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Structural Option
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Thesis Proposal

Executive Summary

The Swedish American Hospital's new Heart and Vascular Center is a 4 story steel structure located in Rockford, IL, west of Chicago. The original design was a 7 story patient facility that was to be constructed in two phases. The first phase was the construction of the existing 4 story structure with mechanical units located on the roof. The second phase includes enclosing the roof and mechanical units into a 5th story and the addition of two more stories above. Each floor is approximately 25,000SF of composite steel and metal deck.

The original 7 story design is based on a "Certificate of Need" requiring the space to be designed to accommodate a specified number of patients based on the future population of the Rockford area. Although the idea of studying the cost savings from the design and construction of only the existing 4 story structure was expressed, it would not satisfy the requirements of the "certificate of need". Therefore, it is proposed to study an economic alternative to the existing floor framing layout and lateral resisting system for the full 7 story structure. A cost/benefit analysis will be completed comparing the construction of the building in one and two phases.

To determine the validity of this thesis, an analysis of alternative framing plans and lateral systems will be completed. The use of computer modeling software, ETABS, will assist in the detailed analysis of various structural systems. A specific study of the column base plate connections at the foundation will be completed to determine the rigidity of the connection in an attempt to help control the overall drift of the structure.

In conjunction with this thesis, two breadth studies will be completed focusing on the façade of the building and construction of the project. The façade study will focus on the architectural panels and precast lintel areas surrounding the windows in the patient rooms. Swedish American provided information of an existing thermal and moisture problem typically observed around the base of the window sills. At the conclusion of this study, a repair will be designed and repair documents will be submitted. The construction management study will research the constructability, construction schedule and cost savings of the final alternative framing plan and lateral system chosen for the Heart Hospital. From the construction schedule, a critical path will be followed to determine what affect the structural framing has on the overall construction time of the project.

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Structural System Overview

Introduction:

The Swedish American Hospital, located in Rockford, IL, is phase 2 in a 3 phase construction project on the Swedish American Health Center. Phase 2 ended with the completion of the 4 story Heart Hospital (see figure above). The Heart Hospital is designed for a total of 7 floors of patient wings based on a Certificate of Need for the city of Rockford and the surrounding areas. Phase 3 of the construction process is to frame in the existing roof of the Heart Hospital creating a 5th floor (functioning as a mechanical floor) and continue on to complete the 6th and 7th floors above. This report will analyze the lateral framing of the initial 7 story design.

Floor System:

The typical building floor framing system is made up of beams and girders acting compositely with a concrete floor slab. Floor sections show 3"-20 gauge LOK Floor galvanized metal deck with 3¼" of lightweight concrete (110 pcf) resting on the steel framing below. Composite action is achieved through 5" long ¾" diameter shear studs welded to the steel framing. Concrete is reinforced with 6x6-W5xW5 welded wire fabric. The span of the metal deck varies depending on the bay location. However, the direction is limited to east-west or northeast-southwest. This assembly has a 2 hour fire rating without the use of spray on fireproofing.

There is no "typical" bay in the structural framing system. However, columns located on the wings are spaced approximately 22'-7 ½" on center. Columns in the interior core area are spaced approximately 32'-0" on center with additional columns located around the core perimeter framing into the wings. The most common and longest span is 32'-0". Typical beam sizes range from W12x14's (typically spanning 10' to 12') to W27x146 (spans ranging from 22' to 32') with the larger beams acting as part of the moment framing system.

Roof System:

The roof framing system is very similar to the building floor framing system. Composite design is still used with 3 ¼" of lightweight concrete and 3"-20gauge LOK Floor metal deck on top of steel framing. Deeper steel beams and girders are used to help carry the heavier loads of the mechanical equipment on the roof.

The lobby roof is slightly different from the typical roof framing. It uses composite action but has a 1 ½" deep 20 gauge metal deck spanning north-south instead of the 3" metal deck used elsewhere on the building. Lower portions of the roof that see a heavier snow loads due to drift use a 3" deep 20 gauge metal deck.

Lateral System:

The lateral load resisting system consists of steel moment frames. The majority of the moment frames extend around the perimeter of the building with a few added moment frames on the interior to help stiffen the structure. Larger girders are framed into columns with bolted flange plate moment connections. The prefabricated steel pieces were bolted in place rather than welded to eliminate the need of preheating for welds. Shear walls were not part of the original design analysis; therefore, masonry cores such as the elevator and stairwell cores were not assumed to provide lateral support during the structural analysis.

