Proposal

THE BRENDAN IRIBE CENTER FOR COMPUTER SCIENCE AND INNOVATION

COLLEGE PARK, MD

Brendan Barrett

Structural Option

Advisor: Dr. Said

Executive Summary

As one of the world's top computer science institutions, the University of Maryland continues to grow. There is no longer enough room in the existing facilities to keep up with the latest advancements in virtual reality. The Brendan Iribe Center for Computer Science and Innovation will help separate the University of Maryland from its competitors.

Six stories of collaborative classrooms, research labs, seminar rooms, offices, and many common areas will welcome students and faculty alike. A 300-seat auditorium will provide the University of Maryland an opportunity to showcase its latest research such as cybersecurity, computational biology, and quantum computing. The open floor plans will help promote collaborating amongst peers, and ultimately set these students up for successful careers.

Structurally, the Brendan Iribe Center for Computer Science and Innovation utilizes steel wide flange girders and columns to support gravity loads. The curvilinear shape of the building results in unequal bays as infill beams change as the shape of the building changes. Due to the irregular shape, there are several unique components of this system such as curved HSS beams along the southern wall. The 300- seat Antonov Auditorium utilizes wide flange girders and columns, as well as a 90' truss to support the different levels and roof.

From a lateral standpoint, the Brendan Iribe Center for Computer Science and Innovation uses ordinary moment frames and vertical trusses throughout each wing of the building and the auditorium. All loads are in accordance with the 2015 International Building Code and ASCE 7-10.

This report will provide a detailed analysis of the current structural system of the building, as well as a proposal for an alternative design. The alternate design will include a voided concrete slab for the gravity system and concrete shear walls for the lateral system. A voided concrete slab will increase the spans, reduce the structural depth, and reduce deflections. This new design should help reduce the overall cost of the building.

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1. Introduction

1.1 Purpose and Scope

This report will analyze the existing structure of the Brendan Iribe Center for Computer Science and Innovation. A detailed overview of the building's foundation, gravity system, and lateral system will be provided emphasizing how these components work together as a system. After the analysis of the existing system, an alternate system will be proposed. Next semester, a redesign will be done using the alternate system to determine the feasibility of this new system.

1.2 General Building Description

Figure 1: Rendering from north-east

The Brendan Iribe Center for Computer Science and Innovation (ICCSI) will increase the number of classrooms available and help sustain the University of Maryland as the leader in virtual reality research. Students and faculty will be provided with a magnificent six story building that will house eight collaborative classrooms, thirteen research labs, five conference rooms, offices, tutoring centers, a café, as well as many common areas. Adjacent to the boomerang shaped main tower will be the 300-seat Antonov Auditorium pictured below which will help the university showcase the latest advancements in the field of virtual reality.

With a main design goal of maximizing collaboration amongst classmates, the curtain wall façade will allow natural lighting to illuminate the buildings open floor plans and common spaces. Another feature of the structure includes a 30 foot cantilever on the west end and a 120 foot cantilever on the east end. Six sloping columns inset from the north and south edge of the building will support this massive cantilever on the east end. Figure 2 below shows the first floor plan, with the highlighted section designating the cantilevers.

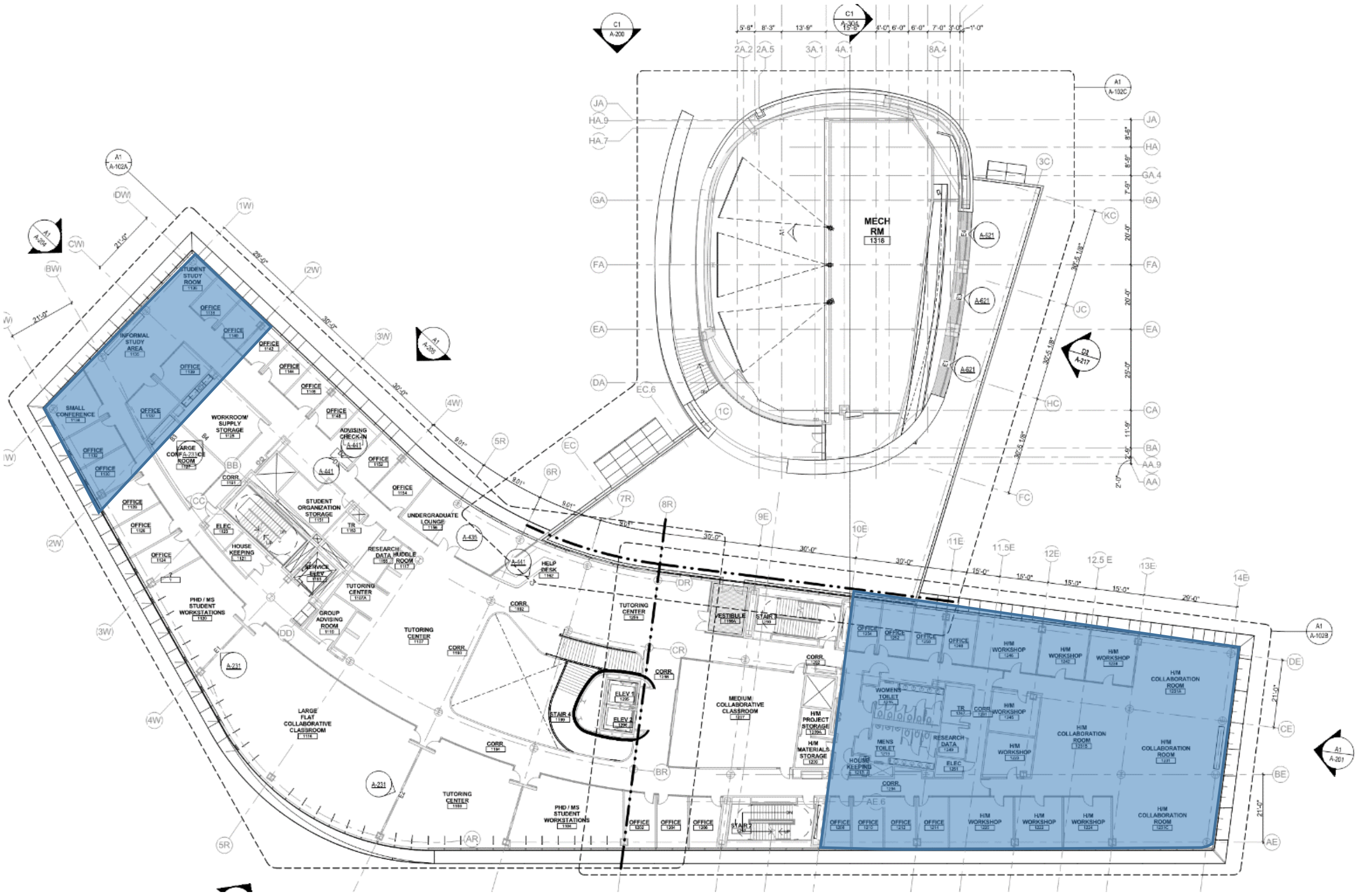


Figure 2: Plan showing cantilevers

1.3 Structural Framing System

The Brendan Iribe CCSI is a composite steel building that uses wide flange girders and columns. Due to the curvilinear sides of the building, structural bays will be of varied sizes. Girders running in the east-west direction and following the curve typically have 30 foot spans, while the filler beams range from 20'-42' based on the column layout. Typical columns range from W12 to W14.The Auditorium only has exterior columns to keep the interior an open space. A 90 foot truss spanning from the north to south supports the roof. The lateral system includes vertical trusses and moment frames at the east and west end of the main tower. The following sections will expand on the structural system of this building.

