House of Sweden

Thesis Proposal

2900 K St. NW
Washington, DC 20007

The Pennsylvania State University
Department of Architectural Engineering
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EXECUTIVE SUMMARY

House of Sweden is located in Georgetown, Washington, D.C. This development is a single foundation with two towers rising from the site. It is a multi-use facility housing the Swedish Embassy, along with office, commercial, and residential spaces. Seven levels exist in the north building and six in the south. The primary structural system is a two-way post-tensioned slab with drop panels. Shear walls exist in the north building for lateral support, but both the north and south buildings are concrete moment frames.

Depth Study: Steel Re-design of the Structural System

During Technical Report II, A Structural Study of Alternative Floor Systems, it was found that a composite deck and beam system might prove to be a viable alternative for the building. This system has comparable slab depth and overall cost, and it is more easily constructed than the post-tensioned. Steel as a solution is also able to cut down on the floor weight by approximately half, which will lead to a reduction in seismic base shear and may cause wind to control the design of the lateral system. A look at moving the mechanical equipment from the penthouse to the basement or a sub-basement will also be considered. This is proposed as two alternatives. Alternative I, the system will be re-designed in steel with too much loss of floor-to-floor height. The room gained from moving the mechanical system will be distributed to the floor to gain back this height. Alternative II, the system will be re-designed in steel and the existing plans remain the same. When the mechanical equipment is moved, an extra floor is gained and will need to be taken into account for load purposes.

Breadth I: In-Depth Cost and Schedule Analysis

Due to the use of steel instead of concrete, curing time and formwork construction time is eliminated, but procurement time may increase and must be considered. The impacts of the re-design on the schedule and project cost will be analyzed to determine if this is an economical alternative to the current system. General contractors, sub-contractors, and vendors will be consulted to ensure this is as realistic as possible.

Breadth II: Mechanical Equipment Movement Analysis

Moving the mechanical equipment will impact many different parts of the building, along with possibly impacting the occupants. Impacts to the foundation will be studied, along with vibration and acoustic considerations for the occupants if time permits. A look at the waterproofing will occur and be detailed for construction. A parking study will be conducted to find a location for the mechanical equipment on the parking level. From this study, conclusions can be drawn as to the viability of the move.

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INTRODUCTION

This Thesis Proposal contains a description of the physical conditions currently existing in the House of Sweden, including discussions on the background of the building and the gravity and lateral framing systems. It also provides a problem statement and proposed solution, along with two breadth topics. Finally, a look at the tools to be used, tasked to be completed, and a schedule for completion is presented.

BACKGROUND

House of Sweden (Cover Figure) is located in Georgetown, Washington D.C. at the intersection of Rock Creek and the Potomac River. This development is built on a single mat foundation with a parking garage level and then two separate towers rise out of the site. The south building consists of 5 stories and a mechanical penthouse; the north building is 6 stories and a mechanical penthouse. Construction of the two buildings began on August 4, 2004 and finished on May 12, 2006. It was delivered in a design-bid-build method where the design of the south building was commissioned as a competition in Sweden.

Wingardh Arkitektkontor AB completed the winning design for the south building and houses the Swedish Embassy along with an exhibit hall, convention center, rooftop terrace, and apartments. They designed this building to be “a shimmering jewel in the surrounding parkland.” To accomplish this goal, the base of the building is clad in light stone, while the upper floors are clad in glass laminated with a traditional Nordic blond wood pattern. This glass façade is backlit at night to create the illusion of the structure floating above the river.

Housed in the north building are offices and apartments, which incorporate expansive balconies and long stretches of ribbon windows to maximize exterior views. The façade employs the same type of light stone on the podium, but the upper floors are clad in metal panels. This lets the north building relate to the south building, yet keep its own identity.

Both building envelopes are steel stud construction with faced blanket insulation and gypsum wallboard attached. A standoff system is used on the north building to attach light stone panels to the podium of the building and metal paneling to the upper floors. This same standoff system is used on the south building to attach light stone paneling on the lower level. The upper levels employ a different standoff system of laminated glass panels as cladding. None of these cladding systems are used as a barrier system, which is why the insulation is faced to prevent moisture penetration.

STRUCTURAL SYSTEM DISCUSSION

Foundation

Cast-in-place piles support a mat foundation. These piles are 16” in diameter with a concrete compressive strength of f'_c = 6,000 psi and exist under the north perimeter of the parking garage. The mat foundation exists over the entire parking garage. It is a minimum of 38” thick, and 42” at the columns with a concrete compressive strength of f'_c = 4,000 psi and rests on a 2” thick mud slab. It is reinforced with rebar varying from #18 bars to #6 bars and at a variety of spacings. This foundation is either set on the piles at the north perimeter, or held with tie-downs. Columns from both the north and south buildings will be supported on the mat foundation.

Framing System

House of Sweden is located in Georgetown, Washington, DC; therefore, the use of a post-tensioned concrete structural system was an obvious choice to help minimize the slab thickness and maximize the number of floors. Most of the floors above grade are two-way post-tensioned concrete flat slabs.

The north building has 6 levels above grade. The first floor slab is a 9”-10.5” thick reinforced with #4 and #5 bars and the drop panels are 5”, 8”, or 10” thick and reinforced with #7 and #8 bars. The second through sixth floors are 7”-8” thick with drop panels reinforced with #5 and #6 bars. Typical concrete strength on these floors is 6 ksi or 8 ksi. Concrete strength and slab thickness vary on each floor, which means that the slabs were not placed as single, monolithic pours and they had to be completed in sections. Because of the irregular building shape, there is no typical bay spacing, although many bays were kept at 30’ x 30’, possibly accounting for the change in slab strength and thickness.

The south building has 5 levels above grade. The first floor slab is a 9”-12” thick reinforced with #4-#6 bars and the drop panels are 8”, 10”, or 12” thick and reinforced with #6- #9 bars. The second through fifth floors are 10”-12” thick with drop panels reinforced with #5 and #6 bars. Typical concrete strength is 6 ksi or 8 ksi. Concrete strength and slab thickness vary on each floor, which means that the slabs were not placed as single, monolithic pours and they had to be completed in sections. Because of the irregular building shape, there is no typical bay spacing, although many bays were kept at 32' x 22', possibly accounting for the change in slab strength and thickness.

The penthouse roof of the north building is similar to the floor slabs. It is a two-way, post-tensioned slab, 7" thick with a concrete strength of 6 ksi. It has drop panels reinforced with #4 and #5 bars. This roof was designed to hold a 30 psf snow load, plus snow drift load around the mechanical equipment.

The main roof of the south building is similar to the floor slabs. It is a two-way, post-tensioned slab, 10" or 12" thick with a concrete strength varying from 6 ksi to 8 ksi. The drop panels are reinforced with #5 and #6 bars. This roof was designed to hold a 30 psf snow load plus snow drift load around the mechanical equipment and the penthouse to the north. Since the south half of the roof has a convention space, it was designed to hold a 100 psf terrace load plus a 25 psf paver load.

Roof System

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Lateral System

Slab-column concrete moment frames make up the lateral system of the north building. This system resists lateral loads in the north-south and east-west direction depending upon the orientation of the frame. Shear walls exist in the north building extending from the first floor to below the fifth floor slab. These walls were added to help alleviate the lateral forces induced in the sloped columns. These walls vary in width and are 8 " or 12" thick with concrete strength of 6 ksi reinforced with #4 bars at 12" spacing in two curtains. They were not added to be part of the lateral system to resist wind or earthquake loading, however, by their very nature, they have become part of this system. Refer to Figure 1. for a layout of the columns and shear walls that contribute to the lateral load resisting system in the north building.

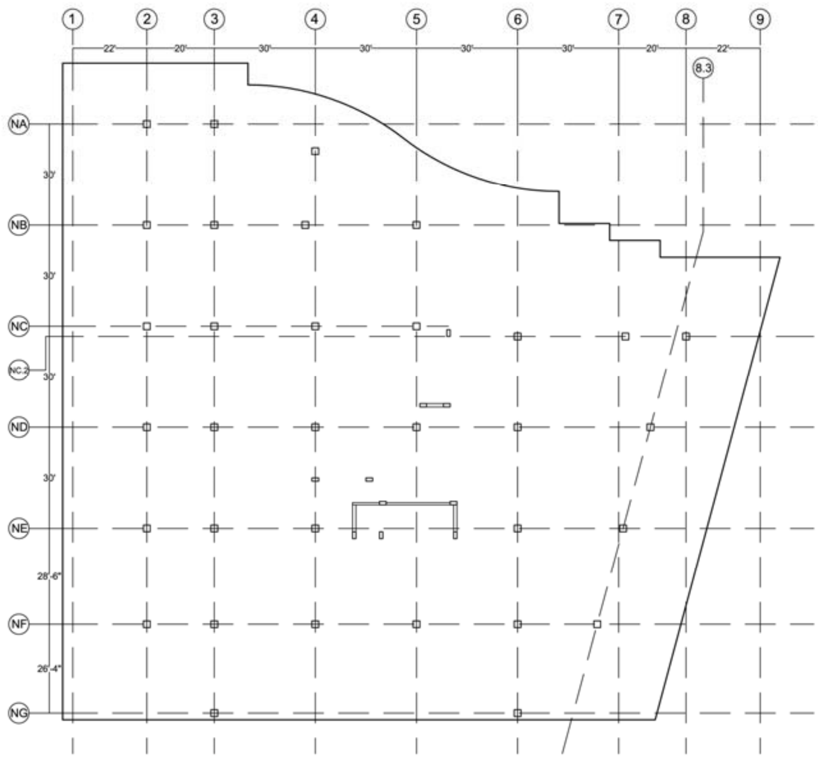

Figure 1. Typical North Building Column and Shear Wall Layout

The south building has a slab-column concrete moment frame to resist lateral loads in both the north-south and east-west directions. No shear walls were necessary in this building because of the lack of sloped columns and the fact that this is a low-rise building and shear walls are not normally present in this type of building in the Washington, DC area. Refer to Figure 2. for a layout of the columns that contribute to the lateral load resisting system in the south building.

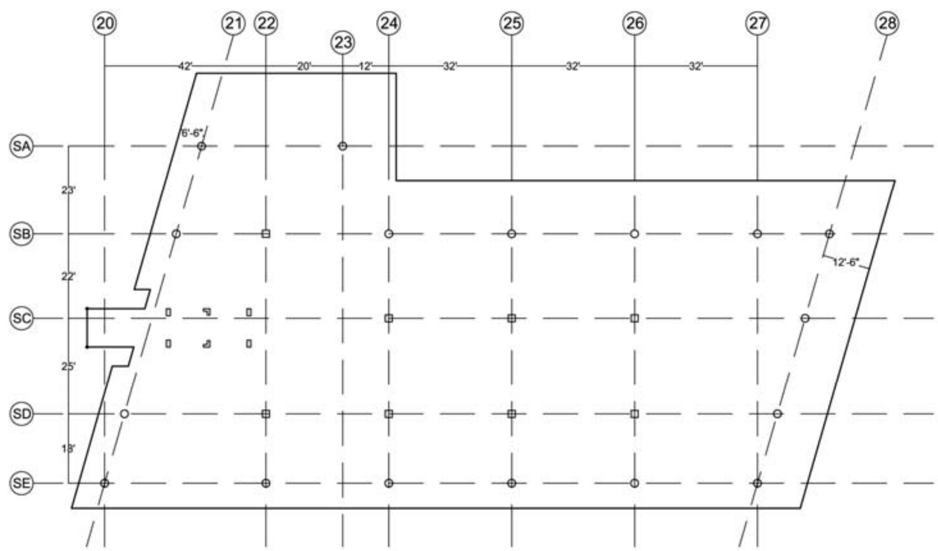

Figure 2. Typical South Building Column Layout

Lateral loads imposed on the buildings are distributed through the following load path and the loads are distributed by relative stiffness, which was discussed in Technical Report III:

1. Exterior glass curtain wall
2. Perimeter slab
3. Concrete moment frames (and shear walls in the south building)
4. Mat slab foundation

PROPOSAL

Problem Statement

In its current design, the House of Sweden is a post-tensioned concrete multi-use facility. The post-tensioned design was a solution to the restricted building height in the Washington, D.C. Metro area. However, during Technical Report II, A Structural Study of Alternative Floor Systems, it was found that a composite deck with composite beam system might prove to be a viable alternative for the building. This system has comparable slab depth and overall cost with the original, and is more easily constructed than the post-tensioned concrete due to the elimination of formwork and curing and stressing time. Steel, as a solution, would also cut down on the floor weight by approximately half, leading to a reduction in seismic base shear and may cause wind to control the design of the lateral system.

Another point of interest is the location of the mechanical room in the north building. The entire penthouse of this building is utilized as the mechanical space. It is noted in the background section of this report that the House of Sweden is located at the intersection of Rock Creek and the Potomac River in Georgetown, Washington, D.C. and the penthouse is the prime real estate in this particular building. An alternative area for the mechanical equipment will be proposed while attempting to keep the architectural layout of the rentable space in mind.

Proposed Solution

As stated above, a proposed solution to the constructability of the design will be to re-design the north building in steel. This building is the tower with a twenty-two foot cantilever, so an economical solution to this will need to be considered during the re-design process. There are two different alternatives to this re-design that will also take into account the prime real-estate space of the penthouse:

Alternative1: Re-design with a floor sacrifice

The first option for the re-design is to complete this design of the gravity system of the building in steel and re-design the lateral system in steel. The gravity system will look at the use of castellated beams and lightweight or normal weight concrete with moment frames or braced frames for the lateral system. The most economical combination will be used. When this occurs, it is found that the floor-to-floor height that results is insufficient for the architectural requirements. If this occurs, a parking study will be conducted for the ground floor parking garage to see if space can be created on that floor to house the mechanical system. If it cannot, create a sub-basement for the mechanical equipment. Then, remove a story above grade and the height will be distributed to the floors to account for the loss in floor-to-floor height due to the re-design.

For this alternative, as discussed above, the weight of the building will most likely decrease and the wind load cases may control the design of the lateral system. Also, the impact on the foundations will need to be considered, along with acoustical and vibration problems that might occur by moving the mechanical system. It is possible that the mechanical system might be optimized now that the main mechanical room will be in the middle of the two towers as opposed to currently being housed at the top of the north tower. Scheduling and cost impacts should also be considered.

Alternative 2: Re-design and gain a floor

The second option for the re-design progresses in the same way as the first, the only difference is the gain of a floor. The design of the gravity system of the building in steel and re-design of the lateral system in steel will be completed. The gravity system will look at the use of castellated beams and lightweight or normal weight concrete with moment frames or braced frames for the lateral system. The most economical combination will be used. When this occurs, it is found that the floor-to-floor height that results is sufficient for the architectural requirements. A parking study will still be conducted for the ground floor parking garage to see if space can be created on that floor to house the mechanical system. If it cannot, a sub-basement for the mechanical equipment will be created. Then, the extra floor that is created by this move will be analyzed as an extra apartment floor.

For this alternative, as discussed above, the weight of the building will most likely decrease and the wind load cases may control the design of the lateral system. The same impacts will need to be taken into account as well. The impact on the foundations will need to be considered, along with acoustical and vibration problems that might occur by moving the mechanical system. It is possible that the mechanical system might be optimized now that the main mechanical room will be centered under the two towers as opposed to currently being housed at the top of the north tower. Scheduling and cost impacts should also be considered.

MAE Option

Also considered in this re-design will be the use of computer models to supplement design. This computer model will take into account information learned from the Computer Modeling of Building Structures masters-level course. This model will at least be used for aiding the design of the lateral-force-resisting system. Using semi-rigid diaphragms for the floors, and 3-D beam and column elements that take into account flexural, shear, axial, and panel zone deformations, the lateral force analysis will consider inherent and accidental torsion, as well as P-Delta effects.

BREADTH OPTIONS

Breadth Study 1: In-Depth Cost and Schedule Analysis (CM)

This breadth study will focus on the scheduling impact and cost-related issues that will be impacted by the proposed structural changes. The notable scheduling changes would involve the additional time that might be needed to excavate for a sub-basement level if it is needed. Also, the different procurement and erection times will need to be considered for the steel design, instead of post-tensioned concrete.

Cost analyses will be conducted separately for the increased revenue that might be possible if an extra story is gained and the additional cost of labor and materials to implement the proposed building alterations. Additionally, the impacted construction time will be considered before directly comparing revenue to cost. The owner is unable to profit from a building until construction is complete so small revenue gains may not outweigh scheduling delays.

Professionals in the field will be contacted to help provide industry and area specific cost and scheduling information instead of just using RS Means as the only source of information.

Breadth Study 2: Mechanical Equipment Movement Analysis (Architecture)

This breadth study will focus on the movement of the mechanical equipment to the basement or sub-basement. First, the mechanical equipment will need a way to draw outside air to condition the spaces. It needs to be determined that Washington, D.C. will allow sub-grade mechanical equipment. Then, an architectural study of parking will be conducted. Waterproofing is another issue due to the high water table next to the river. This will also be considered and detailed for the move.

Depth Related Study

If the extra floor is a viable option, a brief study will be performed to ensure that it is possible for the building to house and supply the additional mechanical and electrical load and equipment. Also, if time permits, a brief study on the effects of the mechanical equipment move on the occupants will be completed including acoustic and vibration effects on the floors above.

TASKS AND TOOLS

1. Re-design of Gravity and Lateral System: Alternatives 1 & 2

Task 1: Conduct initial research

a) Confirm use of castellated beams vs. wide flange beams.

b) Confirm presence, location, and dimensions of sloped columns.

c) Determine if Washington, D.C. allows sub-grade mechanical equipment.

d) Determine if lightweight concrete is available in Washington, D.C.

Task 2: Confirm all superimposed and gravity loads, according to ASCE 7-05

a) Check and revise all calculations for the gravity and superimposed loads.

b) Consult with the structural engineer for confirmation.

Task 3: Establish and check trial member sizes

a) Design trial gravity member sizes based off gravity loads.

b) Determine which alternative will be used.

c) Revise gravity calculations and trial gravity member sizes to reflect alternative to be used.

d) Establish lateral loads based off trial member sizes.

e) Design trial lateral system based off trial lateral loads.

f) Re-check gravity system and check lateral system based off the established lateral loads.

g) Re-design as necessary.

Task 4: Analyze lateral system

a) Create a computer model of the designed lateral system and assess system design based off of shear, overturning moment, building and story drifts and displacements, and fundamental periods. A key aspect of this task is to determine the placement of the braces so as to not interfere with the floor layout. It is also to determine which combination of materials and lateral system is to be used.

b) Determine if results are acceptable for service criteria and re-design lateral system as necessary.

c) If lateral system re-design is necessary, re-check the design of the gravity system to ensure no changes are needed.

Task 5: Consider implications of design

a) Conduct a parking study for the basement floor.

b) Determine where the mechanical system will be placed in the building.

c) Re-design the foundation for the changes implemented.

d) Make minor adjustments to the architecture and floor layout as required.

2. In-Depth Cost and Schedule Analysis

Task 1: Schedule and cost impact

a) Use RS Means as a starting point for the impacts of the re-design.

b) Consult with the general contractor on the project team and some subcontractors from the area for more in-depth schedule and cost impacts.

c) Contact vendors and suppliers of the steel to decide on procurement and erection timing and cost implications.

3. Mechanical Equipment Movement Analysis

Task 1: Equipment movement impact

a) Determine placement of equipment and how outside air will be drawn.

b) Re-design the location of the ductwork.

c) Research waterproofing implications of the movement of the mechanical equipment and detail the waterproofing for the mechanical room.

d) If time permits, conduct an acoustic and vibrations study and the impacts on occupants and suggest ways to mitigate any issues that may arise.

4. Miscellaneous

Task 1: Final submissions

a) Write and organize final report.

b) Organize faculty jury presentation.

SCHEDULE

Tasks	Break Dec. 22-Jan.10	Week 1 Jan. 11-17	Week 2 Jan. 18-24	Week 3 Jan. 25-31	Week 4 Feb. 1-7	Week 5 Feb. 8-14	Week 6 Feb. 15-21	Week 7 Feb. 22-28	Week 8 Mar. 1-7
1.1-a									
1.1-b									
1.1-c									
1.1-d									
1.2-a									
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1.3-a									
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1.4-a									
1.4-b									
1.4-c									
1.5-a									
1.5-b									
1.5-c									
1.5-d									
2.1-a									
2.1-b									
2.1-c									
3.1-a									
3.1-b									
3.1-c									
3.1-d									
4.1-a									
4.1-b									

Milestones are denoted by heavy lines between the weeks. Refer to the list of tasks for a listing of items.

Tasks	Week 9	Week	Week	Week	Week	Week	Week	Week	Week
	Mar. 8-14	Mar. 15-21	Mar. 22-28	Mar. 29-Apr. 4	April. 5-11	Apr. 12-18	Apr. 19-25	Apr. 26-May 2	May 3-May9
1.1-a	Spring Break – No Classes					Presentation to Faculty Jury			Final Exams
1.1-b									
1.1-c									
1.1-d									
1.2-a									
1.2-b									
1.3-a									
1.3-b									
1.3-c									
1.3-d									
1.3-e									
1.3-f									
1.3-g									
1.4-a									
1.4-b									
1.4-c									
1.5-a									
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2.1-c									
3.1-a									
3.1-b									
3.1-c									
3.1-d									
4.1-a									
4.1-b									

Milestones are denoted by heavy lines between the weeks. Refer to the list of tasks for a listing of items.