Senior Thesis

Spring Semester Proposal

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Executive Summary

The Judicial Center Annex (JCA) is a six-story addition to the Montgomery County Circuit Court Systems existing Court Center in Rockville, MD. Standing 114' tall and adding 210,000 sq ft that cost approximately $88.5 million. The building features post-tensioned slabs with reinforced concrete framing and reinforced concrete shear walls. The purpose of this report is to propose a means to redesign the building and outline the schedule and tasks needed to complete this redesign which will then be pursued to completion through the spring semester.

Analysis performed on the JCA as designed suggests a building that adheres to the code and is up to par with today's standards of building performance. Many times design teams have multiple solutions to a problem, however, and often if there is a design in concrete there was a design for the same structure in steel. The proposed redesign is to explore this building using steel framing with the appropriate modifications to floor and lateral systems to see how competitively it would compare to the as designed JCA.

The structural depth will consist of redesigning the floor system and gravity systems to a concrete on metal deck atop steel framing. New lateral loads will be determined which will be used to design the lateral system that will be changed to braced frames. Finally the foundations will be readdressed based upon the new gravity and lateral loads.

Two additional breadths will be conducted. The first of which is a cost/schedule analysis comparing the original design to the redesign to determine the feasibility and competitiveness of the redesign. The second breadth will be sustainability study on the LEED checklist of the original building against the redesign to see if there are any areas to improve in addition to a study on changing the green roofs to photovoltaic panels which will be assessed based upon initial cost, payback period, energy savings, and system impacts.

Graduate level coursework, a requirement of the MAE degree, will be employed throughout the design processes to help achieve a more accurate and definitive result. A schedule of the proposed dates for tasks and their completion is presented in the report.

Building Introduction

The Judicial Center Annex (JCA) is a modern addition to the existing Montgomery County Judicial Center. Located on the corners of Maryland Avenue and East Jefferson Street in downtown Rockville, MD, the JCA is set to provide a bold statement through both its architecture and engineering. Construction on the addition began this past April and is projected to take two years to complete.

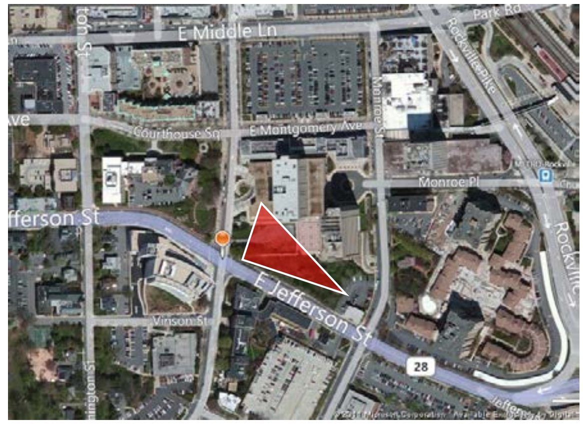


Figure 1: Site Location, Bing.com

The JCA will stand 114' tall at the crest of each of the four lanterns located on top of the building, so tall that limitations on local building codes needed waived for overall building height. Six stories rise above the ground, with garage and terrace levels located below grade, adding approximately 210,000 sq ft to the Judicial Center which includes 10 more courtrooms and several administrative spaces.

The project team, led by AECOM who provided both architectural and the majority of building engineering services, was able to achieve a unique look through both form and material. The East and West Elevations (Figure 2) are dominated by glazing, with the curtain wall that covers the East wrapping around the South corner. This curtain wall system is unique in that it uses glass stabilizing fins instead of traditional aluminum mullions, which enables an all glass look that when combined with the way the slab cantilevers out from the structure gives the illusion of the floors floating without structure. On the North the addition abuts against the original Judicial Center. The elements of the façade not covered in glass are sheathed in either a powder coated aluminum that has a reddish hue or architectural pre-cast panels that are more reminiscent of the exterior of the original building.