2. Structural Systems

2.1 Foundation

The foundation for this project consists of mat foundations and shallow spread footings. The bottoms of all exterior footings are 4' below finished grade to reach frost depth, and a minimum net allowable bearing capacity of 5000 PSF has been used for design. Due to the partial basement being located within 500 year flood plain, the walls and slab on grade are designed for hydrostatic pressure. As a result, a 48" thick mat slab is located 3' below the top of the finished basement floor. Continuous wall footings are 3' wide x 1'-6" deep and reinforced with 3 # 5 bars.

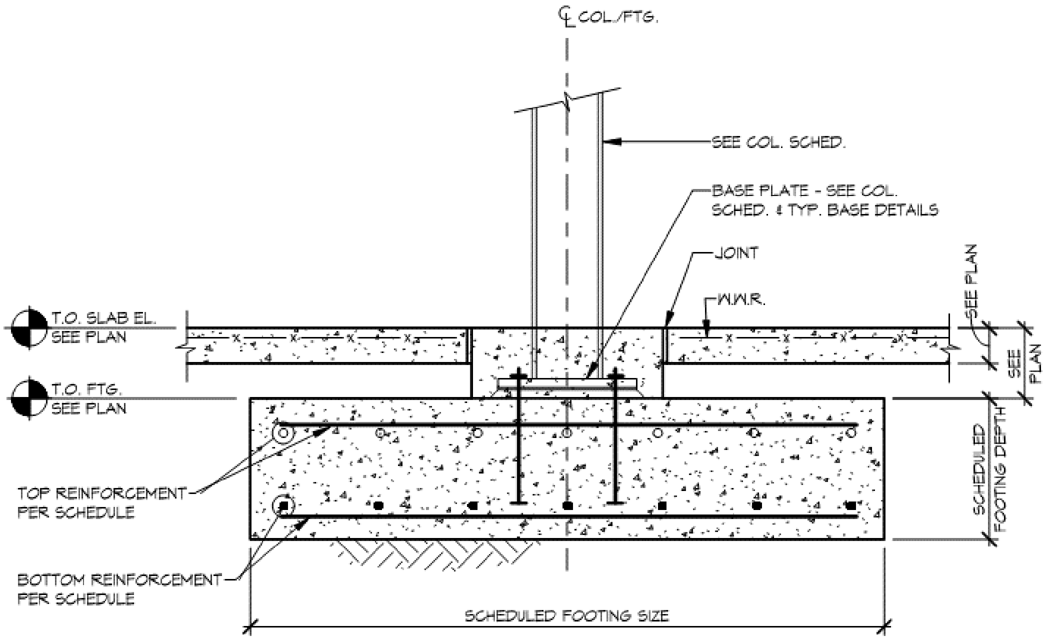


Figure 3: Typical interior column footing without pier

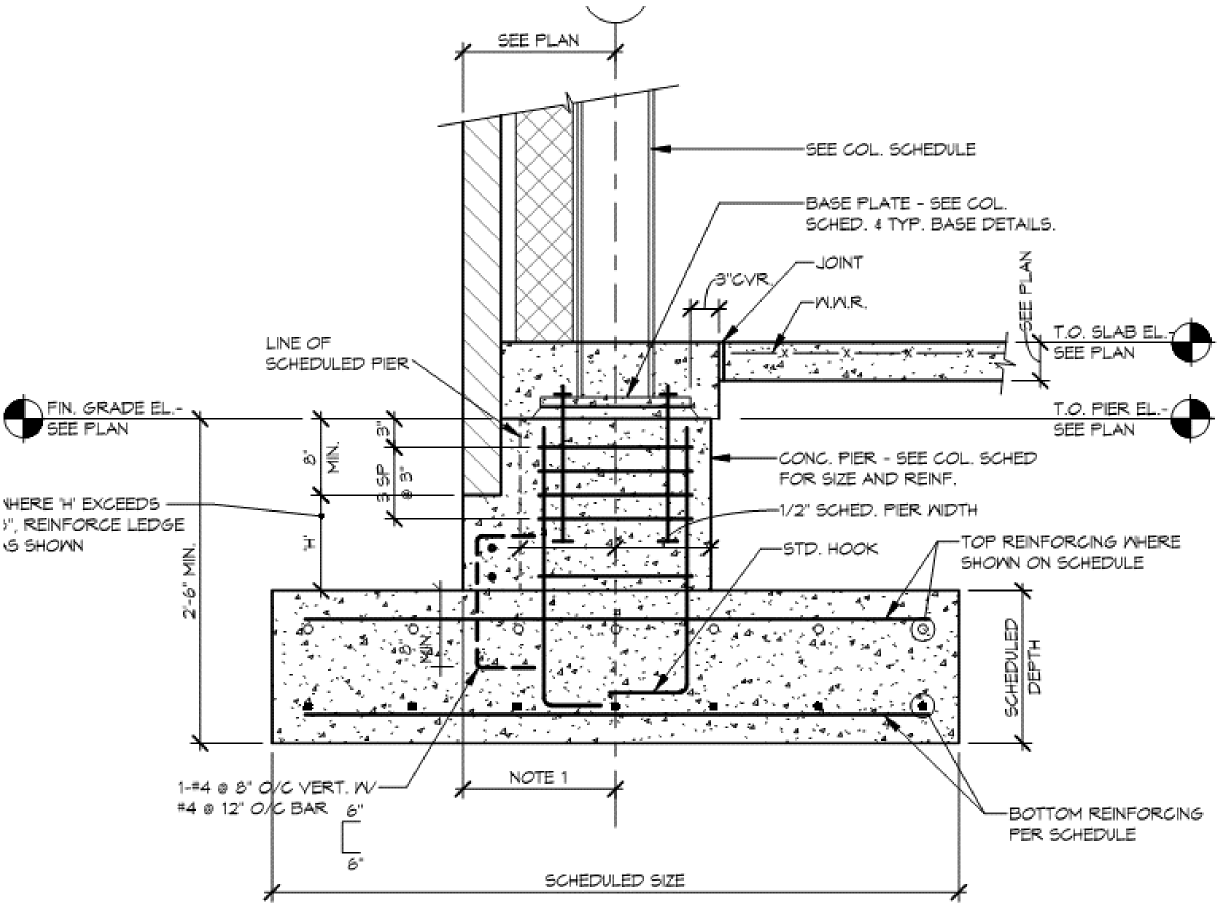


Figure 4: Typical column foundation at exterior wall

2.2 Gravity System

2.2.1 Typical Bay

As previously stated, the boomerang shaped building results in varied bay sizes along the building. At the far east and west ends, infill beams only span about 20’. However, at the center of the building where the north-south distance of the building is at its greatest, infill beams span up to 42’. Figure 5 shows a bay at the east end of the building. Typical girders are 29’ W 21X50 with 30 studs, while infill beams are W21’s with 30 studs ranging from 16’ to 22’. Infill beams are spaced about 10’ o.c.

