Structural Technical Report 1

LIFE SCIENCES BUILDING
STRUCTURAL CONCEPTS AND EXISTING CONDITIONS

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September 12, 2014

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EXECUTIVE SUMMARY

Life Sciences Building is located in north east of the United States (A generic fictitious information of building is requested by the owner). The goal of this project was to create a national model of sustainable design for laboratory buildings and the building was awarded LEED Platinum. The building is a 5 stories and 174,500 square feet. The geometry of building is a L-shape and considered as a long span structure. The building is divided into three sections and each section performs its own function. A greenhouse is placed in the roof to serve as research spaces and improve building energy performance as well. This technical report provides the summary of the structural existing conditions and explores potential alternatives of the system, especially in structure, for the course.

The foundation system consists of cast-in-place concrete spread and strip footings to support a system of wide flange steel columns. The building is design as a composite steel floor system. Typically, 7 1/2" reinforced concrete slab on 3" 20 gauge metal deck supports floor loads and transfer them to wide flange beams with shear stud connection. Web openings in wide flange steel beams could resolve the coordination issues with mechanical, electrical and plumbing systems.

The lateral system was designed as structural steel braced frames. Due to architectural versatility, the layout of braced frames is carefully determined. Hollow Structural Section (HSS) is used as braces with varying its thickness according to the lateral loads resisting by members.

Life Sciences Building was designed in accordance with the states codes, which is compliant to the International Building Code 2006 Edition (IBC 2006) and American Society of Civil Engineering (ASCE) 7-05 for load provisions. Due to the placement of a greenhouse in the roof, the structure was carefully considered in larger design loads. The coordination of MEP systems and structure system was a challenge of the design.

PURPOSE AND SCOPE

The purpose of this technical report is to describe the physical existing conditions with an emphasis on the structural systems associated with Life Sciences Building located in north east of the United States. The scope of this report includes descriptions of the building and all the structural components of the building including the foundation, gravity systems, lateral systems and joint details. It would also cover the codes and materials used in this project.

GENERAL DESCRIPTION OF BUILDING

Life Sciences building is a 5 stories laboratory building, 91 feet tall with 174,500 square feet. It is located in a college town in north east of 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

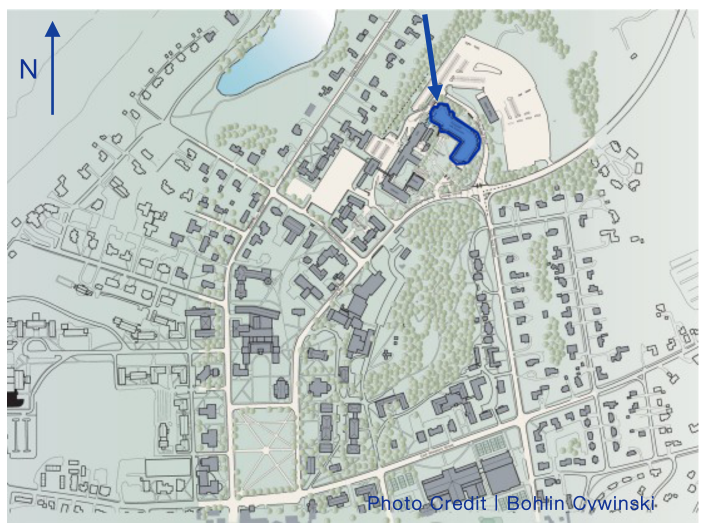

Figure 2 | Buildings Site Plan

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 researching laboratories with the offices. The building is divided into 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 occupied in east side.

The main concept of design in floor plan was to create the space promoting the interaction of idea and technique between people using this building. Laboratories are placed in the first floor to provide better accessibility to who uses the facilities. One of the unique features of the project is a greenhouse on the rooftop. Greenhouse on the roof could improve building performance in energy usage in both summer and winter. However, to place a greenhouse in the rooftop would be a challenge to structural engineer to design to resist heavier loads on the roof.

With great effort and teamwork between project teams, the project is completed on schedule and within the project cost budget when faculty and researchers moving-in during August 2011. To celebrate hard works of everyone involved in, 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 laboratory buildings.

STRUCTURAL SYSTEM

STRUCTURAL SYSTEM

Life Sciences Building is a structural steel frame with composite concrete slabs on metal deck. This structural frame is supported on cast-in-place concrete footings. According to the performance in the laboratory, floor vibrations are strictly limited where vibration sensitive equipment is placed. Cast-in-place reinforced concrete framing 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 slap at the floor.

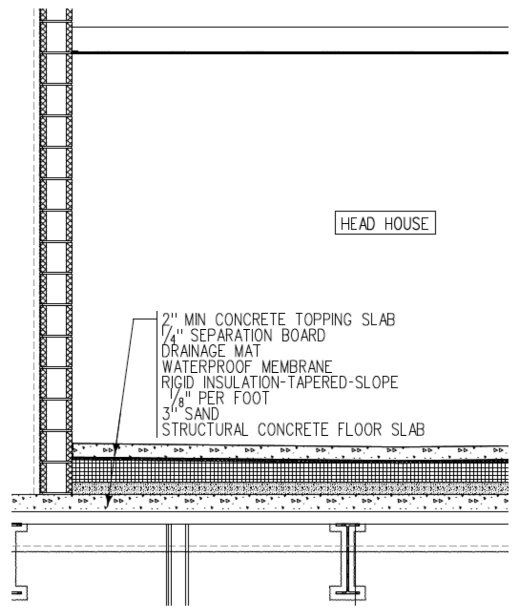

Figure 3 | Greenhouse Section | 1/A4.20

Structural steel may provide the benefit of shorter erection time in construction schedule, especially in harsh winter weather in the location of the project.