Figure 2: West Elevation

From the roof projects four lanterns which have a translucent linear glazing system allowing them to light up the night sky in a truly dramatic manner. The roof is also the site of two of the JCA's sustainable features that enabled it to achieve a LEED Gold Rating. The tops of each of the four lanterns are covered in photovoltaic panels, while green roofs cover much of the remaining roof.

Structural Overview

The JCA sits atop core-drilled concrete piers due to the rather poor soil conditions, all columns coming to bear atop a pier. The floor systems are post-tensioned slabs, with wide-shallow beams running one-way on the typical levels framing into cast-in-place concrete columns. The lateral system consists of five concrete shear walls, which rise continuously to the penthouse level, with some continuing to support the roof.

This building was designed as Occupancy III according to Sheet 1.S001. The reason for this is thought that the holding cells in the building subject it to the “Jail and detention facilities” clause or perhaps a courtroom has the ability for “more than 300 people to congregate.” This Occupancy was assumed due to one of the previously mentioned reasons for purposes of coming up with importance factors in later calculations.

Floor Systems

As mentioned previously, the floor systems for the JCA utilize post-tensioning. The economy is achieved by greater span lengths being possible, with smaller slab depths. The typical floor system, which begins on the terrace level and extends to the 5th floor, has both 8” and 9” slab depths, with wide-shallow beams running in the plan NS direction. The beams extend 8” below the slab and are not centered on the column lines, instead offset in plan to allow for the provisions of ACI 318-08 Section 13.2.5 for a drop panel. The bays are essentially uniform in parts of the building, with an alternating long/short/long span pattern. A small portion of the slab on the second level connecting to the existing building is lightweight concrete on metal deck on steel framing.

The penthouse slab is 11” thick due to the larger loads present on this floor. There is an unreducible 150 psf mechanical live load present, as well as a 55 psf green roof dead load in several areas. The mechanical floor also features a ‘floating’ four inch light weight concrete on metal deck isolation slab, to prevent mechanical equipment vibrations from affecting other parts of the building. The roof slab is 10” and features several large voids. This slab has post tensioned beams 36” x 24” typical for additional span stiffness in lieu of the wide-shallow beams.

Foundations

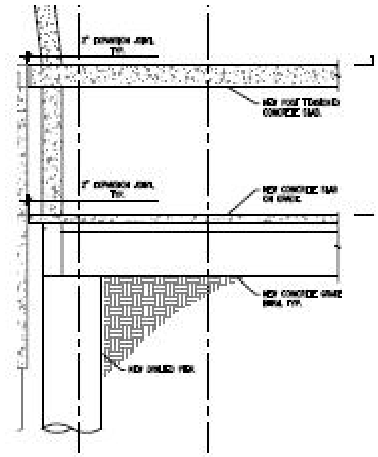


Figure 3: Column adjacent to existing Judicial Center resting on pier foundation

Schnabel Engineering performed the geotechnical services on the JCA project. Reports indicated that for the purposes of shallow continuous wall footings the soil has a bearing capacity of 2000 psi, with any unsuitable conditions requiring excavation and replacement with lean concrete. Core-drilled piers ranging in diameter from 2.5' to 7' are located beneath every column and support much of the shallow wall footings. Grade beams are also used in several locations, specifically beneath the five shear walls. The usage of grade beams beneath the continuous shear walls is due to the extremely large concentration of forces that need transferred into the soil as a result of both the shear walls own weight and the lateral forces that are being transferred through them. Grade beams vary from 24" to 42" in width and 36" to 72" in depth. The slab on grade is 5" thick and reinforced with WWF.

The garage level of the JCA is located 25' below grade. Though soil pressures on basement walls were not considered in this report they are a possible point of investigation in the future.