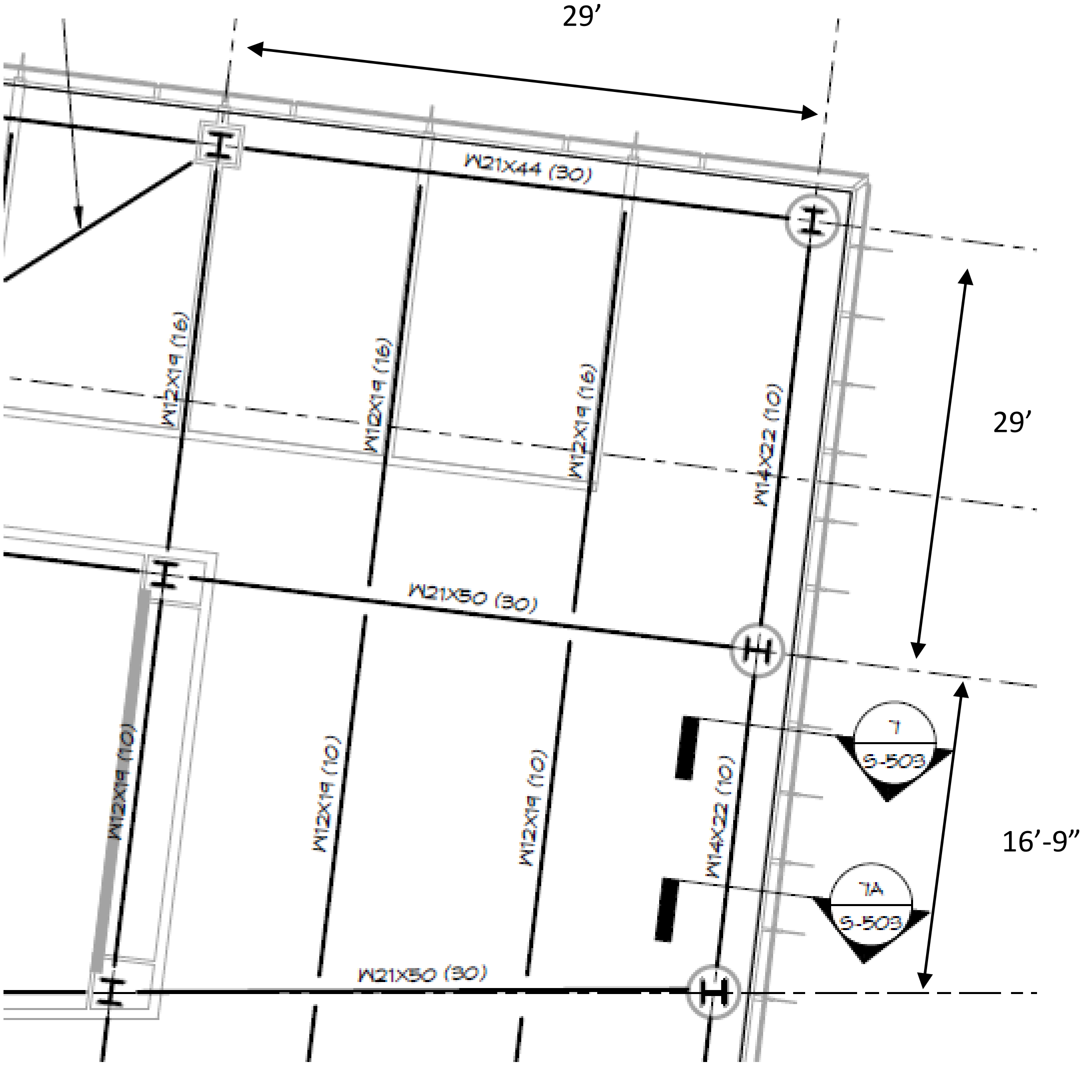


Figure 5: Bay in eastern wing

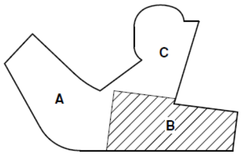


Figure 6 shows a bay close to the center of the building and western stairwell. At this bay, the girder along the curved wall is a W30x116 with 20 studs while the infill beams are W24's reaching spans up to 44'. Infill beams are spaced about 9' o.c. Due to the curve in the building, there is a curved HSS12x6x3/8 to match the radius of the grid arc.

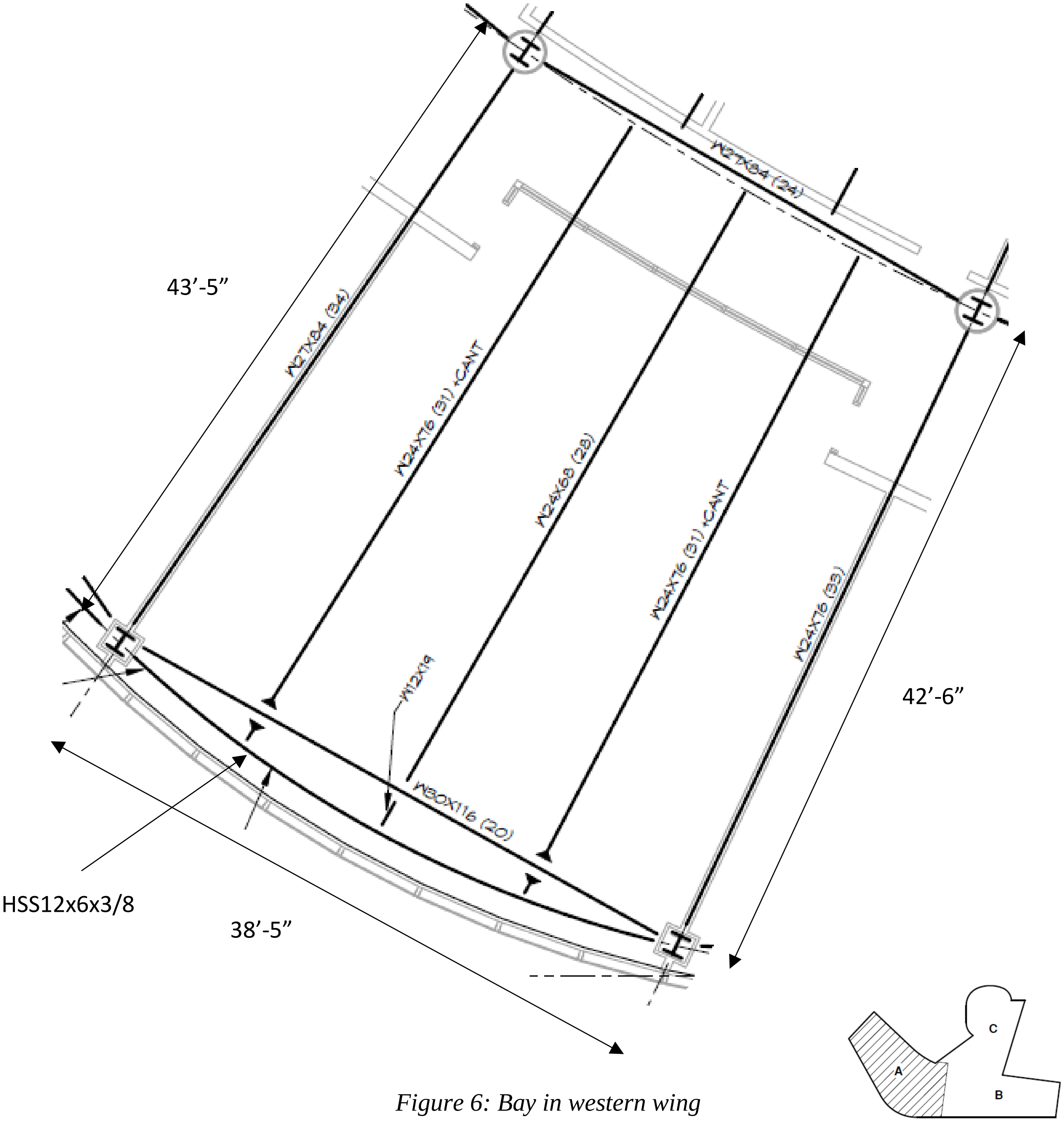


Figure 6: Bay in western wing

Framing for the Antonov Auditorium includes wide flange girders. Figure 7 shows a bay at the north east corner of the auditorium. Girders are W24s and reach spans up to 32’ spaced at 10’. A 90’ truss supports the first floor and the roof in the north-south direction of the auditorium.

