THE PENNSYLVANIA STATE UNIVERSITY

Crocker West Building

State College, PA

Senior Thesis Proposal

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Structural Option

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-- EXECUTIVE SUMMARY --

The Crocker West Building (CWB) is an $18 million, 3-story office building and research facility being constructed in State College, Pa. The 121,000 square foot structure will function as a specialized research facility for a branch of the U.S. Department of Defense. This high-security infrastructure will include lab and office area on all but the third floor level, which was designated mainly for office space. CWB will be constructed using different precast systems, including the twenty-eight shear walls that make up the main lateral force resisting system. Crocker West Building is also being designed to achieve LEED certification.

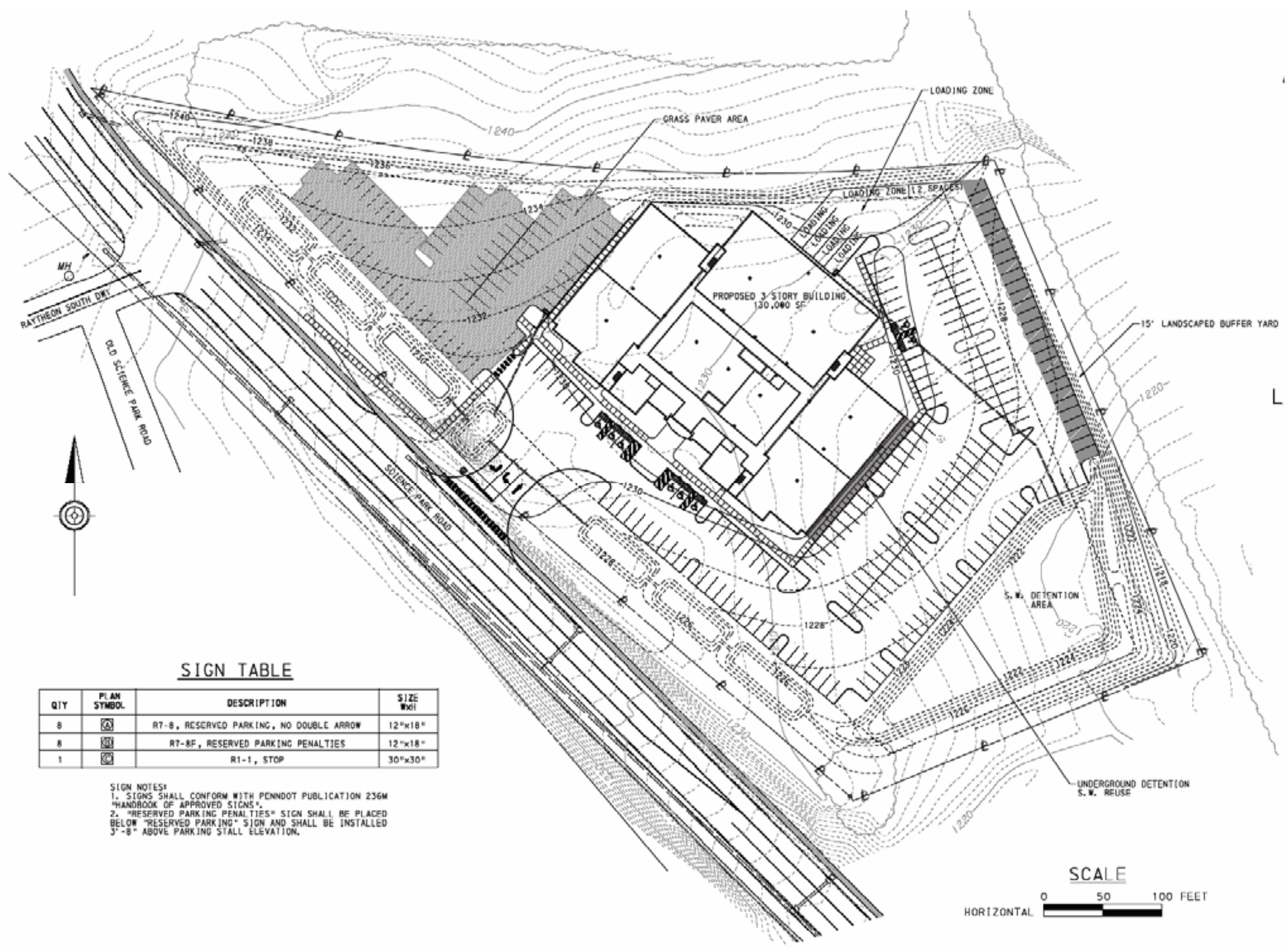
Upon request of the tenant, necessary actions were taken to allow for the addition of several floors needed for office space. The new structure will be designed with 2 additional levels of office space totaling 5 stories, plus an additional portion of the building extending to an overall height of 7 stories. With the addition of these levels, the structure shall be redesigned using steel framing as the main lateral and gravity systems. Research and advice taken from a co-working engineer suggests braced frames be used to maximize the strength of the lateral system. Additionally, a concrete core shall also be considered to aide with torsion and drift criteria. Other structural issues, like the green roofs introduced, will be addressed during design phase to avoid any unnecessary strength calculations.

