Thesis Proposal

LIFE SCIENCES BUILDING

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January 16, 2015

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EXECUTIVE SUMMARY

The Life Sciences Building is located in north east United States. The building is a five stories and 174,500 square feet. The geometry of building is L-shaped and considered a long-span structure. A greenhouse is located on the roof to serve as a research space. The foundation system consists of cast-in-place concrete spread and strip footings that support a system of wide flange steel columns. The building is designed as a composite steel floor system. The lateral system is designed as a structural steel braced frames. Hollow structural section steel (HSS) is used as braces with varying thicknesses based on the lateral loads resisting the members.

The existing structural system of the Life Sciences Building is adequate to meet both strength and serviceability requirements. Therefore, a scenario has been proposed that in which a college campus, which resides in a high seismic area, specifically in San Francisco, CA, requests the design and construction of a building identical to the Life Sciences Building.

A solution to this scenario will be suggested through the proposed structural depths in which the building's lateral system will be redesigned for new location and suggests multiple options to the owner based on economical benefit.

In order to suggest an adequate lateral system to the owner, the cost estimate and the construction schedule will be compared between suggested lateral systems. Since the building has been relocated to San Francisco, CA, the building envelope will be reassessed to the new environment and redesigned for seismic events as well.

In Addition, Master of Architectural Engineering coursework will be incorporated into the proposed redesign through the use of detailed computer modeling (AE 530), the design of steel seismic connections (AE 534 & AE 538) and the design of building envelope (AE 542).

BUILDING INTRODUCTION

The Life Sciences building is a five story laboratory building, 91 feet tall and 174,500 square feet. It is located in a college town in northeast, the United States. It was constructed between September 2008 and August 2011. The total project cost was $91.6 million, and its structural system costs $20 million. The project team's main goal was to create a building that is both aesthetically pleasing and high-functional.

Figure 1 | Building Perspective from North

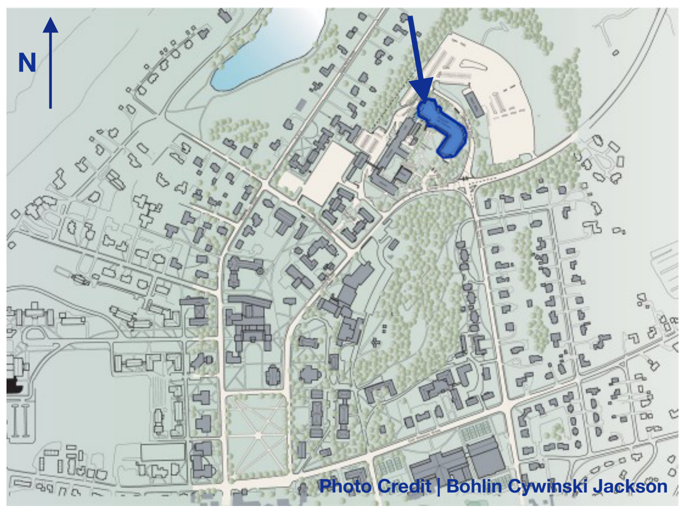


Figure 2 | Buildings Site Plan

The building accommodates a 4,000 square feet nuclear magnetic resonance suite, eight classroom laboratories, a 200 seat auditorium, two 80 seat and two 30 seat classrooms, and 30 teaching and research laboratories with the offices. The building is divided in to three sections: west, north, and east. Each section is clearly distinguished by its own functions. A 200 seat auditorium is placed in west side. Greenhouse and most laboratories are placed in north side. The offices and laboratories are located on the East side.

The main concept of design in the floor plan was to create the space promoting the interaction of ideas and techniques between people using this building. Laboratories are placed in the first floor to provide better accessibility to whom uses the facilities. One of the unique feature of the project is to place greenhouse on the roof top. The greenhouse could improve building performance in energy usage in both summer and winter. However, in order to place greenhouse on the roof top, the structural engineer will have to design the roof to resist heavier loads.

With great effort and teamwork between project teams, the project was completed on schedule and within the project budget when faculty and researchers moved in on August 2011. This project was awarded a Leadership of Energy and Environmental Design (LEED) Platinum and has been considered as a national model of sustainable design for laboratories buildings.

STRUCTURAL OVERVIEW

STRUCTURAL SYSTEM SUMMARY

The Life Sciences Building is a structural steel frame with composite concrete slabs on metal deck. These structural frames are supported by cast-in-place concrete footings. Due to the activities in the laboratory, floor vibrations were strictly limited where vibration sensitive equipment was placed. Cast-in-place reinforced concrete framing was used for this building since the rigidity and mass of the concrete framing naturally limits floor vibrations. In the greenhouse on the roof, a separate concrete topping slab is placed over the structural concrete floor slab at the floor.

Structural steel may provide the benefits of a shorter erection time in construction schedule, especially during harsh winter weather which is common where the project is located.

