



Thesis Proposal

LIFE SCIENCES BUILDING

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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 option to the owner based on economical benefit. In case of building collapse due to structural failure, progressive collapse analysis will be assessed to new structural design as well.

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

In Addition, Master of Architectural Engineering coursework will be incorporated into the proposed redesign through the use of detail 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.

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.



Figure 1 | Building Perspective from North

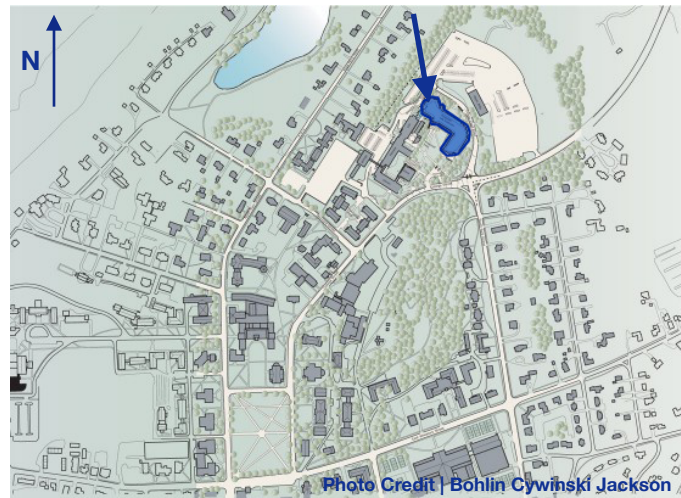


Figure 2 | Buildings Site Plan

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.

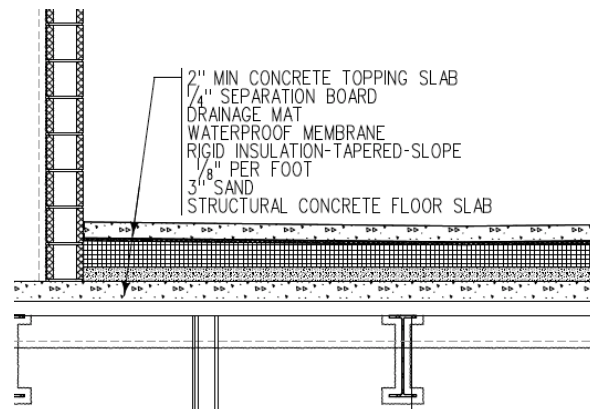


Figure 3 | Greenhouse Section | 1/A4.20

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).

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.

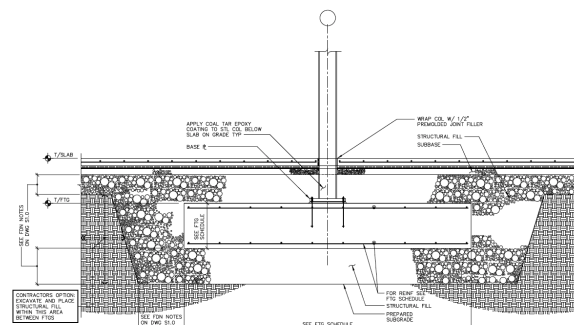


Figure 4 | Section of Typical Interior Footing | 4/S3.02

According to the geotechnical report, presumptive net soil bearing pressure = 2,500 psi on minimum 2-foot thick compacted structural fill. Concrete slab on grade varies on the range from 5” to 1’-6” thick depend on the soil properties on geotechnical report.

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.