Converting the precast structure to a taller, steel framed structure will also stimulate changes to the envelope and overall perspective of the new edifice. An architectural breadth will be conducted to facilitate changes with overall architectural layout and aesthetics. The aesthetics portion of the architectural breadth will be directly related to changes of the structural system, where as additional levels will inevitably change the elevation view of the structure and shall be investigated. In addition to the architectural breadth, a construction management breadth shall also be conducted to compare cost and schedule differences between the existing precast system and the proposed steel system.

This proposal details the tasks to be completed during the second part of the senior thesis project along with a schedule of those tasks broken down over a weekly course of the semester.

-- BUILDING INTRODUCTION --

Crocker West Building will be used as a highly classified research facility, specializing in the development and testing of underwater weapons for the U.S. Department of Defense. Located in State College, Pa, the structure will be a 3-story, 42' low-rise building with typical 35' square bays broken into areas classified as office, light industrial, and warehouse totaling nearly 120,000 square feet. The first floor of CWB will consist mainly of 'closed' lab area, along with technician offices, locker rooms and special test areas. The second floor will include office space, another lab area, computer lab, student room and a room designated to SCIF (a classified security area), while the third floor will be devoted mostly to office space. The entire building will be constructed of Architectural Precast Concrete systems, including: columns, prestressed beams & diaphragms, and walls. CWB utilizes a 16'-0" floor-to-floor height for the ground level, while the remaining two floors have a typical floor-to-floor height of 12'-0". Lateral loads applied to the structure will be collectively distributed throughout the building to specially designed shear walls.



-- STRUCTURAL SYSTEM --

As stated above, the Crocker West Building is a total precast building. The following are detailed explanations of the individual precast members and systems.

FOUNDATION(S):

The foundation system(s) being implemented consists of typical cast-in-place (CIP) strip and pad footings, as well as a standard CIP slab-on-grade. Fifteen inch deep strip footings ranging from 3'-3" to 6'-6" wide are used along the perimeter of the structure. These footings help distribute wall panel loads into the ground. Additionally, the East walls strip footing of the structure will also be used as a part of the underground water cistern that will be used to collect treatable storm water runoff for reuse. Spread (or Pad) footings will be used throughout the interior portion of the building and will be used to pick up loads from columns and stair-towers. Pads used under columns vary in size from 12' square to 14'-5 square, while pads under the four typical stair-towers are 12'-0 x 25'-6. All pad footings are 2 foot thick unless noted otherwise. A six inch thick slab-on-grade reinforced with W4.0 x W4.0 WWF will complete the foundation system(s) and will be used as the ground floor level of the building. See Figures #1 and #2 below for a plan view of the foundation systems and proposed cistern detail, respectively. Please note, the width of the cistern was unavailable at this time.