Structural steel braced frames are used to resist lateral loads such as wind and seismic loads and are compliant to the International Building Code 2006 edition. Braced frames are used over moment frames due to its economy, and the location and configuration of the braced frame are determined carefully without any interference of the architectural and mechanical systems. The design of laboratory buildings typically requires better performance in mechanical, electrical, and plumbing system. Especially in the project, the layout of structural elements is important.

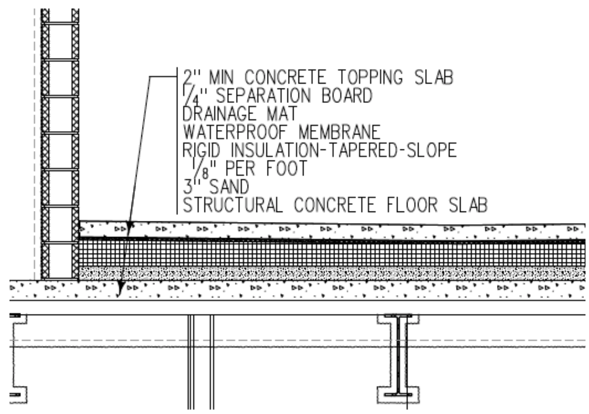


Figure 3 | Greenhouse Section | 1/A4.20

FOUNDATION SYSTEM

According to the geotechnical report prepared from Haley & Aldrich, Inc., foundation design and construction must conform to the applicable provisions of the International Building Code 2000 (IBC 2000).

By the test boring, the existing fill is unsuitable for foundation support. The geotechnical engineer recommend ‘the existing fills should be removed whiten the zone of influence of the foundation and replaced with compacted structural fill.

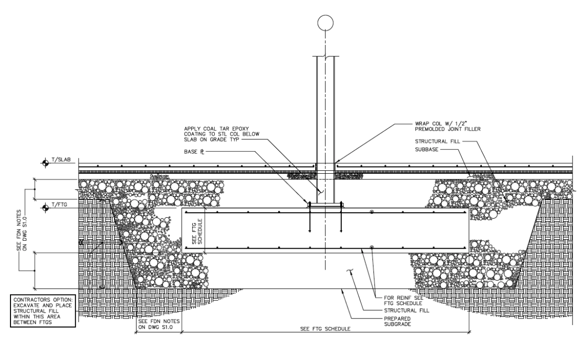


Figure 4 | Section of Typical Interior Footing | 4/S3.02

The design recommends that, “Building walls and columns and other structural elements be supported on reinforced concrete spread or strip footings bearing directly on a minimum of 2 ft thickness of compacted structural fill placed above the glaciolacustrine silt deposits.” The report also recommends that footings should have a least lateral dimension of 24 in or greater.

According to the geotechnical report, presumptive net soil bearing pressure = 2,500 psf on minimum 2-foot thick compacted structural fill. Concrete slab on grade varies on the rage from 5” to 1’-6” thick depend on the soil properties on geotechnical report. Typical concrete slab on grade is 5” thick. However, concrete slab supporting the loading dock is designed for 12” thick and the nuclear magnetic resonance suite, which occupies the vibration sensitive equipment is supported by 1’-6” thick concrete slab on grade.

BUILDING MATERIALS

Structural and Miscellaneous Steel	
Rolled Steel W Shapes	ASTM A 992
Rolled Steel C, S, M, MC, and HP Shapes	ASTM A 36
Rolled Steel Plates, Bars, and Angles	ASTM A 36
Hollow Structural Sections (HSS)	ASTM 500 - Grade B or C
Pipe	ASTM A 53 - Type E or S - Grade B
Reinforcing Steel for Concrete and Masonry	ASTM C 615 - Grade 60
** For connection, provide higher grade as required for capacity.	
Concrete	
Footings	f’c = 3,000 psi
Interior Slabs on Grade	f’c = 3,500 psi
Slabs on Deck	f’c = 3,500 psi
Foundation Walls	f'c = 4,000 psi
Retaining Walls	f'c = 4,000 psi
Piers	f'c = 4,000 psi
Grade Beams	f'c = 4,000 psi
Exterior Slabs	f'c = 4,500 psi
Exterior Equipment Pads	f'c = 4,500 psi
Miscellaneous	f’c = 3,000 psi
Piers	f'c = 4,000 psi
Grade Beams	f'c = 4,000 psi
Exterior Slabs	f'c = 4,500 psi
Masonry	
Concrete Block	ASTM C 90 Average Net Compressive Strength = 2,800 psi
Mortal	ASTM C 27 - TYPE S
Unit Masonry	ASTM C 90 CMU (2,800 psi) Types S Mortar - f’m = 2,000 psi
Grout	ASTM C 476 Compressive Strength = 2,500 psi 8 to 10 inch slump
Brick	ASTM C 216 - Type FBS - Grade SW

GRAVITY SYSTEM

Floor System Overview

The main floor system design is a structural steel framing with composite concrete slab on metal deck. Major members of the beam supporting the floor system are W18x35 and W16x26.