Foundation:

The basement footprint is approximately one half of the square footage of the first floor plan. Hence, there are two slabs on grade: one for the basement and one for part of the first floor. Each slab on grade is 5" thick normal weight concrete (145pcf) with 4x4-W5xW5 welded wire fabric reinforcement.

Interior steel columns rest on spread footings with an allowable soil bearing capacity of 4ksf. Exterior columns and basement walls rest on continuous strip footings. Reinforced concrete pilasters are located where exterior columns rest on the basement wall. Footings below columns in the interior core area extend approximately 18' deep whereas the perimeter strip footings and footings located beneath the wings extend approximately 8' deep. All footings are required to extend a minimum of 4' deep for frost protection.

Columns:

Columns are laid out on two different intersecting grids: one running east-west and the other running northwest-southeast. All columns are ASTM A992 Grade 50 wide flange steel shapes. Columns are spliced between the 3rd and 4th floor. Columns acting as part of a moment frame are spliced 5'-6" above the 3rd floor elevation. Columns acting only as gravity columns are spliced 4'-6" above the 3rd floor elevation. All interior columns that extend to the basement level are also spliced 5'-6" above the 1st floor elevation. Future columns for the 6th and 7th floors are designed to be spliced with existing columns at the 5th floor elevation (current mechanical floor and roof).

Codes

Original Design Codes:

- International Building Code (IBC) 2003
  - with City of Rockford, IL amendment
- American Society of Civil Engineers (ASCE)
  - ASCE 7-02 - Minimum Design Loads for Buildings and Other Structures
- American Concrete Institute (ACI)
  - ACI 318-02 - Building Code Requirements for Structural Concrete
  - ACI 530-02 – Building Code Requirements for Masonry Structures
- American Institute of Steel Construction (ASIC)
  - LRFD 1999 - Load and Resistance Factor Design Specification for Structural Steel Buildings
  - AISC 341-02 – Seismic Provisions for Structural Steel Buildings

Thesis Design Codes:

- International Building Code (IBC) 2006
- American Society of Civil Engineers (ASCE)
  - ASCE 7-05 - Minimum Design Loads for Buildings and Other Structures
- American Concrete Institute (ACI)
  - ACI 318-05 – Building Code Requirements for Structure Concrete

Material Strengths

Concrete:

Normal Weight Concrete (columns, walls, foundations, slabs on grade)……..…4000psi
Light Weight Concrete (floor slabs on metal deck)………………………………4000psi
Reinforcement ………………………………………………………………60ksi

Structural Steel:

Wide Flanges and Channels ……………………………………………………...50ksi
Angles, Bars and Plates…………………………………………………………...36ksi
Hollow Structural Sections (HSS)……………………………………………….. 46ksi
Bolts (A325X or A490X)………………………………………………………3/4"dia
Shear Studs (5"long)……………………………………………………… 3/4"dia

Masonry:

Design Strength (F'_m)……………………………………………………….2000psi
Block…………………………………………………………………………...4000psi

Framing Plans

Typical Framing Plan:

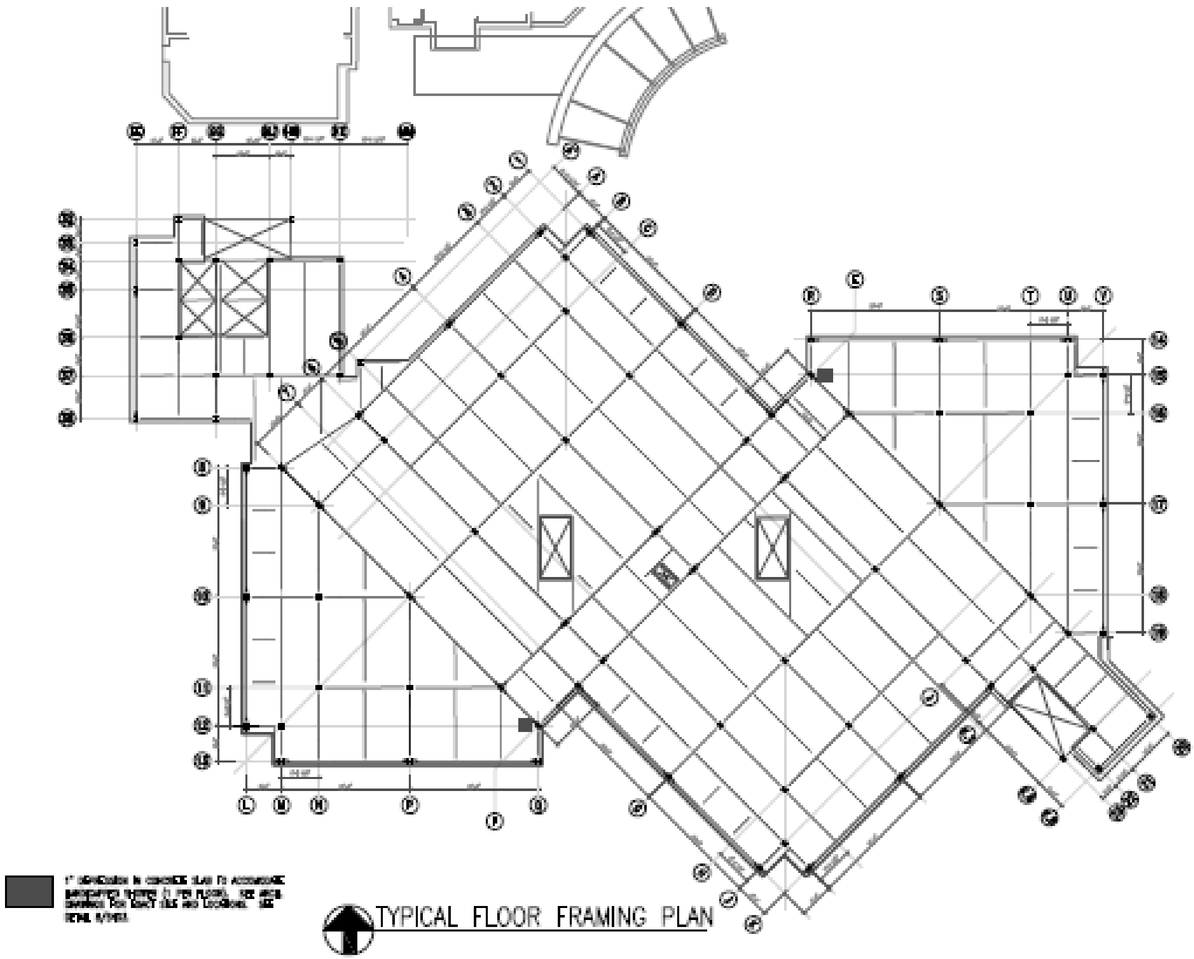


Figure 1: Typical Framing Plan

Lateral Framing Plan:

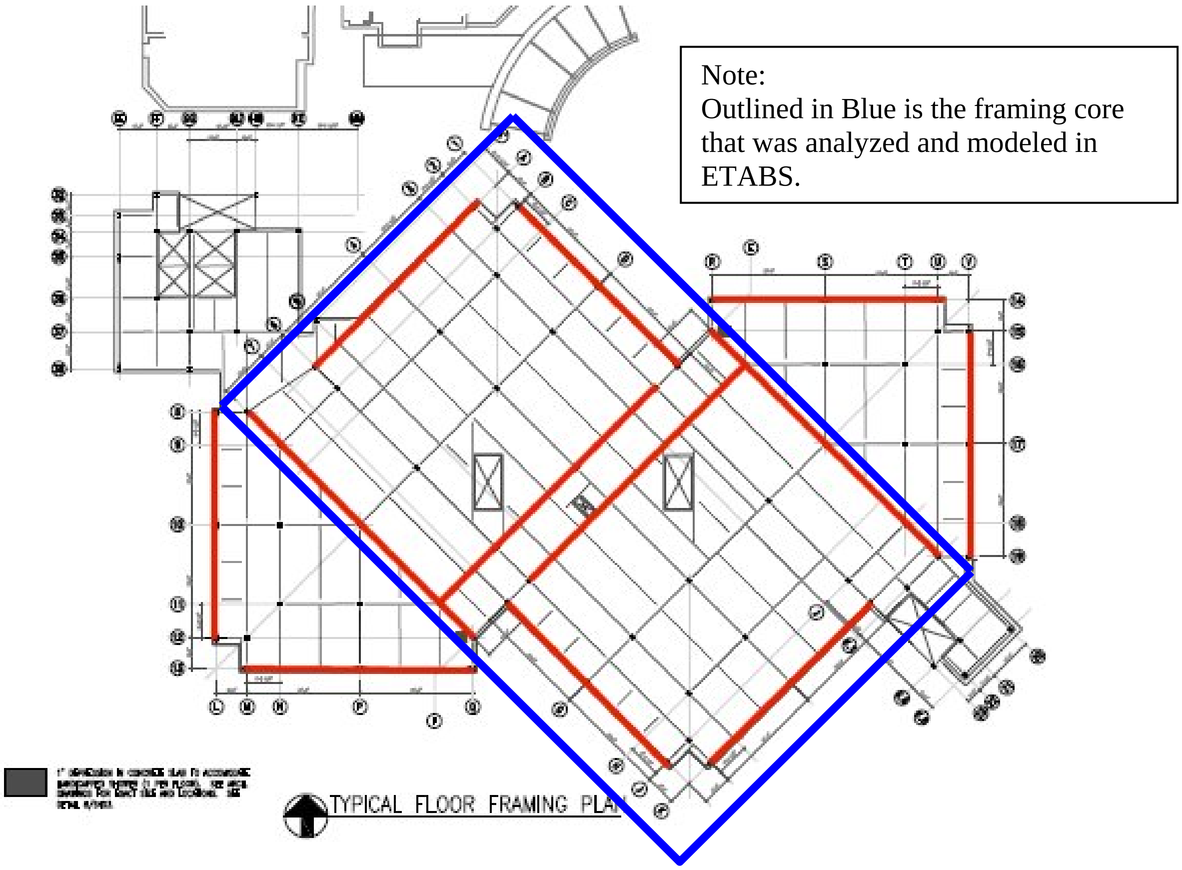


Figure 1: Framing Plan with Highlighted Moment Frames
*Typical moment frames are outlined in RED.

