Final Thesis Report:

Maintaining a Safe and

Functional Building

Environment

The Wilmer Eye Institute Outpatient Surgery & Laboratory Building

Baltimore, Maryland

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Construction Management

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THE WILMER EYE INSTITUTE

Outpatient Surgery and Lab Building

The Johns Hopkins Hospital

Baltimore, Maryland

Architect..Wilmot Sanz
Design Architect...Ayers Saint Gross
General Contractor...The Whiting-Turner Contracting Company
Civil Engineering ....Rummel Klepper Kahl Engineers
Structural Engineering..Cagley & Associates
MEP Engineering..RMF Engineering
Laboratory Design..SST Planners
Code Consultant...Schirmer Engineering
Geotechnical..Schnabel Engineering

Building Statistics

- 200,000 GSF, 1.6 Acre Site
- $65M Construction, $92M Total
- 6 Storeys w/ Mech Core Basement
- Design-Bid-Build w/ GMP Contract
- Outpatient Surgical Center, Offices, Lobby, and Research Laboratories

HTTP://WWW.ENGR.PSU.EDU/AE/THESIS/PORTFOLIOS/2008/TMS349/

Architectural

- Reflective glass curtain wall over the entrance reveals the reflection of the former Wilmer building as you enter (as seen in image above).
- Central atrium/skylight in lobby extends from first floor to roof of building.

Construction

- An existing paved parking lot and spread footings from a prior structure will need to be removed during excavation.
- Scope of work includes the construction of an 8'x10' underground pedestrian/utility tunnel connecting to an adjacent building.
- All sides of site will be shored with drilled soldier piles and wood lagging.
- An existing MTA metro tunnel running under North Broadway will require special sheeting and shoring considerations.
- Partial reconstruction of Orleans and Broadway streets is anticipated.
- Top two floors are core-and-shell only.

Mechanical

- Separate air handling systems for lab, clinical and office spaces, all VAV.
- Water supply systems are designed to utilize energy recovery wheels.
- Four 44,000 CFM 100% outdoor air industrial grade air handling units serve each of the three spaces.
- Four 66" diameter 70,000 CFM SWSI laboratory exhaust fans located on the roof discharge at 10' above the roof line.

Structural

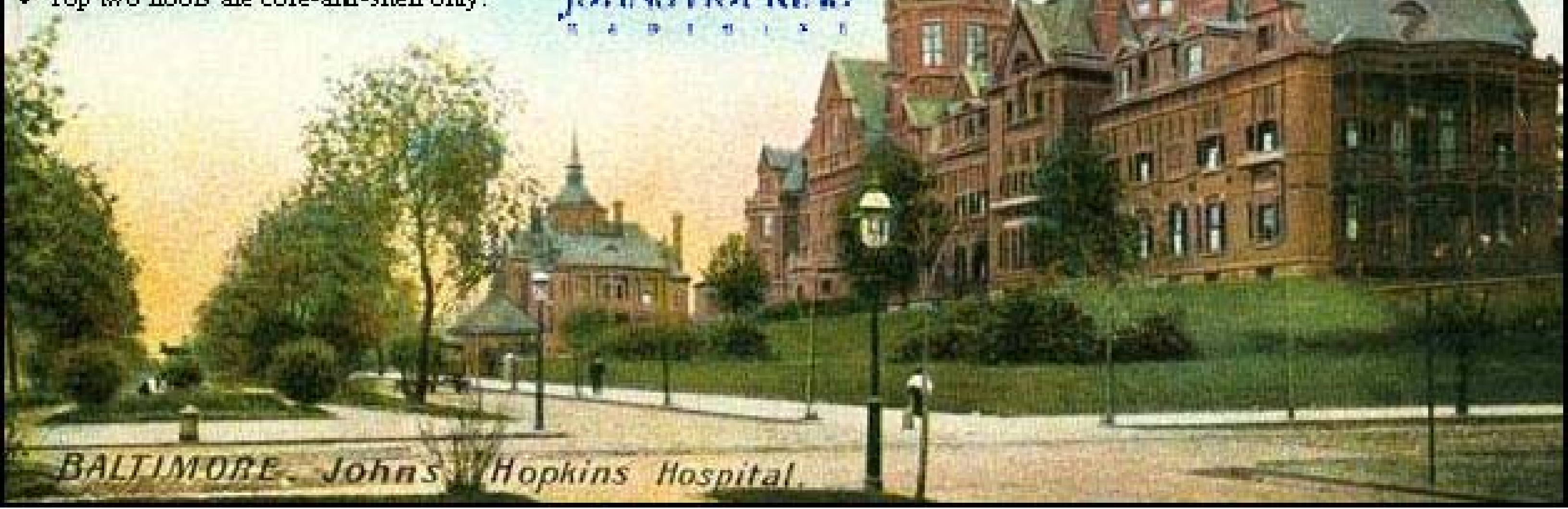
- Cast-In-Place (CIP) concrete structure
- Mildly-reinforced two-way plate system
- Earth-formed spread footings
- Structurally designed for future addition of three additional floors

Electrical

- Two 13.2 KV, #4/0 shielded feeders rated for 15 KV supply normal power
- Double-ended substation transforms feeder service to 480/277V, 3 phase, 4 wire for distribution through building
- 300 KVA transformer on each floor
- Full emergency power, isolated ground, transient voltage surge suppression, lightning protection, telecom and security systems in place

Tyler M. Smith
Construction Management

JOHNS HOPKINS
MEDICINE



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Executive Summary

The investigations in this thesis report uncovered a number of aspects of the project that will help maintain a safe and functional building environment. It is the nature of contemporary hospital buildings to protect their occupants in as many ways as possible.

The exterior enclosure system has a large role in this as the primary component that protects the building environment from the elements of nature. Failures in the building envelope can be costly both in money from lost energy and repair costs, not to mention potential health threats that can arise from mold growth. Common areas of the building envelope failure include interfaces between wall types, penetrations, and seals around openings. The installation processes should be monitored frequently to be sure things are being installed as they have been designed. It is imperative that the building envelope receive the proper attention throughout the entire design and construction process.

Unitization of the curtain wall proved to be unfeasible primarily due to the large expense of renting a crane, a lack of space onsite, and a large risk incurred from trying to prefabricate sections of a complex wall of irregular shape. If the curtain wall covered a much larger and area and were more uniform, off-site fabrication may have proved to be a more efficient method. However in this case it is recommended that the curtain walls be stick-built as planned.

The site of the proposed building is surrounded on three adjacent sides by sensitive hospital facilities. As a major new construction project in proximity to such facilities, the construction of this building is classified in the highest risk group under the AIA's infection control guidelines. All of the precautions outlined in these guidelines should be carried out throughout the entire duration of the project.

Upon investigation, the proposed ultraviolet light system proved itself to be extremely cost effective. The system will prevent microbial growth on the cooling coil and in turn will avoid the costs associated with an increased cooling load and fan pressure. This report demonstrates that the proposed system will pay itself off in savings in only a few years. It is absolutely recommended that the system mentioned herein be installed into all of the air-handling units in the new Wilmer Eye Institute building. Aside from the cost savings to the facility owner, the system's air disinfecting potential is an excellent way to improve the overall indoor air quality of the building.

The key finding upon investigation of the three storey expansion is that it is illogical to design the air handling system around an expansion that may never be built. Any time, effort or money put into to planning the air-handling system around this would be wasted if the expansion is never built. On the other hand, it is reasonable to design the structural system around potential plans for an expansion since it is essentially impossible to retrofit an existing structure to be able support three extra floors. However a mechanical system is significantly less permanent, and constructing an isolated HVAC system with a rooftop penthouse not an unrealistic option.

This thesis project has provided an all around unique opportunity for learning a number of different aspects relating to maintaining a positive building environment. The knowledge acquired here is valuable both personally and to the greater good of the building engineering profession.

Acknowledgements

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- Mr. Andreas Phelps
- My family and friends, especially my parents
- My fellow 5th year Architectural Engineering students

Introduction & Goals of Study

The basis of this thesis study and overall theme revolves around ensuring a safe and functional building environment for its occupants. This building is designed to accommodate a variety of environments including an outpatient hospital center, offices, and four levels of research laboratories. The Johns Hopkins Hospital is a well-established organization, and the Wilmer Eye Institute is a world-renowned eye hospital. It is imperative buildings of this type be built to specification in order to fulfill the diversity of needs for which they have been designed.

The proposed building will house laboratory spaces designed to create scientific “communities” of surgeons, clinicians, geneticists, epidemiologists, clinical trial specialists, biochemists, molecular biologists and other medical specialists, not to mention that there will also be patients and clerical workers there on a daily basis as well. Maintaining the integrity of the indoor environment for all of the different occupants is of the utmost importance.

The different analyses herein this thesis study include ensuring a functional building envelope, maintaining infection control standards during construction, and the investigation of the feasibility of the implementation of an ultraviolet irradiation system. All of these studies will help to improve the building’s indoor air quality and the overall interior environment.

Personal motivation to study the above mentioned analyses varies with the topic. Investigation of the building envelope systems directly relates the profession being pursued upon graduation. The infection control standards are of interest to a prior internship that was done on a project in the medical sector. The ultraviolet system simply seemed to be an innovative technology that is not widely known. It strikes as important to spread knowledge in these areas as openly and freely as possible to ensure positive building environments in the future.

Evaluation Criteria

The following table is the requested grading scale to be used in overall evaluation of the technical analyses prepared within this report.

Weight Matrix

Analysis Description	**Research**	**Value Engineering**	**Constructability Review**	**Schedule Reduction**	**Total**
Building Envelope	15	5	10	5	**35%**
ICRA	5	5	0	5	**15%**
UVGI	10	15	10	0	**35%**
Expansion	0	5	10	0	**15%**
Total	**30%**	**30%**	**30%**	**10%**	**100%**

Project Overview

Project Team

Role	Firm	Website
Owner	The Johns Hopkins Hospital 600 North Wolfe Street Baltimore, MD 21287	http://www.hopkinsmedicine.org/
General Contractor	The Whiting-Turner Contracting Company 300 East Joppa Road Baltimore, Maryland 21286	http://www.whiting-turner.com/
Architect	Wilmot Sanz 18310 Montgomery Village Ave. Gaithersburg, MD 20879	http://www.wilmotsanz.com/
Design Architect	Ayers Saint Gross 1040 Hull Street, Suite 100 Baltimore, MD 21230	http://www.asg-architects.com/
Civil Engineering	Rummel Klepper Kahl Engineers 81 Mosher Street Baltimore, MD 21217	http://www.rkkengineers.com/
Structural Engineering	Cagley & Associates 6141 Executive Blvd. Rockville, MD 20852	http://www.cagley.com/
MEP Engineering	RMF Engineering 190 West Ostend Street Baltimore, MD 21230	http://www.rmf.com/
Lab Planner	SST Planners 1501 Wilson Blvd, Ste 507 Arlington, VA 22209	http://www.sstplanners.com/
Code Consultant	Schirmer Engineering 6305 Ivy Lane, Suite 220 Greenbelt, MD 20770	http://www.schirmereng.com/
Geotechnical Engineering	Schnabel Engineering North, LLC 1504 Woodlawn Drive Baltimore, MD 21207	http://www.schnabel-eng.com/

Building Statistics

Delivery Method

Design-Bid-Build, GMP Contract with Whiting-Turner

Cost

$65M – Cost of Construction
$92M – Total Project Cost

Size & Occupancy

Total Building Floor Area..202,350 GSF

Site Size...1.6 acres = 69,700 SF

1. Basement..31,100 GSF

    Mechanical/electrical rooms, ahu's, pumps

2. First Floor...29,600 GSF

    Outpatient surgical center with six operating rooms
    Recovery/locker facilities, staff offices and atrium waiting room

3. Second Floor...28,950 GSF

    Entrance lobby with security desk and elevator lobby
    Atrium to roof with roof monitor
    Open research laboratories and support spaces
    Staff offices, toilets and break room

4. Third & Fourth Floors..27,850 GSF

    Atrium to roof skylight
    Open research laboratories and support spaces
    Staff offices, toilets, break and conference rooms

5. Fifth & Sixth Floors...27,850 GSF

    Stairway and elevator access

6. Roof Penthouse..1,300 GSF

    Stairway and elevator access

Location

The building is located just west of N. Broadway between Orleans and Jefferson streets in downtown Baltimore, Maryland. It is the former site of an on-grade parking area.

To see the Johns Hopkins Medical Campus Map **click here**.

Start/Finish Dates

The planned timeframe for the construction of the Wilmer Eye Institute is from April 30, 2007 to October 30, 2009, which is 31 months with 657 working days.

Construction Overview

General

The building will be built to the site property lines on three sides and due to other site constraints will require sheeting and shoring on all four sides. The base building design includes the construction of six levels above grade, a mechanical-room basement, and an underground tunnel connecting to an existing adjacent hospital facility.

