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Thesis Proposal

Simmons College School of Management, Boston, Ma

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Executive Summary: Thesis Proposal

The Simmons College School of Management is a newly constructed five story educational facility located in Boston, Massachusetts. The building is 65,000 SF and sits on the south east corner of a five level below grade parking garage. Accommodations have been made in the original design for a future expansion of the building which would top out at a nine story building.

The below grade parking garage is a post tensioned concrete system with a slurry wall as the exterior foundation wall system. Interior columns are W14 shapes extend into the ground to form load bearing element foundations. At the plaza level provisions were made for the use of a crane in the construction of the above grade building. The five story building is steel with composite floors and primarily uses wide flange shapes.

Originally the building was designed under the Massachusetts State Building Code, Sixth Edition. This report used ASCE 7-05 as the primary code to develop the loading and strength requirements for the structure. Therefore, it is expected that there will be variations between the original design and the analysis that appears in this report.

In the following semester work will primarily focus on the building expansion that is proposed for the west end of the building. This expansion will likely top out at nine stories and be structurally tied to the existing structure. Completing the study of the lateral force resisting system indicated that the loads from the future building were taken into account for the design of the current building.

The design of the existing structure and the future expansion will both be analyzed to assess the load carrying capacity of the system. Along with this assessment, the effects of building torsion will be analyzed once the expansion is complete. Modifications to the new expansion will be assessed and redesigned as necessary.

Additionally, the building façade system will be analyzed and redesigned. Energy efficiency and the constructability of the current façade will be assessed. Likewise, the new façade design will address these two areas as primary goals for improvement of the system.

Further study will be performed to address the construction management of the expansion as well as the façade erection. The mobilization of erection equipment on the site will be a main item of concern during the expansion phase. Throughout the design process of the new façade system the reduction of field labor and improvement of safety will be maintained as primary criteria.

Introduction

The Simmons College School of Management is a newly completed five story educational facility to be located on the Simmons College campus in Boston, Massachusetts. The $63 million building which was completed in December of 2008 was designed by Cannon Design.

As part of the project a five level below grade parking structure was provided to replace the parking lot that previously occupied the site. This relocation of parking allowed for the creation of a new green space quad to serve the school.

When the building was completed it achieved the LEED Gold rating by the USGBC. The project received 40 LEED points which included recognition for significant reductions in water and energy usage.

The project includes design considerations for a future building expansion to be topped out at nine stories. This design parameter was considered from the beginning of the design process including the original geotechnical evaluation of the site.

Structural Systems

Foundations

The below grade parking structure was constructed by the top down method with the installation of a slurry wall and load bearing elements (LBE) prior to excavation. Slurry wall panels have varying widths ranging from 10'-0" to 25'-0" with the typical panel width being 24'-0". Penetration of the 10'-0" centerbite into marine sands on site ranges from 1'-0" to 43'-0" depending on the bearing capacity demands of the wall section. See Figure 4 for typical slurry wall panel elevation.

Load bearing elements are constructed with W14 columns from the garage embedded in concrete shafts. Depths of the concrete shafts are divided into four categories summarized in Figure 1. W14 column embedment into the concrete shafts ranges from 16' to 27'. Typical shear studs are 4" long ¾" diameter and arranged in patterns of eight, ten, or 12 studs per foot seen in Figure 2. See Figure 4 for typical LBE configuration below the slab on grade.