ETABS MODEL

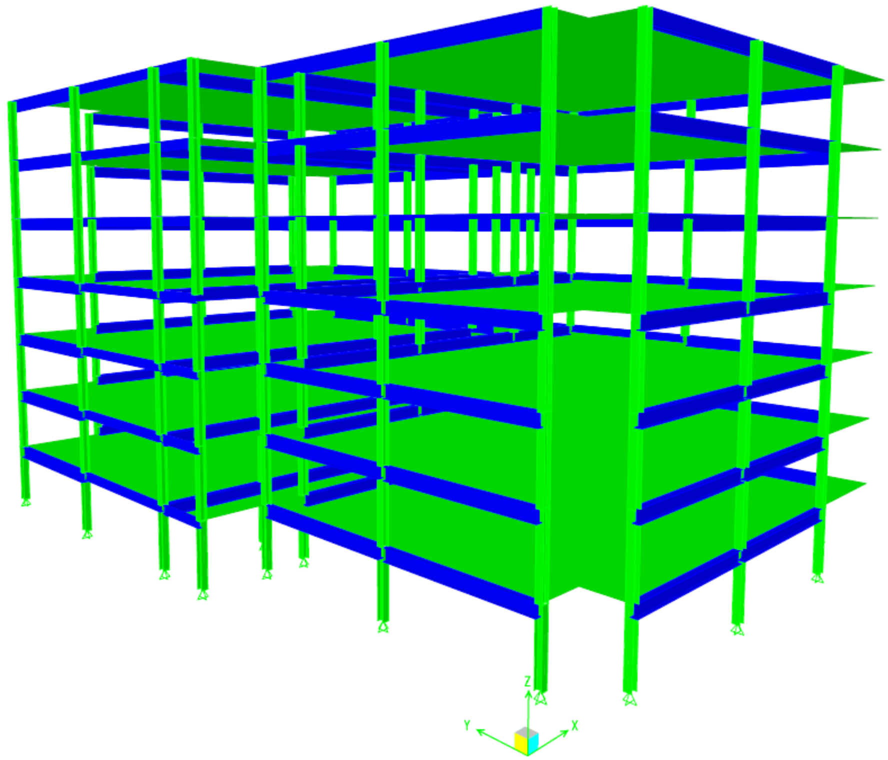


Figure 2: 3D Model of building with Floor Diaphragms

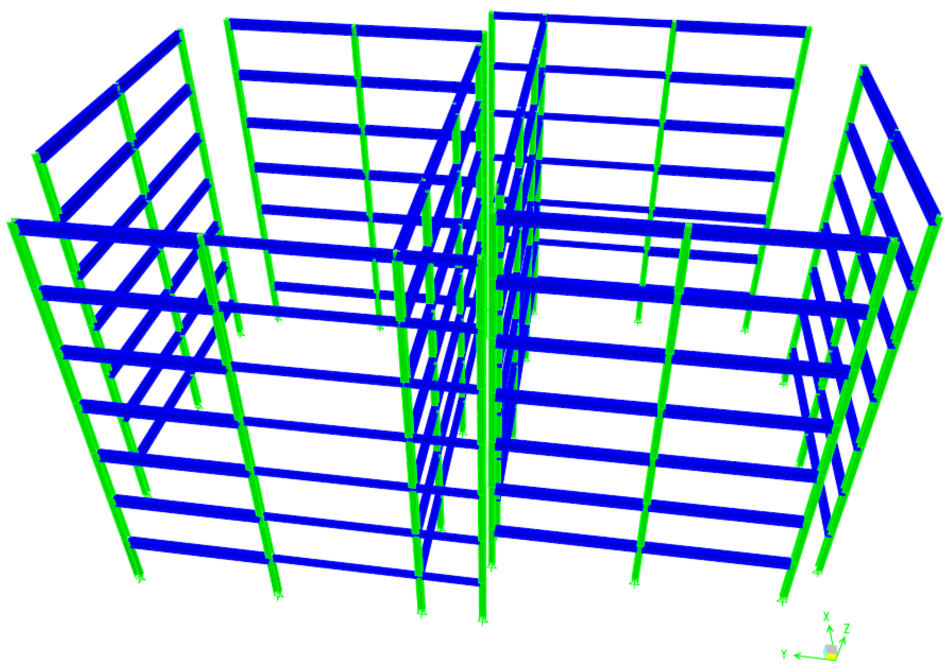


Figure 3: 3D Model of building without Floor Diaphragms

Problem Statement

The Swedish American Hospital's new Heart and Vascular Center is currently a 4 story steel framed structure located in Rockford, IL. The completion of the 4 story structure was the end of phase 2 in a 3 phase construction project on the Swedish American Campus. The original design for the Heart Hospital was a 7 story structure with a large mechanical space located on the 5th floor (the current roof area). The completion of the final 3 stories will be phase 3 of the construction plan.

The initial design for 7 stories is based on a "Certificate of Need" for the city of Rockford and the surrounding area. This requires the hospital to provide space for a certain number of patients stated in the certificate. However, the "certificate of need" takes into account a future prediction of the growing population in that area. In the case of the Heart Hospital, other nearby hospitals would be able to accommodate any increase in patients due to an increased population growth. Hence, they only constructed the hospital to accommodate a certain number of patients based on the current population of the surrounding area.

In a conversation with Swedish American Facilities Manager, Glenn Evans, the idea of studying the significant structural changes between designing the original 7 story structure and the current 4 story structure was expressed. However, the 4 story structure would not meet the "certificate of need" requirements set by the city of Rockford.

Instead, this thesis will research alternative framing methods and lateral resisting systems in an attempt to reduce the total cost and/or construction time for the full 7 stories of the Swedish American Heart Hospital. Following the most up to date codes (ASCE 7-05, IBC 2006, ACI 318-05) and computer modeling software (ETABS), it will be determined if a change in the structural framing layout or lateral system could provide an economic alternative to the existing structure.

Problem Solution/Method

For the structural framing layout, two viable alternative framing plans have already been studied briefly. They are a post-tensioned concrete floor plate and an alternative composite steel framing layout. A cost/benefit analysis between a post-tensioned concrete system and a steel system will be studied further with the help of a local construction management firm that was involved in initial construction project (local to Rockford). The structural engineer of record will also be asked for his opinion on framing designs and materials.

Assuming steel was chosen for a specific reason for the floor framing, other composite steel framing plans will be analyzed and determined if they would be a feasible alternative to the existing system. One possible solution is minimizing the number of gravity columns. By eliminating "unnecessary" columns, longer spans would be created requiring larger members. However, I believe increasing the size of a few beams and reducing the number of columns would decrease the overall building weight and possibly decrease construction time.

When designing the lateral resisting system, the incorporation of shear walls or structural core areas (surrounding the stairs or elevators) will be analyzed to determine the additional stiffness they provide to the structure. Other lateral systems may also be modeled using the computer software to determine if they are a viable solution to the existing moment frames (braced frames, etc).

Another adjustment to the lateral system that must be studied is the column connection at the foundations. The initial design assumption was that the columns were pinned at the base to create a conservative design. However, drift deflections due to wind were found to exceed the industry accepted H/400 approximation. Allowable moments at the base plate will be calculated to determine if the connection is capable withstanding the plastic moment capacity of the beam, and if the connection can be accurately modeled as a fixed connection in the computer model.

Breadth Options

Along with the main study of alternative economic framing plans and lateral systems, two breadth studies will also be completed. They include a study of the Heart Hospital's façade and a construction management study focusing on the cost savings and scheduling impact of the alternative framing plan/lateral system deemed acceptable.

The façade study will focus on the architectural wall panels and precast lintels surrounding the windows at the patient rooms. It was expressed to me, in a conversation with Glenn Evans, that Swedish American was experiencing thermal and moisture issues around and below the sill area of the window units. (See Appendix A for details) I will study the details provided in the plans and seek the help of industry professions with this specialty to develop a reasonable solution and repair for this problem. If able, time permitting, I will develop a set of drawings or sketches to repair the problem.

The façade study will also tie into the construction management study. I will complete a cost analysis of the repair and develop a rough construction schedule for the repair work to be done. This study will also research the constructability, construction schedule and cost savings of the final alternative framing plan and lateral system chosen for the Heart Hospital. A cost/benefit analysis will be completed comparing the construction of the building in one phase and two phases. From the construction schedule, a critical path will be followed to determine what affect the structural framing has on the overall construction time of the project.

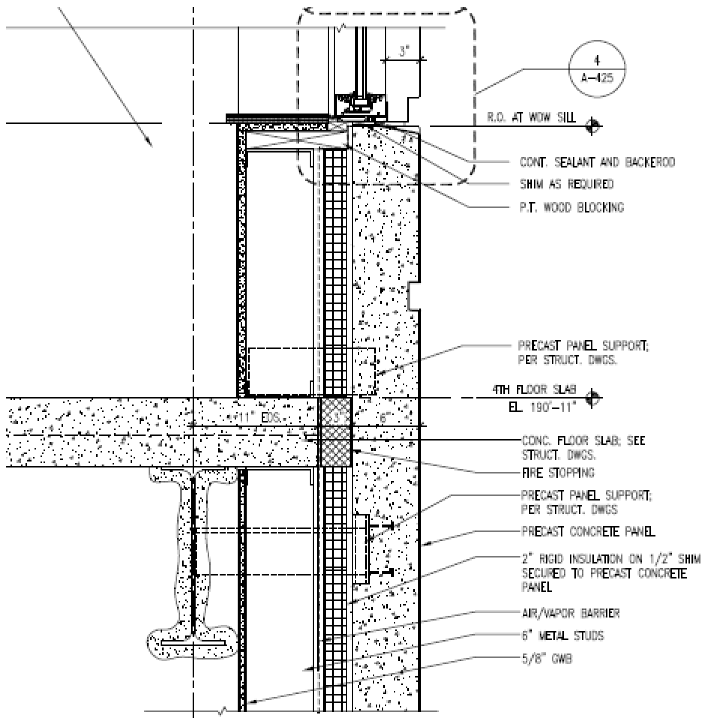
Timetable

	Week -1	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9
Determine Feasibility of Conc./Steel Floor Systems		C								S
Determine Loads		L								P
Formulate Alternative Framing Plans		A								R
Explore Alternative Lateral Systems		S								I
Create ETABS Model		S								N
Analyze Model and Compare to Original Design		E								G
Analyze Detailed Drawings/Specs of Window Units		S								
Compare Bid Drawings to Existing Condition (if available)		B								B
Develop Repair/ Repair Drawings		E								R
Develop Construction Schedule		G								E
Compare Cost Savings		I								A
Print and Prepare for Presentation		N								K

	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17
Determine Feasibility of Conc./Steel Floor Systems					P			F
Determine Loads					R			I
Formulate Alternative Framing Plans					E			N
Explore Alternative Lateral Systems					S			A
Create ETABS Model					E			L
Analyze Model and Compare to Original Design					N			S
Analyze Detailed Drawings/Specs of Window Units					T			
Compare Bid Drawings to Existing Condition (if available)					A			W
Develop Repair/ Repair Drawings					T			E
Develop Construction Schedule					I			E
Compare Cost Savings					O			K
Print and Prepare for Presentation					N			

Appendix A

Detailed Sections of Window Sill at Architectural Precast Wall Panel



SECTION DETAIL AT WINDOW / WDW SEAT

1 1/2" = 1'-0"