As the construction site lies on the Johns Hopkins Medical Campus, all Johns Hopkins Hospital Rules and Regulations are to be adhered to at all times, including work hours (M-F 6:30 AM to 5:00 PM), noise limitations, cleanliness, safety requirements, outage requirements, traffic programs, access requirements, etc.) Any weekend work will require pre-approval by both the construction manager and the owner prior to work being planned or occurring.

Demolition

An existing paved parking lot, as well as several spread footings from a prior structure will need to be removed before construction begins. It is also anticipated that parts of Orleans and Broadway streets will need to be reconstructed due to the proximity of the site to the existing roadways. An existing curb cut and driveway on Orleans Street will be removed and replaced with a sidewalk and grass strip to match the existing conditions of the north side of Orleans Street. The west curb, sidewalk and landscaping along N. Broadway will also be replaced if necessary.

MTA Metro Tunnel

There is an existing MTA Baltimore Metro tunnel running underneath North Broadway Street. It runs parallel to the east side of the site and begins to curve to the west as it passes south of Orleans Street. The outer limits of the westernmost track clip the northwest corner of the Broadway and Orleans right-of-way. The top of track elevation here is approximately 30 feet and the top of the tunnel lining is at approximately 47 feet. Investigation of the tunnel's as-built drawings will be required to confirm the location of the tunnel and plan for underpinning and soil modification methods.

Material Staging

Due to limited staging area, all material shall be delivered to the project in such quantities and at such times as required for its timely installation. Extra care must be taken to minimize trucks/vehicles "standing" on the roadways while waiting to make deliveries or pick-ups. It is imperative that emergency vehicles (ambulances, fire engines, etc.) have full, unimpeded access to all JHH Facilities at all times.

Site Access

Access to the jobsite will primarily be from Orleans Street. Access to site prior to 6:30 AM daily will be prohibited due to noise limitations. Upon completion of the underground tunnel, construction traffic will enter the site from Orleans Street and exit through another gate onto Jefferson Street.

Construction Conveying

Material conveying will be accomplished with a tower crane built by the concrete contractor during the construction of the spread footings. It will be removed after the completion of the superstructure, at which time a man and material lift will be installed on the building's west elevation.

Adjacent Facilities

The project site is in close proximity to the existing JHH Cancer Research Building 1. This building is fully occupied and access to the entrance of this building must be maintained at all times. The contractor is responsible for ensuring minimum interference with roads, walkways, and other adjacent or used facilities.

Building Enclosure/Interior Work

An effort will be made to enclose the building as soon as possible, making it reasonably weather-tight so that interior rough-in and fit-up work can commence as early as achievable. Work will proceed concentrating on the lab areas first, followed by the offices. Rough-in work must proceed on each level as soon as the concrete contractor's re-shores are removed from that floor. Work on successive floors is intended to keep pace with the concrete work.

Temporary Lighting/Power

There will be no temporary electrical power or lighting in place until installed by the electrical contractor by December 1, 2007. Until then all trade contractors must provide their own power/lighting. Temporary electrical service will be 1200 ampere, 480 volt, 3-phase, 4 wire, and will be extended and properly distributed into the building as soon as possible.

MBE/DBE/WBE Participation and 1st Source Hiring Program

This project is aimed to support minority, disadvantaged and women's business enterprises. The MBE/DBE/WBE participation goal for this project is 18%. The First Source Hiring Program was established to provide employment opportunities to residents of the local area. The construction manager is required to have an individual assigned to be the MBE/DBE/WBE First Source Hiring procurement officer on the project.

Architectural Overview

Several unique architectural features of the new facility stand out among the rest. The first is the reflective glass curtain wall over the entrance on the northeast corner of the building. The large glass wall will reflect the image of the former Wilmer's "mini" dome as you enter, symbolically and visually bridging the 83-year-old Institute's old and new presence on Hopkins' East Baltimore campus.

The other main feature of the building is the presence of a central atrium in the lobby/entrance area. The space stretches from the first floor to roof of the building overtop of the lobby and the main hallway.

The building has a primarily brick façade aside from the glass curtain wall. There will be two building entrances, each one story apart, adhering to the natural slope of the site. An 8'x10' service tunnel between Wilmer and the basement corridor of Cancer Research Building 1 will connect to a loading dock/receiving facility being constructed to the west of Cancer Research Building 1. There will be on-grade parking for 24 cars adjacent to the building and will be accessed from an existing curb cut on Orleans Street.

Building Envelope

Exterior Walls

The primary exterior wall system will be modular extruded type FBX brick in cavity wall construction with CMU back-up. Each of the window openings on the south and east walls use jack-arches and brick returns to create an 18-inch deep frame. Window sills will be cast stone. 7-ounce copper laminated type through-wall flashing will be installed in conjunctions with plastic tube type weeps spaced 24"O.C. horizontally. Anchors will be two-piece stainless steel type, spaced 16" O.C. vertically and 24" O.C. horizontally.

The exterior soffits will be aluminum panels finished with a factory applied 3-coat fluoropolymer in custom color. Cavity wall insulation will be extruded-polystyrene board insulation. Foil faced batt insulation combining mineral fibers with thermosetting resins will comply with ASTM C 665, Type III, Class B. Foil faced slag-wool-fiber board safing insulation will also be in place.

Exterior Windows

Typical glazing will consist of 1-inch insulating spectrally selective glass with SHGC (shading heat gain coefficient) exceeding the requirements of ASHREA 90.1. Typical glazed curtain wall windows will be thermally broken, finished in a 3-coat fluoropolymer finish and will be performance tested to the owner's specific criteria. The curtain wall at the north and south ends of the atrium will contain 60 motorized windows as a smoke control system.

Skylight/Glass Canopy

The skylight will be thermally broken aluminum framed and single-sloped finished in a 3-coat fluoropolymer finish of custom color, factory applied. Skylight glazing consists of a laminated safety glass assembly meeting the above mentioned typical criteria for glazing.

The exterior canopy will have a tube steel frame with ornamental metal supports back to the building façade. The canopy will be field painted, contain overhead laminated safety glass, and will be equipped with a dry sprinkler system.

Exterior Doors

Thermally broken stile and rail aluminum doors in aluminum framing will have a 3-coat fluoropolymer finish and will match storefront entrance. Bi-parting automatic sliding doors will have fixed sidelights and will also match storefront entrance.

Exterior utility doors utilize hollow metal frames with mitered or coped and continuously welded corners, fabricated from 0.0635-inch (1.6 mm) thick galvanized steel sheets, factory primed and field painted. 1-3/4-inch (44 mm) thick steel doors are Level 3 and physical Level A (Extra Heavy Duty).

Roofing

Single ply roofing shall be Sarnafil System 1000 IRMA (insulated roof membrane assembly), loosely laid over sloping concrete deck consisting of a leveling layer, thermoplastic polyolefin sheet roofing membrane, protection layer, drainage panel, extruded polystyrene insulation, filter fabric and pavers. Sheet metal flashing and trim will be stainless steel, type 302/304, 28 gage. The building will be provided with roof anchors to facilitate window cleaning and general building maintenance from suspended equipment.

Structural Overview

The building has an overall rectangular shape, with the longer side running along North Broadway. Column bays are typically 32’-0” by 21’-0” to accommodate the proposed laboratory modules. Column spacing is reduced to 10’-6” on the north side of the building to allow for the use of lateral frames. The basic footprint of the building consists of eleven 21’ spans and four 31’-6” spans to make up approximately 29,000 square feet.

The building’s primary structural system utilizes a mildly reinforced two-way concrete plate system. This basically consists of flat floor plates with additional depth in the form of drop panels near the columns. The typical rectangular shape of the bays works fairly well with this system.

Lateral load resistance will require the use of several shear walls. They will be 12” thick and will run from the foundation up to the roof. There will be approximately 70 linear feet of shear wall per floor.

Typical slab depth is 9½" with 5½" drop panels at the interior columns and 7½" drop panels at the exterior columns. Typical column size is 21"x 21" from the third floor up, and 24"x 24" in the basement and first floor.

Beams, columns, and spread footings will all be reinforced concrete. Perimeter walls will be modular brick façade with CMU backup. Floor to floor distance is 15'-4" on the first floor, 25' in basement, and 14'-8" on the remaining levels.

It should also be noted that the building has been structurally designed to be able to support a three future expansion without major reconstruction.

Approximate Reinforcement Quantities:

- Slabs
  - 5.10 psf typical
  - 6.00 psf Roof level (future 7th floor)
- Beams
  - 20 plf, approx. 300 linear feet per floor
- Columns
  - 1.20 psf
- Shear Walls
  - 5.0 psf (per shear wall area, typical)
- Basement Walls
  - 9.5 psf (all basement perimeter walls)
- Tunnel
  - 12" thick walls with 170 plf of reinforcing
- Concrete Strength
  - 4,000 psi typical
  - 5,600 psi for interior and basement columns)
- Reinforcing Steel
  - Grade 60

Mechanical Overview

System Overview

The mechanical system has been designed to serve laboratory, clinical and office spaces. All central utilities including chilled water, steam, domestic water, natural gas, oxygen and both normal and emergency power will be branched off campus central utilities. There will be separate air-handling systems serving the laboratory, clinical and office areas, and all will be variable air volume (VAV). Services such as water, vacuum and air will be separated for the laboratory and clinical areas through cross contamination devices or dedicated equipment. A common redundant AHU will back-up the clinical and laboratory spaces. The exhaust fan system for the laboratories will be designed with a redundant exhaust fan, and the chilled and heated water systems will be designed to support energy recovery wheels.

All air distribution systems have been designed to allow flexibility for future redesign, primarily through accessibility to the duct systems throughout the air distribution system and by providing symmetry and uniformity in the branch duct layout.

All HVAC equipment with the exception of the central laboratory exhaust fans will be located at the basement level. The exhaust fans will be located on the roof within a screened enclosure. Outside air for the AHU's in the basement will be ducted from the second floor of the building.

Distribution

Central shafts at either side of the building will convey ductwork and service piping to all of the floors. Terminal units will be located over the areas they serve both in the clinical and laboratory areas. Piped services will be further distributed through the ceiling spaces for distribution within the laboratories via a horizontal service chase within the laboratory benches.

Air Handling

Four 44,000 CFM 100% outdoor air industrial grade air handling units with a 40" diameter DWDI fan sized for 10" static pressure will serve the lab areas (8" static pressure for the clinical floor, and 6" static pressure for the atrium/office area). Four 66" diameter SWSI laboratory exhaust fans sized for 70,000 CFM each will be located on the roof, discharging at 10' above the main roof line.

Steam Service

The maximum steam load, including process loads, is estimated at 42,000 lb/hr with the incorporation of energy recovery wheels on the laboratory AHU's. A parallel steam reduction station will be used to reduce the incoming steam pressure from 120 PSIG down to 65 PSIG for domestic and industrial steam-to-hot-water converters, as well as down to 15 PSIG for HVAC steam-to-hot-water converters. System HVAC heating will provided by four steam-to-hot-water converters, two pre-heat exchangers and two re-heat exchangers, each sized for 66% of their respective total loads. The pre-heat exchangers have been sized for 2905 MBH and the re-heat exchangers will be sized for 6085 MBH. Redundant pre-heat pumps will be end suction type sized for 195 GPM at 80 feet of total dynamic head, and the re-heat pumps will also be end suction type sized for 405 GPM at 80 feet total dynamic head. The pump system will have variable frequency drives. There will be two stainless steel steam-to-steam generators for clinical use. The distribution piping to the sterilizers and humidifiers will also be stainless steel. Condensate from the incoming steam and building usage will return to the central plant. Heating water will be distributed to terminal heating equipment and central air handling equipment that uses 100% outdoor air. Humidification will come to the central air handling system for both the laboratory and clinical AHU's. Steam filters rated for 3 micron particle removal will be used in all critical equipment.

Cooling

The preliminary total cooling load has been estimated to be 1,612 tons after the incorporation of energy recovery wheels. Chilled water to satisfy this load will be routed from the campus utilities through decoupled tertiary pumps. It will distributed throughout the building by three tertiary pumps sized 1075 GPM at 80 feet of total dynamic head, each with variable frequency drives sized for 50% of design load. A system pump bypass will be in place for emergency use. All chilled water piping and pumps will be designed to optimize the efficiency of the energy recovery wheels.

Laboratory Equipment

One supply and exhaust terminal unit has been provided for each two lab modules and has been sized to accommodate a 6 foot chemical fume hood. Support spaces will house supply and exhaust terminal units where pressurization control is required in both the clinical and laboratory areas. Areas with high internal equipment gains exceeding 30 W/sf have been provided with supplemental cooling only fan coil units where appropriate. The fume hood and bio-safety cabinet designs are constant volume. The bio-safety cabinets will also utilize thimble connections designed for 120% of the cabinet's rated flow.

Environmental Controls

The facility will be environmentally controlled by a pneumatic-electric, direct digital control (DDC) system by Andover. Central systems will employ a direct digital control system with pneumatic driven terminal devices. The DDC system will have a fiber optic connection to the Woods Basic Science Building, a facility which serves as the control hub for the entire medical campus.