LBE INSTALLATION CRITERIA CATEGORIES	
CATEGORY 1	MINIMUM EMBEDMENT OF FIVE (5) FEET BELOW THE TOP OF THE GLACIAL TILL DEPOSIT
CATEGORY 2	MINIMUM EMBEDMENT OF FIFTEEN (15) FEET BELOW THE TOP OF THE GLACIAL TILL DEPOSIT OR MINIMUM EMBEDMENT OF TWO (2) FEET BELOW THE TOP OF THE BEDROCK DEPOSIT AND A MINIMUM TOTAL EMBEDMENT OF TEN (10) FEET BELOW THE TOP OF THE GLACIAL TILL/BEDROCK DEPOSITS
CATEGORY 3	MINIMUM EMBEDMENT OF FIVE (5) FEET BELOW THE TOP OF THE BEDROCK DEPOSIT AND A MINIMUM TOTAL EMBEDMENT OF FIFTEEN (15) FEET BELOW THE TOP OF THE GLACIAL TILL/BEDROCK DEPOSIT
CATEGORY 4	MINIMUM EMBEDMENT OF FIFTEEN (15) FEET BELOW THE TOP OF BEDROCK DEPOSIT

Figure 1 Typical LBE Configuration

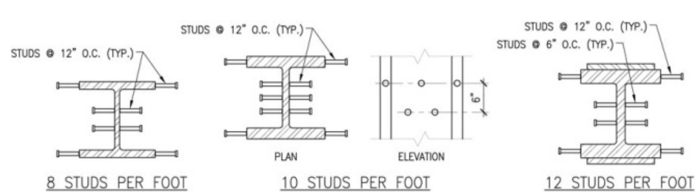
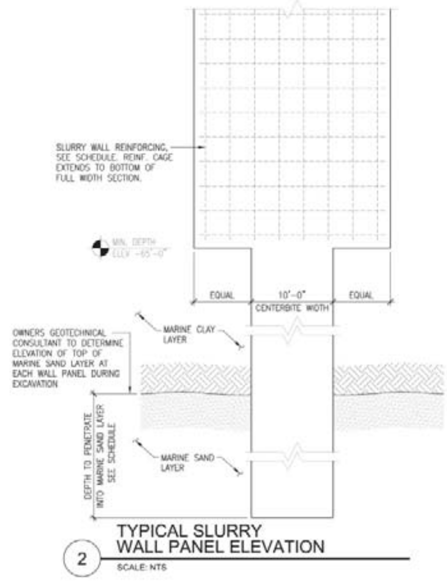


Figure 2 Typical LBE Configuration



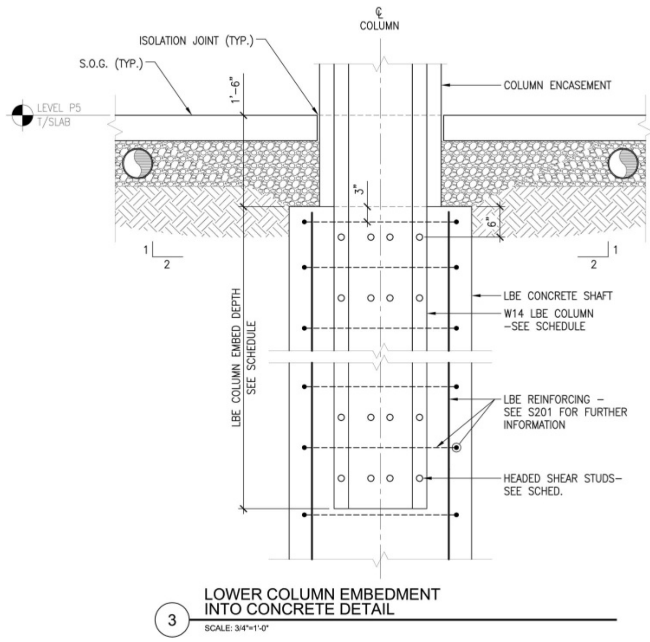


Figure 3 Slurry Wall Foundation Detail

Figure 4 Load Bearing Element Foundation Detail

Beneath the area of the superstructure that is not located on top of the parking garage .365" thick, 10.75" diameter concrete filled steel pipe piles are used for foundations at column locations. Arrangements of piles include three, four, five, and eleven pile configurations. This foundation type is used below the braced frame which will be assessed for its load carrying capacity in the following sections. See Figure 5 for a typical layout of the pipe pile foundation.