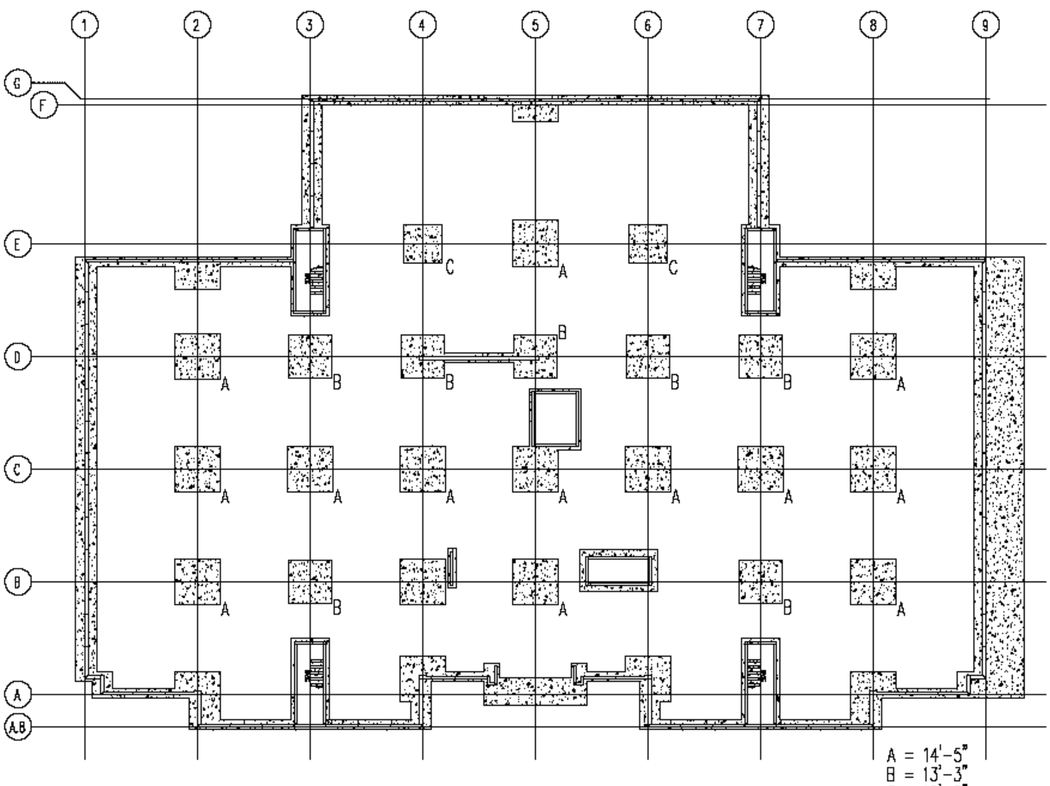


FIGURE #1 – FOUNDATION SYSTEMS

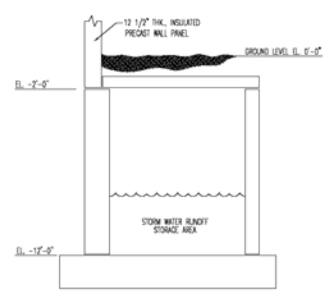


FIGURE #2 – PROPOSED CISTERN SECTION

COLUMNS:

The vertical supporting members for the entire structure are reinforced, precast concrete columns. All columns are 24" x 24" square columns with four (4) #11 longitudinal reinforcing bars and #4 stirrups spaced accordingly (See Figure #3). Columns will be cast for lengths up to 42 feet. Each column will contain haunches and haunch reinforcing (Figure #4) cast monolithically at each floor level, and in the required position for beam bearing and load transfer. The columns are spaced on a 35'-0 x 35'-0 typical bay grid and are connected to the pad footings with four (4) 1 ¼" dia. ASTM A193 threaded rods. See Figure #5 for column grid layout.