Structural steel braced frames are used to resist lateral loads such as wind and seismic loads compliant to International Building Code 2006 edition. Braced frame is used over moment frame due to its economy, but 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 (MEP) system. Especially in the project, the layout of structural elements is important.

The foundation design uses spread and strip footings, which is more economical than a deep foundation and allowed to place foundations on where the slopping ground. Continuous reinforced concrete trip footings were utilized under heavily loaded interior columns, typically loaded 275 kips for dead load and 280 kips for live load. The footings bear on a 2 foot thick layer of compared structural fill placed on top of glaciolacustrine soil deposits of loose to medium dense silty sand and silt.

STRUCTURAL 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/Retaining Walls	f'c = 4,000 psi
Piers	f'c = 4,000 psi
Grade Beams	f'c = 4,000 psi
Exterior Slabs/Equipment Pads	f'c = 4,500 psi
Miscellaneous	f'c = 3,000 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

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 of laboratory, dead loads are higher than other laboratory building projects. Greenhouse floor load is used at 160 psf and other floors are used at 110 psf. Roof dead loads are also higher than regular project, 170 psf for roof gardens and terraces and 30 psf for a 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 calculation based on ASCE 7-05 Chapter 6. Basic wind speed (3 second gust) is 90 mph. Mean roof height is 80 feet.

SEISMIC LOADS

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

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 is recommended 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 recommended that footings should have a least lateral dimension of 24 inches or greater.

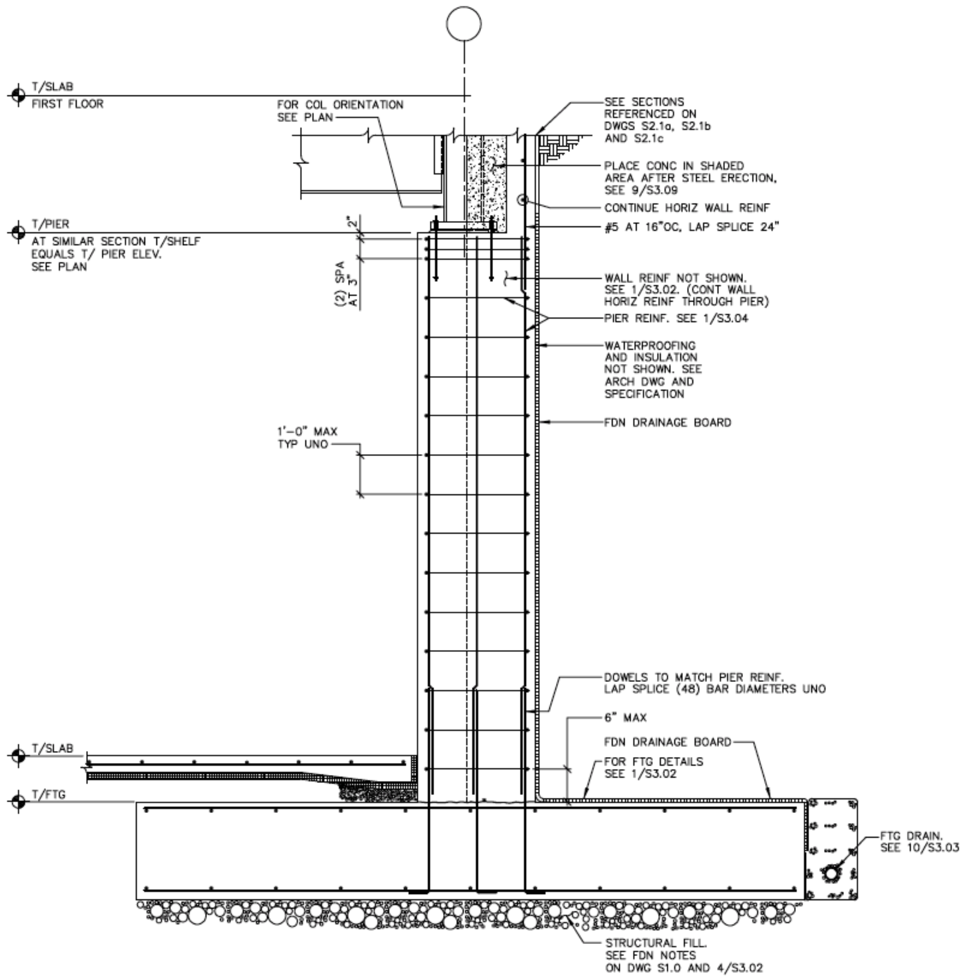

Figure 4 | Section of Footing | 2/S3.02

Exterior below-grade foundation walls should be designed for a static lateral soil pressure using an equivalent fluid unit weight of soil equal to 60 psf assuming drainage is provided behind the wall. Mechanically Stabilized Earth (MSE) wall is considered outside the building to avoid unbalanced soil lateral loads onto the building foundation walls.

