

Thesis Proposal

Nemours Children's Hospital as a part of The Nemours Foundation



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Structural Option

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Executive Summary:

Nemours Children's Hospital as a part of The Nemours Foundation (NCHTNF) is a 7-story building located in Orlando, Florida. The entire complex consists of a hospital, clinic, loading dock data center, central energy plant (CEP), and parking facility. The 600,000 square foot hospital consists of two components: a bed tower and outpatient center. The combined components will provide 85 beds, emergency department, diagnostics and ambulatory programs, educational and research centers, and an outpatient clinic. Stanley Beaman & Sears and Perkins + Will are the architects of the project. Harris Civil Engineers, Simpson Gumpertz & Heger, AECOM, and TLC Engineering for Architecture are responsible for the engineering design of NCHTNF. Skanska USA Building is acting as the construction manager and general contractor of the design-bid-build project, which is scheduled to be completed July 2012 after ground was broken July 2009.

The proposed thesis is a redesign of the lateral system using intermediate concrete moment frames along with concrete shear walls instead of the current concrete shear walls. This will create a more open floor plan by reducing the amount of shear walls required. This design might require less concrete than the current system, but further analysis will need to be performed to determine this. The weight of the building will change, so a seismic analysis and foundation analysis will need to be evaluated.

Additionally, a flat plate system or one-way slab with beams will be considered rather than the current flat slab system. The flat plate system or one-way slab with beams will eliminate the drop panels, which is more cost effective for the formwork of the slab system. The flat plate system and one-way slab will be compared to determine which alternate floor system is most economical. That alternate system will then be compared to the flat slab system to determine which system is the most effective.

In addition to the lateral and floor system redesign, two breadth topics will be explored. One of those is a cost and schedule analysis of the redesign of the structure and the alternate floor system. This will determine if the redesign is the more economic option. The second breadth topic will examine an alternate façade system for energy efficiency purposes. Construction time and life span of the design will also be considered when determining the most efficient design.

Building Introduction:

NCHTNF is a 7-story building located in Orlando, Florida, shown in Figure 1. The entire complex consists of a hospital, clinic, loading dock data center, central energy plant (CEP), and parking facility. The 600,000 square foot hospital consists of two components: a bed tower and outpatient center. The combined components will provide 85 beds, emergency department, diagnostics and ambulatory programs, educational and research centers, and an outpatient clinic. Stanly Beaman & Sears and Perkins + Will are the architects of the project. Harris Civil Engineers, Simpson

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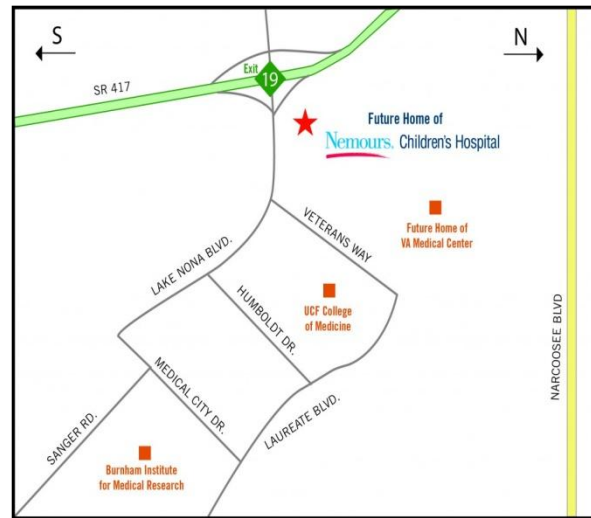


Figure 1 - Location of NCHTNF. Courtesy The Nemours Foundation

The design of this \$400 million building uses 2007 Florida Building Code with 2009 updates. The Florida Building Code is based on the International Building Code and subsidiary related codes. The building is classified as I-2 -while the clinic can be considered business class, the hospital is industrial because of overnight patients, thus making the entire project industrial. The site is an undeveloped parcel of land that underwent clearing and mass grading to reach its current topography. The site location does not have any restrictions presiding over the NCHTNF's design.

The primary structure is concrete with curtain walls dominating the majority of the façade. The glass curtain walls vary between metal sunscreen systems, frit patterns, and insulated spandrels. Other building materials include ribbed metal panel system, terracotta tile wall system, terrazzo wall panels, and composite metal panels to complement the glass systems in the curtain walls. A curved curtain wall, deep canopies, and two green roof gardens provide additional architectural features to the building design.

NCHTNF is designed to withstand the effects of a category 3 hurricane. The National Oceanic and Atmospheric Administration, NOAA, describes a category 3 hurricane as an event where devastating damage will occur, resulting in injury and death. The Nemours Foundation wants NCHTNF to be listed as a place of refuge, more technically known as an Enhanced Hurricane Protection Area, during a category 3 hurricane. This requires the building's design to at least meet NOAA's classification of a category 3 hurricane, having sustained winds of 111-130 mph. To qualify as an Enhanced Hurricane Protection Area, the hospital is designed to these standards with a factor of safety.

This results in a very extensive design for the building envelope. The modular curtain wall, constructed by Trainor, is designed with 30,000 feet of dual sealant joints to allow weeping between the two joints. A probe test is specified to be conducted after the sealant has cured to ensure the sealant joint is working properly. The north side of the building features a curved curtain wall supported by slanted structural columns. The deep canopies and frit pattern glass, acting as sunshading devices, are prevalent throughout the building, and provide adequate shading from the Florida sun. NCHTNF incorporates several different roofing systems to accommodate different functions of the roof. A fluid-applied membrane acts as the roofing system for the roof gardens that are accessible to patients. Thermoplastic membrane roofing and SBS-modified bituminous membrane roofing comprise the other roofs on the building. A mock-up of the NCHTNF has been tested in a hurricane testing lab in Florida. A 2-story 10-bay mock-up was required to pass various tests to ensure the building envelope will be able to sustain the effects of a category 3 hurricane. Laminated glass and extensive use of roof fasteners help the building envelope meet the standards of the hurricane test.

The design of NCHTNF follows the USGBC's LEED prerequisites and credits needed for certification based on LEED for New Construction 2.2. The building has two green roof gardens on the second and fourth floor roofs as mentioned in the paragraph above. The green roofs double as outdoor gardens for patients as well as sustainability features for the building. NCHTNF has numerous sunshades to block the sun from the vast glass façades. Deep canopies provide shade for large spaces on the south façade of the building. Fritt pattern and insulated spandrel glass systems are also implemented in the building's design. These devices block some of the intense Florida sun to lessen the load on the HVAC system of the building.

Structural Overview:

NCHTNF bears on spread footings on either improved or natural soils. The hospital and clinic portion of the building are predominately reinforced concrete structures, with the exception of steel framed mechanical penthouses. The loading dock data center and central energy plant are primarily steel framed structures. The lateral system is comprised of shear walls, most of which continue through the entire building height. NCHTNF has unusual framing techniques for the wave and sloped curtain wall backup.

Foundation:

PSI, the geotechnical firm, performed nineteen borings across the site in January 2009. The soils generally consist of varying types of fine sands graded relatively clean to slightly silty in composition. The boring blow counts record the upper layers of sand to be of medium dense condition, while the lower layers of sand are generally loose to medium dense condition.

PSI recommends utilizing shallow foundations only if the foundation design implements soil improvement to increase the allowable bearing capacity used in the design. PSI proposes another foundation solution, if soil improvement is not desirable implement a pile foundation system. These reinforced augercast piles will withstand a considerably higher foundation loads than the shallow foundation system. The downside of augercast piles are they can bulge or neck where very loose soils are encountered, requiring stringent monitoring and quality control. Due to the specialized nature of the augercast piles for this project, spread footings with soil improvement is chosen as the foundation system for the NCHTNF.

The fact that the water table is measured only 4 feet below the surface raises concerns about excavations. The sump system dewateres shallow excavations while deeper excavations require well-pointing or horizontal sock drains for proper dewatering.

Floor System:

NCHTNF has numerous types of floor construction due to different design requirements in different sections of the building. The building contains 5"-6" normal weight concrete as the slab on grade. A few sections of the foundation system utilize mat foundations, varying from 2' to 4'-3" normal weight concrete. The hospital and clinic are built on normal weight elevated two-way flat slabs, with and without drop panels, varying in depth from 9"-14". A typical structural floor plan detailing a typical 30'x30' bay is shown in Figures 2 and 3. The loading dock data center and central energy plant are constructed with a 4-1/2" 1-way slab on 3"-20 GA. composite metal deck, which is supported by a steel frame system. Some specialty areas, such as the green roof and the slab over the lecture hall, vary slightly from the typical slab in the remainder of the building.

There are 29 different superstructure concrete beam sizes in the NCHTNF. The beams range from 16" x 20" to 89" x 48". The hospital and clinic predominately consist of 15' x 30' bays with a few 15' x 15' and 30' x 30' bays to accommodate for the elevator and stair core. The bays in the loading dock data center are far irregular. They vary from the smallest being 21' x 30'-3" to the largest being 30' x 45' - 2". The central energy plant also has a variety of bay sizes, ranging from 22' x 11'-2" to 22' x 26'-7".

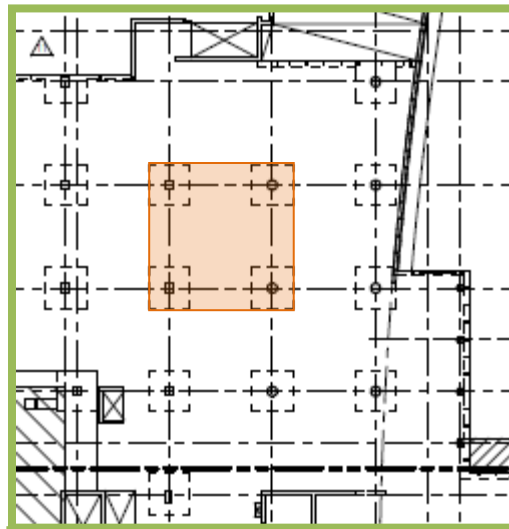


Figure 2 - Level 1 Typical Structural Bay (30'x30') Key Plan. Courtesy SGH.

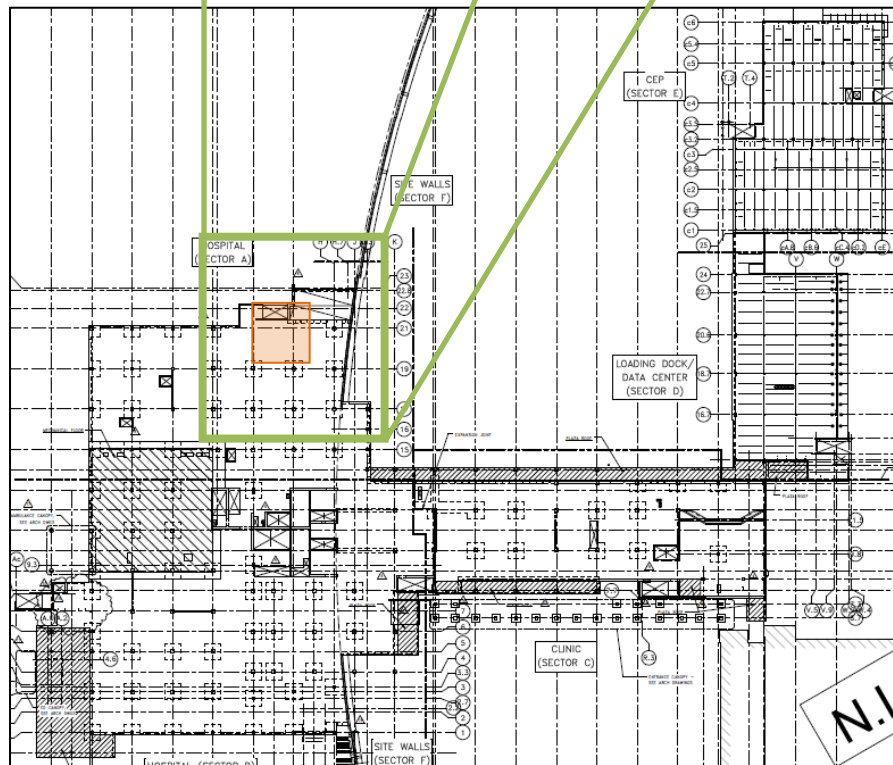


Figure 3 - Level 1 Typical Structural Bay (30'x30'). Courtesy SGH.

Framing System:

The columns supporting the NCHTNF are mostly reinforced concrete columns, with steel columns supporting the mechanical penthouses on the 7th floor. The concrete columns supporting the hospital and clinic typically start at a dimension of 30" x 30" and taper to 22" x 22" at Level 6. The mechanical penthouse is constructed with W12x53 columns on both the hospital and clinic. W14x109, W10x49, W10x60, and W14x68 mainly support the loading dock data center. HSS8x8x and HSS12x8 dominate the central energy plant's supporting structure along with a few W12x65 and W12x79 columns.

Lateral System:

Shear walls resist lateral loads in the hospital and clinic of the NCHTNF. These walls are 12-14" thick and tie into mat foundations with dowels matching the typical wall reinforcement, mostly #8 bars. The shear walls are located in the elevator/stair core in the hospital and in the elevator bays and lecture hall in the clinic, which are highlighted below in green in Figure 4. Also, the central energy plant has one shear wall, the rest of the lateral system of the CEP being braced framing which is discussed in the next paragraph. A few shear walls include knockout panels to plan for future openings.

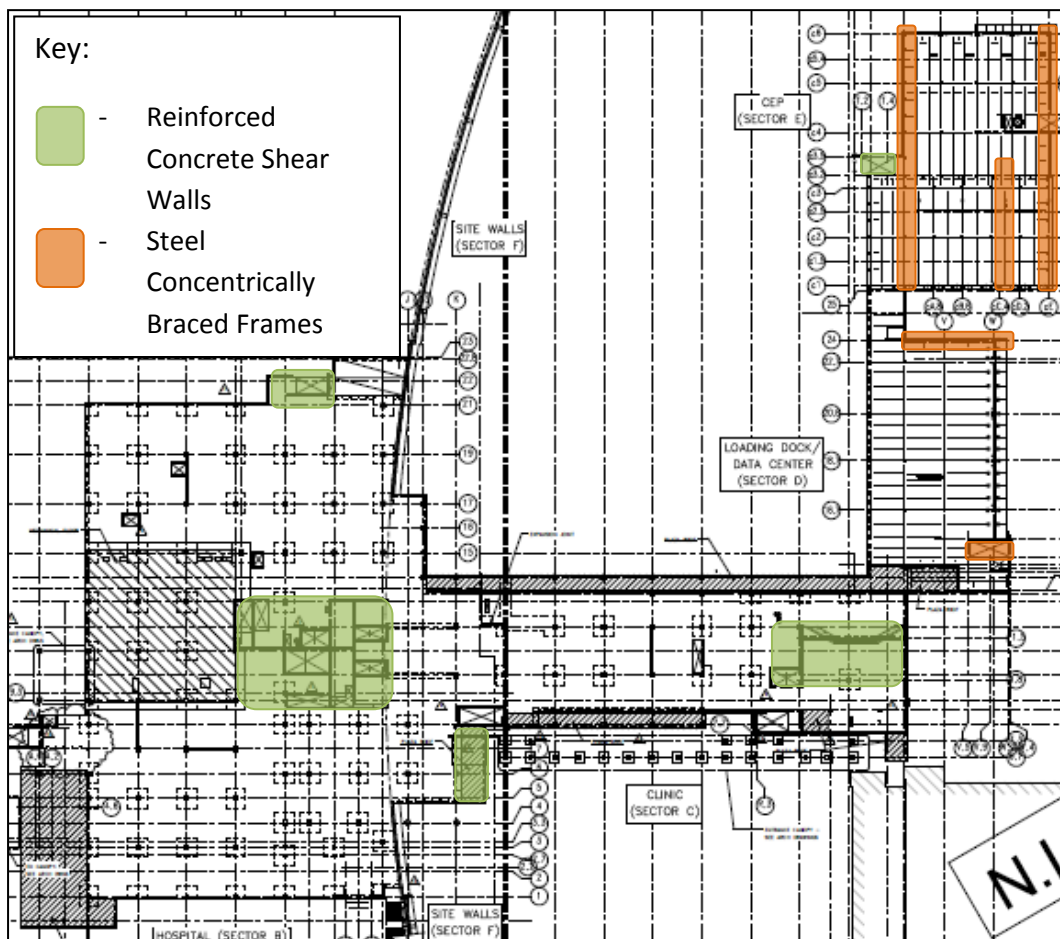


Figure 4 - Level 1 Structural Floor Plan Highlighting the Lateral System. Courtesy SGH.

Steel concentrically braced frames resist lateral loads in the loading dock data center and central energy plant, highlighted above in orange in Figure 3. Diagonal members, HSS6x6 and HSS5x5, brace into W14, W16, and W21 beams in the loading dock data center. Diagonal members, HSS8x8 and HSS8x8, brace into W18 and W21 beams respectively in the central energy plant. As mentioned above, the central energy plant has one shear wall along with the steel concentrically braced frame system.

The load path in NCHTNF starts with the wind load against the façade of the building. Once the load is applied to the façade it is transferred to the diaphragms on each floor. The diaphragms then transfer the load to the lateral elements, being reinforced concrete shear walls in the hospital and clinic and steel concentrically braced frames in the loading dock data center and CEP. These lateral elements transfer the load to the foundation system, the final step of the load path of NCHTNF.

Roof System:

NCHTNF has several different roofing systems to accommodate different functions of the roof. A fluid-applied membrane acts as the roofing system for the roof garden that is accessible to patients and also doubles as a green roof. The fluid-applied membrane utilizes type IV extruded polystyrene board insulation. The other roofs on the building are constructed with thermoplastic membrane roofing and SBS-modified bituminous membrane roofing. Each of these roofs use polyisocyanurate board insulation, which is type II glass fiber mat facer. The other roofing system is 1-1/2" – 18 GA. metal roof deck, located on the loading dock data center, central energy plant, and mechanical penthouses on the 7th floor.

Problem Statement:

One of the primary design principles of NCHTNF is remembering this structure will be used as a children's hospital. So the importance of an open floor plan is paramount, seeing as the goal is to not make the patients feel confined in the hospital. NCHTNF is currently designed with 39 shear walls for the lateral system. The central core in the hospital, where the majority of shear walls are located, has limited floor space due to the placement of shear walls, highlighted in figures 5 & 6. Similarly, floor space is limited in a portion of the clinic due to shear walls shown in figures 7 & 8. Additionally, the shear walls require coordination with the MEP systems to provide penetrations for ducts and conduit passing through the walls.

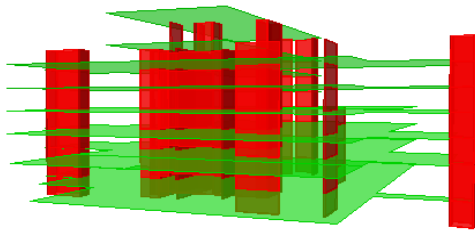


Figure 5 – 3D Hospital ETABS Model

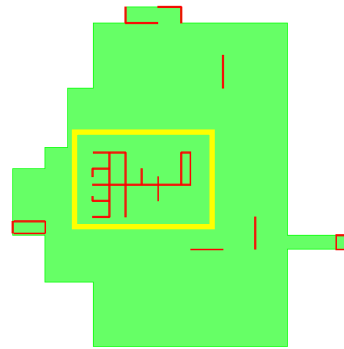


Figure 6 – First Floor Hospital ETABS model

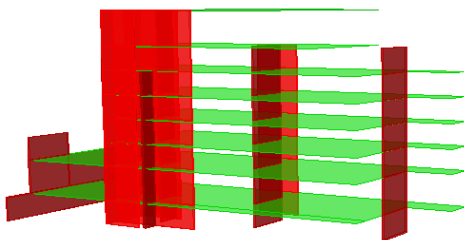


Figure 7 – 3D Clinic ETABS Model

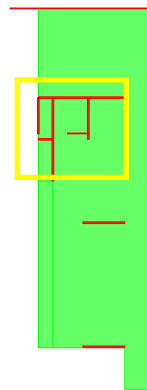


Figure 8 – First Floor Hospital ETABS model

Another design characteristic of hospitals is to strive to have large floor to ceiling heights. The more vertical space provided allows for less complicated coordination in the ceiling plenum. NCHTNF is currently designed with a flat slab floor system. This allows the floor system to be supported without beams or girders, which results in higher floor to ceiling heights. These higher clearances provide more space for MEP equipment, which eases the coordination process. On the contrary, drop panels require additional time to construct because the formwork can be more complicated than with a two-way flat plate system.

Proposed Solution:

The lateral system of NCHTNF will be redesigned using intermediate concrete moment frames. This may reduce the number of shear walls in the building, which will create a more open floor plan. A study to determine whether the moment frames can be integrated in the slab depth, which might require changing the slab thickness, will be performed. The floor system will be analyzed as a flat plate system in efforts to keep the high floor to ceiling heights, but remove the need for drop panels. Removing the drop panels from the floor design may reduce construction time and cost because the formwork for the drop panels will not be required.

Changing the lateral and floor systems will result in a change in the overall weight of the building. The foundation of the building will need to be analyzed to see if either the bearing or uplift capacity has been exceeded with the change in weight. Gravity members will need to be evaluated to determine if they require a redesign with the building weight change. Additionally, a seismic analysis will need to be performed on NCHTNF because the change in weight will change the resulting seismic base shear and overturning moment.

Solution Methods:

The design of the intermediate concrete moment frames will follow guidelines in ACI 318-08. The frames will be modeled in ETABS to determine how many shear walls may still be required for the lateral system. Once the size of the moment frame is determined, it will be determined if the beams in the moment frames can be integral part of the slab. The flat plate floor system will be designed using the CRSI Handbook and ACI 318-08. Foundations will be checked by hand, performing spot checks on critical locations. Gravity checks will be calculated for gravity members to determine their structural adequacy. If they require a new design, it will be in accordance with ACI 318-08 and the CRSI Handbook.

The gravity and lateral loads calculated in Technical Report I will need to be reanalyzed with the change in systems. These loads will be determined according to ASCE 7-05. ETABS will be used to model the complete reinforced structure and determine drift, overturning, and torsion. All applicable load combinations and live load patterns will be considered, similar to the process used in Technical Report 3. Microsoft Project will be used to create a project schedule and RS Means will be used to determine the overall cost of the system.

Breadth Studies:

The façade of the building is predominately glass, by the owner's request. A new sun shading system consisting of specifically sized and placed louvers will be designed to control the sun's exposure into the building. The design will be centered on studying the year-round daylighting of the building in an effort to maximize the performance of the glass wall system. An analysis of the current sun shading devices will be compared to the new design to discuss differences in amount of light exposure, overall cost, and aesthetics of the wall systems.

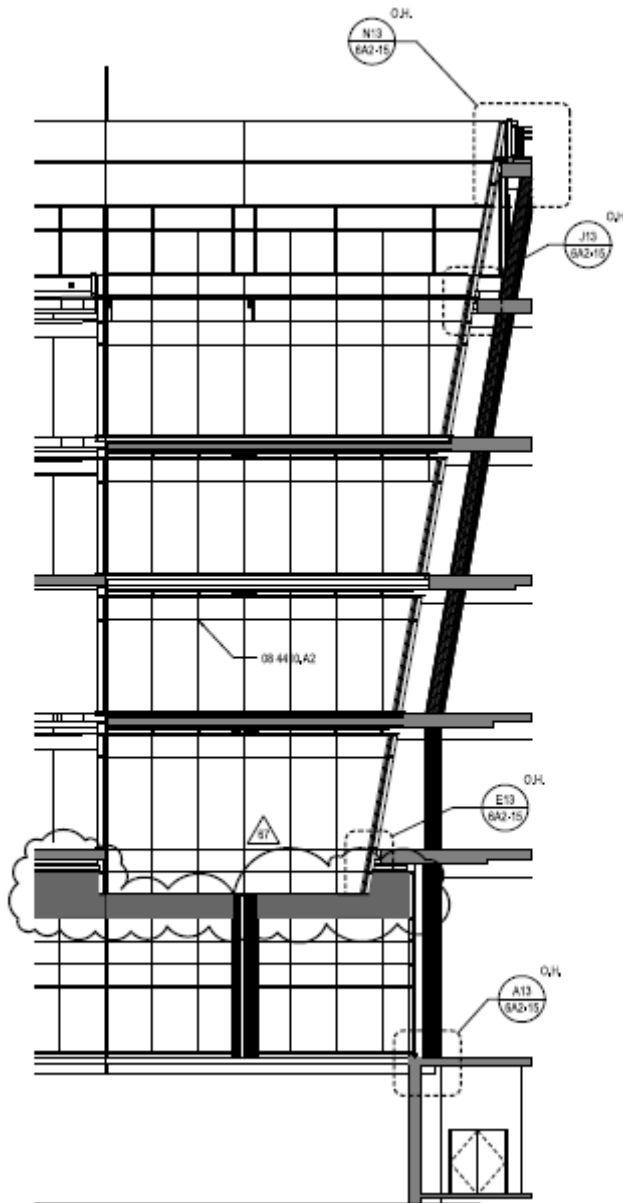


Figure 9 - NCHTNF Building Facade. Courtesy SGH.

The other study will examine the energy efficiency of the current façade, a section view is shown in Figure 9. An alternate façade design will be investigated to compare energy efficiency of each system. The focus of the redesign will center on researching more sustainable building materials along with improving the building's energy efficiency. The new design will consider the effects of thermal, air, and moisture infiltration along with the life cycle cost of the wall system.

MAE Requirements:

The MAE requirement for this class will be met by modeling NCHTNF in ETABS. Generating computer models in various structural analysis programs was taught in AE 597A – Computer Modeling of Buildings. This class taught us how to manipulate building models, within structural analysis computer programs, and study the given results. Additionally, the MAE requirement will be met with incorporating course material from AE 542 – Building Enclosure Science and Design. Design and analysis of building façades will be studied in this course, which will be applied to NCHTNF.

Tasks and Tools:

- I. Redesign Gravity System
 1. Determine most efficient floor system
 - A. Consider vibration, deflection and impact on foundation
 - B. Consider constructability of options based on formwork and integration with intermediate moment frames
 - C. Calculated and compare approximate price of each floor system
 2. Establish floor system
 - A. Determine slab thickness by ACI 318-08
 - B. Once lateral system is designed, check if beam from moment frame can sit within the floor slab.
 3. Calculated floor loads
 - A. Calculate self weight of floor system
 - B. Determine superimposed dead loads from the building plans
 - C. Determine the live loads based on ASCE 7-05
- II. Redesign Lateral System
 1. Calculate new design loads
 - A. Find wind loads following MWFRS Directional Procedure of ASCE 7-05
 - B. Find seismic loads following Equivalent Lateral Force Procedure of ASCE 7-05 using the new building weight
 2. Design intermediate concrete moment frames
 - A. Determine beam and column sizes per ACI 318-08
 - B. Determine if beams of intermediate concrete moment frame can be placed within the slab thickness
 - C. Determine how many concrete shear walls will be needed for the lateral system
- III. Develop ETABS model
 1. Lateral System
 - A. Determine placement of intermediate concrete moment frames
 - B. Determine placement of shear walls
 - C. Check torsional effects of the building
 - D. Verify drift and overturning criteria are met according to ASCE 7-05
 2. Gravity System
 - A. Add gravity members into ETABS model
 - B. Verify gravity members have adequate strength
- IV. Determine impact on foundations
 1. Spot design footings
 - A. Design a few spread footings at critical locations with the new building weight
 - B. Compare the new footings to the current footing designs

- V. Explore daylighting effects on the building
 - 1. Analyze daylighting pattern for an entire year to understand the sun path over NCHTNF
 - A. Calculate sun path and sun angles for Orlando, Florida using Excel
 - B. Determine the sun's impact on the building by tracing the sun's path over the building's orientation on site
 - 2. Design sun shading devices
 - A. Calculate lengths of louvers so they block the sun's light from entering the building during critical times of the year and day
 - B. Show how the sunshades block the sun's light with diagrams and Excel tables
- VI. Analyze façade
 - 1. Research existing building façade system
 - A. Determine building materials and construction
 - B. Calculate energy efficiency of building
 - 2. Design new façade components based on increased efficiency
 - A. Implement design features that reduce energy losses
 - B. Keep redesign within the range of the owner's wishes
 - C. Calculate energy efficiency of building

Conclusion:

This proposal focuses on the structural redesign of NCHTNF. To create a more open floor plan, intermediate concrete moment frames will be designed as the lateral system. In addition, the floor system will be changed from flat slab to either flat plate or one-way slab with beams depending on which is found to be more economical. The goal in performing these redesigns is to see if NCHTNF will be more cost efficient and reduce construction time with different structural systems. While redesigning the structure, the current façade system will be studied for energy efficiency qualities. In addition, alternate façade construction components will be analyzed and compared to the current design to determine the more economic system. Research and analyses will determine if proposed modifications compare to the current design, while still satisfying the needs of the owner.