victoria interval

MTOB [multi-tenant office building]

pennsylvania

ae senior thesis [struc]

proposal + faculty advisor [DR. BOOTHBY] 14 december 2012

[proposal]

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[building introduction]

The Multi-Tenant Office Building [MTOB] is currently being constructed in Pennsylvania and is expected to be done in July 2013. MTOB is designed as a 5-story, 152,000 square foot office building to be leased into different office spaces for multiple tenants. It is designed to hold high-end office spaces and sits in a luxury office park created by a developer. The architecture plays off of the existing buildings in the office park, which is mostly new construction. Over-sized windows allow natural light to penetrate deep into the spaces without being uncomfortable or distracting. It is expected to have full tenant lease agreements before the completion of the building, which will ensure a successful venture.

[executive summary]

MTOB's current structural design has been found to be adequate in both gravity and lateral aspects. For the proposal, a scenario is created which will require a new structural design affecting several other aspects of the building.

With the technological era, the tenants are looking for a more contemporary high-end space. To solve this client's needs, the use of cellular beams throughout exposed ceilings will be used. The lateral system will be replaced with concentrically braced frames in the short direction and moment frames in the long direction.

To accommodate the IBC fire code requirements, the building will use Table 601, note D allowance. This allows the current 1 hour rating required by either coating or ceiling cover to be replaced with automatic sprinklers. In order to fully comply with the IBC and this note, the building height will have to be reduced by 5 feet to a height of 65'.

Architectural and mechanical breadths will be considered since they will have the greatest impact from the structural changes. The contemporary feel of the office building will need to be reflected in a façade redesign. This will also incorporate the concentrically braced frames that are visible through the windows. Mechanically, the building will have two main obstacles. First, the exposed ceiling removes the possibility of a plenum space to be used for return air. This means that all of the return air will have to be ducted in addition to the supply air. Second, the entire mechanical ductwork system will have to fit within the structure to ensure optimal building height. This will require load and ventilation calculations, duct sizing, and duct layout. This proposal suggests a typical floor ductwork layout to be done as the mechanical breadth.

To adequately complete all of the work required in this thesis, several masters courses curriculum will be utilized. A list of specific tasks and a corresponding schedule can also be found in this report.

[structural overview]

MTOB is a 5-story steel structure with eccentrically braced frames sitting on drilled concrete caissons. The floors are concrete slab on grade and concrete slab on deck. All calculations are based on Occupancy Category II, for office buildings [ASCE7-10].

included in this section:

building materials

foundation system

framing system

floor system

lateral system

roof system

building materials

Although the building exterior has some brick masonry work, the steel frame, CMU walls, and concrete floors and foundations are the only structural aspects of this building. The materials used in this building can be found in Figures 1-3. These were found on AES's sheet S001.

steel	
shape/type	**grade**
structural W shape	ASTM A992
structural M, S, C, MC, L	ASTM A36
HSS steel tube	ASTM A500, grade B
round HSS steel pipe	ASTM A500, grade B
plates and bars	ASTM A36

Figure 1: *(left)*

Structural steel shapes and standards for the project

masonry	
shape/type	**strength [psi]**
8" CMU wall	1500
12" CMU wall	1500
18" CMU wall	1500

Figure 2: *(left)*

Masonry wall sizes and standards for the project

concrete		
Usage	**weight [pcf]**	**strength [psi]**
footings, grade beams, caisson caps	> 144	3000
caissons [drilled piers]	> 144	4000
Walls	> 144	4000
slabs on grade	> 144	4000
elevated floor slabs	> 144	4000
balconies, with 2 ½ gallons of corrosion inhibitor per CY	> 144	5000

Figure 3: *(above)*
Concrete usage and standards for the project

foundation system

The foundation system of MTOB was designed by AES after reviewing the recommendations of the geotechnical reports from the geotechnical engineer, Professional Service Industries, Inc.

preliminary geotechnical recommendation

Professional Service Industries, Inc. (PSI) submitted a preliminary geotechnical recommendation report in December, 2011 based on geotechnical information from existing geotechnical reports and drawings from various geotechnical firms. From the existing reports, PSI noted 14 boring logs of interest to the project. From these borings, it was interpolated that rock can be expected between the approximate elevations of 1020-1030 ft, NGVD. PSI agreed with AES's proposed foundation system of drilled piers with grade beams. Initial design values were given as follows:

25ksf net end bearing pressure
2ksf preliminary slide friction

geotechnical report

A new geotechnical survey was conducted by PSI in February, 2012. The geotechnical engineering firm executed a total of 12 additional borings: 6 in the proposed footprint of the building and 6 in the parking lot areas surrounding the building footprint (see Figure 4). From borings B-1 through B-6, PSI recommends the drilled pier foundations extend to the limestone/sandstone bedrock (found between 9 and 27 feet below the finished floor elevation).

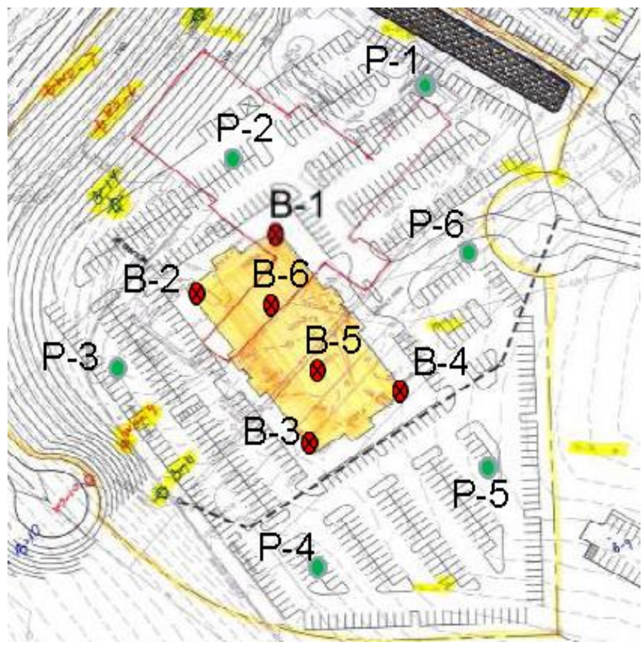


Figure 4: *(above)*
Locations of PSI test borings. Image taken from PSI geotechnical report

For adequate ground water control, sump pumps shall be used to keep water a minimum of two feet below the subgrade elevation.

foundation design

The MTOB foundation is designed as drilled piers and grade beams along the exterior walls. The concrete grade beams range in sizes from 12”-24” wide and 36”-68” deep. Reinforcement varies, but generally the grade beams are reinforced with #7 bars on top and bottom and #5 bars on the sides. The caissons are designed as 30” diameter concrete with reinforcing and caisson caps depending on the corresponding framing. A plan of the caissons and grade beams can be seen in Figure 5. Note that the grade beams have been highlighted in green and the caissons in pink.

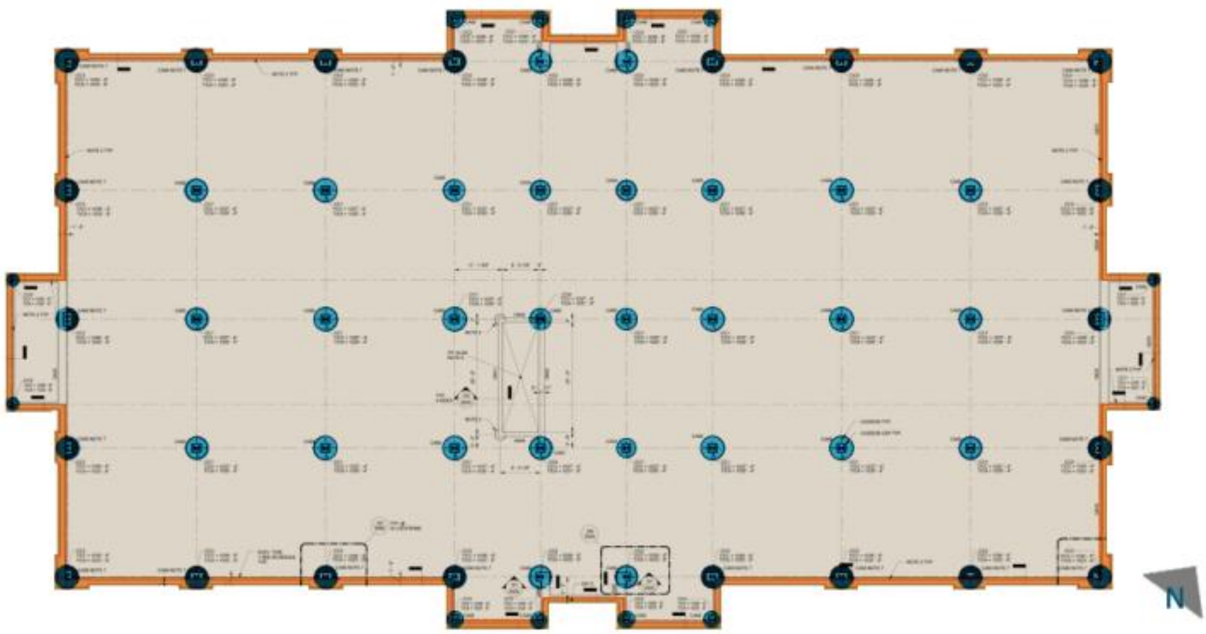


Figure 5: *(above)*
Modified AES foundation plan with caissons highlighted in blue and grade beams highlighted in orange.

framing system

MTOB framing consists of five stories of steel columns. Column splices occur on level four at varying heights so that stability is not jeopardized. The majority of columns range from W12x40 to W12x78, but they reach W12x152 in the areas supporting heavier loads under the mechanical penthouse.

floor system

The rectangular building shape is mirrored with regularly spaced bay sizes. Figure 7 shows a typical floor plan with the two typical bay sizes.

Level 1 floor is a typical slab on grade, and levels 2-5 floors are slab on composite deck. Specifically, 3 ½" normal weight concrete on 2" 20 gauge deck for a total thickness of 5 ½". Because of the building's regularity, this is the only type of floor system. See Figure 6 to see the typical floor system on beams.

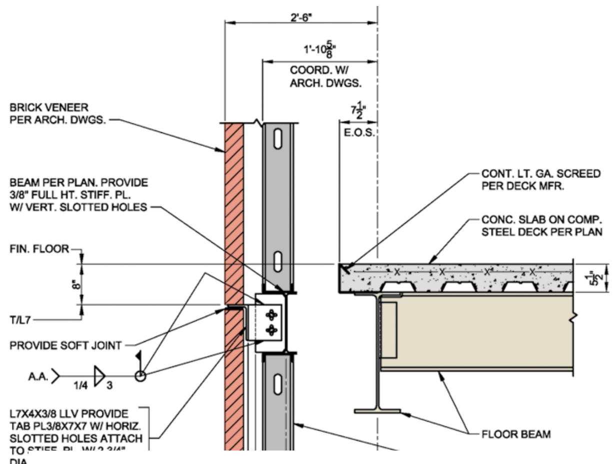


Figure 6: *(above)*
Modified AES section 201 showing a typical floor and exterior wall section.

Figure 7: *(below)*
Typical floor plan with typical bay sizes called out

lateral system

Braced frames resist lateral loads in the MTOB. There are a total of 8 braced frames throughout the building, with three different (though all eccentric) configurations. The frames are eccentric so that none of the bracing crosses behind the large windows that line the exterior walls at every level. See Figure 8 for the typical elevation of MTOB's braced frames. The layout of the braced frames is spaced so that the lateral forces will be adequately acknowledged no matter which direction they approach from. Figure 9 shows the location of each of the 8 braced frames in the building. A components and cladding check has not been included with this technical report, but will be explored in a later report to check that the lateral forces are adequately reaching the braced frames.

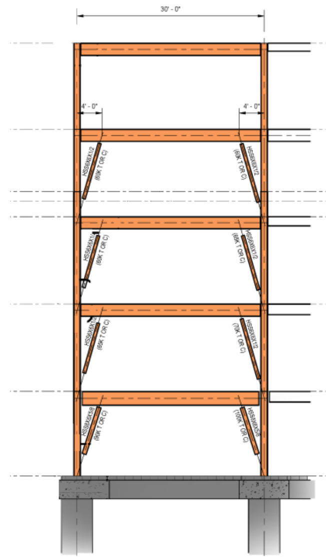
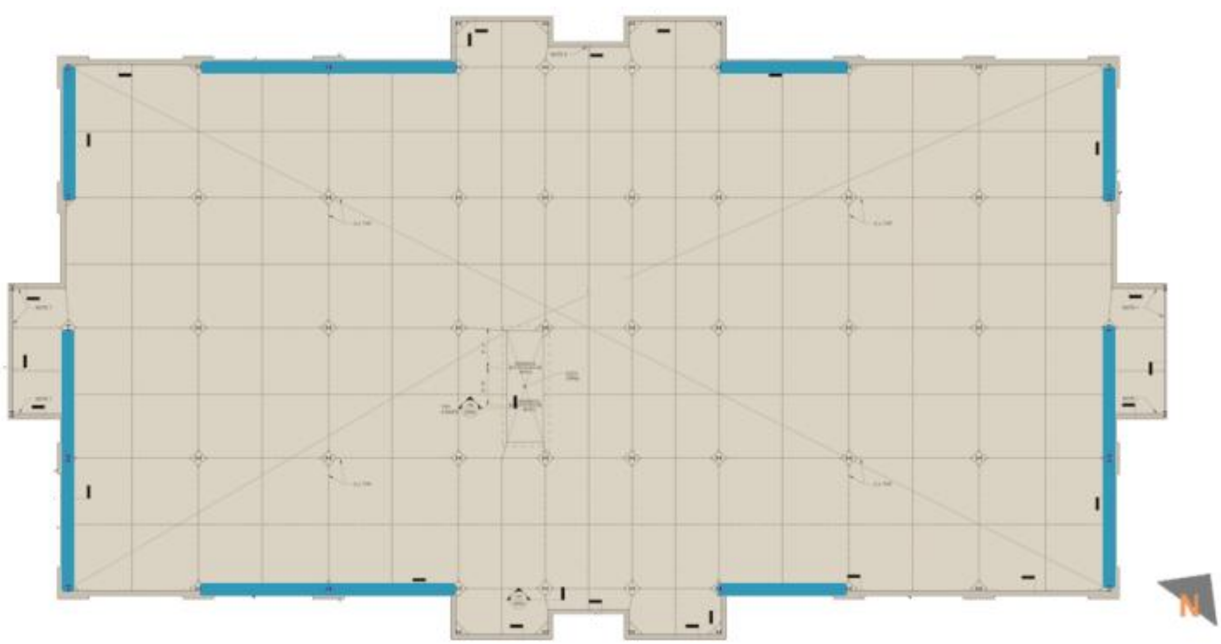


Figure 8: *(above)*
Modified AES braced frame elevation

Figure 9: *(below)*
Modified AES floor plan with locations of braced frames highlighted in pink



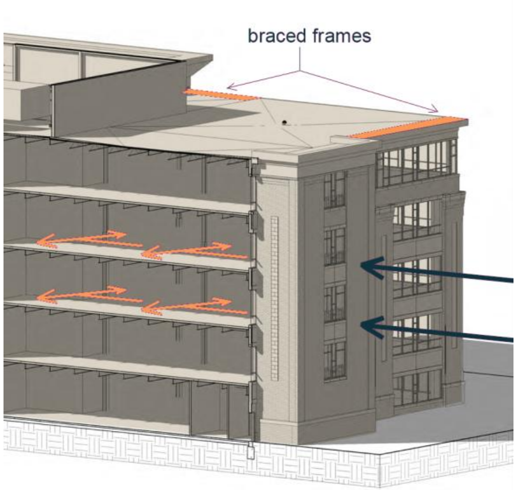


Figure 10: *(above)*
Modified Kernick Architecture building section showing lateral load path

As lateral forces are applied to the building exterior (specifically the components and cladding), bearing connections transfer the loads to the composite floor system. The load travels parallel to the original force. From there, the loads then travel perpendicularly to the braced frames at that particular level through the beams or girders. A lateral load path can be seen in Figure 10.

roof system

The roof of MTOB is an unassuming, simple structure because it does not play an architectural role for the building. The structure consists of 1 ½" galvanized roof deck on supporting beams. Like most steel construction buildings with concrete slabs on deck floor systems, the roof deck does not have any concrete because it is not structurally necessary and the extra weight would cause inefficiencies in the structure. The roof is finished with white TPO Membrane Roof (fully adhered) as the weather resistant covering on top of sloped structure and tapered 20CI insulation. White roofing is becoming more and more popular because of its reflective properties that allow it to minimize heat gain. In an office building, people are often a large contributor to mechanical load and so they have to be cooled most of the year, even in cooler climates like Pennsylvania.

[problem statement]

MTOB is currently designed as a typical office building. All of the structural aspects were found to be adequate and efficient, so there are no major obvious improvements that need to be made to the building. Therefore, a scenario is created which will require a new structural design, which will affect several other aspects of the building.

With the technological era, the tenants are looking for a more contemporary high-end space. This type of a space requires a more open feel and the use of modern materials (or traditional materials in a modern way). MTOB's gravity system (as mentioned previously) is composite beams and girders with a concrete slab. The MEP is hung below the secondary structural members. A suspended ceiling encloses the entire plenum with MEP and structure, which lowers the ceiling height and cramping the space.

In addition to the designed drop ceiling panels, the lateral system also does not fit with the new style of the office building. The lateral system consists of eccentrically braced frames with very large link lengths, which behave like moment frames. While the diagonal member is adequate as far as strength, the building may be better suited with a more defined system of true concentrically braced frames in one direction and moment frames in the other.

In the new scenario with a contemporary office space, a viable structural system must be designed for both gravity and lateral loads. To account for the exposed ceiling, fire ratings must be carefully examined and substituted where possible.

[proposed solution]

The gravity system of MTOB shall be redesigned using cellular composite beams and custom girders. To make the cellular beam system efficient, the original spans of 30’ will be doubled to 60’ in one direction, reducing the number of columns and foundations required for the building.

The size of the gravity members will be analyzed in three different ways to ensure its adequacy and efficiency. First, a RAM model will be created for the new grid and structural system. This will give computer generated sizes for the composite cellular beams, based off of the sizing requirements given by the manufacturer. Second, I will find the tabulated values in the manufacturer catalogue for the span length and load. Third, I will use plastic analysis to approximate the cellular beam as a Vierendeel truss and analyze its adequacy.

To stiffen the lateral system, the eccentrically braced frames will be replaced with concentrically braced frames and moment frames. The existing frames have a link that is 73% the length of the span, which causes the braced frames to act more like moment frames. In the short direction, concentrically braced frames will be used. In the long direction, moment frames will be used. These will be designed according to ASCE 7-10.

[MAE requirements]

Several of the additional MAE coursework will be utilized in the completion of this thesis. To aid in the analysis, a detailed computer model will need to be modified from the one created for the technical reports (AE 597 A, Computer Modeling). With the redesign of the façade necessary with the updated lateral system, an efficient alternative will be designed (AE 542, Building Enclosures).

[breadth studies]

architectural

An architectural redesign is called for to accommodate the structure and to emphasize the new theme of the offices. With the ceiling is exposed, cellular beams are revealed. This is allowed based on IBC if the building height is reduced to 65’ (currently, it is 70’). The web openings (cells) will give the architectural benefit of openness with a contemporary feel. The lateral system in the short direction is now concentrically braced frames. Most buildings try to avoid crossing in front of windows. However, for this contemporary space, the lateral bracing will be emphasized and showcased in the façade redesign.

mechanical

Most mechanical systems are simply hung below the structure. However, to allow the ceiling to expose the structure (no hung ceiling), fire ratings require the building to shorten by 5’ to a 65’ building height. Cellular beam systems are a deeper system, which complicates the necessity to lower the height. In order to meet the height requirement of the IBC, the mechanical system will have to be carefully incorporated into the structure. To complicate the duct system more, the lack of plenum space will require both supply ducts and return ducts, where a typical hung ceiling will use the plenum to collect return air.

As part of the mechanical breadth, load and ventilation requirements will be calculated. This will be used to size main duct runs and feeders, making sure that they are small enough to fit through the cells of the cellular beams and the webs of the girders. A typical mechanical duct run plan will be created to show a possible layout of ductwork for supply and return air.

[tasks]

I. task 1: revise proposal

II. task 2: create RAM model

III. task 3: redesign gravity system (RAM)

   A. computer modeling aid

   B. manufacturer catalog to verify RAM sizes

   C. plastic analysis of cellular beams to verify RAM sizes

   D. girder truss design (Vierendeel girders)

IV. task 4: work on report write-up

V. task 5: redesign lateral system

   A. computer modeling aid (RAM)

   B. hand spot checks

VI. task 6: cost analysis of new system

   A. RS Means online catalog

   B. manufacturer quotes

VII. task 7: breadth 1 - architectural façade redesign

   A. Google SketchUp

   B. Revit

VIII. task 8: breadth 2 – mechanical duct layout

   A. load and ventilation calculations

i. excel spreadsheets

ii. Trace model

B. ductulator to size ductwork to fit inside structural cells

C. ductwork layout for typical floor

i. Revit

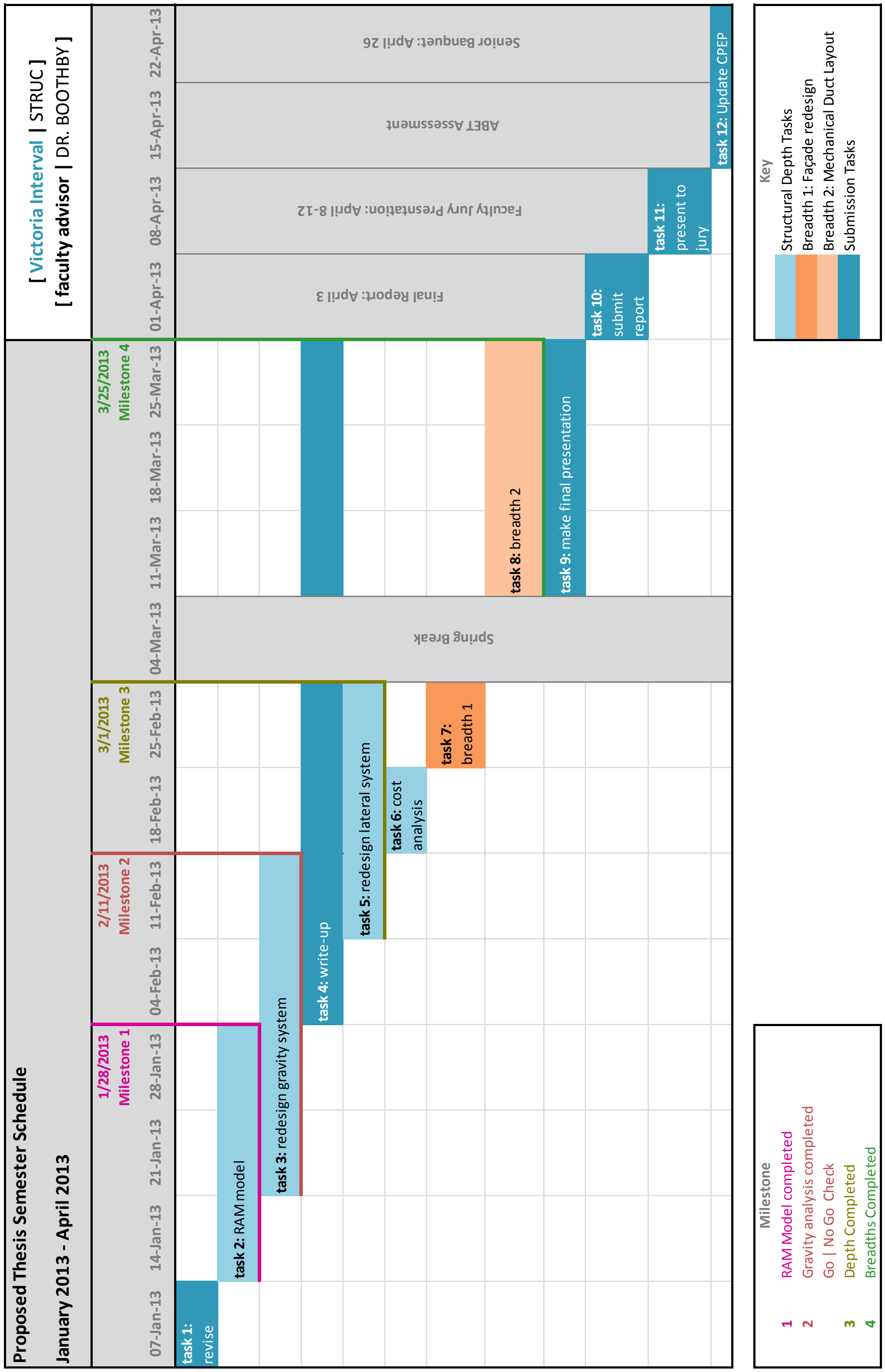
IX. task 9: work on final presentation

X. task 10: submit report

XI. task 11: present to jury

XII. task 12: update CPEP

[schedule]


Proposed Thesis Semester Schedule
January 2013 - April 2013
[Victoria Interval | STRUC]
[faculty advisor | DR. BOOTHBY]
07-Jan-13
14-Jan-13
21-Jan-13
28-Jan-13
04-Feb-13
11-Feb-13
18-Feb-13
25-Feb-13
04-Mar-13
11-Mar-13
18-Mar-13
25-Mar-13
01-Apr-13
08-Apr-13
15-Apr-13
22-Apr-13
1/28/2013 Milestone 1
2/11/2013 Milestone 2
3/1/2013 Milestone 3
3/25/2013 Milestone 4
task 1: revise
task 2: RAM model
task 3: redesign gravity system
task 4: write-up
task 5: redesign lateral system
task 6: cost analysis
task 7: breadth 1
task 8: breadth 2
task 9: make final presentation
task 10: submit report
task 11: present to jury
task 12: Update CPEP
Spring Break
Final Report: April 3
Faculty Jury Presentation: April 8-12
ABET Assessment
Senior Banquet: April 26
Milestone
1 RAM Model completed
2 Gravity analysis completed
Go | No Go Check
3 Depth Completed
4 Breadths Completed
Key
Structural Depth Tasks
Breadth 1: Façade redesign
Breadth 2: Mechanical Duct Layout
Submission Tasks

[conclusion]

The proposal focuses on a scenario change in which the client requests a contemporary space with exposed ceilings. To solve this, the gravity system will be changed to composite cellular beams and custom Vierendeel girders.

The lateral system will be stiffened through the use of concentrically braced frames in the short direction and moment frames in the long direction.

In accommodating the height restriction set by the IBC, the mechanical ductwork will have to be laid out completely within the structural cells. The façade will be redesigned to better house the braced frames and reflect the contemporary style of the building.

The research, design, and analysis of this proposal will determine if the proposed modifications satiate the new client's needs while still comparing to the current design.