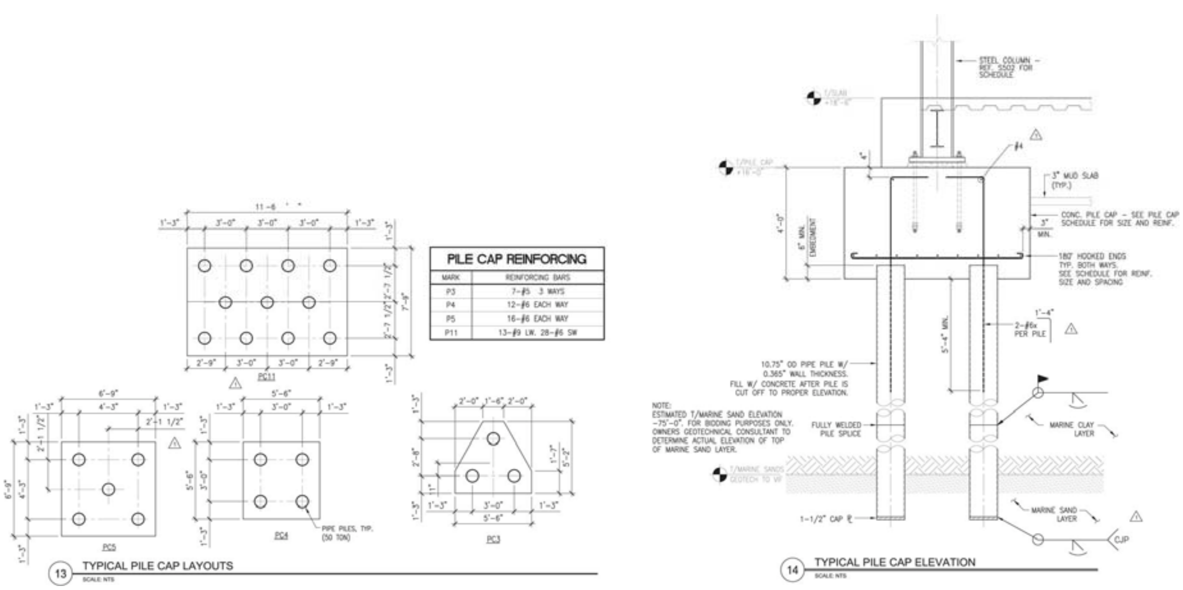


Figure 5 HSS Pile Foundation Detail

Floor Systems

Post tensioned concrete slabs are utilized for the typical floor system in the sub grade parking garage. Slab thickness in levels P1 through P4 is 14” with 6500 psi concrete. Bay sizes in the parking garage range from 36’x32’ to 42’x49’.

Banded reinforcement spans in the north south direction of the parking garage plan with the typical bottom drape in each tendon meeting the minimum concrete cover at 1.75 inches. The typical force after all losses in these tendons is 1600 kips. Distributed reinforcement is placed in the east west direction at a maximum of 48 inches on center. At the column connections various patterns of stud rail arrangements and additional mild reinforcement are provided. For the lower four parking levels steel columns are encased in concrete to form a round 2’-8” diameter round column. The post tensioned slabs provide the permanent lateral bracing for the foundation slurry wall to resist the lateral soil pressures.

At the plaza and first floor level the structural floor system changes from post tensioned concrete to steel beams with composite floor slabs. In the main quad area typical bay sizes remain the same. Typical horizontal framing in this area ranges from W24x76 beams with 52 shear studs to W36x135 beams with 80 shear studs. Three inch deck with 9” of 3000psi concrete is typical for all horizontal surfaces at the main quad space. Plate girders are used to transfer load from superstructure columns above this level to the columns extending through the parking garage. All plate girders are 48 inches deep with weights from 330 to 849 lb/ft.

The use of steel beams with composite action is continued in the floor framing of the building above grade. See the third floor framing in Figure 6 for a typical plan and framing layout.