For a typical floor system, 7 1/2" concrete slab on 3" 20gage galvanized composite metal deck supports the floors and floor slab are reinforced with #4 rebar at 16" o.c. each way. Maximum live load deflection of composite section shall be 1/360 of clear span. In addition to composite metal deck, at greenhouse area, 4" lightweight concrete overlay slab is placed on rigid insulation on 3" cellular concrete slab, reinforced with #4 bar, epoxy coated, at 16" o.c. each way. All of main structural columns in Life Sciences Building are wide flange steel members. The size of columns is varying from W10x49 to W12x136. Most of the columns have a 12" depth vary in weight. W12x120 and W12x72 are used mostly in this building.

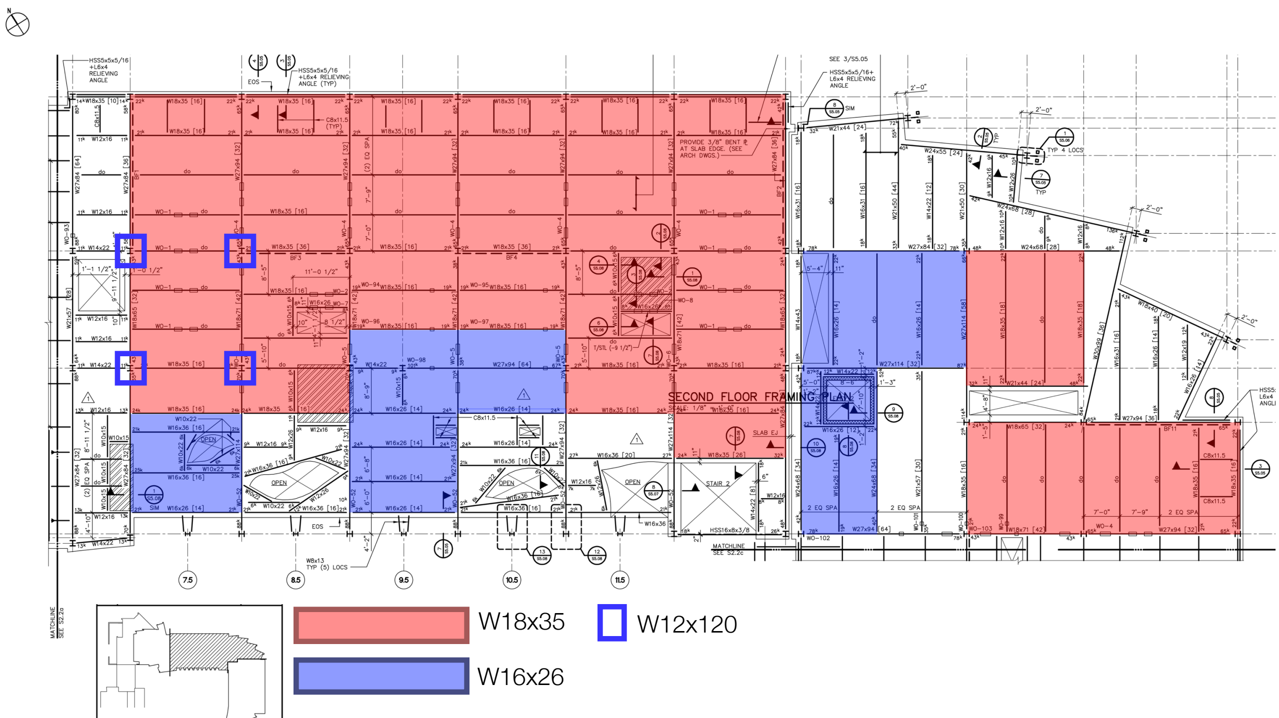


Figure 5 | Typical Floor Framing Plan | S2.2b

Laboratory Floor Vibration Design Criteria

Since this building is a laboratory building, there is a strict floor vibration design criteria. Vibrational velocity should be less than or equal to 3,000 micro-inch/second. Exciting force for vibrational velocity should be idealized footstep pulse of a 185 pound person walking at 75 step/minute, which is classified as moderate walk.

Roof System

Structural steel framing is used as the main roof framing system. A unique feature of the roof in Life Sciences Building is a 6,400 square foot greenhouse on north section and a green roof on west section. A green roof and greenhouse improve building performance in energy, especially in harsh winter in the location.

The greenhouse has metal truss framing system, Figure 6, and a green roof is supported on 6 1/2" concrete slab on 3" 20 gauge galvanized composite deck.

3" 20 gauge Type NS galvanized metal roof deck is used in north section. 3" metal deck is supported by W16x26 beams and W27x84 girders. W12x120 and W12x53 columns are supporting beams and girders

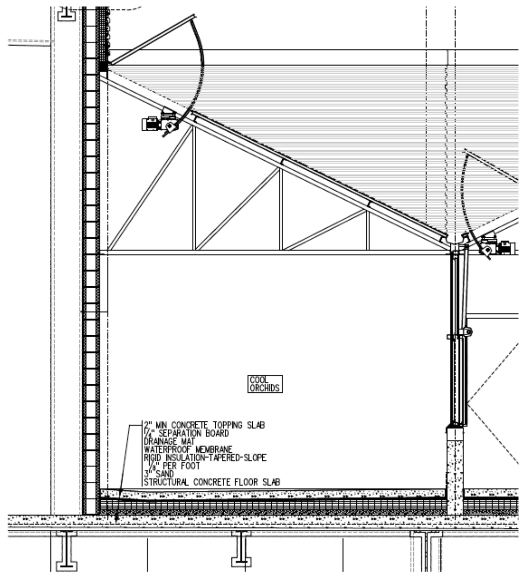


Figure 6 | Greenhouse Section | A4.20

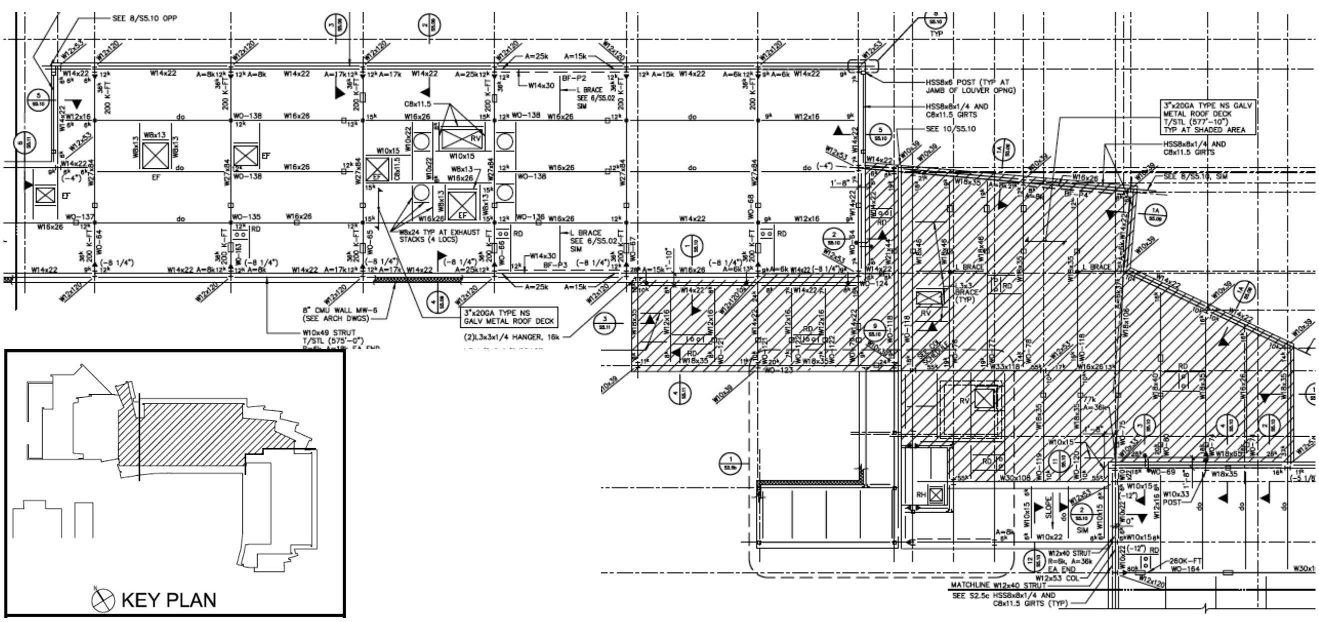


Figure 7 | Roof Framing Plan - North Section | S2.5b

LATERAL SYSTEM

The lateral force resisting system for Life Sciences Building consists of structural steel braced frames. There are sixteen braced frames of varying length and height. Majority of braces used hollow structural section (HSS) 10x10s1/2 and 10x10x3/8. The braced frames are not specially designed for seismic loads. The Figure 8 below shows the location of braced frames throughout Life Sciences Building.

Beams and braces are pin connection and the columns are continuous throughout the heights The major advantage of concentrically braced frames is high elastic stiffness. However, it reduces architectural versatility of the floor plan.

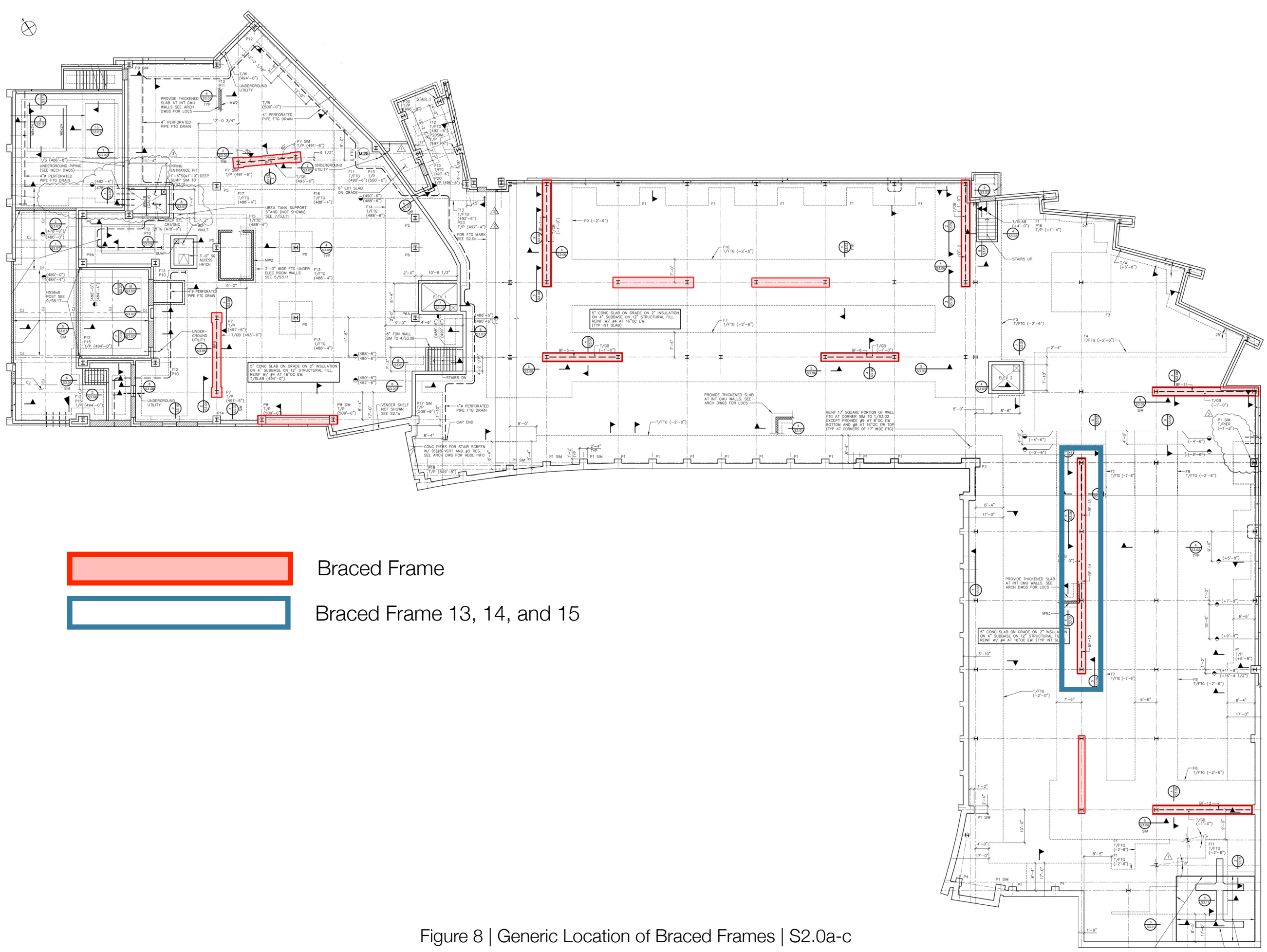


Figure 8 | Generic Location of Braced Frames | S2.0a-c

DETERMINATION OF DESIGN LOAD

NATIONAL CODE FOR LIVE LOAD AND LATERAL LOADS

Live Load - ASCE 7-05 Chapter 4
Snow Load - ASCE 7-05 Chapter 7
Wind Load - ASCE 7-05 Chapter 6
Seismic Load - ASCE 7-05 Chapter 12 - Equivalent Lateral Force Procedure

GRAVITY LOADS

Dead Loads

Due to the greenhouse design on the roof and its function as laboratory, dead loads are higher than a typical laboratory. The greenhouse floor load is 160 psf and other floors are at 110 psf. Roof dead loads are also higher than a typical project, 170 psf for roof gardens and terraces and 30 psf for regular roof.

Live loads

Live loads are referenced using ASCE 7-05 Chapter 4. Live loads reduction in applied when floor live loads are less than or equal to 100 psf.

SNOW LOADS

According to ASCE 7-05, ground snow in the location of the building is 65 psf.

RAIN LOADS

Rain Loads is 50 psf referencing ASCE 7-05 Chapter 8.

LATERAL LOADS

Wind loads

Wind loads are calculated based on ASCE 7-05 Chapter 6. Basic wind speed (3 second gust) is 90 mph. Mean roof heigh is measure 80 feet.

Seismic loads

Seismic design category of the building is classified as B. Equivalent lateral force procedure is used as the analysis procedure in accordance of ASCE 7-05 Chapter 12. Seismic design base shear is calculated as 2,174 kips by the original structural engineer.

DESIGN CODES AND STANDARDS

CODES AND STANDARDS

International Code Council

- International Code Council 2006 Editions
- International Building Code 2006 Edition
- International Building Code 2012

California Building Standards Code

- 2013 California Building Code
- 2013 San Francisco Building Code

American Society of Civil Engineering

- ASCE 7-05 - Minimum Design Loads of Buildings and Other Structures
- ASCE 7-10 - Minimum Design Loads of Buildings and Other Structures

American Concrete Institute

- ACI 318-11 - Building Code Requirements for Structural Concrete

American Institute of Steel Construction

- AISC Steel Construction Manual 14th Edition
- AISC Seismic Design Manual 2nd Edition

Reinforced Concrete Mechanics & Design 6th Edition by Wight and MacGregor

Vulcraft Deck Catalog

Construction Documents and Specifications of the Project

New York State Department of Transportation

- NYSDOT - Standard Specification for Construction and Materials

DESIGN SCENARIO

PROBLEM STATEMENT

The Life Sciences Building utilizes a composite steel framing system and the lateral system uses structural steel braced frames. Based on the previous analysis through technical reports, the existing gravity and lateral system for the Life Sciences Building are sufficient to meet both strength and serviceability requirements.

Since no significant challenges were found in the existing structural system, a scenario has been created in which a college campus, which resides in a high seismic area, specifically in San Francisco, CA, requests the design and construction of a building identical to the Life Sciences Building. The surrounding environment will be assumed to be identical to the current building site. However, in this new location, the soil characteristics, seismological characteristics, and climate conditions will differ significantly from the building's existing location.

As a result, in new building structural system, especially lateral forces resisting system will need to be checked and likely redesigned. In order to change the climate condition in the building, building envelope will be reassessed to the new environment and redesigned as well.

PROPOSED SOLUTION

Since a hypothetical scenario has been created in the problem statement, a fictitious data of the building is used for the design scenario. However, in order to get more detail analysis, it would be attempted to find the actual data related to geotechnical report.

In order to relocate the building, a building will be analyzed for new loads, and additional codes will be reviewed based on new site location such as *2013 California Building Code* and *2013 San Francisco Building Code*. The current state code, *2013 California Building Code*, references *the International Building Code (IBC) 2012 edition* and *American Society of Civil Engineers (ASCE) 7-10*. *2013 San Francisco Building Code* is incorporated with *2012 International Building Code*, *2012 International Residential Code*, and *2013 San Francisco Amendments*. Since the existing building was constructed based on ASCE 7-05 and IBC 2006, the new construction will use ASCE 7-10 and IBC 2012.

In redesign of lateral system, two designs will be suggested to the owner such as structural steel braced frames and structural steel moment frames. During the redesign of the system, the final design will be determined based on both performance and economical benefits to the owner.

To resist the new seismic loads, a high ductility system will be considered since it provide the cost saving by reducing member size. However, high ductility system will increase extra costs in the connection details. Since the building weight will be critical to the structure when seismic events occurred, the lightweight concrete slabs will be considered as an option compared to normal weight concrete slabs.

The redesign of the lateral system will affect the gravity system, and a structural steel framing with composite concrete slabs on metal deck will be kept for new design. However, the change of lateral systems will affect the gravity system and the configuration of lateral system will be carefully chosen due to architectural layout. The construction schedule between the suggestions of the new system will help the owner to find the optimal design for the new construction.

During the redesign of the lateral system, ETABS and RAM will be used to analyze the redesign of system. For better understanding of the existing system in both gravity and lateral, RAM Structure will be used to model the entire structural system. This model will be modified to use for the redesign as well. ETABS will allow to have the model with lateral system only. This will save the time of modeling to optimize the lateral systems.

Due to the relocation of the building, existing building envelope system will be analyzed to be adequate to the new location. However, since the building is moved from heating dominant region to cooling dominant region, the building envelope will be adjusted to the new location. The glazing system in the building envelope will be considered to resist the earthquake events.

BREADTH STUDIES

BREADTH - CONSTRUCTION MANAGEMENT

A comparative cost analysis will be performed in which the cost of the lateral system will be compared to see the advantages and disadvantages between different lateral system designs. The cost analysis will include materials and labor. Construction schedule will be compared to help the owner to make a better decision on the new design. The final design in gravity and lateral system will be chosen for the owner in order to achieve economical benefit and its performance between the lateral systems.

BREADTH - BUILDING ENVELOPE

Due to the relocation of building from heating dominant to cooling dominant region, the building envelope will be investigated for the new location. The heat transfer through the envelope will be investigated based on the climate condition of the site and redesigned for new location. The glazing system in the building envelope will be investigated to survive during the earthquake events.

MASTER OF ARCHITECTURAL ENGINEERING REQUIREMENTS

AE 530: Computer Modeling of Building Structures has provided fundamental theory of computer modeling process and the technical knowledge to model to structure of the Life Sciences Building and redesign the building in new location. Computer modeling software such as ETABS and RAM Structure will be used to analyze the existing structural system of the building and new structural system in a seismic region.

AE 534: Analysis and Design of Steel Connections has provided the foundation of understanding for the steel connections. Incorporated with the materials covered in this course, the seismic detailed connection will be designed.

AE 538: Earthquake Resistant Design of Buildings has provided a background for structural dynamics and structural behaviors in the event of earthquake. It will provide the fundamental understanding of seismic design of the building.

AE 542: Building Enclosure Science and Design has provided the understanding of the science in building envelope. It will help to evaluate the existing envelope design to see whether the existing design would be appropriate to the new environment. The redesign of envelope will also be considered.

TASKS AND TOOLS

Research

1. Acquire detailed cost and schedule information for exiting building
2. Acquire AISC Seismic Manual and Design Manual and review
3. Acquire AISC Design Guide related to lateral system design for earthquake
4. Review the design examples from *AE 538: Earthquake Resistant Design of Buildings*
5. Familiarize with California and San Francisco code and any restrictions that are applicable to the building
6. Determine any differences between ASCE 7-05 and ASCE 7-10
7. Research on the climate conditions for new location
8. Acquire the seismological information for new location

Structural Design

Modeling

1. Create RAM model to analyze both gravity and lateral system for the existing system
2. Modify the existing lateral system model in ETABS to adjust the factors related to a high seismic region
3. Check the existing model is sufficient to resist in the new location
4. Create the ETABS models of braced frame and moment frame
5. Find the optimal design for each systems
6. Create RAM model to analyze both gravity and lateral system for each systems

Design

1. Size members based on analysis
2. Check seismic provisions for design of link and detailing of connection according to AISC Design manual
3. Compare members based on performance of response modification coefficient, R

Building Envelope Design

1. Review the existing envelope design
2. Determine the new climate condition and feasibility of using the existing system
3. Redesign the envelope applicable to the new environment if needed
4. Design the glazing system to resist the earthquake events

Construction Management

Cost Analysis

1. Compare detailed cost estimate of the new lateral systems
2. Compare the cost estimate between different systems

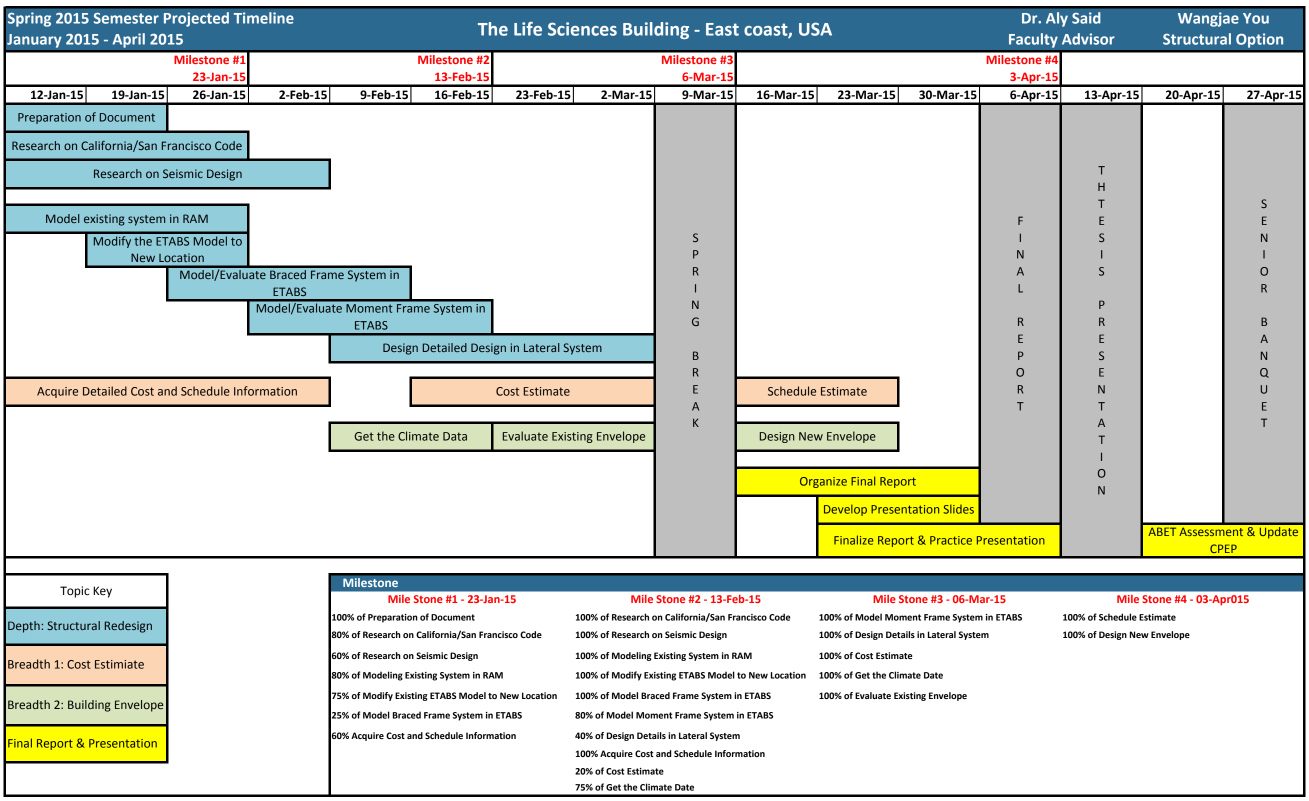
Schedule Analysis

1. Create schedule for new structural system
2. Compare the construction times for each system

Final Report and Presentation

1. Prepare Final Report
2. Prepare Final Presentation

SCHEDULE


Spring 2015 Semester Projected Timeline
January 2015 - April 2015
The Life Sciences Building - East coast, USA
Dr. Aly Said
Faculty Advisor
Wangjae You
Structural Option
Milestone #1
23-Jan-15
Milestone #2
13-Feb-15
Milestone #3
6-Mar-15
Milestone #4
3-Apr-15
12-Jan-15
19-Jan-15
26-Jan-15
2-Feb-15
9-Feb-15
16-Feb-15
23-Feb-15
2-Mar-15
9-Mar-15
16-Mar-15
23-Mar-15
30-Mar-15
6-Apr-15
13-Apr-15
20-Apr-15
27-Apr-15
Preparation of Document
Research on California/San Francisco Code
Research on Seismic Design
Model existing system in RAM
Modify the ETABS Model to New Location
Model/Evaluate Braced Frame System in ETABS
Model/Evaluate Moment Frame System in ETABS
Design Detailed Design in Lateral System
Acquire Detailed Cost and Schedule Information
Cost Estimate
Schedule Estimate
Get the Climate Data
Evaluate Existing Envelope
Design New Envelope
Organize Final Report
Develop Presentation Slides
Finalize Report & Practice Presentation
ABET Assessment & Update CPEP
SPRING BREAK
FINAL REPORT
THESIS PRESENTATION
SENIOR BANQUET
Topic Key
Depth: Structural Redesign
Breadth 1: Cost Estimiate
Breadth 2: Building Envelope
Final Report & Presentation
Milestone
Mile Stone #1 - 23-Jan-15
100% of Preparation of Document
80% of Research on California/San Francisco Code
60% of Research on Seismic Design
80% of Modeling Existing System in RAM
75% of Modify Existing ETABS Model to New Location
25% of Model Braced Frame System in ETABS
60% Acquire Cost and Schedule Information
Mile Stone #2 - 13-Feb-15
100% of Research on California/San Francisco Code
100% of Research on Seismic Design
100% of Modeling Existing System in RAM
100% of Modify Existing ETABS Model to New Location
100% of Model Braced Frame System in ETABS
80% of Model Moment Frame System in ETABS
40% of Design Details in Lateral System
100% Acquire Cost and Schedule Information
20% of Cost Estimate
75% of Get the Climate Date
Mile Stone #3 - 06-Mar-15
100% of Model Moment Frame System in ETABS
100% of Design Details in Lateral System
100% of Cost Estimate
100% of Get the Climate Date
100% of Evaluate Existing Envelope
Mile Stone #4 - 03-Apr015
100% of Schedule Estimate
100% of Design New Envelope

CONCLUSION

The structural system of the Life Sciences Building was adequately designed for both strength and serviceability requirement. As a result, a scenario has been proposed in which a college campus in San Francisco, CA would like to construct the identical design of the Life Science Building in a high seismic region.

In order to relocate the building, the current state code, 2013 California Building Code and 2013 San Francisco Building Code will be reviewed to determine the effectiveness of the existing structural design of the building.

The redesign of structural system in this building will be mostly in lateral system. However, changing of lateral system will affect the gravity system. The lightweight concrete slab will be considered to reduce the weight of building for seismic load and it will affect the floor fire proofing system. The comparison between lightweight concrete and normal weight concrete slab system will help the owner to find the better solution.

In redesign of lateral system, two primary options will be suggested to the owner: structural steel braced frames and structural steel moment frames. A high ductility system will be suggested to reduce the member size. However, it will increase the costs in the connection design, so it will require more detail analysis in the connection.

Due to the relocation of the building to cooling dominated region, building envelope will be investigated and redesigned for new environment during the earthquake events.

Master of Architectural Engineering coursework will be corporate into the redesign through the use of detailed computer modeling of both gravity and lateral system, the detailed connection design, and the understanding of structural dynamics and earthquake resistant design of the building.