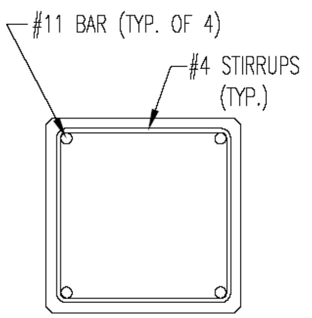


FIGURE #3 – TYP. COLUMN SECTION

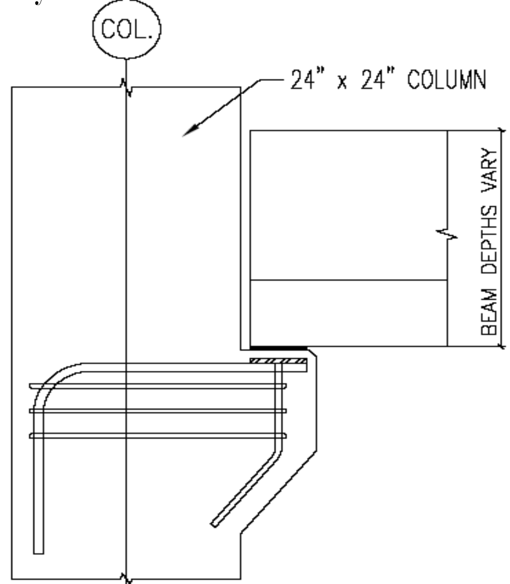


FIGURE #4 – COLUMN w/ HAUNCH

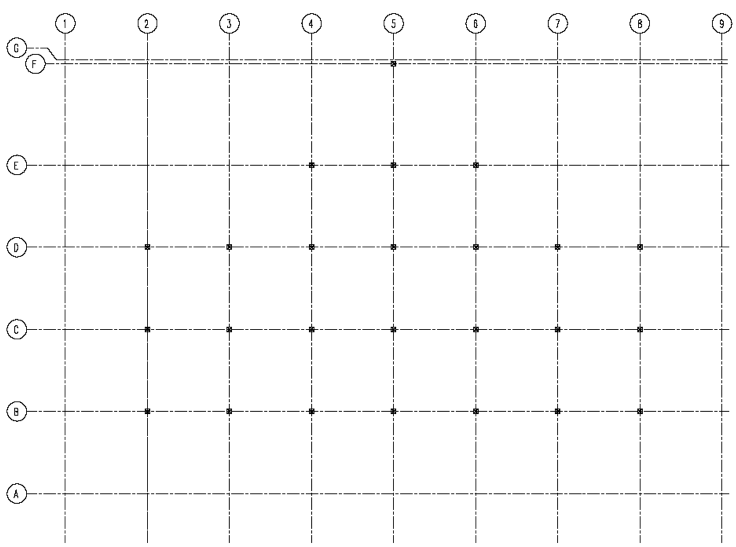


FIGURE #5 – COLUMN GRID

FLOOR SYSTEM:

As previously stated, the 1st Floor (or Ground Level) floor system is a 6" thick slab-on-grade with W4.0 x W4.0 WWF reinforcing. The remaining floor levels are constructed of precast, prestressed hollow-core flat slabs. The 2nd Floor Level will consist of 12 inch and the 3rd Floor Level will be comprised of 10 inch hollow-core flat slabs, each with six (7) 7-wire, ½" SP (special) 270 ksi low-relaxation prestressing strands and a typical 2" topping. Some of the hollow-core floor system clear spans are nearly 33'-0, with individual panels running in an East-West direction.

Furthermore, the hollow-core slabs are supported by one of two methods. If the floor slab is to bear at an exterior wall panel location, the wall panel will be designed with a pocket used for the plank to bear on. For interior bay supports, the hollow-core slabs will be supported by precast, prestressed concrete inverted-tee (IT) beams resting on column corbels. IT beams for the 2nd Floor were designed to be 28" deep, while 3rd Floor beams are 20" deep due to dissimilar live loads.

ROOF SYSTEM:

The roofing system for Crocker West Building's main roof will be constructed by means of similar materials used in erecting floors two and three. The main roof will consist of 8" hollow-core flat slabs with (7) 7-wire, ½" SP, 270 ksi low-relaxation strands supported by 18" deep inverted-tee beams. The low roof, located in the rear storage area of the building, will be constructed of 10'-9 wide x 24" deep precast concrete double-tees (See Figure #6). In addition, each roof will receive a layer of 4" tapered rigid insulation and a 60 mil EPDM roofing membrane rather than a 2" topping which is not needed on the roof.