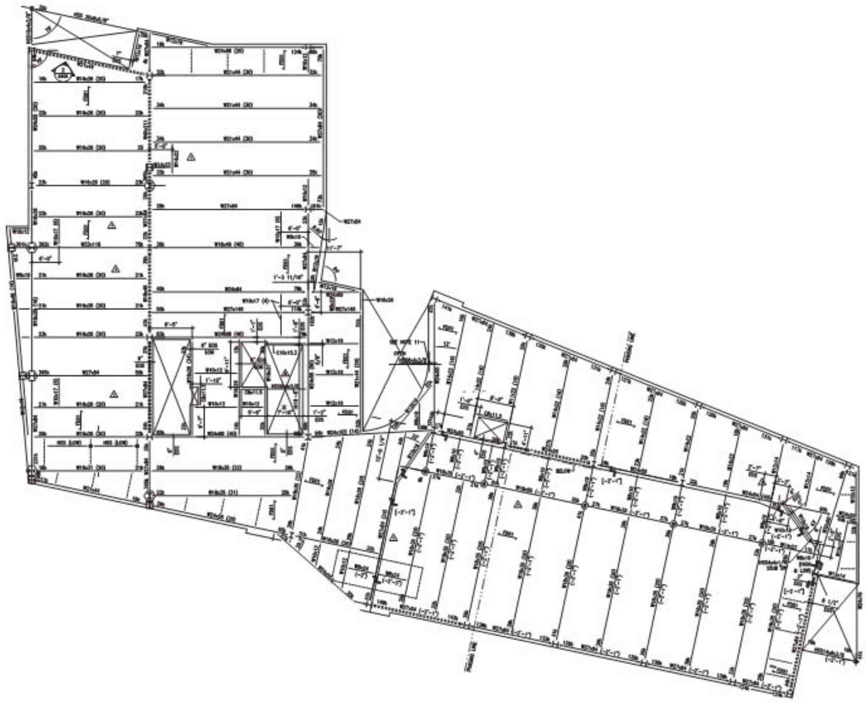


Figure 6 Second Floor Framing Layout

Columns

Typical column sections for the superstructure of the Simmons College School of Management are wide flange sections with some usage of hollow structural steel (HSS) sections. Wide flange sections are all W14s with weights varying from 43 to 109 lb/ft. The most commonly used wide flange column is a W14X90. HSS sections are either HSS6x6 or HSS8x8. In addition to carrying gravity loads the majority of the columns participate in the lateral force resisting systems as part of either the moment frames or braced frames.

Once the building column loads have been transferred by the plate girders W14 column sections continue to carry the load through the parking garage. Weights vary from 159 to 398 lbs/ft. In two different locations W14x398 with side plates or W14x500 columns are used. Here all columns below the first parking garage level are encased in concrete to form a 2’-8” diameter round column.

Supplementary Structural Systems

Two supplementary structural systems are used in the building in addition to the main load carrying elements. At the roof a braced frame screen is used to hide the penthouse and mechanical equipment. HSS sections are used for vertical and horizontal members while angles form the diagonal bracing.

In the parking garage reinforced concrete members are used to form the ramp access to all parking levels. Edge beams span the length of the length of the ramp with a 12 inch slab bridging the 21’-2” for the driving surface. Girders are 2’-7” deep and span below the slab at columns locations.

Lateral Systems

Two structural systems are used in the Simmons College School of Management to resist lateral forces applied to the building. In the north south direction of the building steel braced frames carry lateral loads. The lateral force resisting system in the east west direction is a combination of steel braced frames and steel moment frames. Locations of steel braced frames can be seen in Figure 7 and steel moment frames are noted in Figure 8. The number of steel braced frames used is reduced in the upper floors of the building. In some areas of the building, moment frames are used on in locations on upper floors where braced frames were present on the floors below. The majority of the braced and moment frames transfer load at their bases to transfer girders which frame to the garage columns and carry load to the foundations. An area of note is the offset of the moment frame from the moment frame noted as number 3 in Figure 9 to its location at 4 in the fifth story. The moment frame changes from column line ZE to ZD. Lateral loads are then transferred to the moment frame on column line ZE by W33x141 beams.