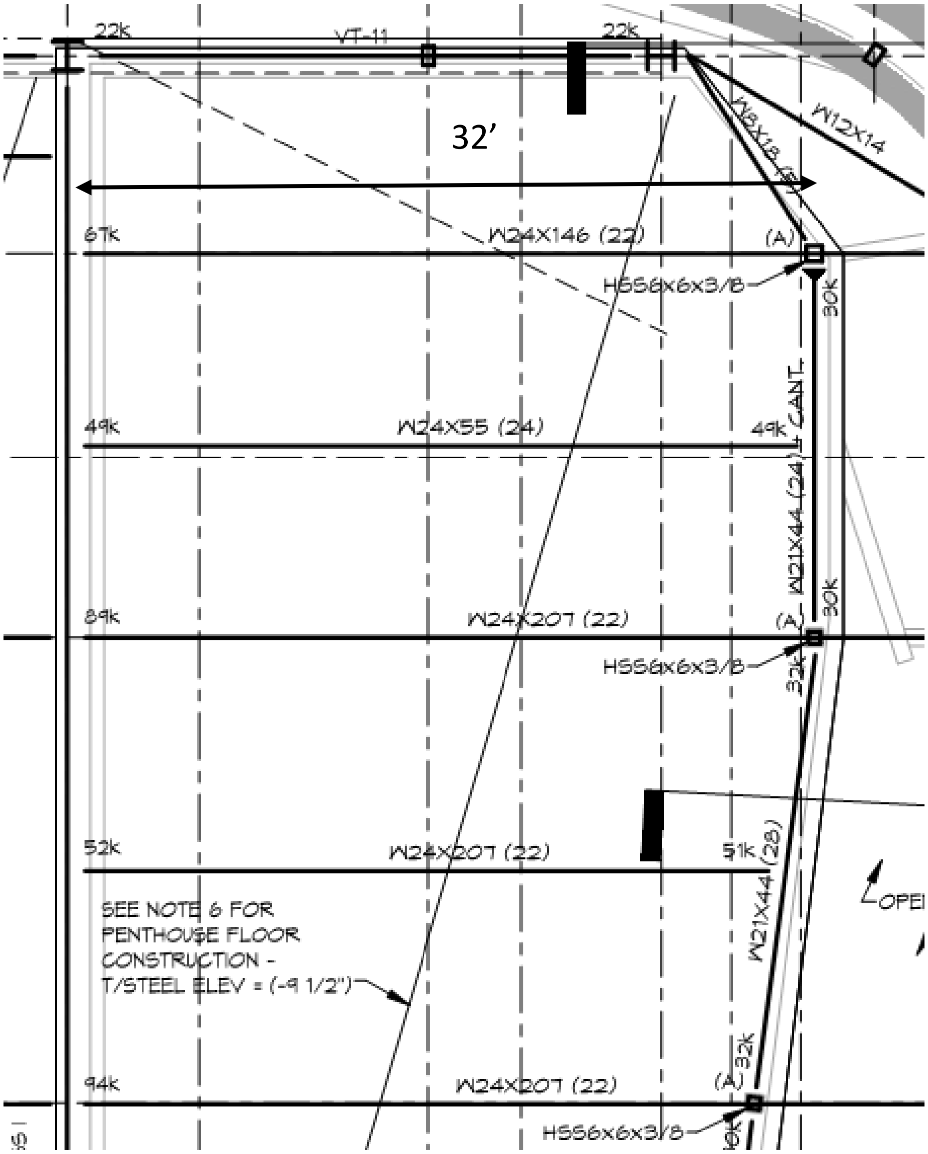
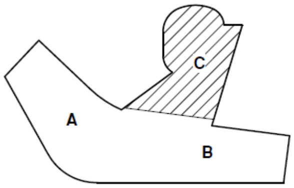


Figure 7: Bay in auditorium



2.2.2 Floor

The floor consists of 3 ¼" lightweight concrete on 3"x 20 gage galvanized metal deck (6 ¼" total thickness) reinforced with 6x6- W2.0 W.W.R. At the penthouse level, the slab is 4 ½" normal weight concrete on 3" x 18 gage galvanized metal deck (7 ½" total thickness) reinforced with 6x6- W2.9xW2.9 W.W.R. The increased thickness will provide additional dampening of the mechanical units to the floors below. Finally the roof level consists of 1 ½" x 20 gage Type B galvanized metal roof deck on steel filler beams and girders.

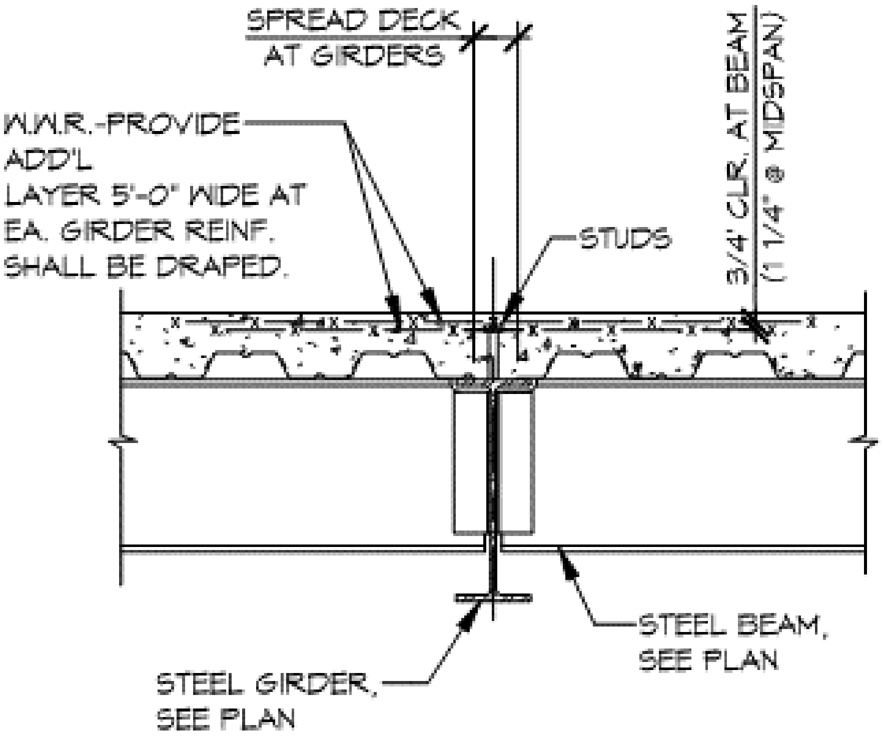


Figure 8: Typical composite floor construction

2.2.3 Columns

All columns in the Brendan Iribe CCSI are W12s or W14s spliced every two stories, usually 1’-6” above the finished floor slab. Splices can be welded or bolted as shown below. Figure 9 shows the welded detail while Figure 10 shows the bolted detail. Some columns can reach sizes up to W14x370 due to the high axial loads acting on it.

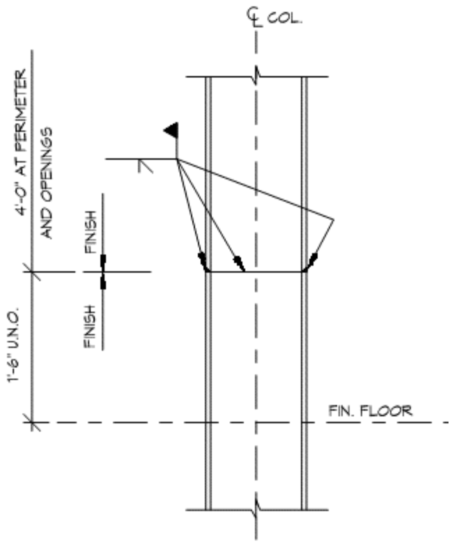


Figure 9: Typical welded detail

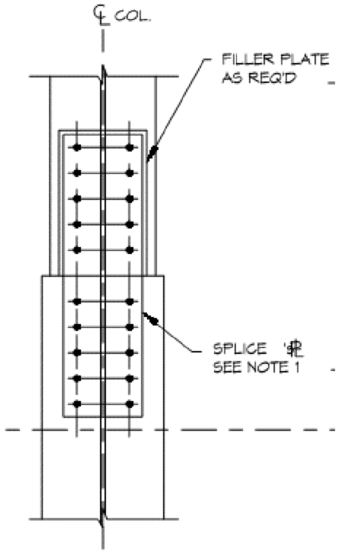


Figure 10: Typical bolted detail

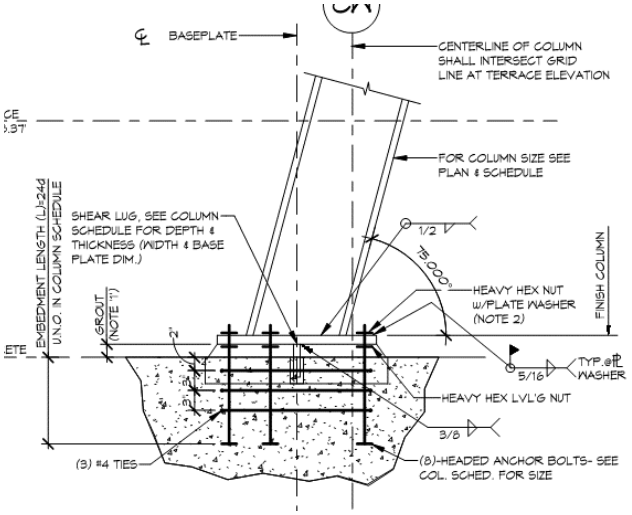


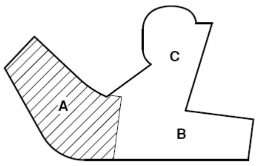
Figure 11: Sloped column foundation

The sloping columns located at the eastern cantilever require significantly larger sizes. As the sloping turns the column into a beam-column, a W14x730 must be used for two of these columns. This large size results in a 48” x 48” x 5” base plate which weighs over 3000 pounds. Figure 11 shows a detail of the sloped column foundation.

2.3 Lateral System

The lateral force resisting system of the main tower consists of moment frames and braced frames located in the eastern and western wings of the building. The next two figures show the configuration on the structural plan where red designates moment frames and green designates vertical trusses. Girders and moment frames are W24's or W27's and range from 8' to 24' spans.

Figure 12: Lateral system in western wing



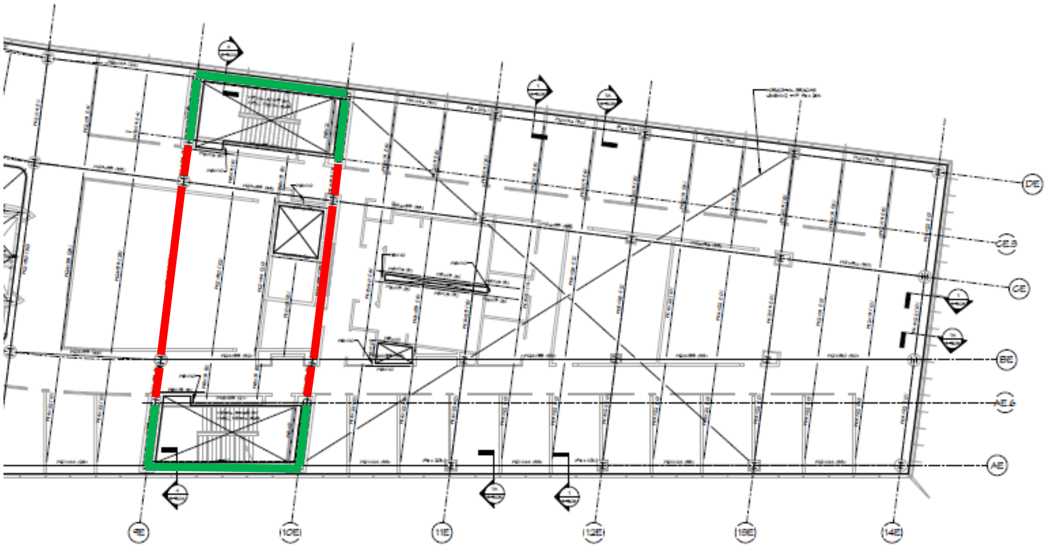


Figure 13: Lateral system in eastern

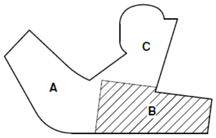


Figure 14 below shows the lateral system in the auditorium consisting of moment frames and vertical trusses. Due to the open floor plan, moment frames and vertical trusses are located along the perimeter of the auditorium.

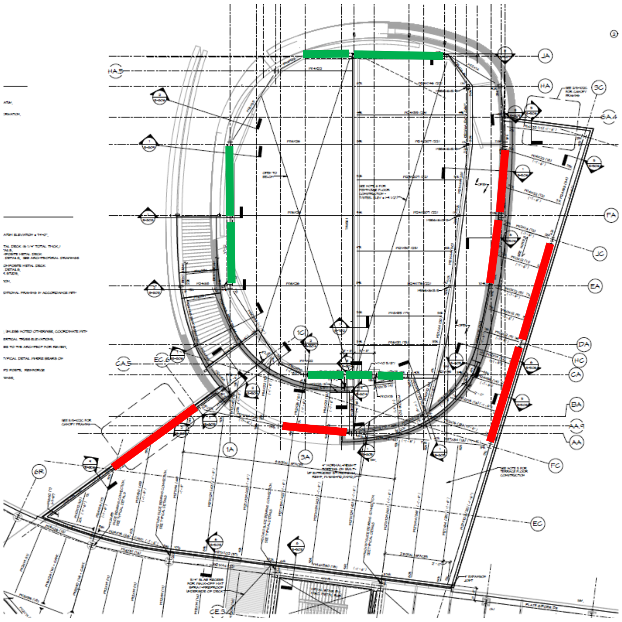
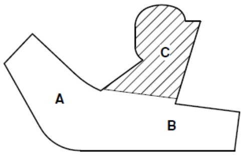


Figure 14: Lateral system in auditorium



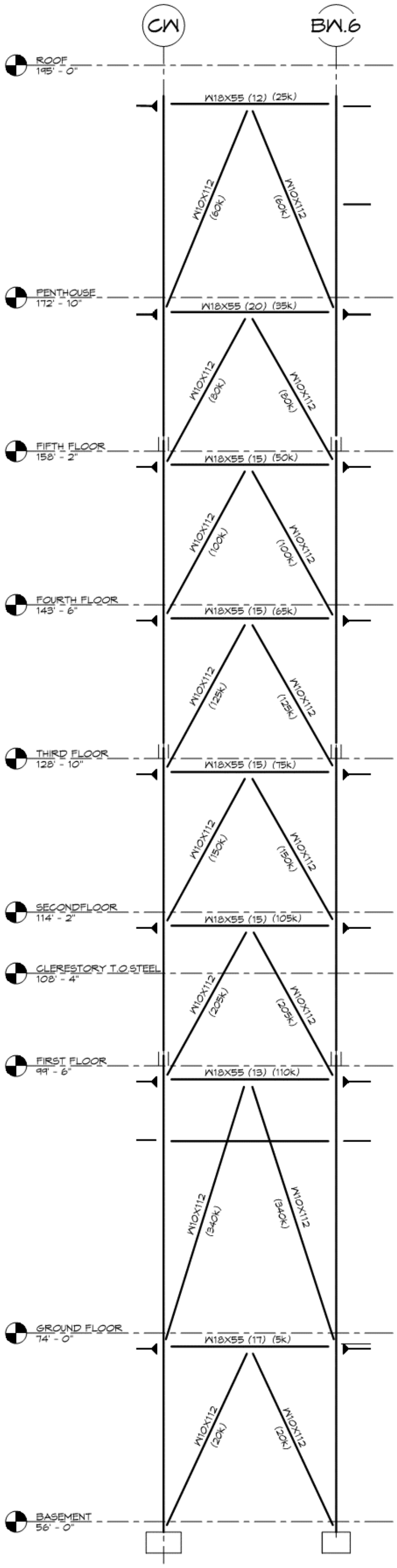


Figure 15: Typical braced frame elevation

There are thirteen separate braced frame configurations located throughout the building including diagonal, double diagonal, and chevron bracing (k-brace). The vertical trusses use W10x112, W12x120 and HSS 20x12x1/2 for the bracing members. Figure 14 shows the elevation for Vertical Truss 1 which is located adjacent to the stairwell in the buildings western wing.