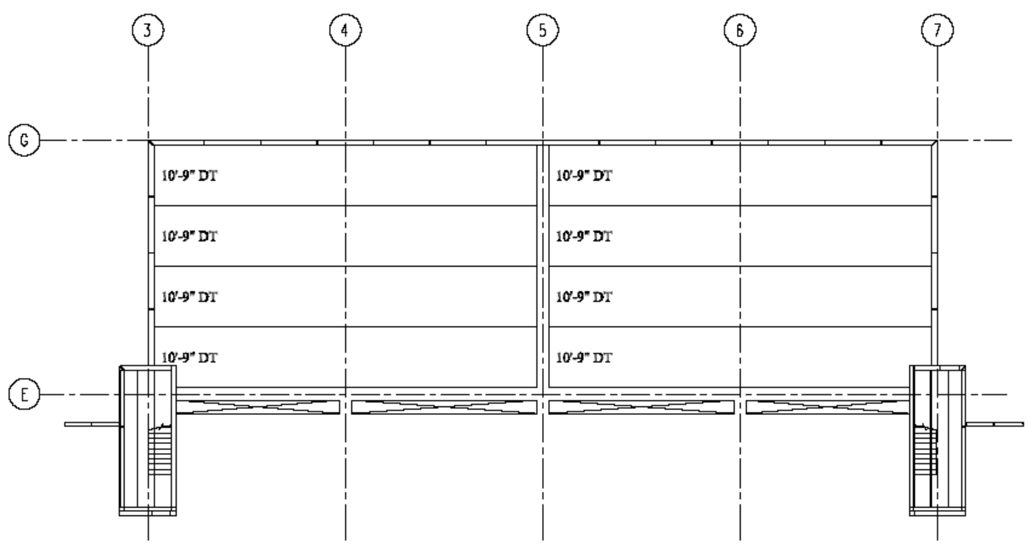


FIGURE #6 – LOW ROOF DT LAYOUT

LATERAL SYSTEM:

One of the key design issues of a total precast structure is the make up of the lateral force resisting system. CWB is no different; its lateral system was designed using a compilation of precast shear walls positioned around the perimeter and throughout the building. Each of the 28 shear walls are constructed with several different thicknesses of insulated and non-insulated precast panels. Exterior wall panels (all insulated) acting as shear walls in the N-S direction are 12 ½" thick, while E-W direction walls are 9 ½" thick. The 12 ½" panels consist of 2 ½" of rigid insulation sandwiched between a 2 ½" (ext. face) & 7 ½" (int. face) concrete slab, while the 9 ½" differs only with a 4 ½" (int. face) slab. Shear walls located on the interior of the structure and around stair-towers are 9" thick and non-insulated. Due to the fact that every panel is individually erected, specially designed connections are required for each piece. A breakdown of the lateral loads and how they are distributed throughout the panels is available in Tech Report III. Figure #7 below illustrates the layout of the shear walls; each represented by a solid line with a SW designation.