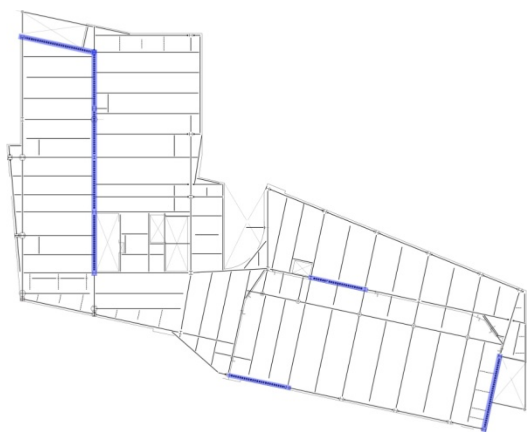


Figure 7 Braced Frame Locations

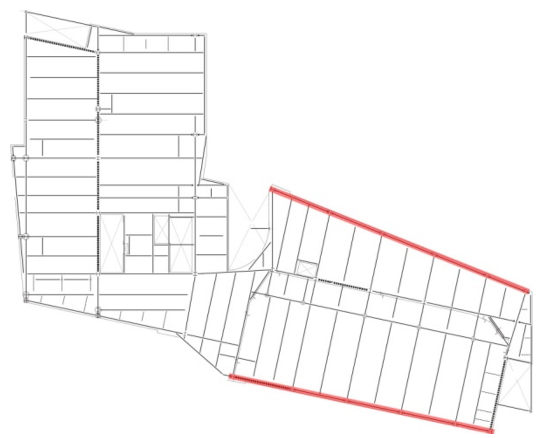


Figure 8 Moment Frame Locations

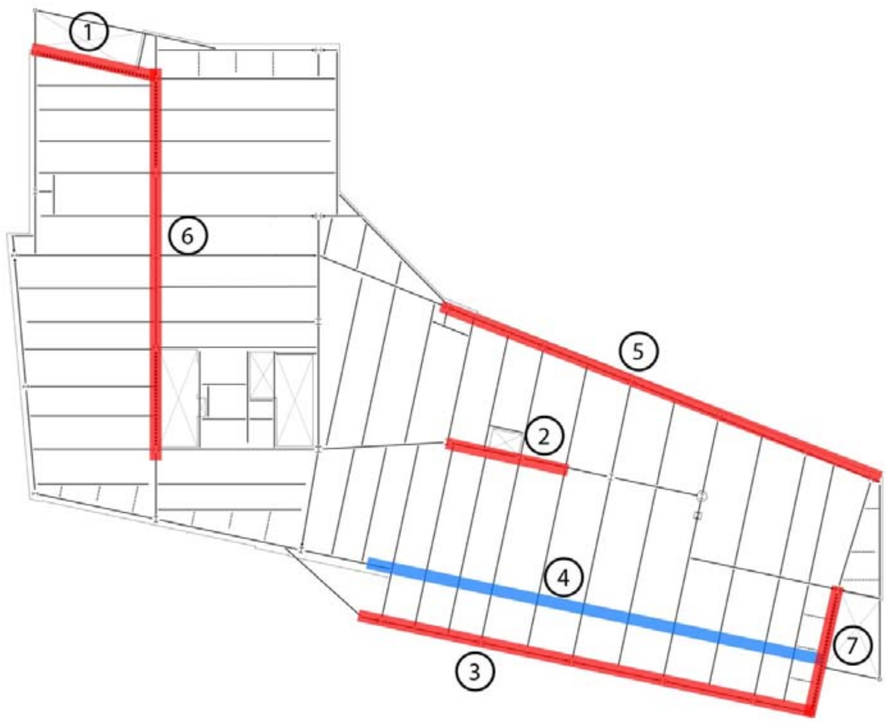


Figure 9 Lateral Frame Identifications

At all levels the concrete floor deck forms a ridged diaphragm which transfers lateral load to either the braced or moment frames. The amount of force that each lateral load resisting element receives is dependent on that element's relative stiffness in the system.