2.4 Structural Details

2.4.1 Secondary Elements

Two architectural features on the Antonov Auditorium include canopies located beyond the southwest corner of the auditorium and at the northeast corner. The canopy consists of L2x2x1/4 kickers bolted to W12x19s with ¼" full depth stiffener plates at each side of the web and kicker. Figure 15 below shows a detail of the northeast canopy.

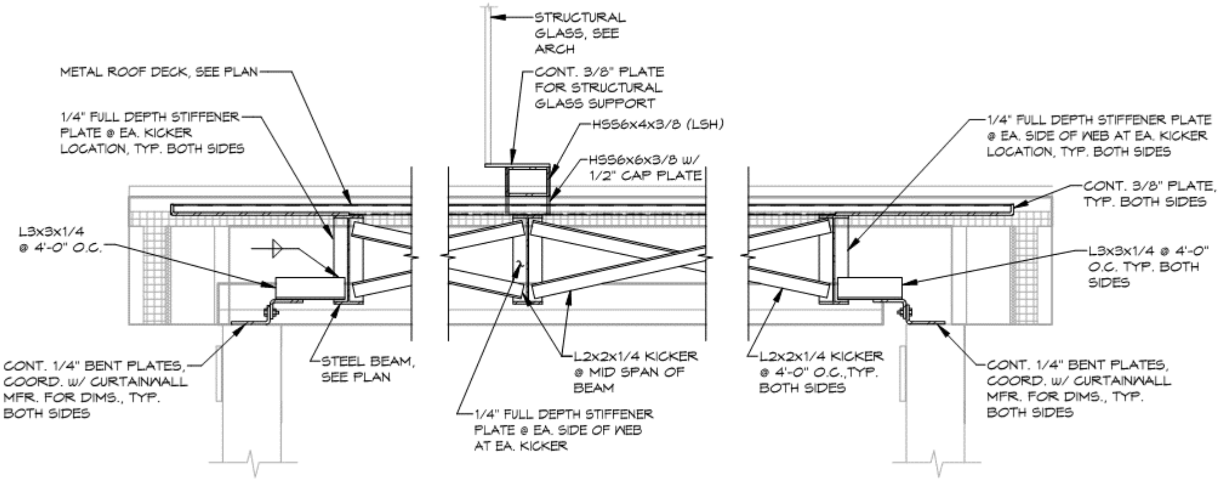


Figure 16: Northeast canopy detail

2.4.2 Joint Details

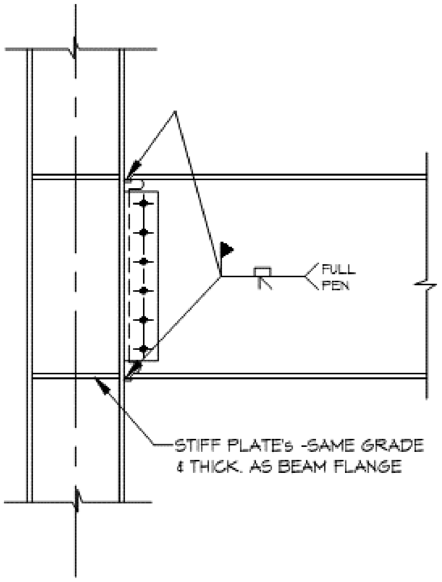


Figure 17: Typical moment connection to column flange

The Brendan Iribe CCSI has many cases where different connection details are required. Several cases include moment connections to wide flange columns, moment connections to HSS, vertical truss connections, and truss connections. All connections have ¾” A325 bolts using single angles unless otherwise noted. Figure 17 shows a typical detail of a moment connection to a column flange. Figure 18 on the following page shows a typical truss connection. A claw angle on each side of the gusset plate connects the diagonal member to the gusset plate.

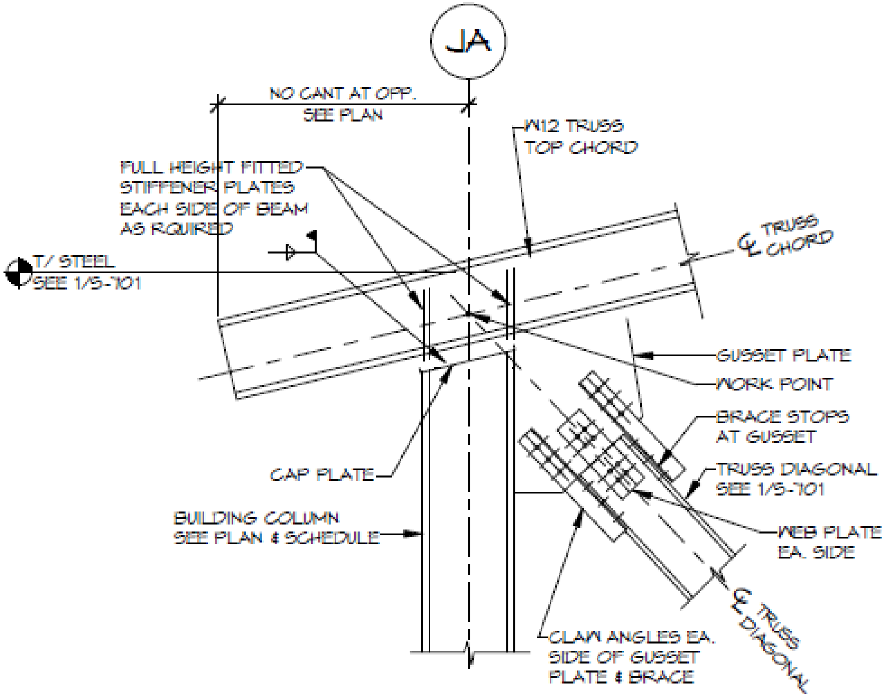


Figure 18: Typical truss

3. Loading and Codes

3.1 Applicable Codes

The following codes and standards apply to the design and construction of this project.

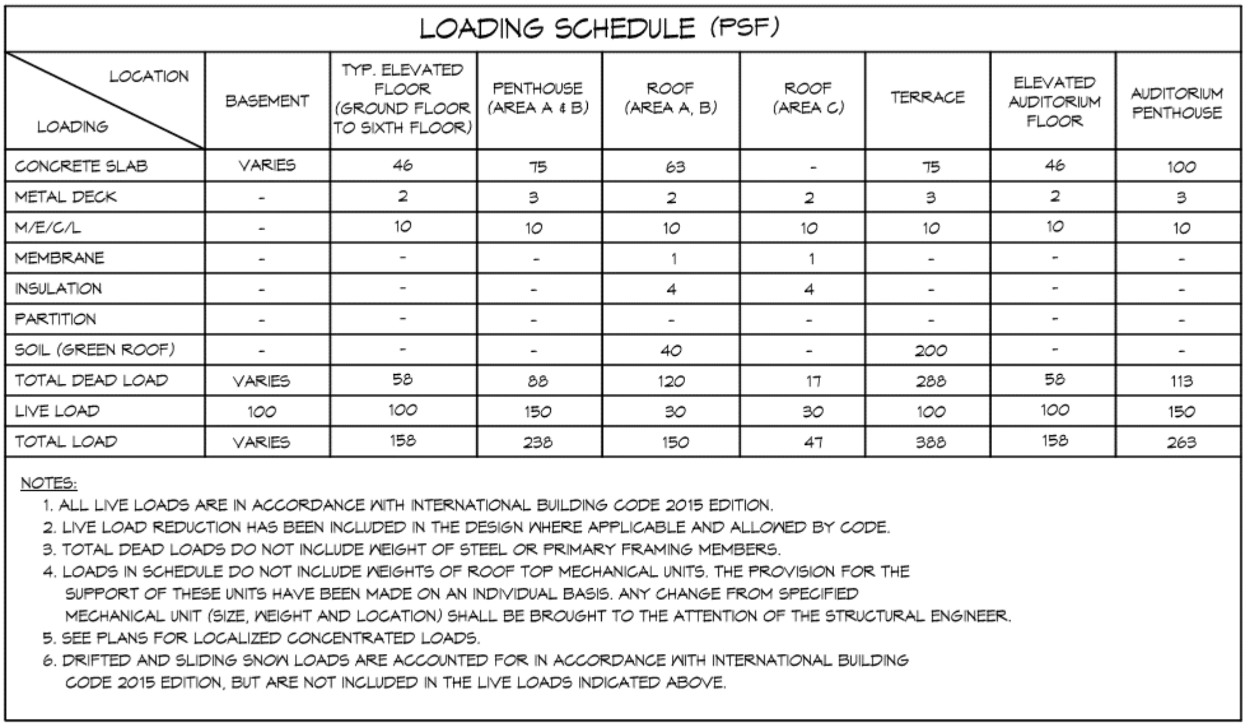
Table 1: Applicable codes

Standard	Applicable Code
International Code Council, Inc.	2015 International Building Code
American Society of Civil Engineers	Minimum Design Loads for Buildings and other Structures (ASCE 7-10)
American Concrete Institute	Building Code Requirements for Structural Concrete (ACI 318-14)
American Institute of Steel Construction	Manual of Steel Construction, 14th Edition
The Masonry Society	Building Code Requirements for Masonry Structures (TMS402-11)
American Welding Society	Structural Welding Code (ANSI/AWS D1.1-2010)

The dead loads used in design consists of the self-weight of the building including structural steel, decking, concrete slab, walls, and roofs. In addition, a superimposed dead load is added which accounts for MEP equipment, interior finishes, and any other miscellaneous load. Live loads are dependent on the occupancy of the room, and are determined from Chapter 4 of ASCE 7-10. Snow loads and its respective unbalanced load/drift load are determined from Chapter 7 of ASCE 7-10. Wind and seismic loads are determined from ASCE 7-10 as well.

3.2 Gravity Loads

Dead Loads have been formulated by the engineers through office standards. Dead loads do not include weight of primary members or rooftop mechanical equipment. Live loads are in accordance with the 2015 International Building Code, and reduction has been included where applicable by code. Drifting and sliding snow loads are accounted for in the 2015 International Building Code, but not included in the figure below. Figure 19 shows the loading schedule provided by Hope Furrer Associates, the structural engineer on this project.



LOADING SCHEDULE (PSF)

LOCATION / LOADING	BASEMENT	TYP. ELEVATED FLOOR (GROUND FLOOR TO SIXTH FLOOR)	PENTHOUSE (AREA A & B)	ROOF (AREA A, B)	ROOF (AREA C)	TERRACE	ELEVATED AUDITORIUM FLOOR	AUDITORIUM PENTHOUSE
CONCRETE SLAB	VARIES	46	75	63	-	75	46	100
METAL DECK	-	2	3	2	2	3	2	3
M/E/C/L	-	10	10	10	10	10	10	10
MEMBRANE	-	-	-	1	1	-	-	-
INSULATION	-	-	-	4	4	-	-	-
PARTITION	-	-	-	-	-	-	-	-
SOIL (GREEN ROOF)	-	-	-	40	-	200	-	-
TOTAL DEAD LOAD	VARIES	58	88	120	17	288	58	113
LIVE LOAD	100	100	150	30	30	100	100	150
TOTAL LOAD	VARIES	158	238	150	47	388	158	263

NOTES:

1. ALL LIVE LOADS ARE IN ACCORDANCE WITH INTERNATIONAL BUILDING CODE 2015 EDITION.
2. LIVE LOAD REDUCTION HAS BEEN INCLUDED IN THE DESIGN WHERE APPLICABLE AND 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 2015 EDITION, BUT ARE NOT INCLUDED IN THE LIVE LOADS INDICATED ABOVE.

Figure 19: Loading schedule

From ASCE 7-10, the ground snow load for College Park, MD is 35 PSF with an exposure factor of 0.9, importance factor of 1.1, and thermal factor of 1.0. The flat roof snow load is 24 PSF plus unbalanced, drifting, and sliding where applicable.

3.3 Lateral Loads

3.3.1 Wind Loads

Wind loads were determined in accordance with ASCE 7-10. College Park, MD has an ultimate design wind speed of 120 mph and a nominal wind speed of 93 mph. The Brendan Iribe CCSI falls under exposure B and risk category III. An internal pressure coefficient of +/- 0.18 has been used. Components and cladding wind loads for parapets have also been determined in accordance with ASCE 7-10.

3.3.2 Seismic Loads

Seismic loads have been calculated using the equivalent lateral force procedure. A risk Category of III, Site Class D, and Seismic Design Category B have been used for these calculations. The basic seismic force resisting system is ordinary braced frames and ordinary moment frames.

3.4 Load Paths

Although construction starts at the foundation, design starts at the top of the building. All gravity loads act downwards, which is absorbed by the composite deck and transferred to the infill beams. After the beams, the load travels to the girder. Finally it is transferred to the column where the load travels to the foundation and is distributed at the ground.

Lateral loads can act horizontally and may even cause uplift. To negate this lateral load, moment frames and vertical trusses have been placed to resist this lateral load. Moment connections in moment frames and bracing in vertical trusses transfer the load to the columns, which ultimately travel to the ground. Columns that are part of moment frames or vertical trusses are typically larger than gravity columns as they have to resist gravity and lateral loads.

4. Structural Design Alternative

The Brendan Iribe Center for Computer Science and Innovation consist of steel wide flange girders and columns to resists gravity loads, and moment frames and braced frames to resist lateral loads. The previous notebook submissions have determined that the structural system is acceptable and meets code. Although the current system is efficient, a study will be done to determine if a new system performs just as efficiently as the existing one.

4.1 Design Proposal

The proposed alternative system consists of a biaxial voided flat slab for the gravity system and concrete shear walls for the lateral system. Plastic voids in the shape of flattened spheres are placed in steel cages and then the concrete is poured resulting in about 35% self-weight than a solid reinforced concrete slab. This allows for larger spans, less depth of the structure which results in lower floor to floor heights and more head room, and reduced deflections. The reduced height of the building can help reduce costs for the façade, pipes, and ductwork. *Figure 20* shows a side by side comparison of a conventional concrete slab system next to the voided concrete slab system. For the gravity system, the current column configuration will have to be rearranged in order to achieve a standard typical bay throughout the building. The redesign of the lateral system will consist of shear walls located in the same place as the current moment frames and braced frames. As shear walls have higher stiffness's than moment frames and braced frames, both drift and strength for the lateral system should perform better.

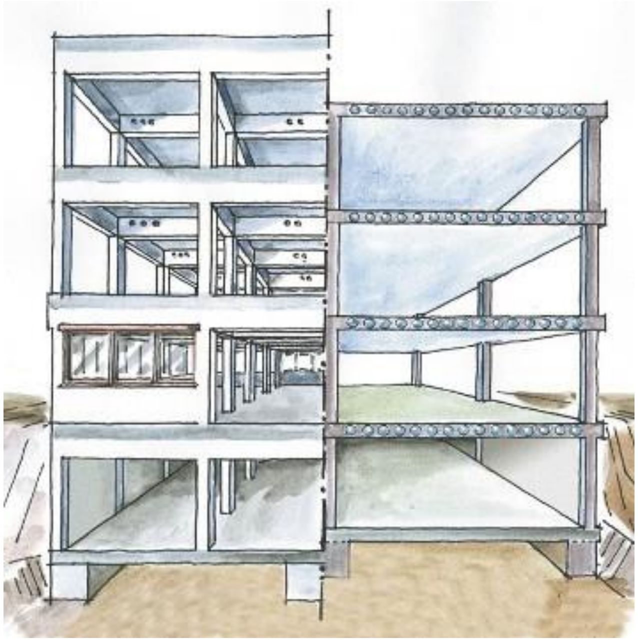


Figure 20: Conventional slab vs voided concrete slab

4.1.2 Research/Analysis Methods

The design of the voided concrete slab will be treated as the design of a two way flat slab with less self-weight. Notes from AE 431, Chapters 8 and 11 of ACI 318-14, and the *Design Guide for Voided Concrete Slabs* from the Concrete Reinforcing Steel Institute will be used for the design of the voided concrete slab and corresponding lateral system. An ETABs model will also be used for verification of the redesign.

4.2 Construction Management Breadth

This alternate system will have an effect on both the time and cost of construction. Since concrete is typically cheaper than steel, the overall cost of the building should be cheaper. In addition, the overall building height will be several feet shorter which will help reduce the cost. Although the current cost is being withheld from the owner, this breadth will determine if the new system will reduce the overall cost, and ultimately the feasibility of the alternate system.

4.3 Mechanical Breadth

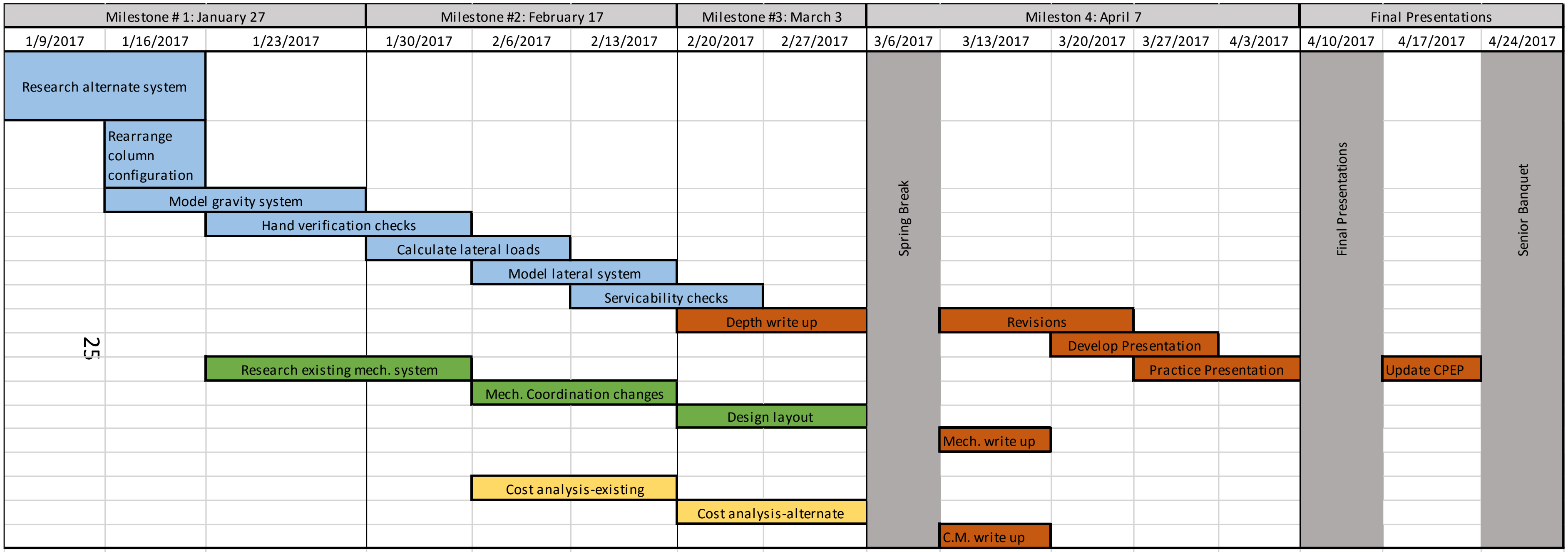
With the depth of the floor system reduced, the sizes of pipes and ductwork will need to analyzed. There will most likely not be enough height for the existing pipes and ductwork with the new alternate design. This breadth will determine how the alternate system will affect the mechanical coordination and mechanical equipment sizes.

4.4 MAE Requirements

The graduate coursework that will be included into this report is from AE 530: Computer Modeling of Building Structures. ETABs will be used to create a three dimensional model to design the new gravity and lateral system.

4.5 Tasks and Tools

1. Research
    a. Voided concrete slab alternative
        i. Research design method using design guide and ACI
        ii. Determine modeling approach
2. Structural depth
    a. Gravity system
        i. Rearrange column configuration to achieve a typical bay throughout the building
        ii. Determine gravity loads
        iii. Model gravity system in ETABs
        iv. Check typical bay by hand to verify computer model
    b. Lateral system
        i. Calculate wind and seismic loads on building
        ii. Model shear walls in ETABs
        iii. Verify lateral loads in ETABs match hand calculations
        iv. Determine total shear into each wall
        v. Perform hand calculations for strength and serviceability checks to verify computer model
3. Construction management breadth
    a. Perform cost analysis of existing system
    b. Perform cost analysis of alternate system
    c. Write up construction management breath report determining if the alternate system's overall cost is cheaper
4. Mechanical breadth
    a. Research existing mechanical system
    b. Determine changes to mechanical coordination based on new floor system depth
    c. Redesign mechanical layout based on these changes
    d. Write up mechanical breadth report documenting these changes
5. Final Documentation
    a. Create outline for final report
    b. Create outline for presentation
    c. Finalize report and presentation
    d. Practice presentation
    e. Update CPEP website



Milestone # 1: January 27			Milestone #2: February 17			Milestone #3: March 3		Mileston 4: April 7					Final Presentations		
1/9/2017	1/16/2017	1/23/2017	1/30/2017	2/6/2017	2/13/2017	2/20/2017	2/27/2017	3/6/2017	3/13/2017	3/20/2017	3/27/2017	4/3/2017	4/10/2017	4/17/2017	4/24/2017
Research alternate system	Research alternate system							Spring Break					Final Presentations		Senior Banquet
	Rearrange column configuration														
	Model gravity system	Model gravity system													
		Hand verification checks	Hand verification checks												
			Calculate lateral loads	Calculate lateral loads											
				Model lateral system	Model lateral system										
					Servicability checks	Servicability checks									
						Depth write up	Depth write up		Revisions	Revisions					
										Develop Presentation	Develop Presentation				
		Research existing mech. system	Research existing mech. system								Practice Presentation	Practice Presentation		Update CPEP	
				Mech. Coordination changes	Mech. Coordination changes										
						Design layout	Design layout								
									Mech. write up						
				Cost analysis-existing	Cost analysis-existing										
						Cost analysis-alternate	Cost analysis-alternate								
									C.M. write up						

Legend	
🟦	Structural depth
🟩	Mechanical breadth
🟨	Construction breadth
🟧	Reports/presentation

Milestones
Milestone #1: Initial research is complete and gravity system is modeled in ETABs
Milestone #2: All modeling is finalized
Milestone #3: Structural depth report is written and breadth analysis is complete
Milestone #4: Report and presentaion are finalized and prepared to present to jury

5. Conclusion

Based on the three notebook submissions throughout the semester, it has been determined that the Brendan Iribe Center for Computer Science and Innovation has been designed appropriately by code and is an effective design. However, there can certainly be more than one efficient design. The proposed alternate system is a voided concrete slab for the gravity system and concrete shear walls for the lateral system. The advantages of this alternate system include less self-weight, longer spans, less structural depth, and reduced deflections. In addition, the shear walls should help reduce drift throughout the building. Next semester will determine whether this alternate system is a feasible design from a structural standpoint, as well as determining the overall cost of the building and the effect on the mechanical system.