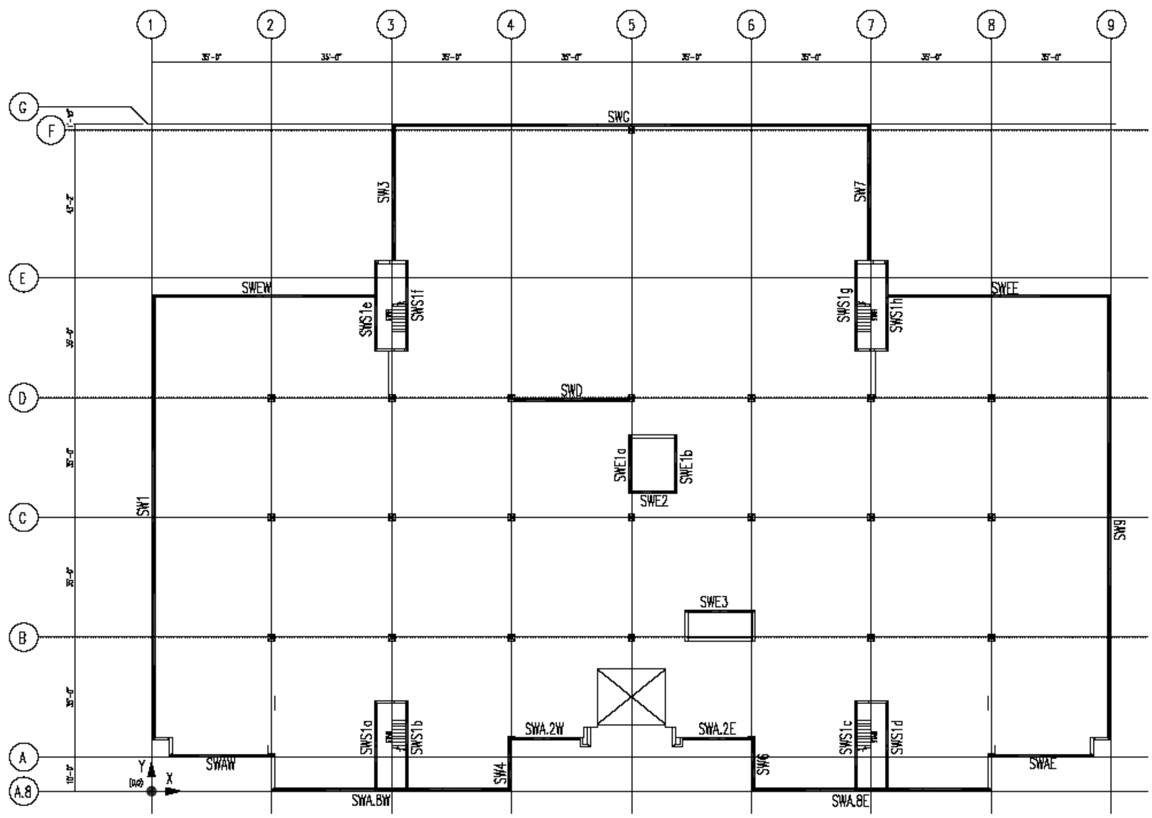


FIGURE #7 – SHEAR WALL LAYOUT

-- PROBLEM STATEMENT --

Having performed several of the actual designs used for the Crocker West Building and the required technical reports for this senior thesis project proved that the structural system utilized in the existing building is adequate of resisting the calculated gravity, wind, and seismic loads.

For the purpose of fulfilling senior thesis project requirements, a petition will assumed to be deemed granted for the addition of several stories needed for office space. The acquired permission was issued with the understanding and intent that the redesign takes on a more architectural appeal than the existing precast envelope.

Negotiating height for aesthetics creates several area of concern. Because the tenant has requested the addition of several levels of office space, the use of precast for the entire building envelope could prove to be insufficient and uneconomical. A conversion of the existing precast concrete system to a braced steel framing system will also introduce architectural issues such as grid layout, core location, and façade aesthetics.

-- PROPOSED SOLUTION –

Due to the additional levels proposed for the structure, a redesign of the lateral system using steel braced frames as the main lateral resisting system shall be examined; with the possibility of an additional concrete core shear wall system to aide in accidental torsion and drift criterion. The lateral system will be modeled and analyzed using computer modeling programs such as ETAB and/or RAM in order to consider and determine the required locations of the steel braced frames and/or shear wall core. These situations will be carefully modeled to ensure proper design of CWB's new structural system by limiting drift, torsion, and vibration design factors for optimal occupant comfort.

In addition to the aforementioned information, an architectural study will be conducted in order to allocate the proposed redesign. Using steel braced frames as the main lateral system may hinder the existing floor plan, thus altering the overall architectural layout and vision of the structure. However, these braced frames will try to be incorporated into the architectural aspect of the design by leaving them exposed in selected areas. The site is also limited in size, thus these issues will be researched in a collaborative effort to reduce the building footprint creating larger areas for impervious ground cover and parking.