Due to the arrangement of the lateral elements throughout the building, the effect of torsion becomes increasingly important. When lateral loads are applied to the building all elements participate in the resistance of load even when the loads are applied in the primary directions.

Code Requirements

Design Codes

Building Code, Design Loads:	Massachusetts State Building Code CMR 780 6^{th} Addition
Reinforced Concrete:	American Concrete Institute (ACI) 318
Structural Steel:	American Institute of Steel Construction (AISC)

Substitute Codes for Thesis

Building Code:	International Building Code (IBC) 2006
Building Loads:	American Society of Civil Engineers (ASCE) 7-05
Structural Steel:	American Institute of Steel Construction (AISC) 13^{th} Edition 2005
Reinforced Concrete:	American Concrete Institute (ACI) 318-08

Problem background

The Simmons College School of Management is a 5-story LEED Gold educational building that includes instructional and administrative spaces to serve the current needs of the school. When designed, allowances were included in the building with the intent that it could later be expanded to top out at a nine stories. This allows for the building to have a longer life, adaptable to the changing needs of the college.

Accommodations in the existing structure include allowances for the increased gravity load to be carried through select areas of the superstructure as well as the below grade parking garage. The existing plans indicate that the expansion will occur primarily on the west end of the building. Due to the current arrangement of lateral load carrying elements it has also be inferred that the addition will be structurally tied to the existing building. See Figure 10 for the proposed area for future expansion. The area limit for the expansion is highlighted in red and the columns with future load consideration are circled.

Figure 10 Partial Plaza Plan with Future Expansion Area

Problem Statement

Analyze the ability of the existing structure to be expanded and resist the resulting increased load.

Solution Method

A study is to be conducted of the new expansion of the building and its effects on the existing structure. This study of the altered structural system will incorporate both elements of structural design and analysis. If the design information is available, the area of the new building will be incorporated into the structure and analyzed accordingly. The lateral system will then be analyzed for the change in torsional effects that the addition will have on the building.

In the case that design information for the expansion is unavailable or not fully developed and new design will be proposed for the expansion area. Primary goals for this design will be constructability and the impact on the structure as a whole. The existing structure experiences a significant amount of torsion due to the arrangement of lateral elements and the eccentricity between the center of mass and center of rigidity. Therefore future design must take into account the effects on mass and rigidity of the entire system.

Indications from the study of the seismic forces acting on the building and the building’s lateral system resulted in the seismic load case being a critical loading condition. Depending on the response of the new structural system to lateral loads, a dynamic analysis of the structure may reduce the magnitude of the seismic load. This section of the solution method will be contingent on the analysis of the expanded structure and will be assessed upon completion of the initial study.

Breadth Study One: Façade Study

The existing façade of the Simmons College School of Management will be investigated as one of the additional areas of study. Upon completion of this study it will be determined if there are further ways to increase the energy efficiency and constructability of the curtain wall systems. If there are no clear options to improve the existing system a design for the expansion will be produced to maintain a similar energy efficiency of the wall system with considerations for the constructability of the system.

Breadth Study Two: Construction Management

Constructability will be a key concern while performing the new expansion to the Simmons College School of Management. The ability to mobilize erection equipment will be assessed as it applies to the newly expanded areas of the building. Areas of the plaza level above the parking garage were designed to support construction loading during the initial construction. As applicable these areas will be checked along with other construction zones utilized.

The façade design will be assessed for constructability considerations. Reduction of field labor and improved safety will be primary focuses for the design of the façade system.