Framing Systems

Cast-in-place columns rise from the garage level to the roof, with the four lanterns extending the extra fourteen feet with steel framing. The column concrete has a compressive strength of 7000 psi at the base, which is reduced to 5000 psi at level 2. Typical column sizes are 24”x24”

Each lantern has a flat roof framed in structural steel with a slight slope on the edges. HSS tubes make up the columns, with the majority of the framing being small steel shapes with spans in the range of 5’ and typical sizes of L3x3x1/4, HSS4x4x1/4, and C6x13. In the center of the roof are several W12x40 girders with a maximum span of 33’ that are framed into by smaller wide flange shapes. These heavier shapes are intended to carry the photovoltaic panels mounted on top of the lanterns. Several HSS braced frames provide lateral stability to the lanterns. The lanterns were given a 30 psf dead load in the shaded region to account for the photovoltaic panels.

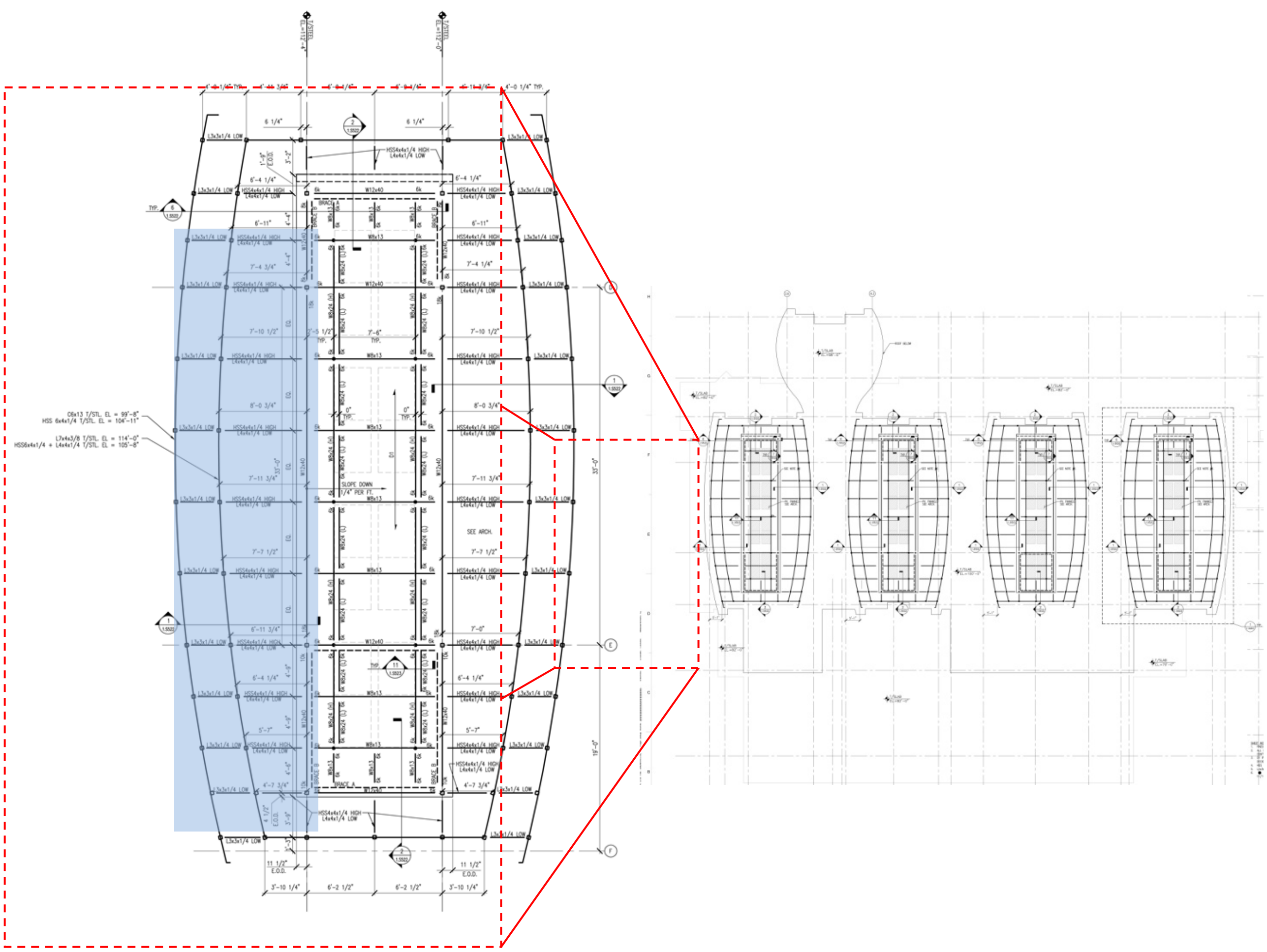


Figure 4: Lantern Framing Plan

Lateral System

The main lateral resisting elements of the JCA are the five cast-in-place reinforced concrete shear walls that rise continuously through the building. Analysis performed in Technical Report 3 showed that the concrete frames also had a significant contribution to resisting lateral loads on certain levels, particularly the frames running in the North/South direction and formed by the wide/shallow beams.

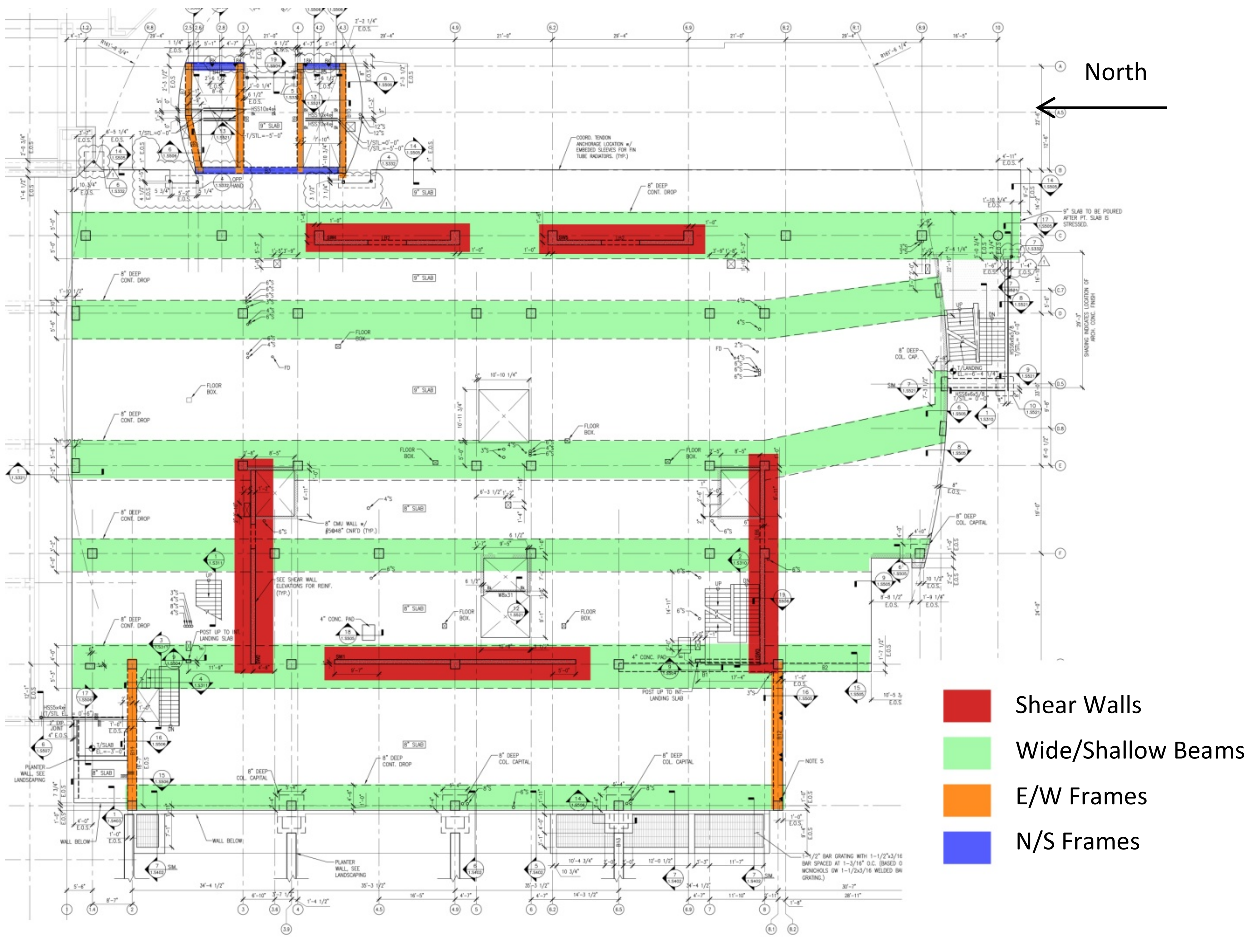


Figure 5: Lateral Elements

Roof Systems

The roof varies in height in several locations with the floor slabs described earlier in *Floor Systems*. The varying heights made snow drift a concern, and the large loads associated with the penthouse floor, which is the heaviest floor on the building, add a significant contribution to both seismic base shear and overturning. The green roof and pavers on the penthouse and upper roof levels lay overtop a hot applied fluid membrane.

Proposal

Structural Depth

The current reinforced concrete building, with post-tensioned floor slabs and cast-in-place shear walls was analyzed in three previous technical reports and found to be adequate in all respects. It is hypothesized however, that with no height restrictions, converting the building to steel would be a competitive solution.

The conversion to steel will mean changing the floor system to concrete on metal deck, employing either the composite metal deck construction with light weight concrete that was explored in Technical Report 2 or a more cost effective deck should one be found. The gravity system will be designed based upon the loading outlined in Technical Report 1, with the initial framing based upon existing locations of columns, though this may need to be adjusted as the design is further developed. Composite steel beams and girders will be used to take advantage of the slab strength so that smaller member sizes can be employed.

After the initial framing has been completed lateral loads will be recalculated using ASCE 7-05 prescribed procedures. Braced frames are proposed to replace the existing reinforced concrete shear walls, acting in their stead as the lateral system of the JCA. As with the columns, the initial trials will use the locations of the shear walls to place the braced frames, to minimize architectural impacts and due to the symmetrical layout that did not have torsion issues as reported in Technical Report 3.

Once both gravity loads and lateral loads have been recalculated the existing foundation system will be investigated to see if it can be reduced to a more efficient solution. Considerations for further exploration, should time be found permitting, will be included in a later section.

Breadth Study One: Cost and Schedule Analysis

Breadth One will explore a common question in today's industry, "Concrete or Steel?", by evaluating the impacts that changing the system will have on the overall cost and schedule of building. Often designers will push one concrete and one steel solution deep into the design phase before one ends up being chosen, a scenario being emulated by the Structural Depth. The object here is to see if the redesign will lead to a cheaper, faster to construct building that performs on par with the concrete design, and determine if steel was truly a feasible solution for this project. This depth requires that a schedule be established for both the existing construction and the redesign and that both options be priced based upon their materials, associated construction costs, and schedules; the better option will therefore be based upon which structure is completed quicker and for less cost.

Breadth Study Two: Sustainability

The JCA achieved a LEED Gold rating by featuring such sustainable features as green roofs and photovoltaic panels. Breadth Two will explore whether the building lived up to its full LEED potential by attempting to tally the LEED points the system achieved and exploring how certain points that were not attained could be easily achieved with the intent that the system redesign will lead to a more sustainable building that may garner a higher LEED score.

In addition a comparison will be made to determine if replacing the sections of green roof with more photovoltaic panels would be a cost effective and energy efficient redesign. The two options will be compared on several levels, including initial cost and payback period, life cycle and carbon footprint. Structural, MEP, LEED and schedule impacts will also be determined as a basis for comparison.

Further Development

The purpose of this section is to outline goals above and beyond the proposal that may not be achieved due to the time constraints of the semester. However, they are areas of interest that will be explored if the proposal as outlined in previous sections is adequately completed.

Due to an interest in seismic design, and the strong possibility that the steel redesign will be controlled by wind, it would be of interest to explore moving the building to a high seismic zone which would require more stringent seismic design; a cost comparison could then be shown between the buildings in the two regions. The design could be further enhanced by exploring viscous fluid damping devices.

MAE Requirements

Graduate level coursework will be employed throughout the redesign of the building, drawing on a knowledgebase from several courses. AE 597A – *Computer Modeling of Building Structures* will be employed heavily by using knowledge of how to model with techniques that ensure efficient but accurate results, in particular in E-tabs, which will be employed heavily in the lateral design phase. Additionally RAM Structural will be employed in the beginning of the analysis for the ease with which it designs gravity members.

AE 534 – *Analysis and Design of Steel Connections* will be taken advantage of through the conversion to steel by designing typical shear connections for beam-to-column and beam-to-girder as well as the connection for the brace in the braced frame configuration chosen most efficient.

AE 538 – *Earthquake Resistant Design of Buildings* has given a solid knowledge base with which to design aspects of the building that the seismic loading control, which will certainly be the case should the Further Development stage be reached.

Tasks and Tools

Task 1: Design Steel Gravity System

- Choose cost effective concrete on metal deck system: composite vs. non-composite
- Layout initial column grid
- Size typical gravity members by hand; column, beams, and girders using AISC steel manual
- Employ RAM Structural to efficiently design entire building, ensuring consistency between hand calculations

Task 2: Calculate Lateral Loading

- ASCE 7-05 Equivalent Lateral Force procedure
- Method 2 Main Wind Force Resisting System (Technical Report 1)
- Perform Modal Response Spectrum Analysis

Task 3: Design Braced Frames

- Research braced frame layouts to determine efficient configuration
- Create finite element model using E-tabs

Task 4: Reevaluate Foundations

- Based upon results from gravity and lateral loading revisit design of foundation systems and redesign if appropriate