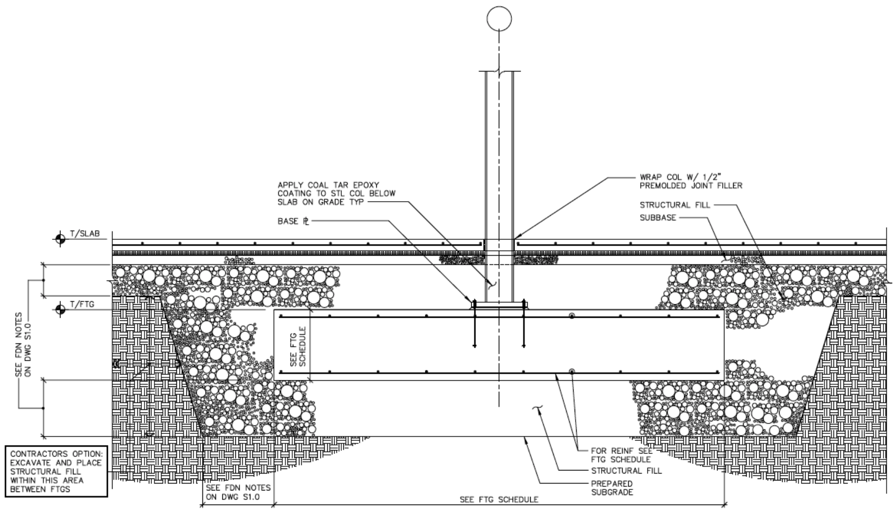

Figure 5 | Section of Typical Interior Footing | 4/S3.02

According to the geotechnical report, presumptive net soil bearing pressure is equal to 2,500 psi 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 the geotechnical report.

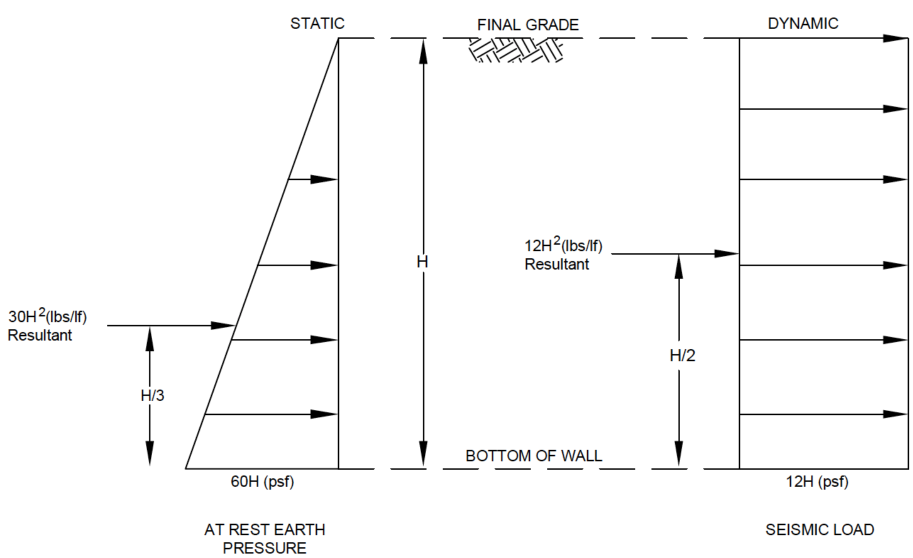

Figure 6 | Recommended lateral Loads at Rest Conditions | Geotechnical Report

GRAVITY SYSTEMS

Floor System

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 W16x22.

For typical floor system, 7 1/2" concrete slab on 3" 20gage galvanized composite metal deck supports the floors and floor slabs are reinforced with #4 rebar at 16" o.c. each way. According to the general note in the drawing, 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.

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 pounds person walking at 75 step/minute, which is classified as moderate walk.

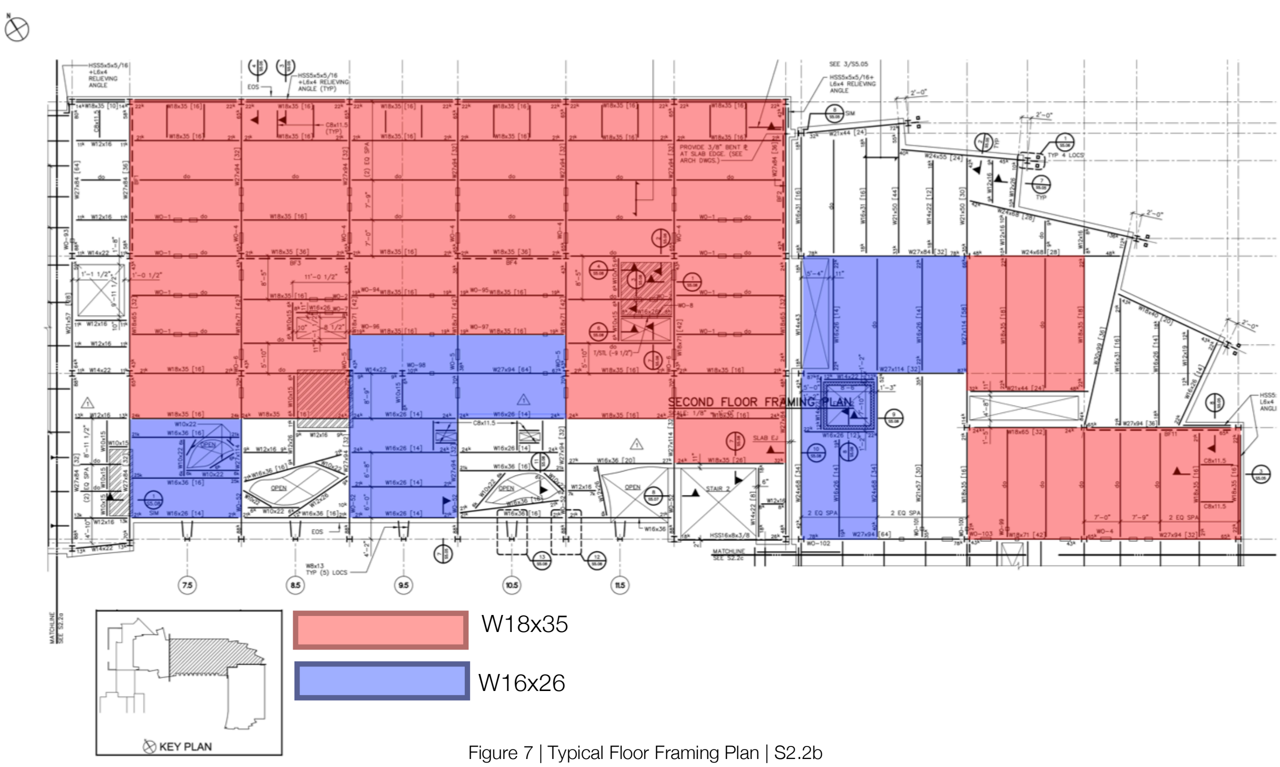

Figure 7 | Typical Floor Framing Plan | S2.2b

Framing system

W18x35 beams are supporting typical laboratory floors. The figure 7 above is shown a second floor framing plan. W21x68 is used as the girder to support W18x35 beams. The girders transfer the loads, picking up from W18x35 beams, to the columns of W12x120 and transfer down to the foundation. Beside these typical bays, irregular bays are supported other spaces such as corridor, gallery, staircase, and offices where the loads are smaller compared to laboratory.

A typical bay is selected from north section of the second floor and highlighted in the Figure 8 below. A typical bay is 21'-8" x 22'-9" and supported by 7 1/2" concrete slab on 3" 20 gauge galvanized composite deck, reinforced with #4 bar in 16" o.c. each way. One of the main advantages using a composite beam is to have a greater strength than a bare steel beam. Due to concrete slabs on metal deck, the composite sections increase elastic moment of inertia compared to non-composite. Since a building requires greater values of dead and live loads, Composite beam would be better option. However, it would increase the project cost by adding shear studs.

Floor loads in a typical bay is transferred to concrete slab on metal deck. The steel beams, W18x35, collect the load from composite decks and carries to girders, W21x68, and columns, W12x20. 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.

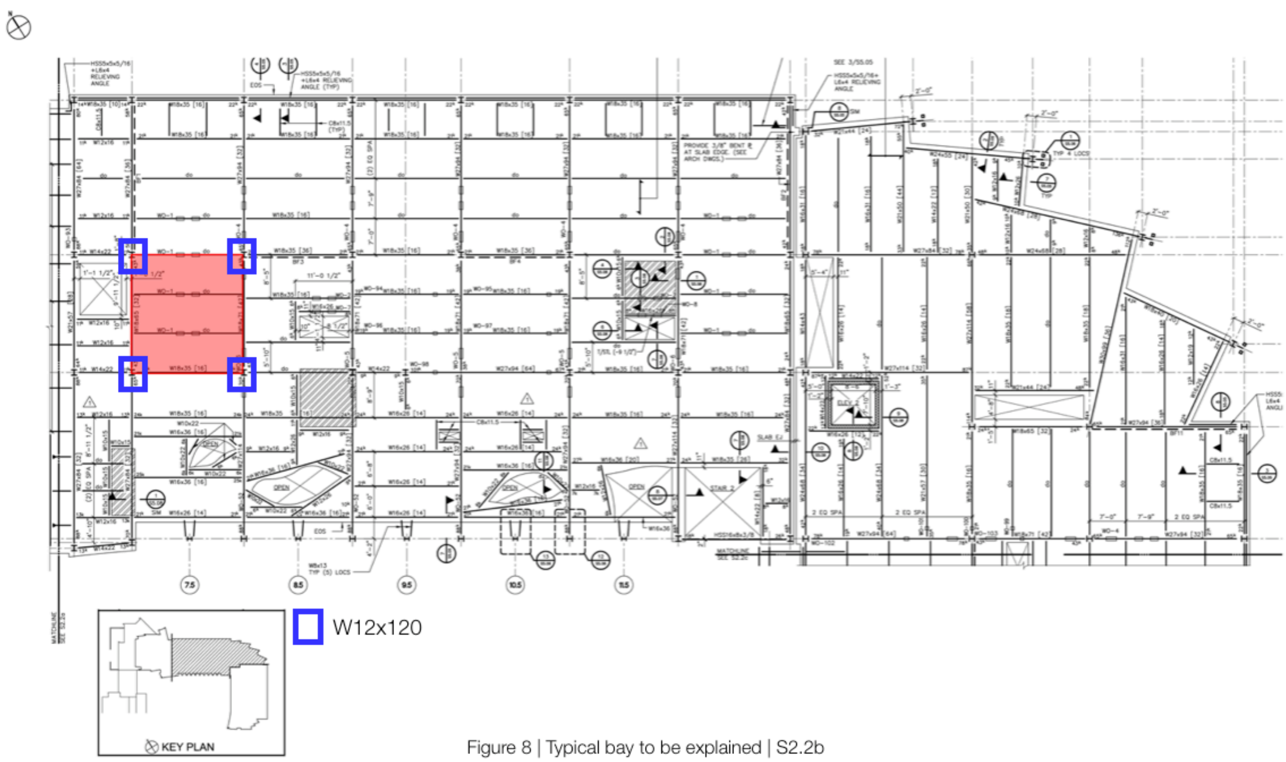

Figure 8 | Typical bay to be explained | S2.2b

Roof system

Structural steel framing with a composite deck is used as a main roof framing system. However, the unique feature of the roof in Life Sciences Building is a 6,400 square foot greenhouse on north section and green roof on west section.

A greenhouse has metal truss framing system, Figure 9, and a green roof is supported on 6 1/2" concrete slab on 3" 20 gauge galvanized composite deck. The green roof and greenhouse improve building performance in energy, especially in harsh winter in the location.

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.

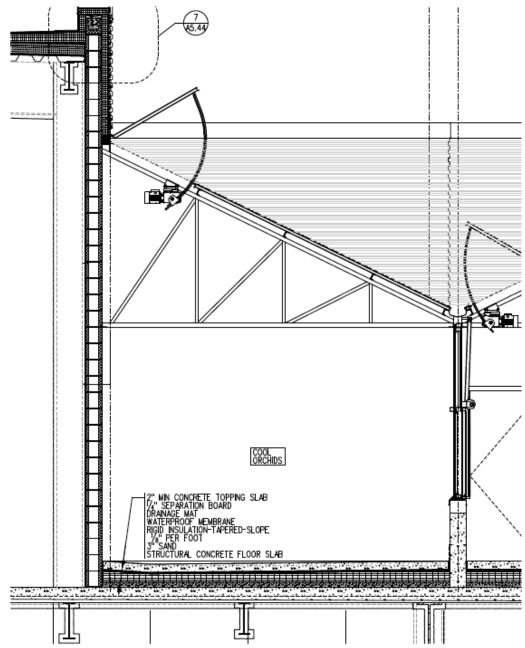

Figure 9 | Greenhouse Section | A4.20

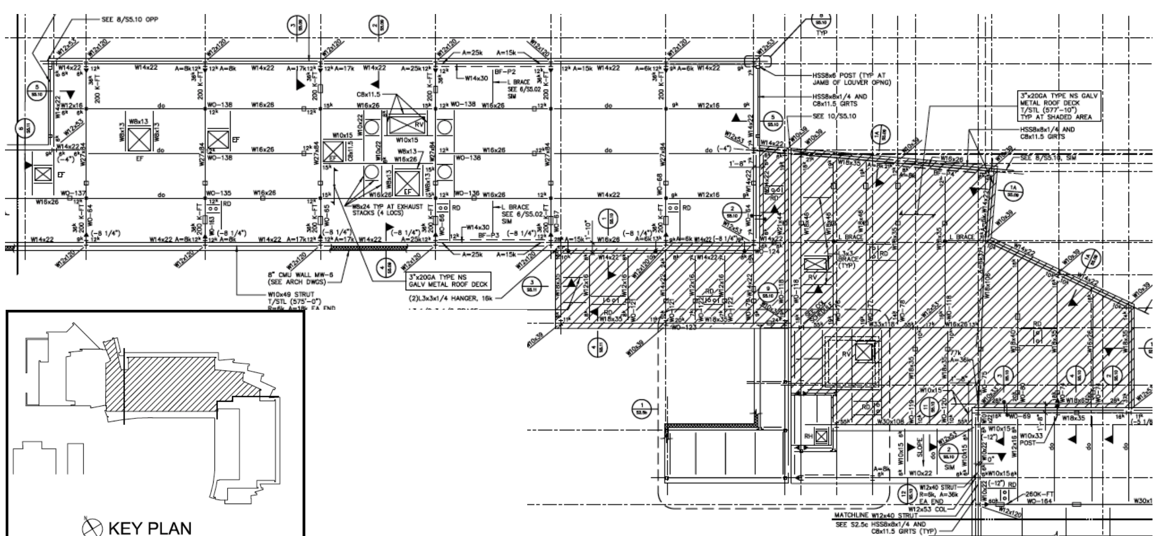

Figure 10 | Roof Framing Plan - North Section | S2.5b

LATERAL SYSTEMS

The lateral force resisting system for Life Sciences Building consists of structural steel braced frames. There are sixteen braced frames placed with varying length and height. Majority of braces used hollow structural section (HSS) 10x10x1/2 and 10x10x3/8. The braced frames are not specially designed for seismic loads. The Figure 11 below shows the location of braced frames throughout Life Sciences Building.

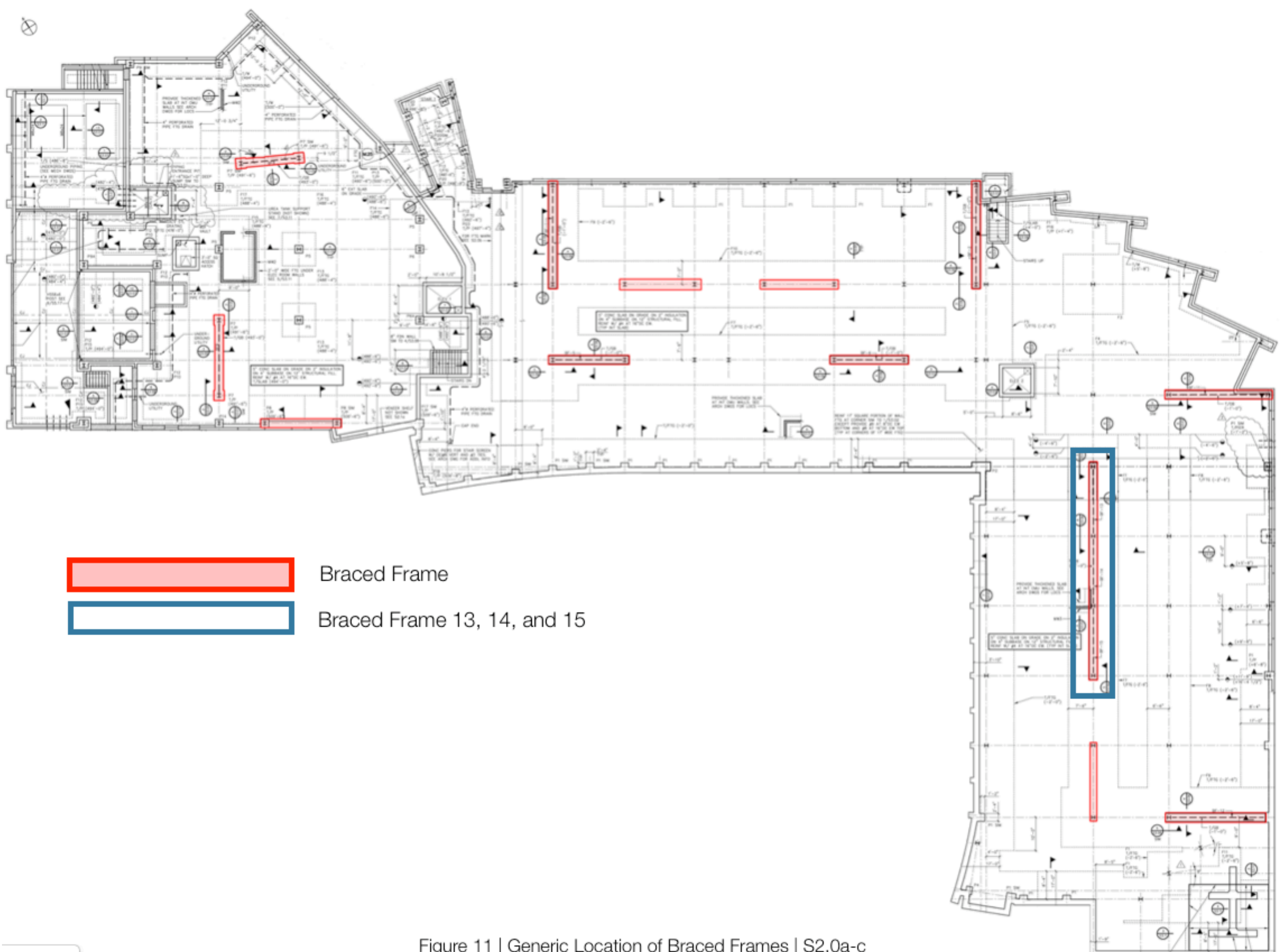

Figure 11 | Generic Location of Braced Frames | S2.0a-c

A typical braced frame13, 14, and 15 are concentrically braces frames, Figure 12 below. They have inverted V-brace between lower level and first floor and single diagonal braces from first floor to fourth floor. Beams and braces are pin connections and the columns are continuous throughout the heights. The major advantage of concentrically braced frames is to provide high elastic stiffness. However, it reduces architectural versatility on floor plan. The columns used in braced frame 13, 14, and 15 are W12X120 and column splices at Elevation 550’-4”.

1 3/4" Grade 55 anchor rods are embedded 34" into concrete footings. Below in Figures 14 and 15 is detail of the connection.