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

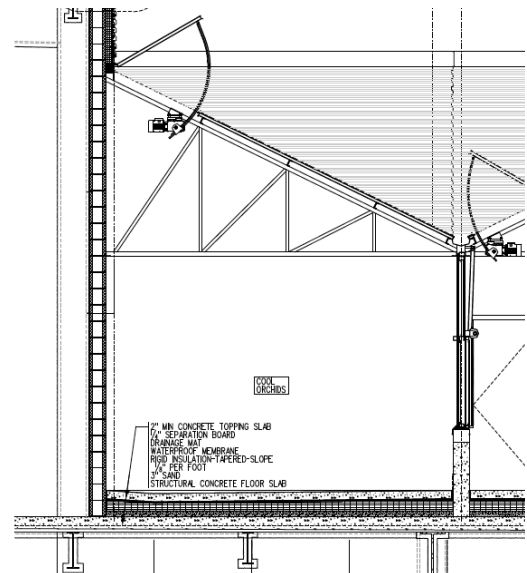


Figure 6 | Greenhouse Section | A4.20

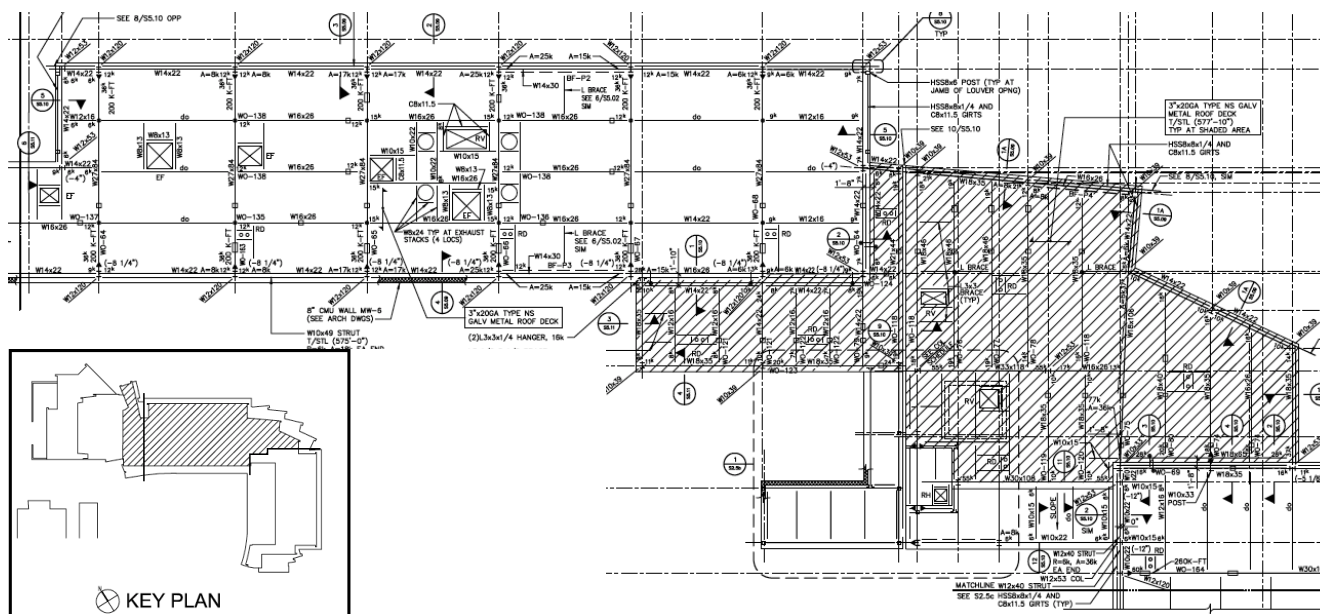


Figure 7 | Roof Framing Plan - North Section | S2.5b

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.

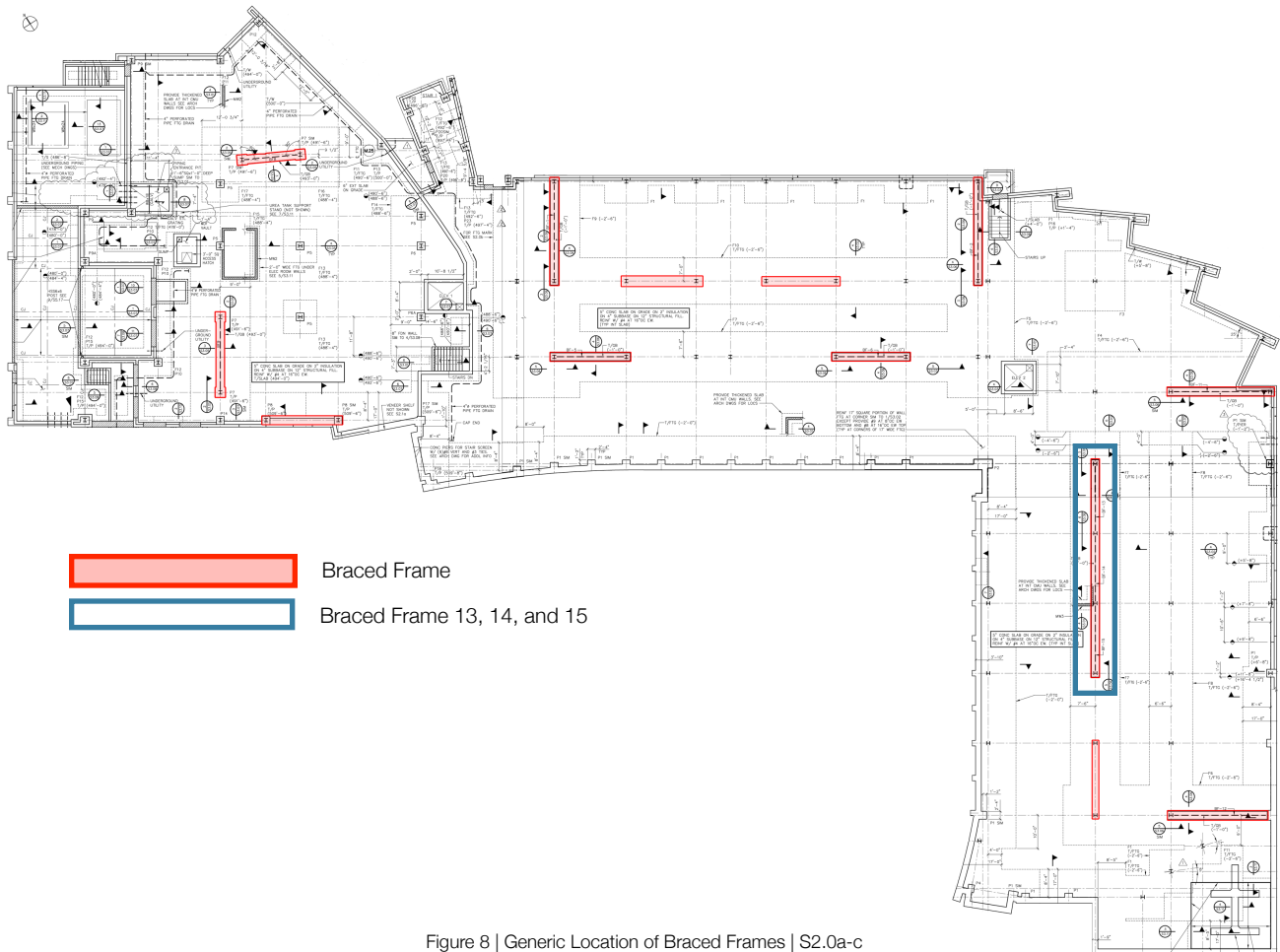


Figure 8 | Generic Location of Braced Frames | S2.0a-c

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 is 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 height is measured 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.

DESIGN CODES AND STANDARDS

CODES AND STANDARDS

International Code Council

International Code Council 2006 Editions

International Building Code 2000 Edition

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

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 case of building collapse due to the structure failure, progressive collapse analysis will be assessed to new structural design. 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 in new site location. The current state code, 2013 California Building Code, references *the International Building Code 2012 edition* and *American Society of Civil Engineers (ASCE) 7-10*. In progressive collapse analysis, *Unified Facilities Criteria (UFC) - Design of buildings to resist Progressive Collapse* and *GSA Progressive Collapse Analysis and Design Guidelines* will be used as a guideline.

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. Structural braced frames will be considered as a prior design based seismic loads. 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.

To resist the new loads, the floor system will be redesigned with the least amount of weight since the seismic load is based on the building weight. The reduction of the building weight will be benefit to design the lateral system. Compared to normal weight concrete, the lightweight concrete slab will be considered as floor system redesign, and it will affect the floor fire proofing system.

In redesign of lateral system, several designs will be suggested to the owner such as structural steel braced frames, structural steel moment frames, or reinforced concrete shear walls. A high ductility system will provide the cost saving by reducing member size, but increasing extra costs in the connection details.

Through a progressive collapse analysis and design, it would be critical that floor girders and beams would be capable of support two full bays and the connections would be sufficient to support structural elements. The detailed connection design in beams to columns will be carefully inspected.

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. 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.

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 existing building
2. Acquire AISC Seismic Manual and Design Manual and review
3. Acquire AISC Design Guide related to lateral system design for earthquake
4. Familiarize with California code and any restrictions that are applicable to the building
5. Determine any differences between ASCE 7-05 and ASCE 7-10
6. Research on the climate conditions for new location

Structural Design

Modeling

1. Modify the existing lateral system model in ETABS to adjust the factors related to a high seismic region
2. Create RAM model to analyze both gravity and lateral system
3. Duplicate the models to different lateral 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. Evaluate 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

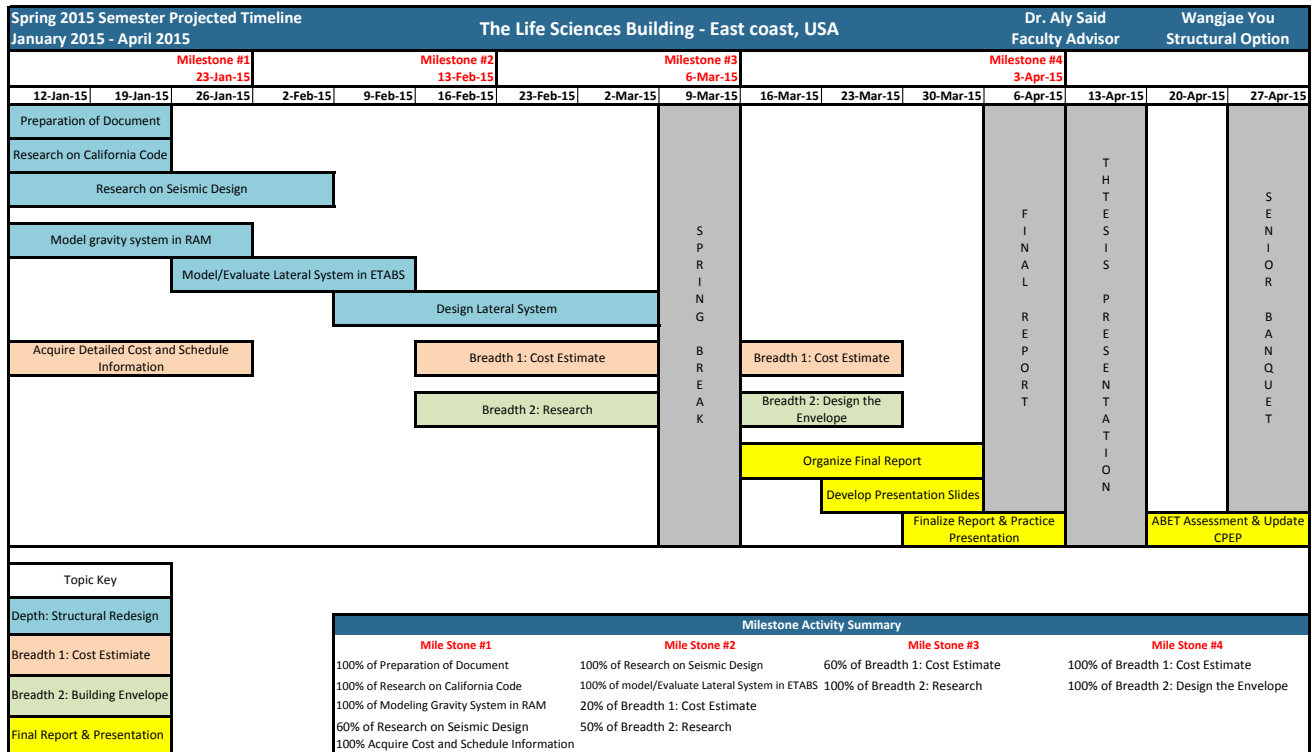
Construction Management

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

Final Report and Presentation

1. Prepare Final Report
2. Prepare Final Presentation

SCHEDULE



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 will be reviewed to determine the effectiveness of the existing structural design of the building. In progressive collapse analysis, both UFC design guide and GSA design guide will be applied.

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 reduce the weight of building for seismic load and it will affect the floor fire proofing system.

In redesign of lateral system, multiple options will be suggested to the owner: structural steel braced frames, structural steel moment frames, or reinforced concrete shear walls. 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.

In progressive collapse analysis and design, it would be critical that floor girders and beams would be capable of support two full bays. The connection design will be carefully inspected to resist progressive collapse.

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

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.