Task 5: MAE Steel Connections

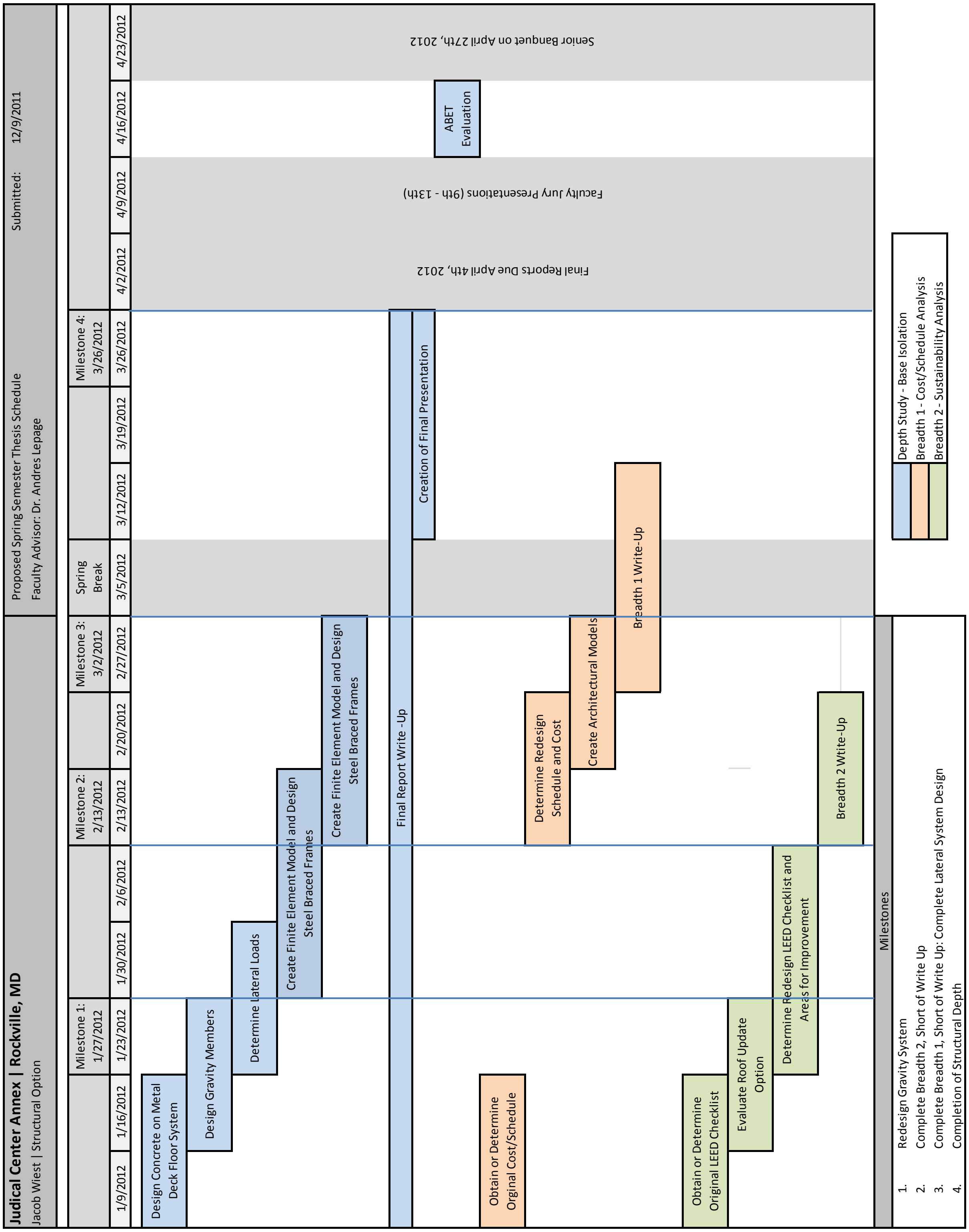
- Use AISC steel manual to aid in design of typical shear connections for beam-to-column and beam-to-girder
- Extract reactions from E-tabs to design braced from connections

Task 6: Breadth One

- Using RS Means determine schedule and cost of redesign
- Based upon contacts and RS Means determine schedule and cost of existing system for comparison purposes

Task 7: Breadth Two

- Obtain original LEED checklist or determine using the LEED Rating System Documentation
- Determine any changes in the LEED checklist due to the redesign and look for opportunities to gain more points
- Compare roof consisting of green roof and photovoltaic panels to roof with only photovoltaic panels in place of the existing green roof systems in terms of initial cost, payback, carbon footprint, and other pertinent categories
- Evaluate changes to LEED system due to this redesign



Proposed Schedule

Conclusion

Detailed in this proposal is the intent to pursue a steel alternative to the as designed concrete JCA. The floor system will be redesigned using a concrete on metal deck system, which will then be supported by composite steel beams/girders and columns that will consist of the gravity framing. Lateral loads will be reevaluated, which in turn will lead to the design of braced frames which will act as the lateral system in replacement of the shear walls. Once a configuration for the braced frames has been finalized the foundation systems will be reevaluated to see if they can be reduced.

The first breadth will be a cost/schedule analysis. The cost and schedule of the existing design will be obtained or determined and compared to the cost and schedule for the redesign to determine which building is a better option based primarily upon cost and schedule.

The second breadth involves sustainability. The LEED checklist for the original building will be obtained or determined. A study on placing photovoltaic panels atop a larger portion of the roof instead of the green roofs will be undertaken to see which solution would be better do to reasons such as initial cost and payback timeline as well as their impacts on other systems. Finally a LEED checklist will be recreated for the redesign with an effort to garner more LEED points.

The presented schedule will act as a gage to determine if adequate progress is being made, and there will be an emphasis on using MAE coursework in the design.