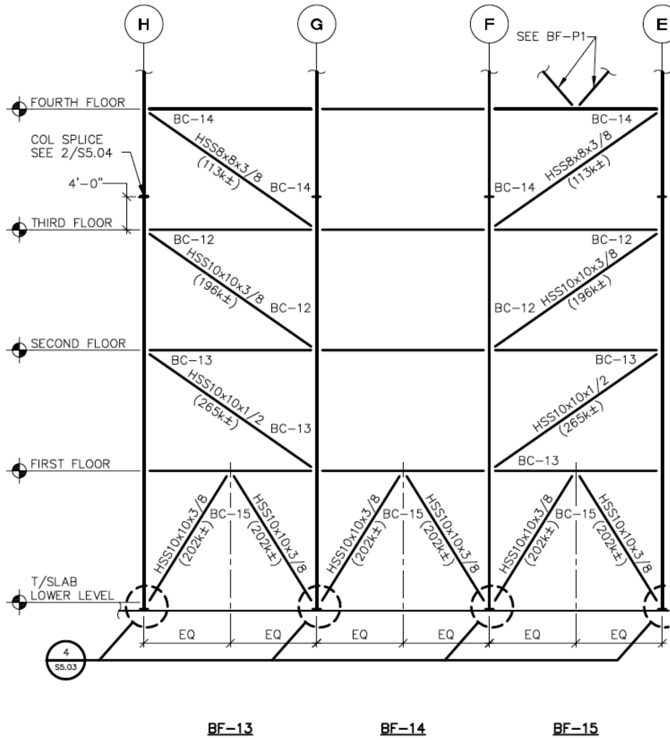

Figure 12 | Braced Frame 13, 14, and 15 Section | S5.01

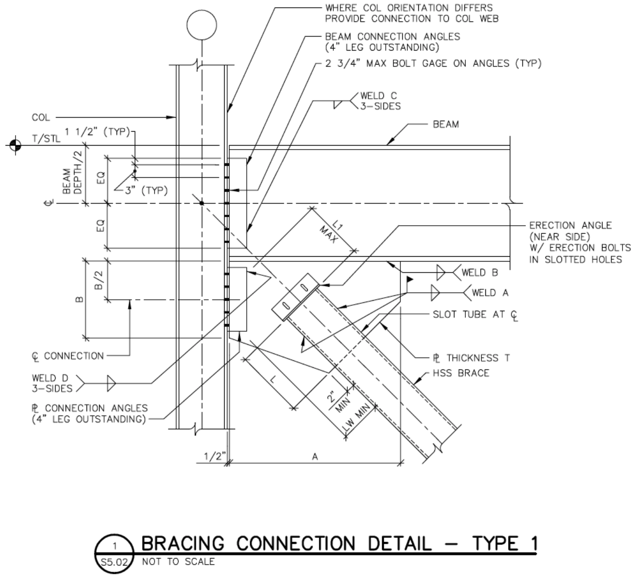

Figure 13 | Bracing Connection Detail |

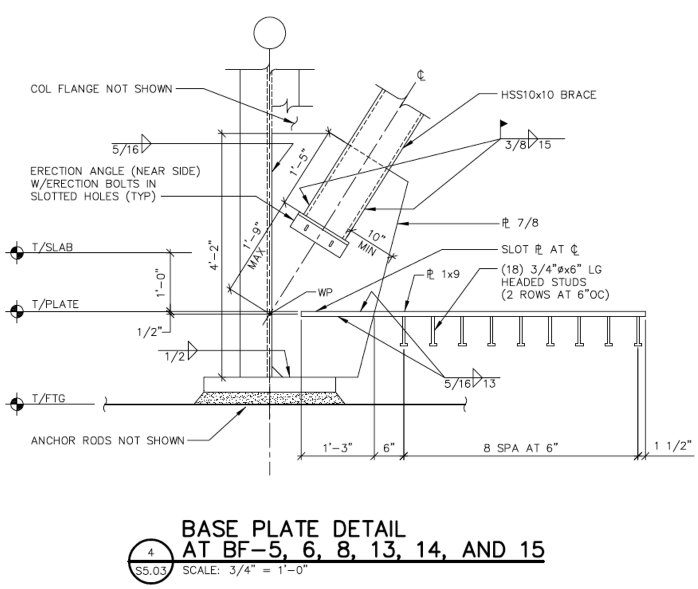

Figure 14 | Base Plate Detail | 4/S5.03

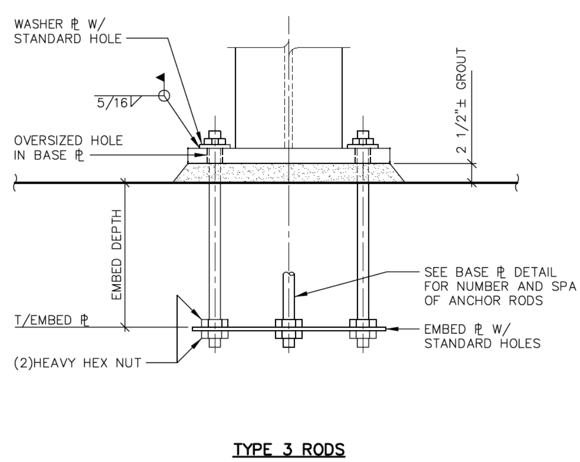

Figure 15 | Anchor Rod Details | 2/S5.03

JOINT DETAILS

Moment Connections

A typical moment connection in Life Sciences Building is a direct-welded flange. It requires the fewest parts compared to other welded methods in flange. The flanges are welded in the field to the supporting member such as columns and girders with joint penetration groove weld. Typically, thickness of flange plates is equal to beam flange thickness. Two 3/4" diameter A325 bolts are used, as minimum size of connection and connection design by fabricator will be under review by engineer.

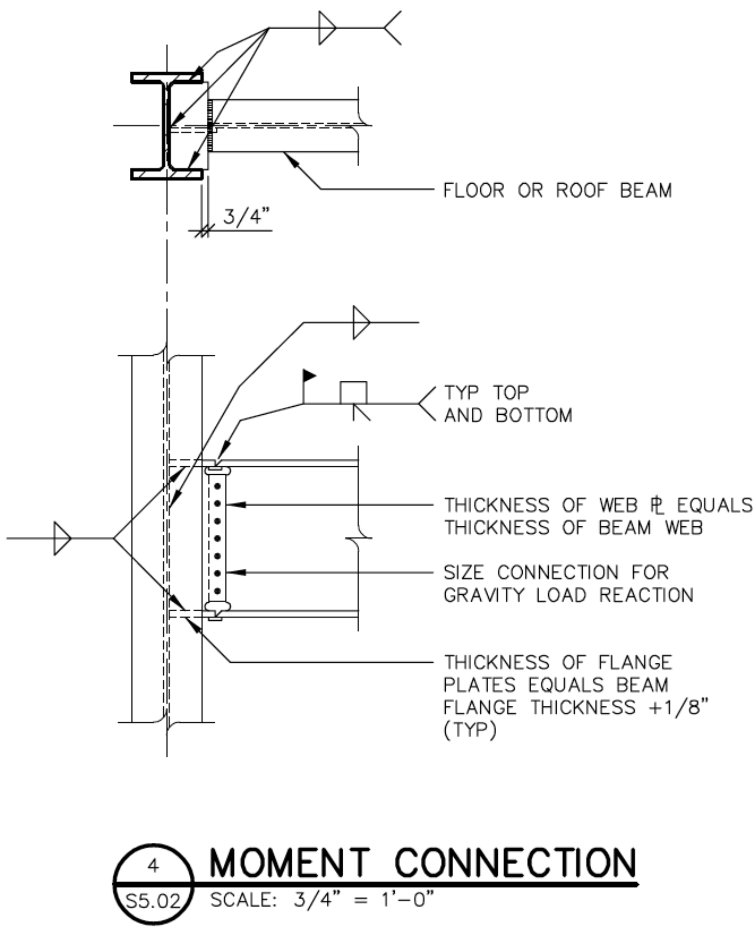

Figure 16 | Typical Moment Connection | 4/S5.02

DESIGN CODES AND STANDARDS

Codes and Standards

International Code Council

    International Code Council, 2006 Edition
    International Building Code, 2000 Edition

American Society of Civil Engineering (ASCE) 7-05

American Concrete Institute

    ACI 211.1 - Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete"
    ACI 301 - Specifications for Structural Concrete for Buildings
    ACI 302 - Guide for Concrete Floor and Slab Construction
    ACI 303 - Guide to Cast-in-Place Architectural Concrete Practice
    ACI 304 - Guide for Measuring, Mixing, Transporting, and Placing Concrete
    ACI 305 - Hot-Weather Concreting
    ACI 306 - Cold-Weather Concreting
    ACI 311 - Guide for Concrete Inspection & Batch Plant Inspection and Field Testing of Ready-Mixed Concrete
    ACI 315 - Details and Detailing of Concrete Reinforcement
    ACI 318 - Building Code Requirements for Structural Concrete
    ACI 347 - Guide to Formwork for Concrete
    ACI SP-15 - Field Reference Manual

American Institute of Steel Construction

    Manual of Steel Construction

American Welding Society

    AWS - Structural Welding Code - Reinforcing Steel
    AWS D1.1 - Structural Welding Code - Steel
    AWS D1.3 - Structural Welding Code - Sheet Steel
    AWS C5.4 - Recommended Practices for Stud Welding

Concrete Reinforcing Steel Institute

    CRSI - Manual of Standard Practice

New York State Department of Transportation

    NYSDOT - Standard Specification for Construction and Materials

CONCLUSION

Structural Technical Report 1 described the physical existing conditions of Life Sciences Building in north east of the United States. The report provided an overview of the building and detailed descriptions of the structural materials, design loads, foundation system, composite floor systems, gravity systems, lateral systems, joint details, and design codes and standards.

The gravity system was used a composite deck with steel beams and girders. The main goal of this building is to represent a national model of sustainable design for laboratories buildings. Web openings are often found in building due to the coordination with MEP system. The future analysis should demonstrate how the web openings behave in the strength of bending and shear in the system.

Structural steel braced frames were designed as the main lateral resisting system in Life Sciences Building. The current design has sixteen braced frames in the entire building and arranges them according to the architectural coordination. Compared to braced frames, concrete shear walls and moment frames provide greater stiffness on the structure and it could eliminate the number of lateral resisting elements in the building. Since braced frames reduce architectural versatility in the plan, concrete shear walls or moment frames could be considered as alternative options in the current design in the future analysis.

Life Sciences Building has several challenges of analysis. There are several spaces where top of floor slab is not aligned each other. Some braced frames do not have braces in certain floors and the locations of bracing connection are offset. The existing lateral system is not specifically designed for seismic loadings, so seismic design should be analyzed to make sure the structure could resist seismic loadings. The geometry of building, L-shape, would be challenge to analyze.

Life Sciences Building will offer a great opportunity of educational challenge due to its geometry, elevation change in floors and lateral systems.