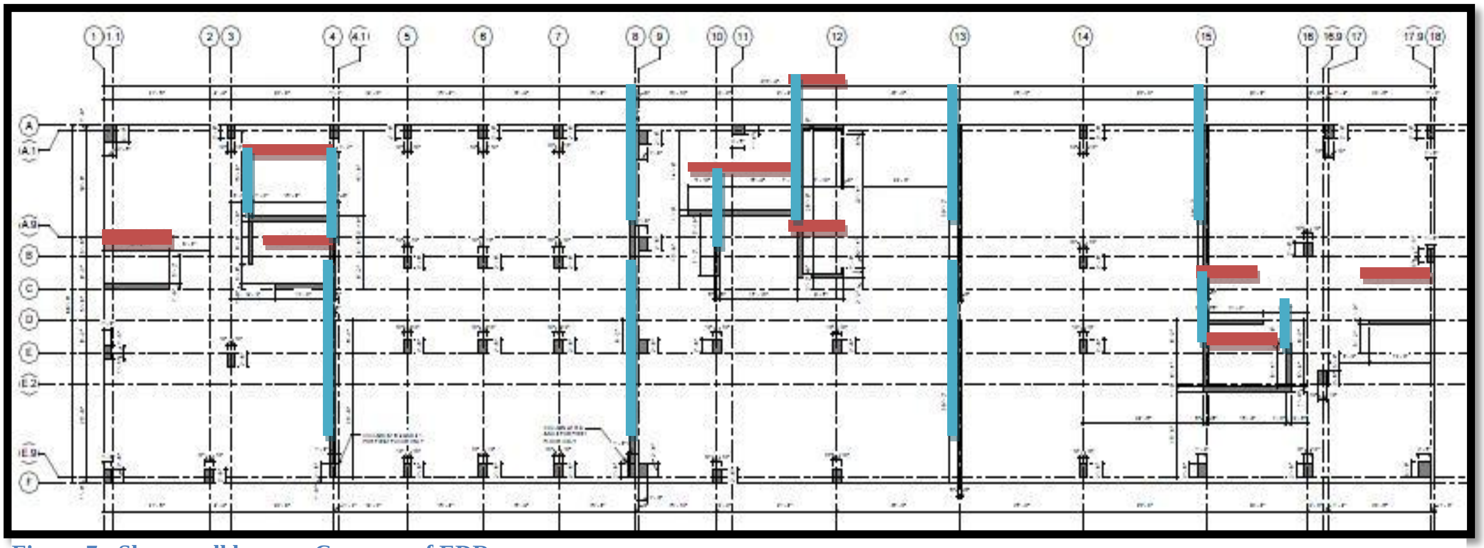


Figure 7 - Shear wall layout. Courtesy of EDR.

Problem Statement –

After performing a gravity and lateral analysis, the Johns Hopkins Graduate Student Housing project was found to be efficient and sufficient. In order to create problems in the structure and provide a learned experience in seismic area, a scenario has been proposed where the project site has been changed from Baltimore to San Francisco, California. The site change results in the structure being classified in seismic design category D.

Once the building location has been changed, the first problem occurs in the lateral system. ASCE 7-05 does not permit ordinary reinforced shear walls in SDC D; therefore, a dual system with moment frames capable of resisting at least 25% of the seismic loads will need to be designed. Lateral loads will be resisted primarily through eccentrically braced frames which need to be designed.

To reduce the seismic weight and loads on the building, the post-tensioned floor system will also need to be redesigned using a composite floor system. Using a steel frame will also provide more ductility to the structure as well.

The original design goals such as cost, minimal floor-floor depth, and appealing architecture, must also be of importance for the redesign. The project was found to be torsionally sensitive in Tech Report 3, so an additional goal for this redesign is to minimize torsional effects.

Problem Solution –

To solve the problems associated with moving the building to a seismic region, a steel framing system needs to be designed to withstand the gravity loads as defined by ASCE7-05. The steel structure will be designed to be as economical as possible while keeping the floor-to-floor heights at a minimum just like Tech Report 2. To minimize the structural depth, a composite system will be used to take advantage of concrete's strong compression properties. IBC 2006 mandates a 2-hour fire rating; therefore, the deck will also need to be designed accordingly. The gravity system also needs to satisfy strength and serviceability requirements such as L/240 for total load and L/360 for live load.

Once the gravity system has been designed, a lateral system needs to designed to resist wind and seismic loads. Eccentrically braced frames will be the main lateral force resisting system. In order to reduce the torsional sensitivity of the building, braced and moment frames will be placed near the core of the building as well as the exterior. The frames also need to satisfy strength and serviceability requirements. To maximize the ductility in the system and the architectural flexibility, an eccentric braced frame, and moment frames will be designed. For eccentric frames the link element, the beam between braces, is the critical element because it will deform the most. Deformation will provide ductility for the system and absorb seismic loads and reduce the chances of a sudden failure. The lateral system will need to comply with ASCE standards regarding drift limits according to table 12.12-1.

Breadth Topics –

Construction Management:

Changing the main construction method will significantly impact the schedule and cost. Steel erection typically results in quicker schedule than concrete because there is no need for formwork construction and tear down which would save the owner money. A expedited schedule would result in some cost savings; however, steel is typically more expensive than concrete. Steel connections are also an increased expense, and if the building height isn't kept to a minimum, the façade will cost more money as well.

Comparisons will be made with regards to cost and schedule analysis at the current location between concrete and steel, and then again once the site is moved to a seismic region. The seismic region will result in more detailed connections, larger members, and possibly more members.

Architecture:

Altering the lateral system from shear walls to a steel braced frame will change numerous architectural features. With regards to the interior, small openings such as doors, mechanical equipment, and elevator shafts will need to be inspected to ensure they can maintain their function. Eccentric braced frames were chosen so that they can be arranged to avoid major conflicts.

Once the project site has been moved to a seismic location, torsion is undesirable; therefore, braced frames may need to be added in additional locations and possibly along the exterior. The modern façade appearance is an important aspect to the design so care must be taken to ensure the braced frames do not intrude on the architecture. Columns may also need to be added to ensure the building can be constructed without shoring. Areas of concern are where shear walls are currently located without columns; therefore, those areas need to be inspected as well.

Solution Method –

Gravity loads will be calculated using dead loads and live loads from ASCE7-05. A summary of the loads used in the existing project and the proposed design can be found in figure 8 and table 1. Beams and girders will then be designed by hand for typical bays to minimize structural depth and in accordance with AISC. Once the gravity frames are designed, the next step will be calculating the lateral loads and determining the controlling case. Due to the weight reduction, it is expected that wind loads will control. After the controlling load case is determined, the next step will be sizing the braced frames for the projects current location. Eccentrically braced frames will be designed at the current location (SDC B) first so cost and schedule comparisons between a concrete and steel structure can be accurate. Comparisons will be made using industry advice and RS means.

LOADING SCHEDULE (PSF)

LOCATION / LOADING	TYPICAL FLOOR	7TH FLOOR TERRACE	HIGH ROOF	PENTHOUSE ROOF	EXTERIOR MECHANICAL AREAS (7TH + 22ND)	7TH FLR. PLANTER AREAS
CONCRETE SLAB	100	125	112.5	-	100-113	125
METAL DECK	-	-	-	2	-	-
M/E/P/L	8	8	8	8	8	8
MEMBRANE	-	-	-	1	-	-
ROOFING	-	-	-	6	-	-
INSULATION	-	-	-	6	-	27
PARTITION (LIVE LOAD)	15	-	-	-	-	-
GREEN ROOF	-	30	30	-	-	85
4" TOPPING SLAB	-	50	50	-	50	50
TOTAL DEAD LOAD	108	213	201	23	158-171	295
LIVE LOAD	55	100	30	30	150	30
TOTAL LOAD	163	313	231	53	308-321	325

NOTES:

1. ALL LIVE LOADS ARE IN ACCORDANCE WITH INTERNATIONAL BUILDING CODE 2006 EDITION.
2. NO LIVE LOAD REDUCTION HAS BEEN TAKEN INTO ACCOUNT.
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 LOCATIONS SHALL BE BROUGHT TO THE ATTENTION OF THE STRUCTURAL ENGINEER.
5. SEE PLANS FOR LOCALIZED CONCENTRATED LOADS.
6. DRIFTED AND SLIDING SNOW LOADS SHALL BE CALCULATED BY TRUSS MANUFACTURER BASED ON ROOF/BLDG. GEOMETRY AND 'DESIGN CRITERIA' ABOVE.

Figure 8 - Summary of loads used by designer. Courtesy of EDR.

Table 1-live load comparison between designer and ASCE

Area	Designed for… (psf)	ASCE7-05 (psf)
Typical Floor	55 (includes partitions)	40 (residential) + 15 (partitions)
Corridors	N/A	100
Stairs	N/A	100
Assembly	N/A	100
First story retail	N/A	100
Roof used for garden/assembly	100	100
Exterior Mechanical areas	150	N/A
High Roof	30	N/A
Penthouse Roof	30	N/A
Planter Areas	30	N/A

After the initial analysis and comparisons between steel and concrete at the current location, the project site will be moved to San Francisco (SDC D). More stringent seismic criteria in this location require that the lateral system be a dual system with at the moment frames being capable of resisting 25% of the seismic loads. This dual system is required due to height limitations on shear walls and eccentrically braced frames according to ASCE7-05 chapter 12.

The preliminary design of eccentric frames will be through AE 538 notes and the AISC manual. Once preliminary designs are done, an ETABS model will be created similar to Tech Report 3 to check the lateral displacements. As stated earlier, story drifts must be limited to those prescribed by chapter 12 of ASCE 7-05. Member forces will be checked to ensure sufficient strength. If anything is not compliant or the building is still torsionally sensitive, the braced frames will be redesigned or the positioning of the frames will be re-evaluated.

Once the design has been completed in San Francisco, a comparison will once again be made between the two steel structures to determine how much more it would cost the owner to move the building from Baltimore to San Francisco.

Task and Tools –

Task 1: Design steel gravity system

- Determine slab/ deck size based on Vulcraft design guides
- Determine preliminary members using AISC while complying with strength and serviceability requirements and minimizing structural depth
- Add Columns as necessary to allow un-shored construction

Task 2: Design steel eccentrically braced frames for current location SDC B

- Identify controlling lateral loads. Wind loads will be based on ASCE7-05 criteria for wind, and seismic loads determined from building weight and equivalent lateral force method.
- Determine layout of frames to minimize torsional and architectural impacts.
- Create a model in ETABS to ensure frames are adequate
- Check member forces and relative stiffness values by hand.

Task 3: Prepare cost and schedule analysis between steel and concrete structure.

- Need to obtain a current schedule and cost information from the construction manager.
- Create adjusted schedule and run cost comparisons using industry recommendations, RS Means, and Microsoft Project.
- Compare the two systems.

Task 4: Design dual system to resist lateral forces

- Change to project site to a new location (SDC D).
- Research types of connections necessary and construction difficulty.
- Design eccentrically braced and moment frames based on new lateral loads.
- Create ETABS model to ensure code drift limitations are met.
- Check member forces and relative stiffness values by hand.

Task 5: Compare the changes between systems in SDC B and SDC D.

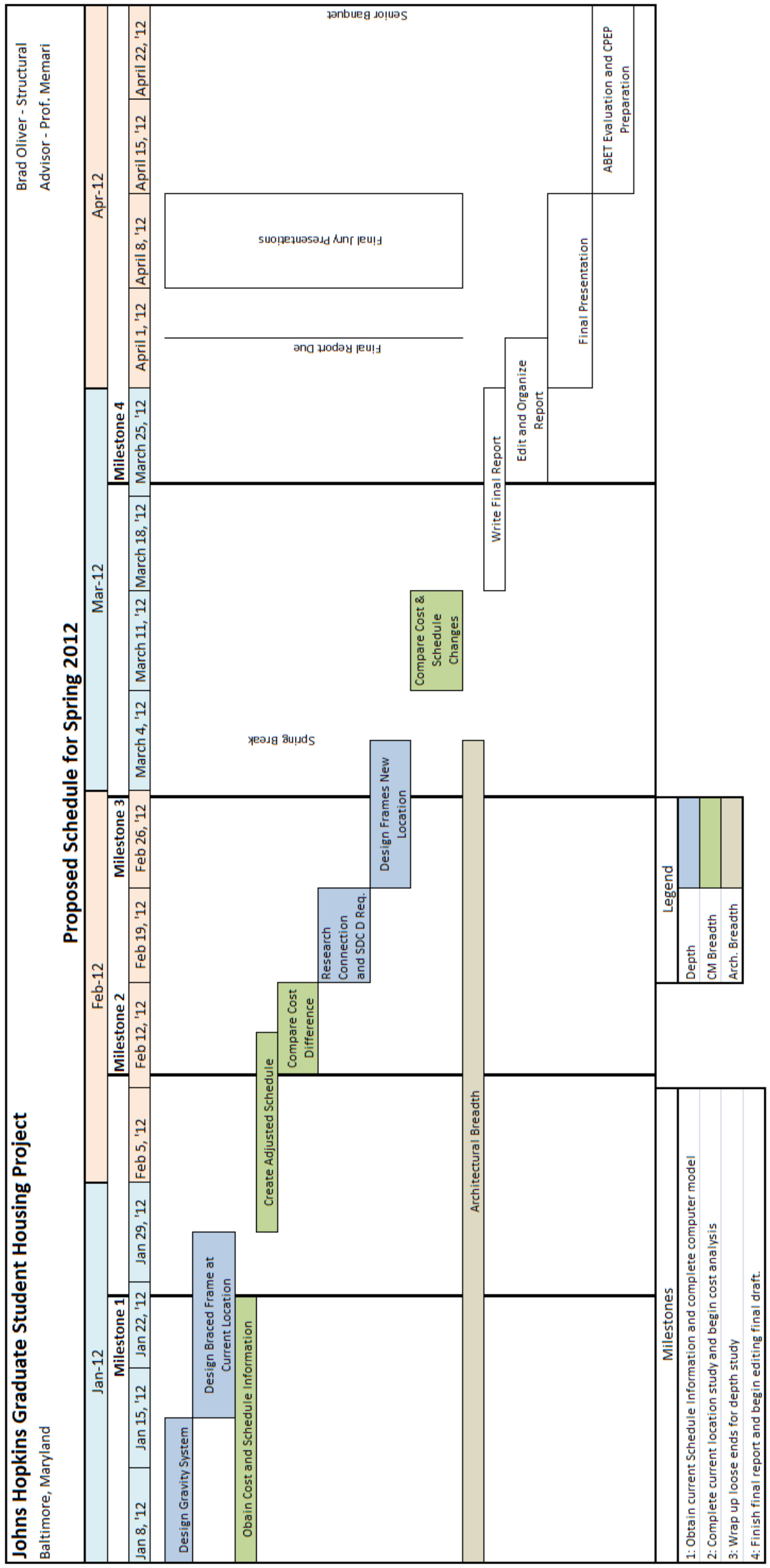
- Compare member sizes, cost, and possible increase in schedule due to more complicated member connections.

Task 6 (ongoing): Architectural Breadth

- Analyze exiting architecture and locate openings in lateral system.
- Ensure braced frames are not impacting functional spaces.
- Confirm additional columns are not impacting functional spaces.
- Check that braced frames are not impacting the façade appearance.

Task 7: Final Presentation

Schedule –


Johns Hopkins Graduate Student Housing Project
Baltimore, Maryland
Proposed Schedule for Spring 2012
Brad Oliver - Structural
Advisor - Prof. Memari
Jan-12
Feb-12
Mar-12
Apr-12
Milestone 1
Milestone 2
Milestone 3
Milestone 4
Jan 8, '12
Jan 15, '12
Jan 22, '12
Jan 29, '12
Feb 5, '12
Feb 12, '12
Feb 19, '12
Feb 26, '12
March 4, '12
March 11, '12
March 18, '12
March 25, '12
April 1, '12
April 8, '12
April 15, '12
April 22, '12
Design Gravity System
Design Braced Frame at Current Location
Obain Cost and Schedule Information
Create Adjusted Schedule
Compare Cost Difference
Research Connection and SDC D Req.
Design Frames New Location
Spring Break
Compare Cost & Schedule Changes
Architectural Breadth
Write Final Report
Edit and Organize Report
Final Presentation
ABET Evaluation and CPEP Preparation
Final Report Due
Final Jury Presentations
Senior Banquet
Legend
Depth
CM Breadth
Arch. Breadth
Milestones
1: Obtain current Schedule Information and complete computer model
2: Complete current location study and begin cost analysis
3: Wrap up loose ends for depth study
4: Finish final report and begin editing final draft.

Conclusion –

Johns Hopkins Graduate Student Housing will be redesigned using a steel structure at the current location. A redesign will attempt to minimize structural depth, cost, and architectural impacts. Once the gravity system has been designed, a lateral system of eccentrically braced frames will be devised to resist the controlling loads, most likely wind. Eccentrically braced frames will be the primary resisting system due to the architectural flexibility.

During design, architectural features affected will be investigated and solutions will be implemented along the way. Once the design in Baltimore has been completed, a construction management breadth will be completed to compare the steel structure to concrete. A steel structure will most likely result in a faster schedule, but also more expensive material and façade costs.

Once accurate comparisons are made, the site will be moved to San Francisco, California changing the seismic design category from B to D. To compensate for this change, a dual system utilizing moment frames and an eccentrically braced frame will be designed. As in the previous location, frames will be placed to minimize torsion and architectural impacts.

After completing the steel structure in a new location, comparisons will be made once again. Cost comparisons will determine how much more expensive it is to alter the steel structure to be resist loads in a high seismic area.