--BREADTH STUDIES --

ARCHITECTURE:

Introducing a completely different steel framing method for Crocker West will have ramifications to the existing floor plan and overall design. Great effort will be taken in order to maintain a majority of the existing layout spaces and areas, relocating areas as deemed necessary. In an attempt to minimize deflection and vibration concerns, the 35'x35' typical bays will be considered and possibly reduced to incorporate shallower floor plenums and stiffer diaphragms. Special interest will be devoted to floors 1 & 2 based on the amount of open lab space desired and other occupant requests. Furthermore, removing the precast panel envelope around the perimeter lends itself to a variety of different façade and glazing finishes. The change induced on the exterior of the edifice due to the redesigned steel framing and glass curtain façade will be analyzed and incorporated in the appearance overhaul.

In addition, with the existing structure striving for LEED certification, additional green space shall be incorporated into the floor plan. Determination of additional LEED points from adding the green roof, altering the building's perspective, and switching the structural system shall be considered.

CONSTRUCTION MANAGEMENT:

Transforming the existing structural system from architectural precast concrete to a modern steel framed design, plus the accumulation of construction materials for the additional levels will lend itself to an assortment of construction management issues. A project schedule shall be constructed based on the new steel system and related materials; also, an overall cost shall be determined from the new specified material list. Information gathered regarding each systems schedule & cost impact shall be compared and used to recommend one system over the other.

-- TASKS & PROPOSED SCHEDULE --

TASKS & TOOLS:

Task 1. Architectural Breadth (Part 1):

Sketch a schematic redesign of the existing structure, including: altered floor plans with new steel framing and grid pattern, elevations of the proposed structure detailed with story heights and overall building height, and potential wall sections displaying feasible building components (i.e. – glazing, column covers, etc.) required of the new structure.

Task 2: Preliminary Design:

Verify the buildings existing/new gravity loads. Determine trial sizes for structural members using a combination of hand calculations and computer modeling, along with an experienced, working engineer's guidance. Similar to Tech II, this requires typical bay floor systems be analyzed and designed via hand calculations & computer modeling for the various gravity loads to obtain relative member sizes.

Task 3: Preliminary Analyses:

Use the schematic design information & estimated member sizes acquired in Tasks 1 and 2 to perform a lateral load analysis. Analyses will consist of wind and seismic forces estimated from existing information (gravity loads, superimposed loads) and assumptions taken from the schematic design (seismic weight of the structure, overall height due to plenum depth variance).

Task 4: Model System:

Construct 3-D model of proposed structure using ETABS, RAM, or any other program capable of performing the task. Determine practical locations to introduce braced frame(s) and determine whether or not a concrete core should be incorporated to oppose the effects of torsion and drift.

(TASKS & TOOLS cont.)

Task 5: Lateral System Design:

Perform any necessary adjustments to the structure found through computer based modeling and hand calculations to come up with a finalized lateral force resisting system design for the new structure; making sure all required braced frames are in their respective positions.

Task 6: Lateral Analysis:

The preliminary analysis performed in Task 3 should yield the controlling lateral load combination(s). The governing load combination(s) shall be reanalyzed similar to Tech III with the finalized system of Task 5 in order to determine how the lateral loads will be distributed throughout the building, and the amount of load each member is required to resist. Also, determine if the new structure will require the foundation system to be redesigned.

Task 7: Architectural Breadth (Part 2):

Research the impact of additional levels on essential LEED credits. Determine whether or not feasible to try for a Platinum rating. Incorporate green roofs considered during structural design phase.

Task 8: Construction Management Breadth:

Construct an updated project schedule relating to the new construction materials using Primavera computer software (existing project schedule built in Primavera). Performing all necessary calculations for strength and sustainability prove the selected blast resistant components are practical.

Task 9: Final Presentation:

Conclude any results and final design problems which may have arose, organizing these results into a written final thesis report. A 10 minute presentation summarizing this report will be composed and presented to the faculty and jury of the Architectural Engineering Department.

PROPOSED SCHEDULE: