Thesis Proposal

Piez Hall Extension

Oswego, NY

Min Gao Li
Structural Option
Faculty Advisor: Dr. Thomas E. Boothby
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Executive Summary

Piez Hall is an educational facility located at Oswego University of New York. A new extension, conservatory, and planetarium will be designed and attached to the old Piez hall as one unified building. The current structural system of the new extension is two-way concrete slab with drop panels and reinforced concrete shear walls as its main lateral force resisting system, while the rest of the building is composite steel system. The proposed thesis will include a redesign of the entire floor system in the new extension as composite steel with long span trusses and eccentric braced frames as its main lateral system. However, there are few concerns about the redesign of the building using a composite steel system. For example, a composite system may increase the total floor depth and cost of the project. Zoning law in the Oswego University area must be thoroughly investigated to make sure the increased building height will not violate the local zoning requirement. Also, spray fiber is needed to achieve a 2 hour fire rating. In addition, vibration may be a concern since steel system is well known for its poor vibration control.

The author decided to choose a composite system in the new extension to unify the structural system of the building because it may reduce construction time and cost, as well as to reduce the level of miscommunication and confusions between different contractors and workers. Another reason to choose a composite redesign is because of the building's location (New York), which has many experienced steel contractors and workers. The intent of the redesign is to increase the flexibility of the building and the number of ductile members in the building to better resist seismic loads. By eliminating the number of columns and shear walls, the building can be provided with more usable interior spaces as well as longer deck span. Although thorough analysis is needed to confirm the impact of the redesign on the current foundation, the lighter weight steel building may actually benefit the foundation system. Overall building torsion of the redesign will also be examined and minimized. If time permits, floor vibration issues related to redesign will be analyzed and addressed.

The composite system with long span trusses will be designed using RAM and ETABS. Hand calculations will be performed to check the validity of the model generated by the structural programs. In the ETABS model, placements of the lateral braced frames will be experimented to minimize torsion. Structural members will be sized using RAM based on the most economical wide flange.

Two breadth topics are included in this proposal that focus on the construction and sustainability aspect of the building. The scheduling and cost will be analyzed for the redesign. A comparison of the composite system with long span trusses versus the original two way flat slab with drop panels will be performed to determine the feasibility of the redesign. The breadth study also included green roof and green wall concepts in hopes to reduce the annual energy cost by providing passive cooling in the summer and better indoor air quality to promote health and wellness.

Building Introduction

The new Piez hall extension at Oswego University located in New York will provide high quality classrooms, teaching and research laboratories, as well as interaction spaces for all of the university's engineering departments. Inside the new facility, there will be a planetarium, meteorology observatory and a greenhouse.

Figure 2: Aerial map from Bing.com showing the location of the site

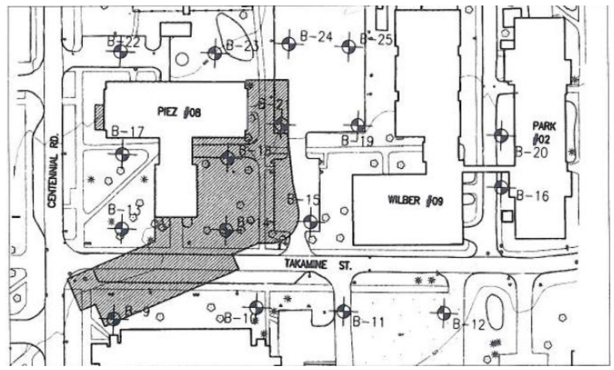


Figure 1: Site map showing existing Piez hall and the new extension (shaded area)

The Piez hall addition will add approximately 155,000 square feet to the existing Piez hall. Snygg hall, which is next to the Piez hall, will be demolished to make way for the new addition. In the back of the U shaped Piez hall, there will be a walkway connecting Wilbur hall and the new addition. The construction of Piez hall extension began as early as April 2011. It is anticipated to be complete by April 2013 with an estimated cost of $110 million dollars. The building has 6 stories and it stands 64 feet high. The new 210,000 square feet concrete framed extension was designed by Cannon Design. The building is designed so that its exterior enclosure looks somewhat similar to the existing Piez hall (see Figure 3). The building is decorated with a skin of curtain wall. Brick is used in the south side facade. The second and third levels have spaces cantilevered slightly out to the west.

The Piez hall extension has numerous sustainability features to attain LEED Gold Certification. The building energy efficient curtain wall with a high R value will reduce heat loss. The mechanical system includes a large geothermal heat pump with a design capacity of 800 tons will be implanted to cool and heat the building. Occupied spaces have access to daylight. The roof has photovoltaic array, skylight and wind turbines. These features together will reduce the total energy use of the building to 47% and save 21% of the energy cost each year.

Figure 3: Exterior rendering showing the building enclosure

Structural Overview

Foundation

According to the soil report for Oswego County, the proposed site will be suitable for supporting the renovation and addition with a shallow spread foundation system. The maximum net allowable pressure on soil is 6,000psf for very dense till layers and 4,000 psf for medium dense clay and sand layers. All grade beams, foundation walls and piers will have a concrete strength of 4000psi while all other footings and slabs-on-grade will have a concrete strength of 3000psi.It is estimated that all foundations will undergo a total settlement less than 1 inch. Differential settlement is estimated to be less than 0.5 inch. Details of typical footings are given in Figure 4.

Basement non-yielding walls have granular backfill with drains at locations where surcharge effect from any adjacent live loads may cause problems. These non-yielding walls are designed to resist lateral soil pressure of 65pcf where foundation drains are placed above groundwater level. Any cantilever earth retaining walls are designed based on 45pcf active earth pressure. All retaining wall are designed for a factor of safety equal to or greater than 1.5 against sliding and overturning. The frictional resistance can be estimated by multiplying the normal force acting at the base of the footing by a coefficient of friction of 0.32.

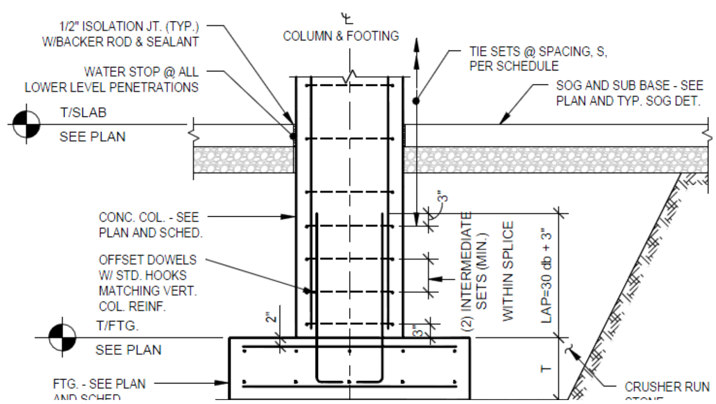


FIGURE 4: TYPICAL COLUMN FOOTING SHOWING REINFORCEMENT PLACEMENT

NOTES:
1. T = FOOTING THICKNESS - SEE FOOTING SCHEDULE.
2. S = COLUMN TIE SPACING - SEE COLUMN SCHEDULE.
3. EVENLY SPACE FOOTING REINFORCEMENT. PROVIDE 3-INCHES CLEAR COVER UON.

Floor System

The typical floor structure of Piez Hall addition is a cast-in-place flat slab with drop panels. The slab thickness of the floors is 12" throughout the entire building with primarily #6 @ 9" o.c top and #6 @ 12" o.c bottom bars in 5000 psi strength concrete. 42"x24"concrete beams spans a length of 46.2' with 4 #8 @ top and 6 # 10 @ bottom reinforcement bars are placed in the edge of the floor slab primary located to support the cantilevered portion of the building in the second and third floor. Also, 24"x24" interior concrete beams are placed along the corridor of building to support areas where the slab is discontinuous such as stair and elevator shaft locations. A continuous 50"x10" edge beam each spans a length of 31.5' is placed on the north side of the south wing where the conservatory is connected to the building. The total depth of the floor system is 20". A typical framing plan of the south wing can be found in figure 10 and 11.

A drop panel is placed in almost every column location to increase the slab thickness in order to magnify the moment carrying capacity near the column support as well as resisting punching shear. Typical drop panels are 10.5'x10.5'x8" (see Figure 6)

In the conservatory the structural engineer employed composite steel floor system primary because lateral forces is not a concern due to the fact that the conservatory is embraced by the Piez hall building. Thus expensive moment connections are not necessary.

In addition, reinforcements for temperature change are #6 bars at 18" spacing, which is the maximum permitted spacing for temperature reinforcement. Typical steel reinforcement placement for the slab is given in figure 5.

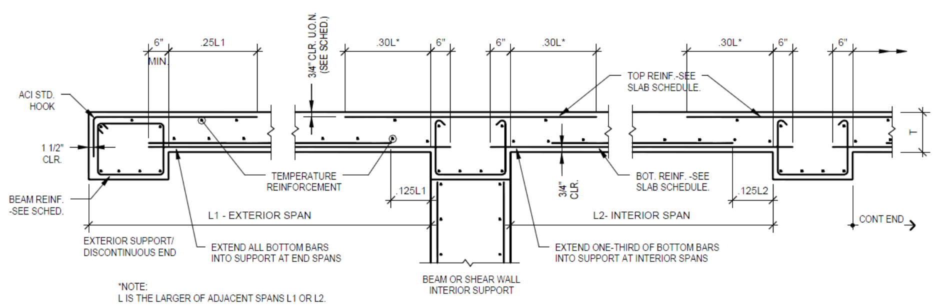


Figure 5: Typical one way slab showing reinforcement placements

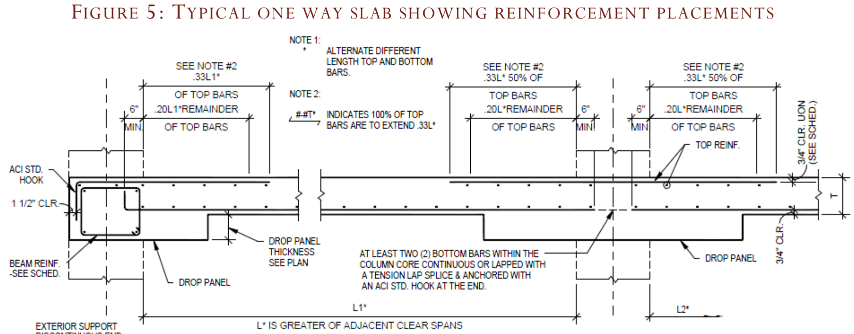


Figure 6: Typical column strip detail with drop panel and edge beam

Framing System

Typical bay in the new south wing of the building are 31.5'x31.5'. Corridor areas have a bay size of 10.3'x31.5'. The 10.3' span is less than two third of its adjacent span of 31.5'. Thus, this limitation suspends the use of direct design method. The equivalent frame method will be used to analyze the slab.

Typical columns are 24"x24" square concrete columns with eight #8 vertical reinforcing bars and #3 ties at 15" spacing. The upper east part of the new addition is supported by circular concrete columns with 30" diameter extending from the foundation to the top of second floor. Typical beams are 24"x24" doubly reinforced concrete beams with #6 top reinforcing bars and #8 bottom reinforcing bars. Because beams are framed into slabs, beams are treated as T-section beams. Typical reinforcement placements for beams are shown in Figure 7.

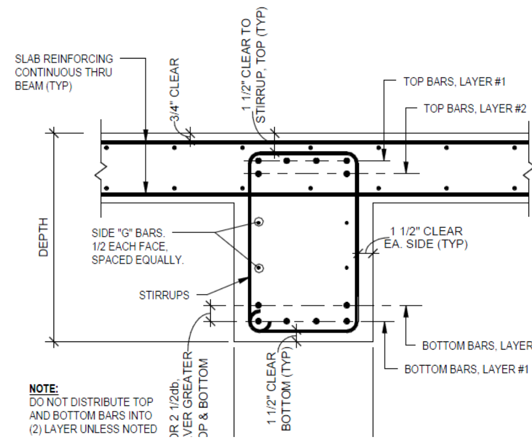


FIGURE 7: TYPICAL BEAM SECTION

The planetarium and conservatory in the middle of the "U" of building is built with structural steel framing. The floor system is a composite steel deck supported by W-shape beams. The sizes of the beams are typically W 14x22, W16x26, and W16x 31. Columns consist of various kinds of hollow structural steel and W10x33. Again, a typical framing plan of the south wing can be found in figure 10.

Lateral System

Shear walls and diagonal bracing are the main lateral force resisting system in the Piez hall new addition. They are evenly distributed and orientated throughout the building to best resist the maximum lateral loads coming from all direction. Typical shear walls are 12” thick and consist of 5000psi concrete. Shear walls extend from the first level to the top of the roof. Loads travel through the walls and are distributed down to the foundation directly. Diagonal bracing are concrete struts that framed into concrete beams. They are located on the second to fourth level and placed on the sides of the cantilevered portion of the building. Since the building is a concrete building, concrete intersection points also serve as moment frames. Together, these elements create a strong lateral force resisting system.

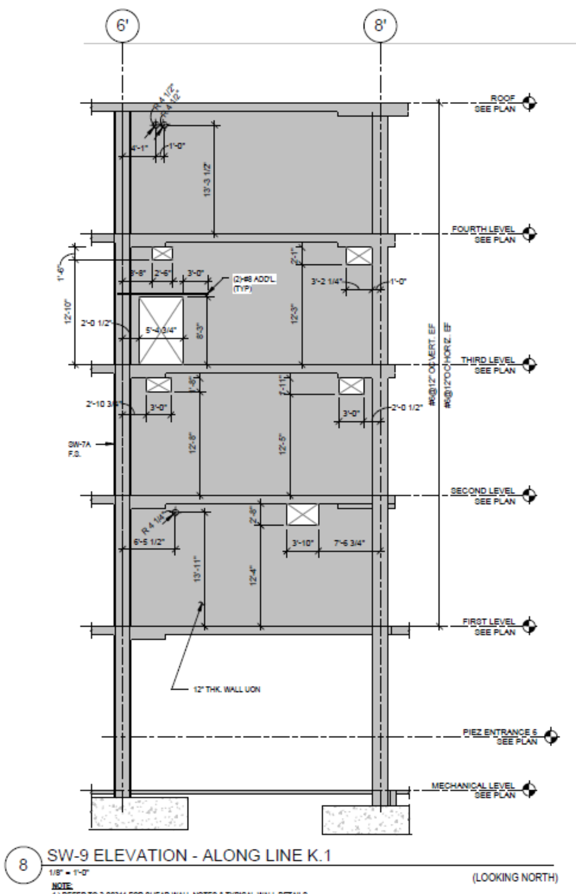


Figure 8: Typical concrete shear wall

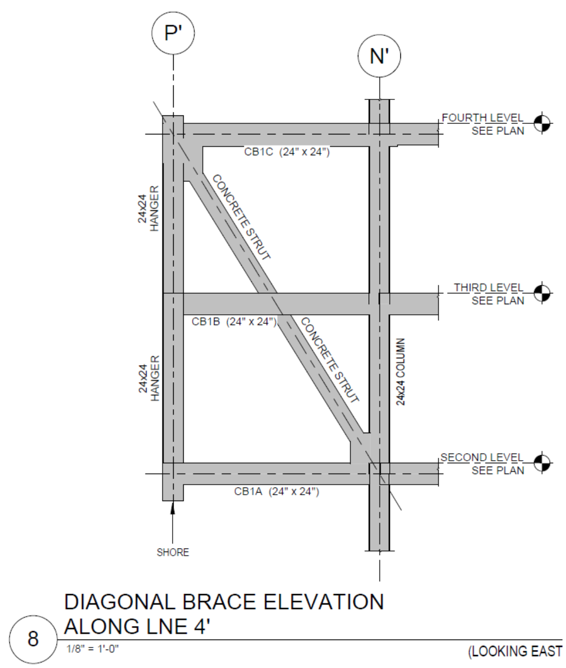


Figure 9: Typical concrete diagonal braces

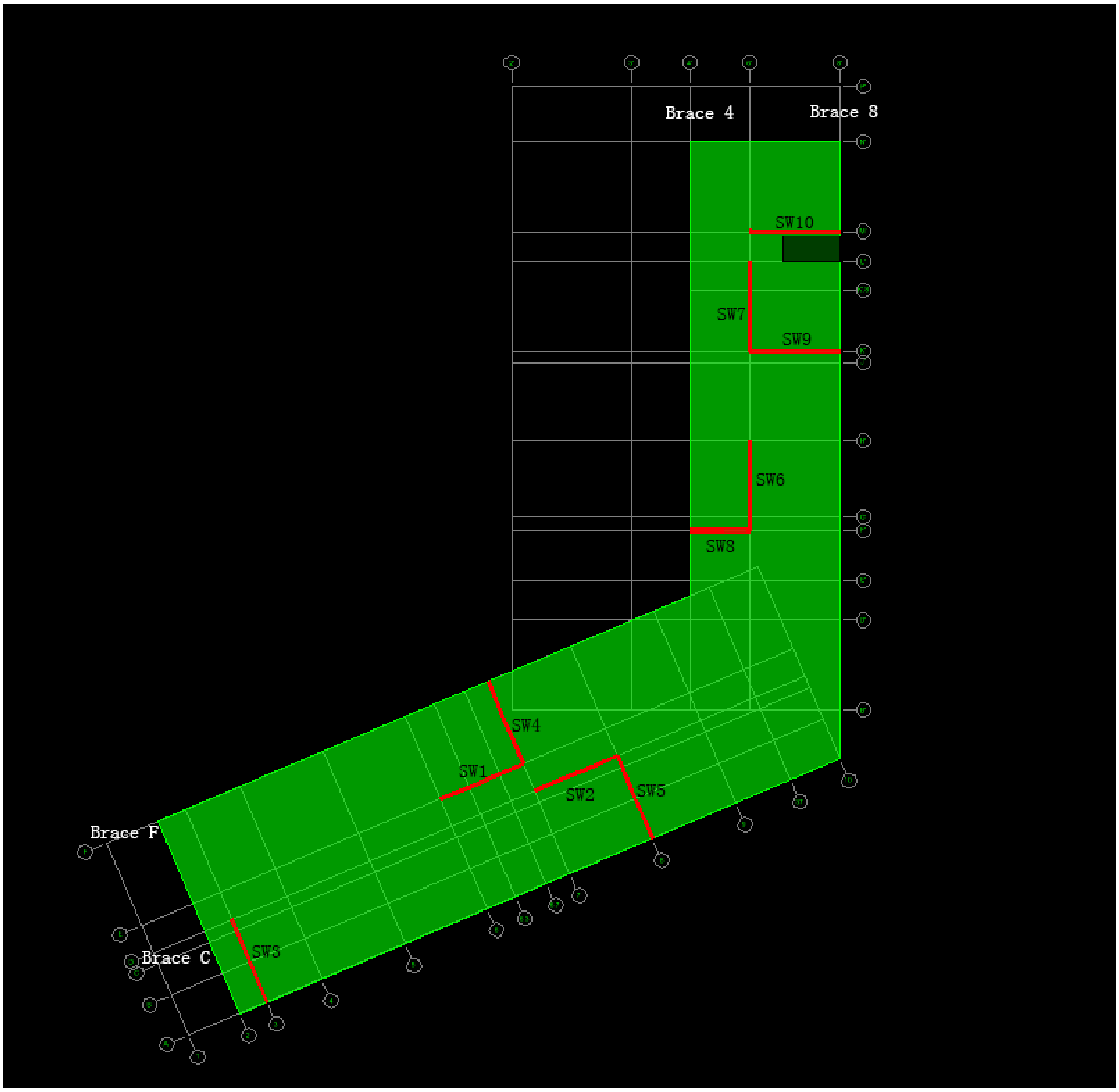


FIGURE 10: SHEAR WALL LOCATIONS OF A TYPICAL FLOOR

Roof System

There are three different kinds of roof system for the Piez hall extension. Steel decks and steel beams are used to support the roof for the planetarium. The roof for the cantilever part of the third level is designed to let people walk on top of them. Therefore, a fairly thick roof of 10" concrete is required. All other roof for the fourth level uses 6.5" thick concrete because they are not intended for excessive live load. On top of the roof, there are photovoltaic array, skylights, wind turbine and mechanical equipment that contribute to LEED.

Design Codes

- Building Code Requirements for Structural Concrete (ACI 318-05)
- Specifications for Masonry Structures (ACI 530.1)
- Building Code Requirements for Masonry Structures (ACI 530)
- Masonry Structure Building Code Commentary (ACI)
- AISC Specifications and Code (AISC)
- Structural Welding Code – Steel (AWS D1.1 2002)
- Structural Welding Code – Sheet Steel
- Building Code of New York State 2007
- Minimum Design Loads for Buildings and Other Structures (ASCE 7-02)

Design Codes used for Thesis

- Minimum Design Loads for Buildings and Other Structures (ASCE 7-10)
- International Building Code (2009 Edition)
- Building Code Requirement for Reinforced Concrete (ACI 318-11)
- Steel Construction Manual (AISC 14th Edition)

Materials Used

Concrete		
Usage	**Strength (psi)**	**Weight (pcf)**
Footings	3000	Normal
Grade Beams	4000	Normal
Foundation Walls and Piers	4000	Normal
Columns and Shear Walls	5000	Normal
Framed Slabs and Beams	5000	Normal
Slabs-on-Grade	3000	Normal
Slabs-on-Steel-Deck	3000	Normal
All Other Concrete	4000	Normal

Table 1: Summary of material used with strength and design standard

Steel		
Type	**Standard**	**Grade**
Typical Bars	ASTM A-615	60
Welded Bars	ASTM A-706	60
Steel Fibers	ASTM A-820 Type 1	N/A
Wide Flange Shapes, WT's	ASTM A992	50
Channels and Angles	ASTM A36	N/A
Pipe	ASTM A53	B
Hollow Structural Sections (Rectangular & Round)	ASTM A500	B
High Strength Bolts, Nuts and Washers	ASTM A325 or ASTM A-490	N/A
Anchor Rods	ASTM F1554	36
Welding Electrode	AWS A5.1 or A5.5	E70XX
All Other Steel Members	ASTM A36 UON	N/A

Table 2: Summary of material used with strength and design standard

Gravity Loads

Dead, live and snow loads are computed and compared to the loads listed on the structural drawings. After determining the loads using ASCE 7-10, spot checks on members of the structural system were checked to verify their adequacy to carry gravity loads.

Dead and Live Loads

Although the Structural engineer has given a superimposed dead load of 15psf for all levels, but a more conservative and general superimposed dead load of 20psf were used in the calculation. Façade, column, shear wall and slab were all taken into account to obtain the overall dead load in each level. The exterior wall consists of curtain wall, CMU, precast concrete panels in different location. Thus to simplify the calculation, a uniform 30psf were taken as the load of the façade in all sides of the building. The overall weight of the building is found to be 29577 kips. This total weight is needed to compute the base shear for seismic calculation later on.

Weight Per Level		
Level	**Weight (kips)**	**Weight (psf)**
1	5293.10	197.67
2	6449.73	221.54
3	6246.66	222.84
4	6246.66	222.84
Roof	3265.58	121.95
Total Weight	29577.02	

Table 3: Distribution of weight per level and total weight

Live Loads shown in the middle column of Table 4 are given by the structural engineer. The structural engineer is rather conservative to use all design live load to be 100psf when an 80psf can typically be used for educational occupancy. Since this is a University building, typical floor is likely to be classrooms which have live load of 50psf as defined by ASCE 7-10. Similarly, public spaces can be interpreted as corridor above the first floor which has a live load of 80psf.

Live Load		
Space	**Design Live Load (psf)**	**ASCE 7-10 Live Load (psf)**
Typical Floors	100	50
Public Spaces	100	80
Exit Corridors	100	100
Stairs	100	100
Lobbies	100	100

TABLE 4: COMPARISON OF LIVE LOADS

Snow Loads

Following the procedure outlined in ASCE 7-10, the result of snow loads were obtained. The resulting snow loads were found to be 46psf. This is close to what the structural engineer had calculated.

Problem Statement

The current design of Piez Hall extension was determined to meet both strength and serviceability requirements as proved in Technical Reports 1 to 3. However, all shear walls resided in the new extension while the conservatory, planetarium, and old Piez hall had steel framing system with no lateral force resistance. (Typical plans of the conservatory and planetarium can be found in appendix G of page 97). The author was not sure why the structural designer used two different systems in one unified building. This approach might cause confusion during the construction phases of the building. Different groups of iron workers for steel and concrete rebar, concrete crews, and other contractors were needed to construct the building. Coordination and communication might become difficult between this many different groups of people and the budget to hire all of them may be very expensive as well. In this report, a unified design was explored to create a more flexible building while lowering construction cost, time, confusion, as well as seismic loads and building torsion.

Proposed Solution

Based on technical report 2, either a composite system or a two way flat slab with drop panel will be selected to unify the design of Piez Hall. Since the old Piez hall, conservatory and planetarium is already a steel frame structure, the new extension will be redesigned as a composite system with long span trusses spanning a length of about 60 feet. K-series joists will be used in between the spans of the long span trusses. Moreover, since New York had many experienced steel crews and contractors, construction time and cost of the building should be reduced. The weight of the building will be greatly reduced as well, which benefits the foundation. After the redesign of gravity and lateral system of Piez Hall, the author will not have time to perform a foundation and vibration analysis. Thorough investigation will needed to determine the impact of the proposed design on the existing foundation. It was determined in technical report 3 that seismic load was the controlling lateral force in all directions, thus a flexible building with ductile members was desirable to dissipate energy in an earthquake. The redesign incorporated eccentric braced frames as the main lateral force resisting system. The shear walls in the current design will be eliminated and the column layout will be rearranged to achieve more usable interior spaces and longer deck span while it still meets all strength and serviceability requirements. A model of the proposed design will be generated using ETABS to compare with the current design. The model will be a unified composite steel system with long span trusses and eccentric braced frames. The criteria of comparison include constructability, strength, feasibility, construction cost, construction time, building torsion, and drift limits.

Breadth Topics

Construction Breadth

The redesign of Piez Hall addition might alter the construction process and the time and cost associated with it. The goal here was to lower the cost and time to construct the building. A construction schedule using Microsoft project was created for the proposed system. Detailed cost estimate was performed using RS means cost work. The cost and construction time of the proposed and current system was analyzed and compared. Another issue that needed to be addressed was the temporary supports and bracings that resist construction load. Since a structure has not developed its full strength during early construction phase, there exist many possibilities that the structure will collapse if temporary supports were not properly designed. Finally construction site logistics was established for the new proposed system.

Sustainability Breadth

The current Piez Hall was rated LEED Gold. However, there were still rooms to improve. The goal for the redesign of Piez Hall was to improve sustainability by further reducing annual energy load of the building. An extensive green roof was incorporated into the proposed design. It benefited Piez Hall addition by increasing the thermal resistance of the roof assembly throughout the year, especially in summer by helping to reduce cooling costs. A green roof also acted as a sound barrier to improve the building's overall acoustic performance. Lastly, it reduced storm water run-off by 50 to 90%, which minimized the impact on the existing sewer system. A thicker roof was accounted for the additional load brought by the green roof. An energy model will be created using Trace 700 to conduct an energy study for the green roof system.

MAE Coursework

Concepts learn in course AE 530 (Computer Modeling), AE 538 (Earthquake Design), AE 537 (Building Performance Failure), and AE 542 (Building Enclosure Design) were incorporated into the proposed design of Piez Hall over the spring. ETABS knowledge learnt in AE 530 was used to create the model of Piez Hall extension. Seismic design concepts learnt in AE 538 was incorporated into the redesign in order to allow the structure to better resist seismic loads. Principles learnt in AE 537 were used to avoid human mistakes made in the construction phase of the building and to ensure better building performances after the building is constructed. Energy analysis and concepts learnt in AE 542 were applied to evaluate the amount of energy saved annually.

Tasks and Tools

Depth: Composite system with long span trusses

Task 1: Design the unified system

- Check the zoning requirement in the Oswego University area
- Eliminate columns and shear walls to achieve greater floor spans and make the building more flexible
- Draw new gridlines using AutoCAD
- Determine slab thickness based on the loading established in the original structural drawings for typical floor and roof. (Roof must be design to include green roof loads)
- Consider special areas such as cantilevered spaces and edges

Task 2: Determine required loads using ASCE 7-10

- Determine gravity loads based on the previous task
- Determine the lateral loads
- Determine the story forces

Task 3: Design eccentric braced frames

- Construct ETABS model
- Do hand calculation for center of rigidity and center of mass to check the model
- Experiment with various locations to place lateral braces to reduce torsion in the ETABS model
- Check drift requirements

Task 4: Design structural members

- Construct RAM model
- Sizes beams/girders/columns in the RAM model
- Do hand calculations to check the typical beams/girders/columns selected by RAM to make sure it meets strength and serviceability requirements
- Complete the ETABS model by inputting the members (beams/girders/columns) selected by RAM

- Run the strength and serviceability test in ETABS to verify the validity of the members selected by the RAM model

Task 5: Evaluate the effect of the proposed design on foundation

- Investigate the current foundation system
- Check whether or not the current foundation system will be sufficient for the redesign
- Modify the foundation system if there was a problem

Task 6: Vibration control

- Research the cause of vibration problem in a building and various dampers to address them
- Determine whether or not the redesign will have a vibration problem
- If there was a problem, select a damper system to address the vibration issue
- Analyze the cost and maintenance fee of the selected damper system

Breadth: Construction and Sustainability

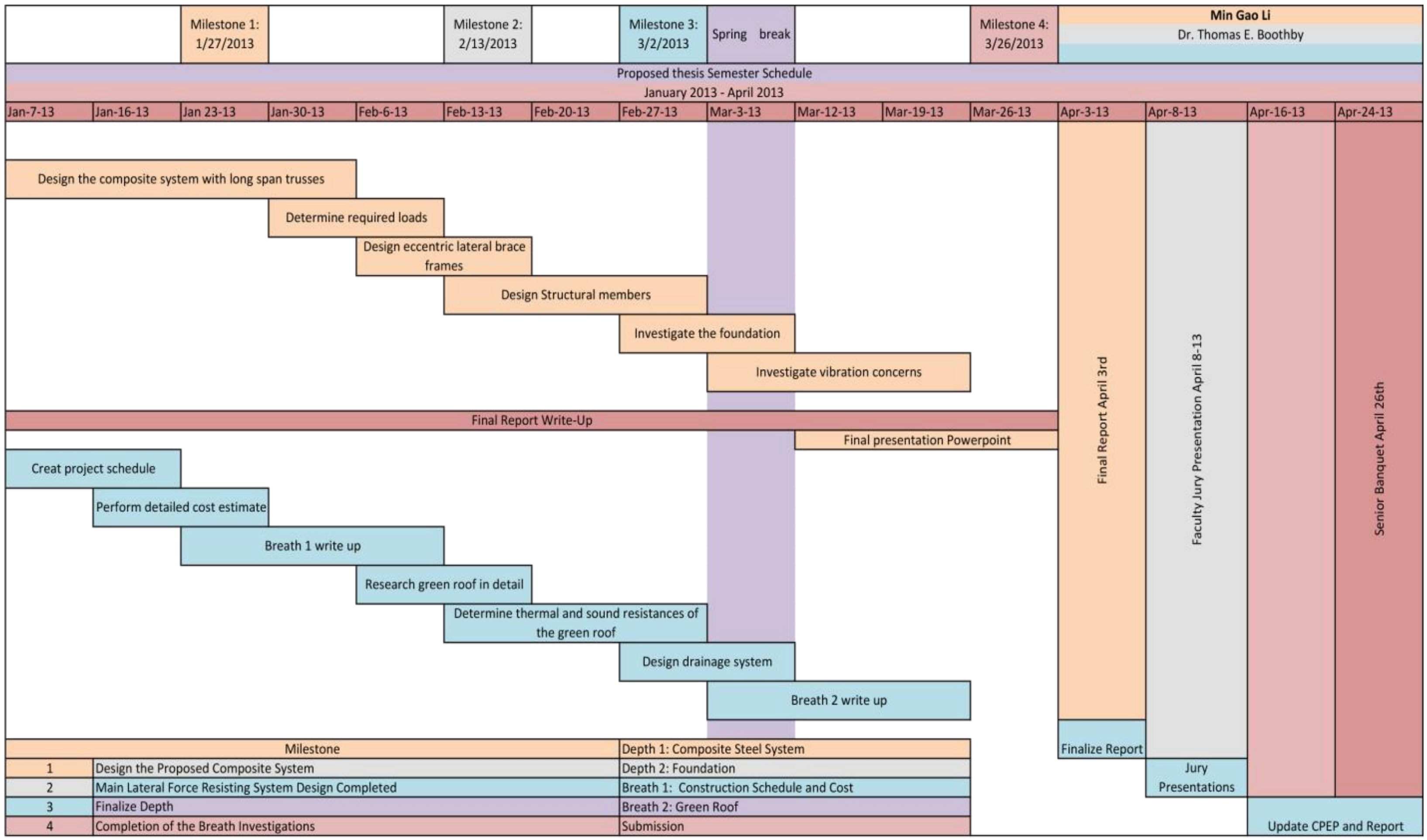
Construction

- Obtain the schedule and cost information for the existing building
- Create a schedule and cost information for the composite steel redesign
- Compare the current system with the redesign
- Design temporary supports for construction

Sustainability

- Further investigate the roof of Piez Hall addition and decide where to place the green roof
- Research green roof properties and design it accordingly
- Calculate the thermal and sound resistance provided by the green roof
- Design water drainage system of the green roof
- Compare the current Piez Hall with the redesign

Time Table


Milestone 1: 1/27/2013
Milestone 2: 2/13/2013
Milestone 3: 3/2/2013
Spring break
Milestone 4: 3/26/2013
Min Gao Li
Dr. Thomas E. Boothby
Proposed thesis Semester Schedule
January 2013 - April 2013
Jan-7-13
Jan-16-13
Jan 23-13
Jan-30-13
Feb-6-13
Feb-13-13
Feb-20-13
Feb-27-13
Mar-3-13
Mar-12-13
Mar-19-13
Mar-26-13
Apr-3-13
Apr-8-13
Apr-16-13
Apr-24-13
Design the composite system with long span trusses
Determine required loads
Design eccentric lateral brace frames
Design Structural members
Investigate the foundation
Investigate vibration concerns
Final Report Write-Up
Final presentation Powerpoint
Creat project schedule
Perform detailed cost estimate
Breath 1 write up
Research green roof in detail
Determine thermal and sound resistances of the green roof
Design drainage system
Breath 2 write up
Final Report April 3rd
Faculty Jury Presentation April 8-13
Senior Banquet April 26th
Finalize Report
Jury Presentations
Update CPEP and Report
Milestone
1 Design the Proposed Composite System
2 Main Lateral Force Resisting System Design Completed
3 Finalize Depth
4 Completion of the Breath Investigations
Depth 1: Composite Steel System
Depth 2: Foundation
Breath 1: Construction Schedule and Cost
Breath 2: Green Roof
Submission

Conclusion

In spring 2013, an alternative system will be designed and compared with the current system. The main goal in this proposal is to create a unified system to reduce overall lateral stiffness, building weight, construction time, project confusion and project cost. In addition, the foundation will be benefited from the lighter weight building. The number of columns and shear walls in the current structural system will be eliminated to allow more usable interior space and to achieve a long deck span. Torsion in the proposed design will also be analyzed and minimized. Specifically, this will be accomplished through composite steel system with long span trusses and eccentric braced frames with the help from ETABS and RAM. The breadth studies will focuses on construction and sustainability associated with the redesign. In the construction breadth, the schedule, cost, and site logistics of the redesign will be studied. In the sustainability breadth, a green roof and green interior walls will be incorporated into the redesign. If time permits, vibration concern will also be evaluated and addressed.