MAE Requirements

The primary Master of Architectural Engineering course that will be utilized during the completion of the thesis course in spring of 2010 will be AE 597, Computer Modeling of Building Structures. ETABS, and SAP 2000 modeling will continue to be used to analyze the building structure. The existing 3D model used in the third technical report will be modified during to address the expanded structure.

Additionally the façade study will require the use of information obtained through 500 level coursework. Principles learned in AE 537, Building Failures, and AE 542, Building Enclosure Science and Design, will be imperative to the completion of this section of work.

Task and Tools

I. Structural Depth
    1. Research the Extent of Nine Story Building Expansion.
        i. Contact the engineer of record to obtain information regarding the proposed expansion to the structure
        ii. Research methods by which the construction of the expansion will be implemented
        iii. Investigate the extent of the design information for the expansion and assess the need for additional design.
    2. Implement the Expanded Layout Into the Building
        i. Perform the analysis of the modified forces on the building
        ii. Implement the structural elements into the existing 3D ETABS model. (AE 597)
        iii. Modify the existing 3D model to include the below grade parking structure
            a. Assess if explicit modeling or property modifiers are appropriate
        iv. Analyze the adequacy of the existing and proposed structure
    3. Assess the Appropriateness of Dynamic Seismic Analysis of the Structure
        i. Pending assessment of results obtained in steps 1 and 2, Step three will be performed as appropriate
    4. Perform Modifications to the Lateral System as Appropriate to Reduce Effects of Torsion on the Building
        i. As appropriate modify the lateral system to reduce inherent eccentricity of the building.

II. Breadth Study I: Façade Study
    1. Research existing information on the façade system
        i. Contact the design engineers to obtain design and construction information
        ii. Assess the façade details for potential enclosure deficiencies (AE 537)
        iii. Analyze the existing system for energy efficiency
        iv. Analyze the existing system for constructability
    2. Design New Façade System for Increased Energy Efficiency and Constructability
        i. Compare energy efficiency of the existing and proposed systems (AE 542)
        ii. Compare the constructability of the existing and proposed systems

III. Breadth Study II: Construction Management
    1. Analyze the Construction Methods to Erect the Expansion
        i. Determine as appropriate the ability to mobilize erection equipment in existing construction loading zones.
    2. Assess the Constructability of the Façade System
        i. Compare the labor necessary to erect the existing and proposed façade system
        ii. Analyze the potential for improved safety during erection of the façade system

Schedule

		TASK	Jan. 11-15	Jan. 18-22	Jan. 25-29	Feb. 1-5	Feb. 8-12	Feb. 15-19	Feb. 22-26
Structural Depth	1i	Contact Engineer							
	1ii	Research Construction							
	1iii	Assess Information							
	2i	Perform Load Analysis							
	2ii	3D Modeling							
	2iii	Modify Model							
	2iv	Analyze Structure							
	3i	Dynamic Analysis							
	4i	Modify Lateral Design							
Breadth Study I	1i	Contact Engineer							
	1ii	Assess Façade Design							
	1iii	Analyze Energy Efficiency							
	1iv	Analyze Constructability							
	2i	Compare Energy Efficiency							
	2ii	Compare constructability							
Breadth Study II	1i	Determine Expansion Construction Methods							
	2i	Compare Labor							
	2ii	Analyze Construction Safety							
		Finalize Report							
		Final Presentations							

TASK			March 1-5	March 8-12	March 15-19	March 22-26	March 29-2	April 5-9	April 12-16
Structural Depth	1i	Contact Engineer							
	1ii	Research Construction							
	1iii	Assess Information							
	2i	Perform Load Analysis							
	2ii	3D Modeling							
	2iii	Modify Model							
	2iv	Analyze Structure							
	3i	Dynamic Analysis							
	4i	Modify Lateral Design							
Breadth Study I	1i	Contact Engineer							
	1ii	Assess Façade Design							
	1iii	Analyze Energy Efficiency							
	1iv	Analyze Constructability							
	2i	Compare Energy Efficiency							
	2ii	Compare constructability							
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