Electrical Overview

Overview

Electrical lines will be distributed throughout the building via conduit and wire systems. Feeders and branch circuit wiring will be encased in electrical metallic tubing (EMT) except in outdoor/hazardous locations which will use rigid steel conduit or Intermediate Metallic Tubing (IMT). Raceways encased in concrete will be Schedule 40 PVC.

It should be noted that all transformers, ductbanks and feeders have been sized to accommodate a future three-floor expansion.

Normal Power

Two redundant 13.2 KV feeders from the hospital's distribution network will supply normal operational power. The feeders will be run to the building via rigid steel conduits and underground concrete encased 4" PVC ductbanks. They shall be 15KV shielded size #4/0 with a 600 volt insulated ground conductor. The new ductbank will tie in with an existing system under Jefferson Street and will be approximately 300 feet in length.

A double-ended substation will transform the feeder service to 480/277 volt, 3 phase, 4 wire for distribution throughout the building. It will include 15 KV fused primary switchgear, 2,500 DVA silicon filled transformers as well as secondary distribution switchgear.

One 300 KVA dry type, shielded isolation transformer with K13 rating will be provided on each floor. Distribution panel boards rated at 600 amperes will be provided for supply to the branch circuit panel boards located in the laboratories and offices. Operating rooms will have two 2.75 or 5 KV 277/120 volt isolated power panels per room and sized to support the equipment loads. Switchboards and variable-frequency drives (VFD's) will be in place for the basement mechanical equipment as necessary.

Emergency Power

A 13.2 KV underground emergency feeder will be run in from the hospital's South Generator Plant. The feeder will be three single conductor #4/0 15KV shielded cables and one #4/0 600 volt insulated ground conductor in an underground PVC encasement. The length of this feeder/ductbank is approximately 700 feet. It will feed into a single-ended substation in the basement that contains a 1000 KVA transformer with a secondary 480/277 volt, 3 phase, 4 wire system for distribution to the emergency switchboard.

In the event of a power outage, automatic transfer switches will reroute the electrical load from normal to emergency source. The switches will be isolation bypass type to allow for routine maintenance, and each will have Square D power meters installed.
Emergency power will be distributed throughout the building by a system of panel boards and feeders. Power will divert to life safety branch loads, critical loads on the Surgery Level and equipment branch loads as needed.

Isolated Ground

An isolated ground system will be provided for the protection of sensitive electronic equipment. A ground cable riser originating at the building main ground field will route upward through the building.

A ground cabinet will be placed on each floor with a copper ground bar pre-drilled for the connection of ground cables from lab/computer equipment.

Transient Voltage Surge Suppression

Transient Voltage Surge Suppression (TVSS) measures will be in place to protect the building's electrical systems from external power surges and lightning strikes. 208/120 volt distribution panel boards will be protected from internal transients by TVSS equipment rated for category B3 environments in accordance with IEEE C62.41. Service entrance equipment will have a one-time surge current rating of 120,000 amperes, and branch channel equipment will have a rating of 80,000 amperes.

Lightning Protection

The building will have lightning rods mounted along the top perimeter of the building on the parapet walls. The rods will have dedicated ground conductors routed down the building to copper ground rods in the earth.

Telecommunications

Telecommunications system design will be up to par with Johns Hopkins' standards. Raceways for communication systems wiring will be provided throughout the building, as well as a communications closet on each floor in a stacked pattern to allow for vertical distribution. A minimum of four 4-inch conduits will be run through the floor at each level. Cable trays will be aluminum ladder style and will be provided in corridor spaces. The main distribution frame room will located in the basement.

Security

The building will be equipped with security equipment supplied by Hopkins, including security doors and a closed-circuit television (CCTV) system with four outdoor perimeter cameras. Cameras will have full pan, tilt and zoom capabilities and their monitors will be located at the security desk in the main lobby/entrance area.

Lighting Overview

Fluorescent lighting fixtures will be found throughout most of the project to provide energy efficiency and easy maintenance. Incandescent and tungsten-based lighting will be used in areas that require special appearance and dimming capabilities. High-ceiling areas, mechanical spaces and exterior applications will utilize high-intensity discharge (HID) metal halide lamps.

Fluorescent fixtures will use T8 lamps and solid-state electronic ballasts with a total harmonic distortion limit of 10 percent. Furthermore, fluorescents will have a minimum color-rendering index (CRI) of 80 and a color temperature of 3,500 Kelvin. Metal halide fixtures will use coated lamps, and parabolic louvers shall be of low iridescent type.

Exterior lighting must provide adequate security and building access. Walkway and plaza lighting will be decorative, pole mounted HID fixtures in accordance with Johns Hopkins Hospital's guidelines. The building façade will be lit with a combination of HID floodlights and wall mounted decorative sconces.

Interior office and laboratory space light fixtures will generally be controlled by wall-mounted occupancy sensor switches. General circulation and exterior lighting fixtures will be controlled by the building's energy management system. Restroom lighting will be controlled via ceiling mounted occupancy sensors.

Fluorescent lighting with dimming capabilities will use dimming ballasts and controls. They will have 1 to 100 percent dimming range, UL listing, Class P thermal rating and Class A sound rating.

Emergency lighting will run off the building's emergency power system. In the event of an outage, dedicated fixtures will light the corridors, lobbies, toilet rooms, stairs, etc. Exit signs will be lit by highly energy efficient light emitting diodes (LED's).

Plumbing Overview

Site Utilities

Utility piping, structures and installation shall be in accordance with the City of Baltimore Department of Public Works Specifications, dated, 2006, and Book of Standards.

An 8" water service and meter from Broadway Street will be installed to provide domestic water and fire protection. In accordance with city standards, the piping will be class 54 ductile iron pipe with harnessed joints.

A proposed 12" RCP private storm drainage connection to transmit roof drainage will extend from an existing inlet in Jefferson Street to the north wall of the new building. The parking area will drain into a concrete sandfilter water quality structure at the south end of the parking lot. The sandfilter will then connect to the existing storm drain manhole constructed during the CRB I project at the southwest corner of the site.

8" DIP Class 52 sanitary services will extend from an existing manholes (also constructed during the CRB I project) and enter at the southwest corner and the north wall of the new building.

According to geotechnical study, the groundwater elevation is anticipated to be at elevation 35-ft. The current lowest floor elevation is at elevation 50-ft, approximately 15-ft above the groundwater elevation. Therefore, a special below-slab subdrainage system will not be needed. However, a perimeter foundation drainage system around all below grade walls will be required.

Roof Drains

Roof drains will empty into rain leaders that run vertically through the building and dump into the storm sewer. Where possible, condensate from air handling units will tie into the storm system as well. Storm water that finds its way to the sub-basement will be pumped to a gravity storm main that is located outside the building. Foundation drain tile will also be pumped by a pump station on the building's exterior.

Domestic Water Supply

Domestic cold water will be provided through a 10-inch combined domestic and fire protection feed service that is separated with a backflow preventer. It will be moved by a 200 GPM triplex domestic water booster pump with a 65 PSIG boost. Domestic hot water and laboratory hot water will be provided by two 25 GPM steam hot water heaters and two 50 GPM steam hot water heaters, respectively. Mixing valves will be provided for each system, as well as the use of independent backflow preventers to separate domestic, laboratory and mechanical make-up water systems. Piping for both systems will be seamless copper water tube, ASTM B 88, Type L, Hard. Fittings will be copper solder joint fittings, 150 lb, ANSI B 16.22-73. Joint solder shall be ASTM B32-78 tin-antimony 95-5.

Drain Waste Vent

Laboratory waste will be directly connected into the sanitary sewer line at the base of the vertical lab stacks. Any toxic, radioactive or high concentration wastes will be disposed of through local "in-lab" safety containers, without the use of piped systems. Vertical toilet stacks will be cast iron no hub type with sanitary risers as needed. Sanitary piping from the labs to the base of the vertical stack will be an Enfield polypropylene mechanical joint piping system. The basement and clinical floors sanitary will need to be pumped to an exterior gravity sanitary drain system.

Sanitary/Sump Pumps

Duplex 20 GPM storm water sump pumps and sanitary sewage ejector pumps will be provided for storm water or sanitary flows that cannot be drained by gravity. All elevators will be equipped with a simplex 10 GPM oil miser sump pump. All pumps will have NEMA 1 standard controls.

Gas Systems

Natural gas service feeds will be run through the mechanical shafts and terminated via valve and cap. Service will later be extended to the labs as required. Specialty laboratory gases, such as N2, will be delivered, handled and distributed from cylinders located just outside the building. The anticipated system will consist of 2-5 cylinders with back-up manifold assemblies. Oxygen and nitrous oxide will be provided through one-inch service piping extended from the Outpatient building across Jefferson Street by a buried schedule 40 PVC conduit system approximately 200 feet in length. Natural gas piping will be black steel pipe, ASTM A 120-78, ANSI Schedule 40, with joints according to the American Standard for piping threads ANSI B2.1-68. Specialty gas piping will be the same as the vacuum system.

Central Compressed Air

Both the laboratory and clinical areas require a supply of dry, oil-free compressed air capable of providing 100 PSIG. The lab system is anticipated to be a duplex 36 SCFM system, while the medical air system is estimated to be a duplex 25 SCFM. Piping will be the same as the domestic water supply, with the exception that the piping is labeled for oxygen service and sealed when delivered to site, and that the joints shall be brazed silver alloy brazing.

Vacuum System

Similar to the compressed air system, both the laboratory and the clinical areas will require separate water ring vacuum systems capable of providing 20 inches of vacuum pressure. The lab system is estimated to be a triplex 172 SCFM system, and the clinical to be a triplex 70 SCFM. Piping, fittings and joints shall be the same as the central compressed air system.

Reverse Osmosis (RO) Systems

A centralized reverse osmosis (decontaminated drinking) water system with a continuous loop design capable of providing one mega-ohm resistivity has been recommended for the facility. The piping system for this water will be a socket or butt fused pigmented polypropylene plastic piping system with true union diaphragm valves at the points of use.

Fire Protection Overview

The building will have complete sprinkler coverage by a combination wet sprinkler-standpipe system. A 1250 GPM electric fire pump will be required to maintain 100 PSI at the top of the standpipe systems, which will be located at the stairwells with floor control valves extending from one stairwell only.

A complete fire detection and alarm system will be in place as well. The system will include a Fire Command System with voice communications and AHU control capabilities, smoke detectors, heat detectors, audio-visual devices and other associated measures throughout the entire building. The main entrance will be equipped with a central graphic annunciator panel to be monitored by Johns Hopkins Hospital's Facilities Department. All wiring for the system will be installed in a dedicated conduit system.

Fire safety considerations have also been accounted for in the design of the building's central atrium. The curtain wall at the north and south ends of the atrium will contain 60 motorized windows, and two 80,000 CFM exhaust fans will be a dedicated smoke control measure. The motorized windows will be connected to the emergency power and fire alarm systems so as to be interfaced with the smoke evacuation system. The atrium will also be equipped with a deluge system that covers both sides of the structural separation glass between the laboratory and atrium spaces.

Zoning & Codes

There exists a PUD (Planned Unit Development) zoning requirement in the area that limits the height of the building to 80' (as measured from grade at the intersection of Broadway and Orleans). Johns Hopkins Hospital is pursuing an amendment to the PUD to increase this height limitation, possibly allowing the addition of three extra floors at a later date.

Applicable Building Codes

Building, Fire, and Related Codes of Baltimore City (July 31, 2006)
International Building Code (IBC), 2000 Edition
Americans with Disabilities Act Accessibility Guidelines (ADAAG)
Published July 23, 2004
Building Code Requirements for Structural Concrete, ACI 3-18
National Fire Protection Association (NFPA) National Fire Codes (NFC)

- NFPA 101, Life Safety Code (LSC), 2003 Edition
- NFPA 45, Standard on Fire Protection for Laboratories Using Chemicals, 2000 Edition
- NFPA 13, Installation of Sprinkler Systems, 2002 Edition
- NFPA 14, Standard for the Installation of Standpipe and Hose Systems
- NFPA 72, National Fire Alarm Code, 2002 Edition

- NFPA 30, Flammable and Combustible Liquids Code, 2002 Edition as referenced by NFPA 45

Should a conflict between the IBC and NFPA codes occur, the architect has proposed that the more restrictive of the two requirements will be applied.

Electrical Codes and Standards:

- National Electric Code 1999
- ANSI/ASME A17.1, Safety Code for Elevators and Escalators
- ASHRAE/IESNA 90.1 – 1999, Lighting Requirements
- ANSI C-2, ANSI C-37, National Electric Safety Code
- IEEE, Institute of Electrical and Electronics Engineers

Mechanical Codes and Standards:

- 2000 International Building Code with 2003 Baltimore City Supplements
- 2000 International Mechanical Code
- 2001 National Standard Plumbing Code
- 2000 International Fire Code
- 2000 International Energy Code
- ASHRAE Handbooks
- ANSI/AIHA Z9.5-1992 American National Standard for Laboratory Ventilation
- AIA Hospital Guildelines

Geotechnical Analysis

After taking eight test borings at a maximum depth of 80', Schnabel Engineering's geotechnical report identifies the soil on site to be mostly existing fill soils placed during previous site construction and demolition, and Patuxent Formation soils of the Potomac Group. These Coastal Plain soils are Cretaceous Aged deposits and are locally known to be highly over consolidated. Below these agents are residual soils and disintegrated rock derived from the physical and chemical weathering of the underlying bedrock. Local geologic maps describe the rock as undifferentiated crystalline rock. Subsurface water was encountered at depths of 43 to 59.5 feet below the ground surface (EL 16.5 to EL 31). As mentioned before, the current lowest floor elevation is at elevation 50-ft, over fifteen feet above the water table. Therefore no dewatering system will need to be in place during construction.

Granular soils of Stratum B may be used as backfill. Theses soils consist of lean clay (CL), silt (ML), and sand (SM, SC, SP). All structural fill for wall backfill and slab support should consist of material classified ML, SC, SM, SP, SW, GM, GC, GW, or GP in accordance with ASTM D-2487. The liquid limit of the fill soils should be less than 50, and the plasticity index should be less than 25 when tested in accordance with ASTM D-4318. Compacted fill should be free of organics, roots, debris, and rock larger than 4-inches in diameter. Compacted fill should be placed in loose, level lifts not exceeding 8-inches in thickness, and compacted to at least 95% of the maximum dry density per ASTM D-698, Standard Proctor.

Allowable bearing capacity

An allowable bearing capacity of 8.0 ksf is to be used for spread footings founded on dense Potomac Group Sands (dense sands of Stratum B), 6.0 ksf for spread footings founded on hard clay (Stratum B Lean Clay) that are anticipated in the southwest corner of the building, and 4.0 ksf for wall footings.

Predominant Soils on Site

- Stratum A – Existing Fill Soils – depths of 5.0 to 18.5-ft below grade
  - Consists of FAT and LEAN CLAY (CH,CL), SILT (ML), and SILTY, CLAYEY, and Poorly Graded SAND (SM, SC, SP), with various amounts of gravel, rock fragments and root hairs.
- Stratum B – Patuxent Formation – depths of 49.0 to 78.5-ft below grade
  - Consists of LEAN CLAY (CL), SILT (ML), and SAND (SM, SC, SP) with various amounts of gravel and ironite.
- Stratum C – Residual Soils – depths of 64.0 to 78.5-ft below grade
  - Consists of LEAN and FAT CLAY (CL, CH) and SILT (ML), with various amounts of sand, mica, and rock fragments.
- Stratum D – Disintegrated Rock – encountered below or within Stratum C
  - Defined as residual earth material with a Standard Penetration Resistance between 60 blows per foot and refusal.

Compaction Requirement under Slabs and Foundations

A modulus of sub grade reaction (k) of 200 pci is to be used for slabs supported on firm natural soils, with an unconfined compressive strength of at least 3 tons per square foot in cohesive soils. Fill, floor and pavement sub grades should be rolled with at least four passes of a minimum static weight, 5-ton roller under Schnabel's observation.

Foundation Analysis

Similar buildings adjacent to the proposed site are founded on either deep foundations (caissons, piles, etc.) or spread footings. The soil borings surrounding the proposed site suggests that either system would be acceptable for this building. Considering the allowable soil bearing pressure and the cost and time advantages of spread footings over deep foundations, spread footings were chosen for the foundation system.

Local Conditions

The mildly reinforced two-way concrete plate system is a very common structural framing system in the Baltimore area. There is a planned unit development (PUD) zoning ordinance in the area that limits the height of the buildings to 80'. Concrete plate construction is advantageous in this situation as the floor and beam structure is generally shallower, creating a larger plenum space and allowing a lower floor-to-floor height. This essentially creates the opportunity for more floors to be constructed in a given building height than a steel frame system. This practice is commonly employed in the Washington D.C. metropolitan area as well as other areas that employ height restrictions.

Similar buildings adjacent to the proposed site are founded on either deep foundations (caissons, piles, etc.) or spread footings. The soil borings surrounding the proposed site suggests that either system would be acceptable for this building. Considering the allowable soil bearing pressure and the cost and time advantages of spread footings over deep foundations, spread footings were chosen for the foundation system.

Whiting-Turner has a small parking lot in front of their offices (which are located in the median space of N. Broadway) for their own staff and project managers. Subcontractors and general construction workers must find parking on their own; there is no designated area for construction parking. There are a few public garages in the area as well as a number of street spaces. Parking in Johns Hopkins Hospital garages is highly discouraged, as they have their own issues with employee parking.

The project is not LEED rated and there is currently no plan for the recycling of construction waste. However there is the possibility that some subcontractors may have their own recycling program in place.

Looking west from site towards Hopkins' Weinberg Building, which houses the Sidney Kimmel Comprehensive Cancer Center

Client Information

The Wilmer Eye Institute is an entity of The Johns Hopkins Hospital and Johns Hopkins Medicine. The institute has been around for 83 years and is world-renowned. Wilmer has always been at the forefront of both laboratory research and clinical testing and treatment of modern eye diseases such as macular degeneration, glaucoma, and corneal disease, among other blinding afflictions.

The institute has essentially outgrown its old building and the technology which it provides. Wilmer's faculty of 80 is currently conducting $25 million worth of federal and other research, and performs more than 8,000 major eye surgeries annually, both inpatient and outpatient.

The building will house an outpatient surgery center with six operating rooms, as well as up to five floors of open research laboratories and support spaces, while also allowing for the possibility of a three-floor future expansion. It has been designed with the intention of meeting a patient demand for over 9,000 annual operations, and will accelerate discovery for the prevention and treatment of blinding diseases, particularly macular degeneration, which is the leading cause of blindness in Americans over the age of 55.

The open-type "laboratories without walls" are intended to create scientific "neighborhoods" and have been designed to get the most out of having many experienced people together in the same area. Surgeons, clinicians, geneticists, epidemiologists, clinical trial specialists, biochemists, molecular biologists and other medical specialists will all be able to work together and share expertise to solve critical problems.

The building is being constructed on the site of a former on-grade parking lot, and is in a prime location, virtually across the street from the main hospital entrance. It will be connected to the adjacent Cancer Research Building I via underground tunnel, and is less than one city block from their current facility. The new Wilmer building is part of a $1.2 billion Johns Hopkins Medicine campus redevelopment program designed to replace existing, aging structures on the 80-acre campus. The centerpiece of the redevelopment is the hospital's New Clinical Building, which consists of two clinical towers, one for cardiovascular and critical care services and one for a children's hospital. The Wilmer building is scheduled to be completed and occupied by mid 2009.

Looking east into the tunnel trench at utility connections to the adjacent Cancer Research Building I

Project Delivery System

The Wilmer Eye Institute project utilizes a traditional design-bid-build project delivery system with The Whiting-Turner Contracting Company. In this situation, all of the subcontracting is handled by the general contractor. This alleviates an extensive amount of time and effort from the owner, as there are many different subs that need to be hired on a job of this magnitude. Johns Hopkins Hospital's Facilities department has trained project managers to oversee the project and protect the interests of the institution, but they do not have the capacity to handle all of the functions of a licensed general contractor.

The contract for the construction of the building is a negotiated guaranteed maximum price (GMP). This protects the hospital from paying more than was agreed in most situations, although there can be changes made to the agreed amount if they are legitimate.

It should be noted that the permitting process in this particular project is quite extensive. Baltimore City has a number of regulations that must be adhered to, and being on Johns Hopkins Medical Campus brings yet more requirements. For one, there is fee to tap into the city's utilities that essentially must be paid throughout the entire duration of the project. Hopkins also had to provide a bond to the Department of Public Works to ensure that they would maintain proper storm water drainage throughout the construction process.

Completed column footings

Site Logistics

The major earthwork will commence to three different elevations, and all other non-shaded areas on the plan will be sloped accordingly. This is illustrated in the excavation sequencing plan in the appendix of this report.

Additionally included are the locations of the temporary subcontractor office trailers, temporary utility connections, tower crane, man/material hoist, and the construction ramp needed for excavation prior to the crane erection.

There will also be a temporary scaffold bridge for foot traffic over the tunnel trench throughout the duration of the tunnel construction. After the tunnel is completed the earth will be backfilled and the construction gate on Jefferson Street can function as a vehicle exit.

Temporary electric, as well as future permanent electric and water services have been routed straight across North Broadway Street from the adjacent Weinberg Building. This deviates from the original infrastructure utility documents. There is a fee associated with running utilities and like objects under public roadways, and this option essentially costs less because there is less length underneath the street. In the northeast corner of the site is the hub for the campus utilities located underground that will be the future connection point for all permanent HVAC lines.

Also note that there is no area designated for material lay-down. All material deliveries will either be directly constructed into the building or staged within the building footprint.

The updated site logistics plan can be found in the Appendix at the end of this document.

Temporary excavation ramp to be removed.

Project Schedule Summary

The schedule generated for this project is generally organized by space rather than by trade. This represents the fashion in which the building is to be constructed.

The foundation work is scheduled to begin on the 24th of October, 2007. Spread footings will be excavated and concrete will be placed directly into the earth form. The installation of column footings and perimeter walls will immediately follow, and eventually waterproofing and backfilling. Tower cranes will also be erected during this time.

The structure of the sub-basement and basement, and each subsequent floor will be constructed in sequence after the foundation and cranes are in place. The slabs for each floor will be put up two days after the columns and walls for the previous floor were poured.

Building enclosure will begin with the perimeter walls. These will begin to be put in place on each floor after the reshoring has been removed from the adjacent floor above. The skin of the building (vapor barrier, brick veneer, glass curtainwall, etc.) will begin about 75% through the perimeter wall process, and will wrap around the building clockwise starting on the north face. As the building becomes enclosed, each of the interior trades will begin their work in sequence as the floors become available, eventually ending with the finishes and construction cleanup. In general, the interior work will commence by floor from bottom to top as the superstructure is constructed, and work within the floor is organized by type of space (i.e. general sterile, laboratory, operating room, etc.).

*A detailed schedule is located in the Appendix at the end of this document.

Looking south from site

Estimate Summary

Exterior Enclosures Costs

Exterior Enclosures Summary Total Exterior Enclosures Costs:			
	Material	Installation	Total
Brick Face Cavity Wall	$379,401	$698,023	$1,077,424
Tubular Aluminum Framing	$284,325	$266,938	$551,262
Curtain Wall Glazing	$187,163	$194,323	$381,486
Total	$850,888	$1,159,284	$2,010,172

The exterior wall assembly consists of a brick face cavity wall and glass curtain wall glazing with tubular aluminum framing. The cavity wall primarily consists of standard bricks with an 8" CMU back-up, 2" polystyrene insulation and a 2" air space.

For simplicity in this estimate, it was assumed that all curtain wall glazing is double-pane ¼" insulated glass. Cavity wall figures include a brick shelf, ties to the backups and necessary dampproofing, flashing, and control joints every 20'. All unit prices were referenced from R.S. Means Assemblies Cost Data 2008.

Square Foot Extrapolation Exterior Enclosures Costs Per S.F. of Building Floor Area:	
Material	$4.21
Installation	$5.73
Total	$9.93

A more detailed estimate broken down by elevation can be found in the Appendix at the end of this document.

Structural Systems Costs

Structural Systems Summary	
Total Structure Costs:	
Material	$2,240,986
Labor	$598,658
Equipment	$48,865
Total	$288,509
Total w/ Overhead & Profit	$3,508,646

The superstructure of the Wilmer Eye Institute building consists of a mildly reinforced two-way concrete slab system with drop panels around the columns. Typical slab depth is 9½" with 5½" drop panels at the interior columns and 7½" drop panels at the exterior columns. Typical column size is 21"x 21" from the third floor up, and 24"x 24" in the basement and first floor. The foundation walls are cast-in-place concrete as well as the mat foundations and strip wall footings.

The building will require an estimated 12,650 cubic yards of concrete and 760 tons of rebar.

Square Foot Extrapolation	
Structural System Costs Per S.F. of Building Floor Area:	
Material	$11.07
Labor	$2.96
Equipment	$0.24
Total	$14.27
Total (O&P)	$17.34

The detailed structural estimate and calculations can be found in the Appendix at the end of this document.

General Conditions Costs

General Conditions Summary	
Personnel	$1,425,173
Trash Removal	$101,000
Temporary Building Enclosure	$63,240
Temporary Facilities/Utilities	$52,552
Other	$168,244
Total	$1,810,209

General conditions for this project are fairly straightforward. A few items of interest are the scaffolding bridge for foot traffic over the tunnel trench, and the temporary building enclosure so interior work can commence in the winter of 2009.

Personnel salaries were estimated based on average numbers from R.S. Means 2008, and their durations on the project were established by the area in which each staff member is managing (i.e. shell/core manager is on for the scheduled duration of the shell/core construction).

Monthly Cost Breakdown	
Category	Cost per Month
Personnel	$56,080
Office Supplies	$415
Temporary Offices	$700
Temporary Utilities	$527
Trash Disposal	$2,760
Temporary Facilities	$685
Total Monthly Costs	$61,167

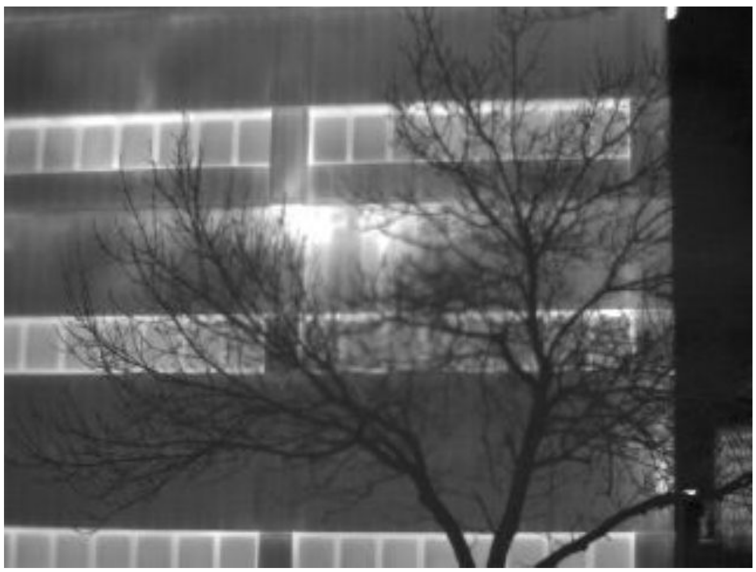
A detailed breakdown of the general conditions costs can be found in the Appendix at the end of this document.

Building Envelope Analysis

Introduction

The building envelope is a critical component of any facility since it both protects the building occupants and plays a major role in regulating the indoor environment. One of the most important properties of the building envelope is its ability to keep water from entering the building.

Unwanted water penetration in buildings can cause many problems. If water penetrates or condenses in the envelope it can saturate or deteriorate the elements that make up the wall, causing them to not function as designed. The picture below is infrared image of the outside of an office building. The white area of the wall is a hot spot where the insulation has become wet and is taking longer to cool than the rest of wall around it.



According to Peter Grech, building operations expert, author, consultant, and president of the Superintendents Club of New York, building envelopes tend to fail for five basic reasons:

- Improper design
- Poor workmanship during installation
- Inadequate maintenance and inspection
- Faulty or mismatched materials
- Mishaps like lightning, rooftop furniture, or heavy objects puncturing the roof or floor

In general, any opening in the building is a large potential for air and water leakage if it is not designed and installed correctly. The infrared image below is a prime example of how heat (and in turn energy and money) can be lost due to leaks in the building envelope. Careful detailing is required to avoid such convective losses.

The doors and portions of the wall in this image show failures in the building envelope and missing insulation when viewed with a thermal imaging system.

Intent

This section is the most personally important part of the capstone as it directly reflects area of study that will be practiced upon graduation. The overall goal of the analysis of the building envelope was to learn as much as possible about the exterior enclosure system and its design and construction procedures.

Specific technical goals of analysis:

- Identify potential areas of issue with regards to ensuring water tightness
- Investigate thermal bridging prevention
- Investigate opportunities to unitize curtain walls in the northeast corner of the building
- Investigate potential areas of mold growth in cavity wall system

Overview of Envelope Systems

- Brick face cavity wall
    - Standard 4” modular face brick, ASTM C 216, Grade SW, Type FBS
    - 8” CMU back-up, ASTM C 90, classified lightweight
    - Mortar for unit masonry: ASTM C 270BIA
    - Grout for unit masonry: ASTM C 476
    - 2” extruded polystyrene board insulation and drainage panels, ASTM C 578, Type IV, 1.60 lb/cu.ft. with increased R-value (5.6 deg F-h-sq.ft./btu)
    - 2” air space
    - Modified bituminous sheet waterproofing, 60-mil-thick with adhesive on one side

- Flexible copper-laminated flashing, 7 oz./sq.ft. bonded with rubber based adhesive between two layers of glass-fiber cloth
- Compressible filler strips
- Elastomeric sealant, ASTM C 290
- Preformed control joint gaskets, ASTM D 2000
- Cellular plastic weep vents, UV resistant
- Free-draining polyethylene strand mesh weep vent
- Steel bent-plate brick shelf support

- Glazing with tubular aluminum framing (includes curtain wall, skylights and glass entry doors)
  - Thermafiber insulation CW-90: mineral wool insulation with FSP scrim-reinforced foil
  - 1" clear space between insulation and back side of spandrel glass
  - Foil tape seal on perimeter of curtain wall insulation
  - Tubular aluminum framing
    - Sheet and plate: ASTM B 209
    - Extruded bars, rods, shapes, and tubes: ASTM B 221
    - Extruded structural pipe and tubes: ASTM B 429
  - Double pane ¼" glazing system of varying types:
    - Insulating PPG solarban 60 on clear glass
    - Tempered and non-tempered
    - Laminated ceramic fire-rated glass
    - Decorative laminated glass
    - Reflective insulating glass panels

- Roofing
  - Bond-breaker strips: asphalt saturated organic roofing felt, ASTM D 226, Type I
  - Hot fluid-applied waterproofing, rubberized asphalt
  - Modified bituminous flashing sheet: SBS-modified bituminous sheet, 160 mil-thick
  - Polyisocyanurate board insulation, ASTM C 1289, Type II, average R-30, sloped ¼" per ft.
  - Heavyweight concrete walkway roof pavers
  - PVC roofing membrane, ASTM D 4434, Type II, Grade 1, 72-mils-thick, Sarnafil G410
  - Sarnifil drainage panel

- Cast-in-place foundation walls
  - Pre-applied integrally bonded sheet waterproofing membrane, 1.2mm nominal thickness
  - 2" extruded polystyrene board insulation and drainage panels, ASTM C 578, Type IV, 1.60 lb/cu.ft. with increased R-value (5.6 deg F-h-sq.ft./btu)

Potential Areas of Weakness

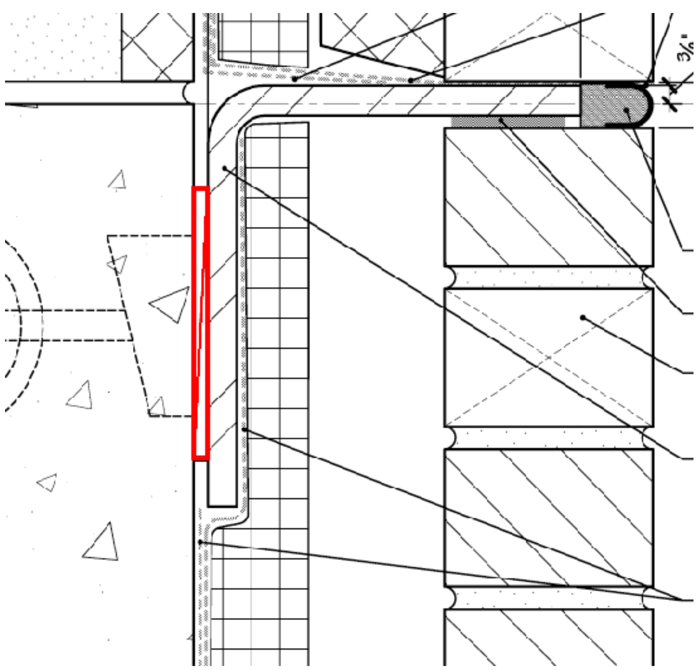
Upon investigation and research, the following areas have been identified as potential points of moisture and thermal penetration if proper care is not taken during construction:

- Interface details between exterior wall types
  - Edges between curtain and cavity walls
  - Interface between concrete foundation walls and CMU cavity wall
- Door and window frame seals
  - Motorized smoke-control windows
  - Automatic glass storefront entry doors
  - Steel access doors
- Thru-wall and roof penetrations
- Flashing and moisture barrier at brick shelves and concrete sills

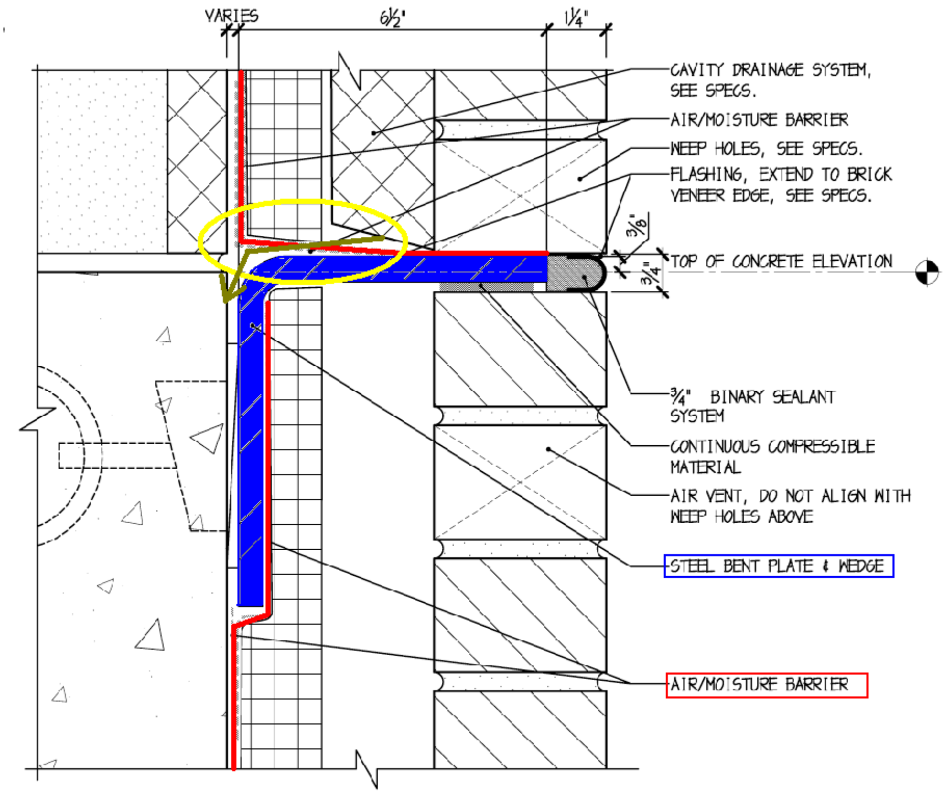
Brick Shelf Thermal Bridging

Thermal bridges can be defined as regions of relatively high heat flow conductance in a building envelope. The steel bent plate that supports the brick shelf is an area of concern because of the high heat transfer rate of steel and the fact that the item penetrates the vapor barrier. In extreme winter conditions, the steel could potentially transfer heat from the concrete floor slab supporting it, causing radiant heat losses due to a cold spot created on the floor area near the exterior walls.

Upon investigation of the typical brick shelf connection detail it was noticed that there is a material between the connection of the steel bent plate to the concrete floor slab, as seen in the image below. So long as this material is made of a some type of plastic or other material with a low thermal conductance it should act as a sufficient thermal break.

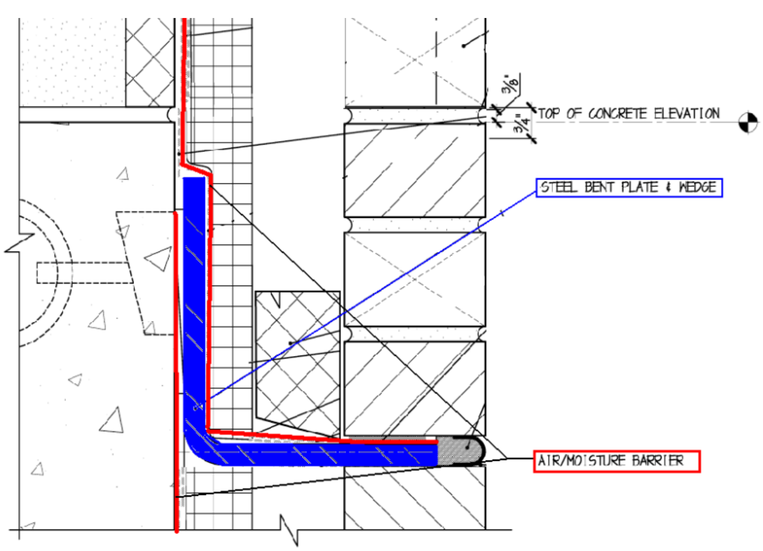


Another concern with this brick shelf detail is the orientation of the steel bent plate. The image below shows the current orientation of the brick shelf and the flashing/vapor barrier. The area inside the yellow oval represents a weak area, as there is a potential for water droplets to rest on the level steel bent plate, possibly weakening the bond of the waterproofing to the steel. If this happens, water could eventually seep into the wall (path of the dark yellow area) and cause mold growth problems or deterioration of wall elements.

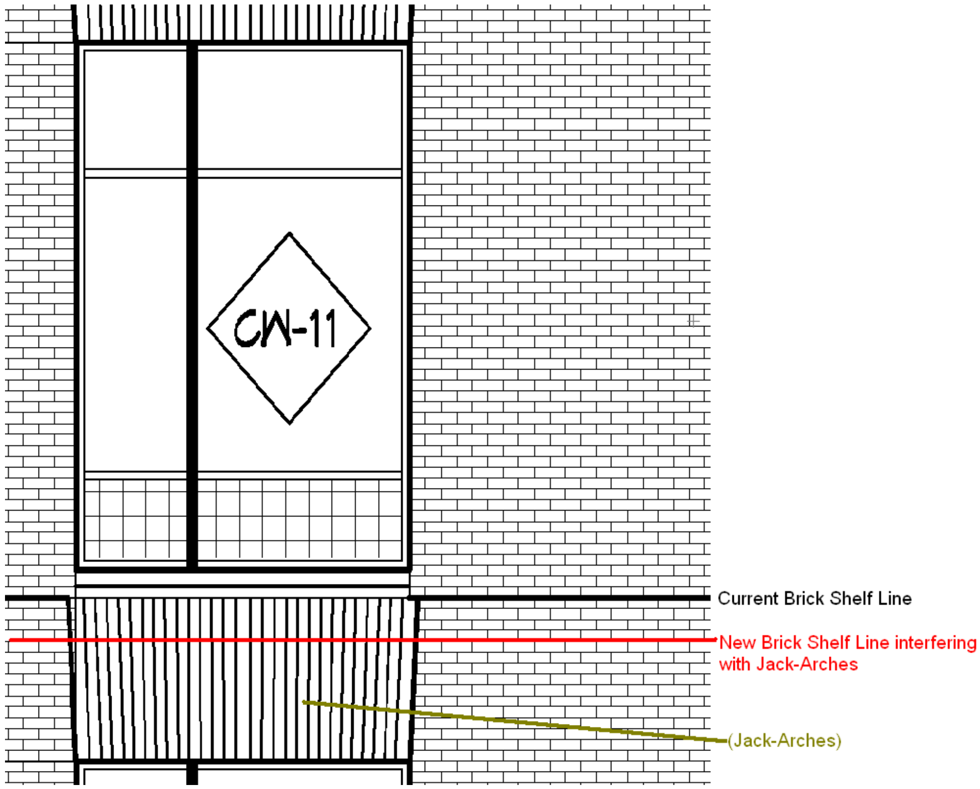


5
A7.04
SECTION DETAIL @ SHELF ANGLE
SCALE: 6"=1'-0"

An alternative design is shown below that is visibly more effective, not only eliminating the weak area, but also allowing the vapor barrier to be run behind the steel angle, creating a back-up and more secure design.



The problem here is that this will not work with the current architectural design of the window system. If this was to be implemented, it would lower the brick shelf line, effectively interfering with the jack-arches above the windows. This can be seen in the partial building elevation below. A decision such as this would have needed to happen much earlier in the design process.



Curtain Wall Prefabrication

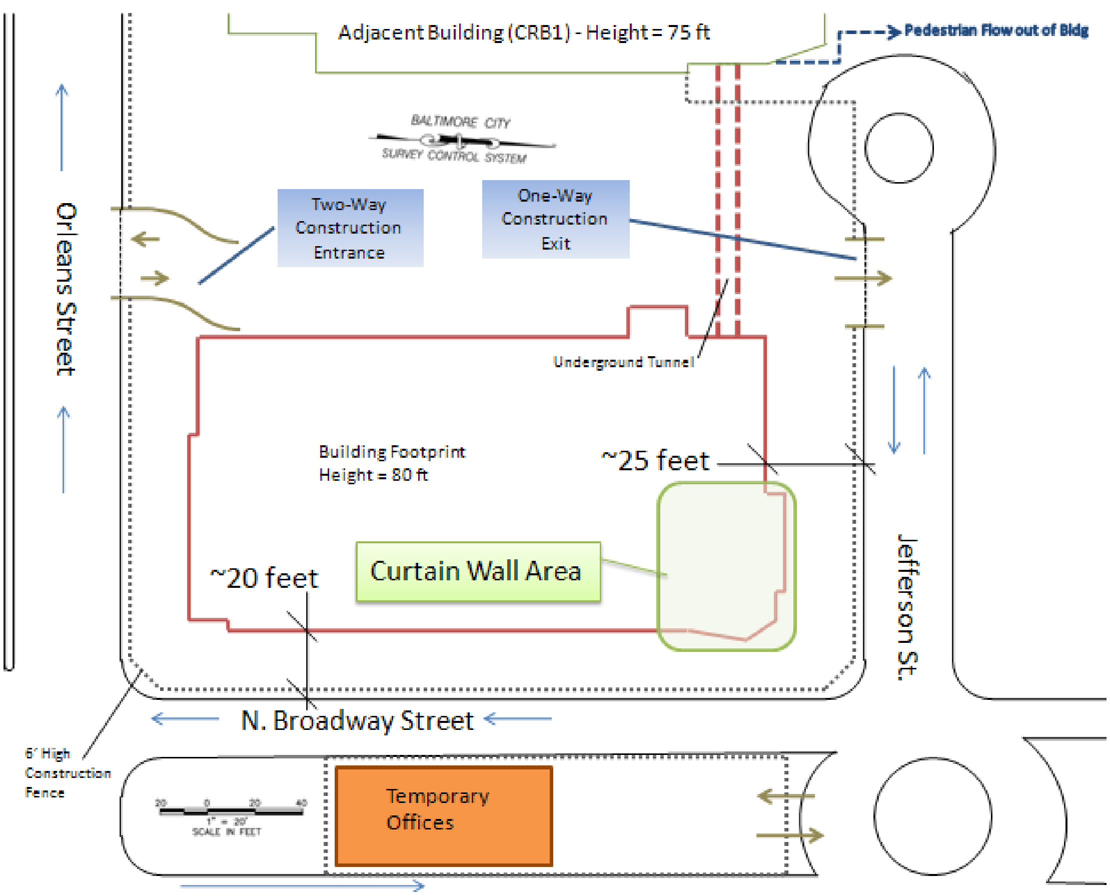
The northeast corner of the building quarters two fairly large curtain walls that span the entire height of the building and cover an area of over 3000 square feet.

Many curtain wall installers have the ability to assemble walls like this in pieces at an offsite location, typically in sections one storey in height and 5-6 feet wide, and then have them delivered to site and lifted into place by crane. Service Glass, the curtain wall installers on this project, reports that they do in fact have the capability to do this, but that it was not the best decision on this project.

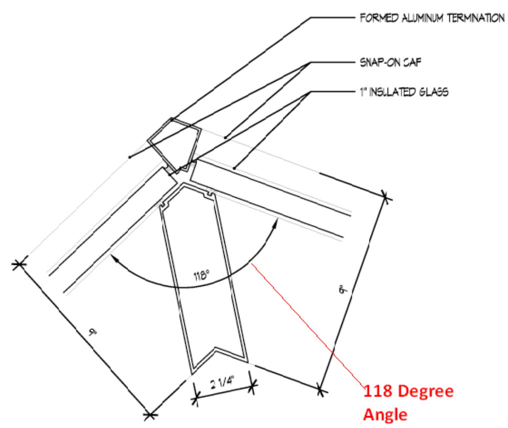
The ultimate deciding factor in making the decision between stick building and prefabrication is the cost-per-manhour breakdown. In estimating each scenario, the total cost of the process in each method is divided by the number of man-hours required in each, producing a cost-per-manhour. Bottom-line being that the option with the lower cost-per-manhour is essentially the more feasible option.

There are several factors in this case that make stick building a more feasible decision over prefabrication. A large part if it is the need for a crane. There will be no crane on site during the curtain wall installation as the tower crane is being disassembled immediately after the superstructure is complete. So essentially the only way to make unitization possible is to rent a crane, which is extremely expensive.

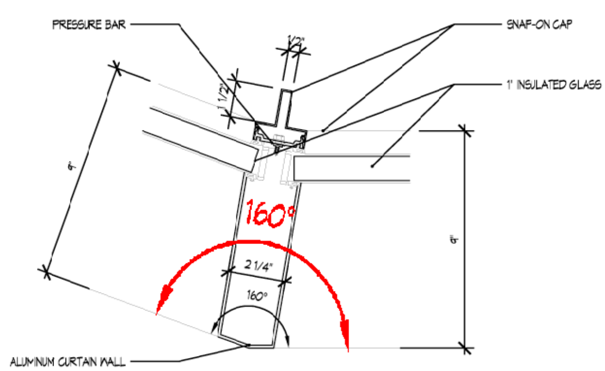
Another issue with using a crane is the fact that the orientation of the site would make it extremely difficult. Reference the site plan below. There not a very convenient area on site for a crane to do this job. It would need to be placed either on Jefferson Street, or in the slim areas between the building and the site fence on the north (right) or west (bottom) sides. Also, the delivery trucks would need an area to sit as the sections are taken off and put into place. Assuming Jefferson Street as the ideal place for this, the trucks would either have to traverse the site (enter from Orleans Street, exit by turning right onto Jefferson Street), or do a turnabout at the end of Jefferson Street. Note that there are also trees and a narrow sidewalk lining North Broadway Street. Any way you look at it, trying to work this out would be a pain and could potentially cause many issues with clogging up the site and restricting access for other machinery to maneuver in the already tight area.



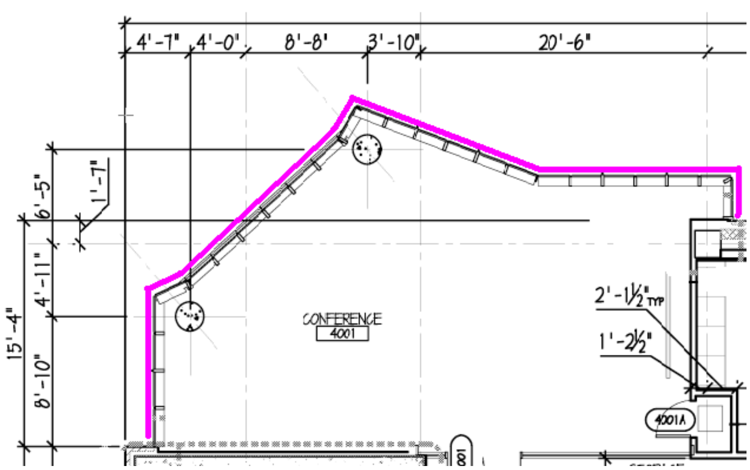
The other deciding factor revolves around the irregular shape of the northeast curtain wall. As seen in the illustrations below, the wall has many different shapes, including 118° and 160° angles and three large triangular sections. Attempting to fabricate this many irregular pieces in an offsite facility would be extremely difficult, and it would be likely that not every piece would fit correctly upon installation. If any items are fabricated too small, wrong angle, etc., they will have been wasted, and will have also created the need for another to be fabricated correctly and redelivered to site. Missing an essential piece could also hold up the rest of the installation, wasting even more time and money. So essentially attempting to unitize a wall of this complexity is very risky, as the smallest error could end up costing quite a bit of money and man-hours. When walls are stick-built on site, it is much easier for the workers to visualize what is being built, and they can take measurements and fabricate each piece to its exact dimensions.



2 CORNER MULLION DETAIL
A0.09 NE CORNER CURTAINWALL SCALE: 3"=1'-0"



3 INSIDE CORNER MULLION DETAIL
A0.09 NE CORNER CURTAINWALL



Conclusions

The exterior enclosure system is an extremely important part of maintaining a building's performance and quality. Failures in the building envelope can cause a number of different problems, including thermal and water leaks, mold growth, and deterioration and failure of envelope materials. And these problems will add up to a costly setback between the costs of repairing damaged elements and the higher energy bills generated from components not performing to design standards. It is imperative that the building envelope gets the proper attention throughout the entire design and construction process.

Common areas of the building that have a strong potential for moisture and thermal penetration include interfaces between varying types of envelope systems (i.e. dividing edge between curtain wall and cavity wall), door and window frame seals, wall and roof penetrations, and flashing and vapor barrier details at terminating areas (sills, brick shelves, etc.). These details must be specifically outlined in shop drawings and should be reviewed by a design professional to ensure quality. Furthermore, the installation process should be monitored frequently to be sure things are being installed as they have been designed. Again, creating a fully functional and efficient building envelope is a process that involves many parties and must be acknowledged throughout the entire design and construction process.

Thermal bridging is another common problem in envelope systems, particularly common in steel elements that support brick façade systems. A common method of preventing this from creating a cold spot on the building interior is to insert some kind of plastic or other thermally insulating material in between the steel and the concrete to which it connects. This creates the thermal break that is needed to stop such a problem from occurring.

Unitization of the curtain wall proved to be unfeasible for a number of different reasons on this project, primarily being the large expense of renting a crane, a lack of space onsite, and a large risk incurred from trying to prefabricate sections of a wall of such complexity and irregular shape. If the curtain wall covered a larger and area and were more uniform, off-site fabrication may have proved to be a more cost effective and faster method. However in this case, stick-building was ultimately the wiser decision.

Infection Control Analysis

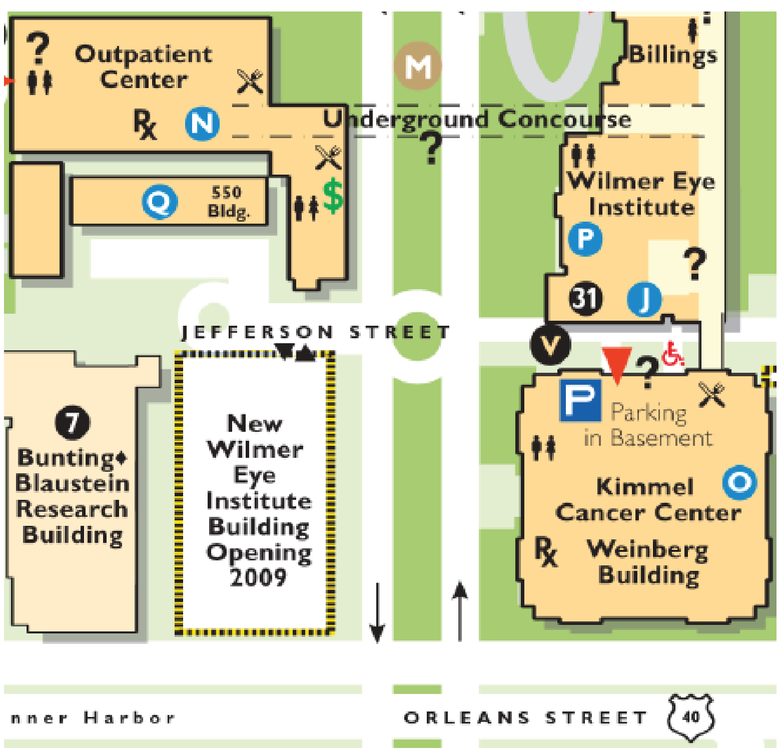
Introduction

The main intention of this analysis is to become familiar with infection control practices in contemporary healthcare construction. Hospital buildings and construction projects such as this one hold the safety of many people's lives, including patients and workers alike. It is imperative that the construction process be carried out in the safest manner possible. Becoming familiar with common precautions will help aid the spread of knowledge in this regard and will ultimately create an equally productive and less harmful building industry.

Overview of Building Site and Adjacent Facilities

The Wilmer Eye Institute Outpatient Surgery and Laboratory Building is being constructed on the fully functioning medical campus of Johns Hopkins Medicine. Bordering the construction site immediately adjacent to the west is Hopkins' Cancer Research Building I, a multi-storey complex that is occupied daily and accommodates sensitive scientific experiments. This building will connect to the new Wilmer building via underground tunnel.

Across North Broadway Street to the east is Hopkins' Weinberg Building. Weinberg houses the Sidney Kimmel Comprehensive Cancer Center, which has active programs in both clinical and laboratory research. On any given day the building holds a broad variety of people, including patients, nurses, doctors, researchers, etc. Across Jefferson Street to the north is the hospital's general outpatient center. This building is operational twenty four hours and also holds a large variety of different people every day.



ICRA Guidelines

Infection Control Risk Assessment (ICRA) as a pressing concern in contemporary healthcare construction. An alarming number of patient deaths in hospital facilities are related to the after-effects of construction and renovation projects. Dust and other debris generated by projects can affect nearby facilities' indoor air quality, while vibration from large equipment has also been known to damper patient recovery, among other extremely legitimate concerns. This is a tremendously critical aspect of medical construction, as mistakes in this regard can easily result in patient fatalities.

The AIA outlines an Infection Control Risk Assessment (ICRA) program that focuses on the reducing the risk of infection throughout the phases of facility planning, design, construction, renovation, and even facility maintenance. This document is an extremely useful tool for a hospital in assessing current construction practices, as it weighs knowledge about infection, infectious agents, and care environment, providing the institution with a recommended set of precautions for renovation and new construction projects.

A copy of the ICRA guidelines can be found in the appendix of this report.

The construction of the new Wilmer building is classified as a 'Type D' project—a major new construction project that includes activities which require consecutive work shifts and requires heavy demolition. Due to the sensitivity and nature of the adjacent facilities (outlined above), the project is also categorized in the patient risk group of 'Highest Risk'. The combination of 'Type D' project and 'Highest Risk' patient group places this project in the 'Class IV' set of precautions.

The following 'Class IV' precautions must be taken during construction:

- Isolate HVAC system in area where work is being done to prevent contamination of duct system.
- Complete all construction barriers before construction begins. Request an inspection from the Owner prior to construction.
- Maintain negative air pressure within work site utilizing HEPA filtered ventilation units or other methods to maintain negative pressure.
- Seal holes, pipes conduits, and punctures to prevent dust migration.
- Construct anteroom and require all personnel to pass through this room. Wet mop or HEPA vacuum the anteroom twice per 8-hour period of construction activity or as required to minimize tracking.
- Wet mop or HEPA vacuum the construction interior once per 8-hour shift, minimum.
- During demolition, dust producing work or work in the ceiling, disposable shoes and coveralls are to be worn and removed in the anteroom when leaving work area.
- Contain construction waste before transport in tightly covered containers.
- Place dust-mat at entrance and exit of work area and replace or clean when no longer effective.
- Keep work area broom clean and remove debris daily.
- Wet mop hard surface areas with disinfectant at completion of project. HEPA vacuum carpeted surfaces at completion of project.

- Maintain barrier integrity.
- Close doors and install project sign.
- Establish traffic patterns that minimize exposure to patient care areas.
- Quickly dry water spills.
- Wipe casework and horizontal surfaces at completion of project.

While there are other references that provide adequate precautions, these ICRA guidelines must be followed. The AIA guidelines are outlined in Division 1 of the specifications booklet, including the above activities, recommended products to carry these out (i.e. adhesive walk-off mats, HEPA filtered vacuum and zip-up door manufacturers, etc.), and execution guidelines. All activities will be closely monitored by both the general contractor on site, and Johns Hopkins Hospital's Facilities staff.

Conclusions

The new Wilmer Eye Institute building is being constructed on the fully functioning Johns Hopkins medical campus and is surrounded on three sides by sensitive hospital facilities that contain patients and many others on a daily basis, some on a twenty-four hour basis. The AIA's Infection Control Risk Assessment (ICRA) Guidelines outline a number of precautions that must be adhered to throughout the entire construction process.

The construction of this building is classified as a 'Type D' project under these guidelines, which is the category of highest patient risk, as it is a major new construction project in proximity to so many sensitive medical facilities. It is extremely important that all of the above mentioned actions be carried out throughout the entire duration of the project.

Ultraviolet Germicidal Irradiation System – Mechanical and Electrical Breadth Studies

Introduction

Microbial growth can be comprised of fungi, bacteria, or even algae, and can occur anywhere that air comes into contact with moisture. Cooling coil equipment has moist air running through it that is constantly creating moisture on the fins. Cooling coils and other air-handling equipment that become mediums for microbial growth can cause respiratory infections in building occupants.

Ultraviolet light from the sun is nature's way of regulating micro-organisms. Once a micro-organism is exposed to UV light, its DNA becomes altered so as to prohibit its reproduction. With the relatively short lifespan of these organisms, and no way to reproduce, their populations essentially die off drastically and rapidly. Theoretically, direct exposure to ultraviolet light can sterilize any surface given the proper amount of time.

The ultraviolet region of the electromagnetic spectrum occurs at the frequency just below that of visible light. Research suggests that UV light of wavelengths shorter than 300 nanometers is extremely effective in eliminating micro-organisms. Ultraviolet germicidal irradiation equipment typically uses a wavelength of 254 nanometers.

In typical air-handling disinfection systems, a lamp or an array of lamps is placed in a position so as irradiate the cooling coils. It is optimal to irradiate both the upstream and downstream side of the coil, although there often is not enough room in the air-handling unit to install a system on both sides. Lamps are typically installed perpendicular to the fins of the cooling coil. However the orientation is not at all critical as long as the entire area of the coils is being irradiated.

The effects of ultraviolet light on micro-organisms were first discovered in the 1800's, and several scientific studies were even published over a century ago. The first ultraviolet system designed specifically to disinfect the inside surfaces of air-handling equipment came about in 1974. More recently, in 2006, Dr. Kowalski, PE, Ph.D., of Penn State University, produced a valid report presenting that UV can be cost justified as a capital expenditure by the savings it provides. This report has provided a solid framework for much of the research and cost-benefit analyses in this section of the report.

Benefits

Applying ultraviolet light to the surface of cooling coils and other air-handling equipment will prevent micro-organisms from growing. An ultraviolet system will not clean a system that has become fouled, but it will prevent a clean system from becoming fouled. An ultraviolet system does not replace the need for filters in an air-handling system; it is simply a supplemental tool used to prevent microbial spores from growing and entering the airstream, creating a cleaner and safer indoor air environment.

Ultraviolet cooling coil irradiation systems provide a facility owner savings in energy and maintenance costs, as well as the enormous benefits of a healthier indoor environment, which is even more crucial in a hospital setting. The energy savings come from a combination of two effects, the first being a reduced fan pressure from removal of airflow-constricting fouling and the other is the increased rate of heat transfer achieved by the cleaner coils. Cooling coil irradiation systems essentially keep the equipment operating at the original design conditions, likely extending the operational life of the coils. And since the coils wills stay clean as long as they are irradiated, the system also removes the need for periodic cleaning, continually saving an owner in maintenance costs.

Cost-Benefit Analysis

The savings associated with an ultraviolet cooling coil irradiation system can be quantified by comparing the operating costs before and after the installation, minus the initial cost of installation. The costs and savings breakdown as followed:

1. Costs
    a. First cost of installation
    b. Operating cost of UV lamps
    c. Maintenance costs of UV (annual lamp replacement)
2. Savings
    a. Fan energy savings
    b. Cooling energy savings
    c. Maintenance savings

In order to quantify cost savings, it is necessary to assume that the coils will become fouled, which according to Kowalski will be true of most systems, and also that the UV system will completely prevent fouling from occurring. The calculations in this report were generated directly from the method described in Section 6 of Kowalski's aforementioned 2006 report.

Detailed tables of the costs and benefits can be found in the appendix of this report. The following table is a summary of the energy savings and payback periods associated with the respective level of coil fouling. In other words, if the cooling coils reach the level of fouling listed in the white column, the green column represents the cost of the extra energy that would be needed, and the yellow column represents the amount of time it would take for the UV system to pay itself off at this level of fouling.

% Fouling	Annual Energy Savings	Payback Period (years)
20%	$293,268	0.26
10%	$144,473	0.53
5%	$70,075	1.10
2%	$25,436	3.04

The following assumptions were made in sizing the UV system and calculating the savings and payback periods:

- Assumed coil maintenance (cleaning) cost of $1000/year before UV per Kowalski example
- Assumed $0.1139 average retail electricity cost in MD at end of 2007 per U.S. Department of Energy statistics
- Assumed cooling coil COP of 4.1 - typical for chilled water system (from Kowalski report)
- Assumed a rate of $35/hr for installation workers

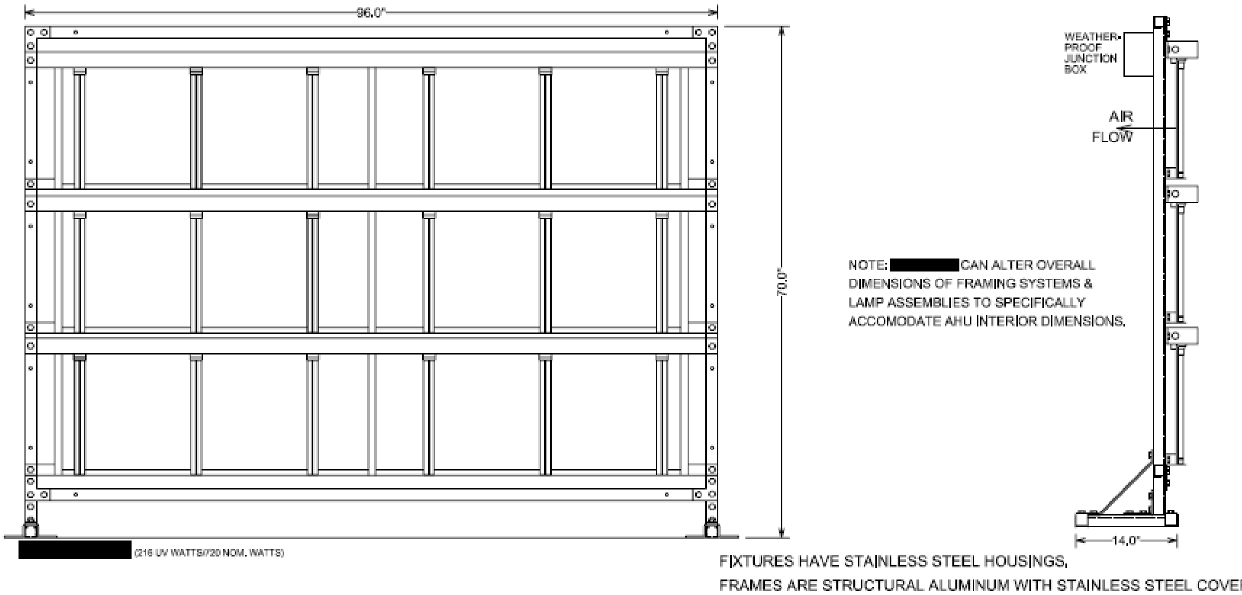
Brief recap of air-handling system:

- 7 AHU's
  - 44,000-50,000 CFM
  - 2600-3000 Mbtu/hr = 217-250 tons
  - 10-14 fins/inch max fin spacing
  - 12.5' tall x 13' wide
  - 0.82-1.53 in.w.g. pressure drop
  - 48-53 degree F cooling coil leaving air temperature

The following cost data was gathered from an undisclosed company that provides ultraviolet systems in buildings:

- Each AHU requires 18 Philips PL-L60WTUV lamps, 60 nominal watts, 18 UV Watts, high output and wind chill corrected for this application
- Ballasts are Advance PureVOLT UV lamp ballasts
- End-user list price of $8250 per floor (per AHU)
- Installation requires about 4 hours per unit, figure 8 hours for the first unit. This installation should take 2 installers a total of 4 days, less the electrical connections.
- Project requires 156 Lamps; replacement cost is $30 per lamp.
- Replacement intervals at 1 year allow for 15% depreciation in output. 2 year replacement must allow for 25% depreciation in output.

Systems are complete UV systems designed for Air and Coil Disinfection as described in the upcoming ASHRAE Handbook (Summer 2008, Chapter 16). Below is a diagram of elevations of the typical unit.



Conclusion/Recommendations

Ultraviolet light is an extremely useful tool in protecting indoor air quality and preventing microbial growth on cooling coil systems. Upon investigation, the system proved itself to be extremely cost effective. The cost savings are preventative in the way that the system prevents microbial growth on the cooling coil and in turn avoids the costs associated with an increased cooling load and fan pressure.

This report demonstrates that if the system prevents the cooling coils from even losing a mere 2% of operating capacity due to fouling, the UV system will pay itself off in only 3 years. As the building's expected life is most likely well over twenty years, it seems the system will pay itself off in any condition.

It is absolutely recommended that the above mentioned system be installed into all of the air-handling units in the new Wilmer Eye Institute building. Aside from the cost savings to the facility owner, the system's air disinfecting potential will improve the overall indoor air quality of the building, which is an important issue in contemporary hospital buildings.

Future Three-Storey Expansion Analysis

Original Intent

Johns Hopkins Hospital has tentative future plans to add a three storey vertical expansion to the Wilmer Eye building. The expansion is contingent on an amendment to an 80' building height restriction from a local zoning code (Planned Unit Development—PUD—see Building Statistics for more details on the code). With this in mind, the building's structure has been designed to be capable of supporting the loads associated with three extra storeys without major reconstruction.

It was originally thought that the air-handling system had been designed in the same manner, and that the air-handling units would be running below full capacity until the expansion was added, effectively wasting a lot of energy and in turn money. Had this been the case, there would have been some definite leeway to find alternative, more efficient system designs with regards to planning for the expansion.

Investigating alternative designs for the air-handling system would have offered a number of opportunities for analysis and research. The original goal of the analysis was to identify alternative system designs and/or construction methods that were more proficient regarding cost, constructability and energy efficiency.

Findings

Upon investigation and concurrent discussion with the mechanical designers at RMF Engineering, it was quickly learned that the air handling system had not been sized for the expansion. Stefan Domby, of RMF, reported that the air handling units for such an expansion would be located in a new roof-top mechanical penthouse and that the ductwork would extend downward, essentially isolating the new system from the original system.

At this point it was assumed that perhaps the air-handling system could be designed in a manner that would make it easier and less costly to add to the existing system, eliminating the need to construct a new mechanical penthouse on the roof. However, upon investigation it was learned that there is not enough room in the basement for more air-handling units, nor is there enough free space in the mechanical shafts to increase the size of the vertical duct runs. Initially increasing the size of the vertical duct runs would also create a need for a greater system pressure, putting more work on the fans than is needed, essentially wasting energy and money. Yet another dilemma with this approach is the issue of system shut-downs while the building is fully operational; adding onto the existing HVAC system will create a need to shut down the system to add onto it, which is a complicated process that can get messy with a fully occupied building.

After discussion with Chuck Smith, project manager in the hospital's Facilities department assigned to the Wilmer building, a number of other strong deciding elements were learned. First off, the code amendment process is a very labor-intensive process with a lot of permitting and paperwork involved. It is estimated that the process would take about a year to complete. This being said, the hospital has no plans at this point to pursue neither the code amendment nor the expansion itself. It is estimated that it could be over fifteen years before the expansion is constructed, if at all. This is essentially because the hospital has no programming to meet the needs of an expansion at this point in time.

Another project currently under construction on Hopkins' Medical Campus is their New Clinical Building (NCB), which the largest hospital single-expansion project in the United States. It features two large towers (13+ storeys) totaling to about 1.5 million square feet. With a building of this magnitude opening up in a few years, there will be a large expanse of space opening up in existing facilities from entire units being relocated into the new complex. The Wilmer Eye building, though not as large as the NCB, will have the same type of effect. Between backfill spaces from the two new buildings, there is absolutely no need for another 90,000 SF of floor space that would be incurred from a three-storey expansion of the Wilmer facility.

Artistic rendering of Hopkins' New Clinical Building

Conclusions

The main thing learned in this analysis is that it is illogical to design the air handling system around the expansion in this situation. This is mainly because the hospital will not have a need for this space for a long time, and has absolutely no plans at this point to construct the expansion. And any time, effort or money put into to planning the air-handling system around this may end up being completely wasted if the expansion is never built.

It makes sense to design the structural system around potential plans for an expansion like this, because it is essentially impossible to retrofit an existing structure to be able support three extra floors. However a mechanical system is significantly less permanent, and constructing an isolated HVAC system with a rooftop penthouse is completely possible and really not unrealistic at all. Furthermore, with at least a fifteen year time frame, there is a possibility that innovative new technologies could render current planning efforts useless.

Conclusions and Recommendations

The exterior enclosure system is extremely important as, failures in the building envelope can cause a number of different problems that can add up to a be costly setback between the costs of repairing damaged elements and the high energy bills generated from components not performing to design standards. It is imperative that the building envelope gets the proper attention throughout the entire design and construction process.

There are a number of common areas of the building that have a strong potential for moisture and thermal penetration. These mostly include interfaces between wall types of envelope systems, penetrations, and seals around openings. It is recommended that these details be specifically outlined in shop drawings and reviewed by a design professional to ensure quality. Furthermore, the installation process should be monitored frequently to be sure things are being installed as they have been designed.

Thermal bridging in steel brick shelves is another common problem in envelope systems that can be prevented by inserting a plastic or other thermally insulating medium in between the steel and the concrete to which it connects. This creates the thermal break that is needed to stop such a problem from occurring.

Unitization of the curtain wall proved to be unfeasible for a number of different reasons on this project, primarily being the large expense of renting a crane, a lack of space onsite, and a large risk incurred from trying to prefabricate sections of a wall of such complexity and irregular shape. If the curtain wall covered a larger and area and were more uniform, off-site fabrication may have proved to be a more cost effective and faster method. However in this case, stick-building was ultimately the wiser decision. For this project however, it is recommended that the curtain wall be stick-built as is planned.

The site of the proposed building is surrounded on three adjacent sides by sensitive hospital facilities. As a major new construction project in proximity to such facilities, the construction of this building is classified in the highest risk group under the AIA's infection control guidelines. It is recommended that all of the precautions required by these guidelines be carried out throughout the entire duration of the project.

Upon investigation, the proposed ultraviolet light system proved itself to be extremely cost effective. The system will prevent microbial growth on the cooling coil and in turn will avoid the costs associated with an increased cooling load and fan pressure. This report demonstrates that the proposed system will pay itself off in savings in only a few years.

It is absolutely recommended that the system mentioned herein be installed into all of the air-handling units in the new Wilmer Eye Institute building. Aside from the cost savings to the facility owner, the system's air disinfecting potential will improve the overall indoor air quality of the building, which is an important issue in contemporary hospital buildings.

The key finding upon investigation of the three storey expansion is that it is illogical to design the air handling system around the expansion in this situation. This is mainly because the hospital will not have a need for this space for a long time, and has absolutely no plans at this point to construct the expansion. Any time, effort or money put into to planning the air-handling system around this would be wasted if the expansion is never built.

On the other hand, it makes sense to design the structural system around potential plans for an expansion like this, because it is essentially impossible to retrofit an existing structure to be able support three extra floors. However a mechanical system is significantly less permanent, and constructing an isolated HVAC system with a rooftop penthouse is completely doable.

Personal Summary and Goal Achievement

The most legitimate part of the senior thesis capstone project is the amount of real-world knowledge and skills achieved throughout the process. A good portion of the content analyzed here will transfer right into the post-graduation building science career that is being pursued.

Researching the different aspects of medical construction and infection control were also especially interesting. It is fulfilling to know that the research being presented is aiding in a general spread of knowledge that will help keep people safe who need it the most. This interest was generated while working an internship this past summer at Johns Hopkins Hospital on the New Clinical Building.

A number of crucial skills were refined throughout completion of this project, including but not limited to industry correspondence, construction methods and products research, document reading, progress reporting, setting personal goals, and maintaining deadlines. These skills will be extremely useful to have developed upon entering the industry post-graduation. This senior thesis project has been a truly unique opportunity.

Appendix

Infection Control Risk Assessment
Matrix of Precautions for Construction & Renovation

Step One:
Using the following table, *identify* the Type of Construction Project Activity (Type A-D)

TYPE A	**Inspection and Non-Invasive Activities.** Includes, but is not limited to: ▪ removal of ceiling tiles for visual inspection limited to 1 tile per 50 square feet ▪ painting (but not sanding) ▪ wallcovering, electrical trim work, minor plumbing, and activities which do not generate dust or require cutting of walls or access to ceilings other than for visual inspection.
TYPE B	**Small scale, short duration activities which create minimal dust** Includes, but is not limited to: ▪ installation of telephone and computer cabling ▪ access to chase spaces ▪ cutting of walls or ceiling where dust migration can be controlled.
TYPE C	**Work that generates a moderate to high level of dust or requires demolition or removal of any fixed building components or assemblies** Includes, but is not limited to: ▪ sanding of walls for painting or wall covering ▪ removal of floorcoverings, ceiling tiles and casework ▪ new wall construction ▪ minor duct work or electrical work above ceilings ▪ major cabling activities ▪ any activity which cannot be completed within a single workshift.
TYPE D	**Major demolition and construction projects** Includes, but is not limited to: ▪ activities which require consecutive work shifts ▪ requires heavy demolition or removal of a complete cabling system ▪ new construction.

STEP 1:____

Steps 1-3 Adapted with permission V Kennedy, B Barnard, St Luke Episcopal Hospital, Houston TX; C Fine, CA
Steps 4-14 Adapted with permission Fairview University Medical Center, Minneapolis MN
Forms modified and provided courtesy of J Bartley, ECSI Inc 2002

Step Two:
Using the following table, ***identify* the Patient Risk Groups** that will be affected.
If more than one risk group will be affected, select the higher risk group:

Low Risk	Medium Risk	High Risk	Highest Risk
▪ Office areas	▪ Cardiology ▪ Echocardiography ▪ Endoscopy ▪ Nuclear Medicine ▪ Physical Therapy ▪ Radiology/MRI ▪ Respiratory Therapy	▪ CCU ▪ Emergency Room ▪ Labor & Delivery ▪ Laboratories (specimen) ▪ Newborn Nursery ▪ Outpatient Surgery ▪ Pediatrics ▪ Pharmacy ▪ Post Anesthesia Care Unit ▪ Surgical Units	▪ Any area caring for immunocompromised patients ▪ Burn Unit ▪ Cardiac Cath Lab ▪ Central Sterile Supply ▪ Intensive Care Units ▪ Medical Unit ▪ Negative pressure isolation rooms ▪ Oncology ▪ Operating rooms including C-section rooms

Step 2____

Step Three: ***Match* the**

Patient Risk Group (***Low, Medium, High, Highest***) with the planned …
Construction Project Type (*A, B, C, D*) on the following matrix, to find the …
Class of Precautions (*I, II, III **or** IV*) or level of infection control activities required.

Class I-IV or Color-Coded Precautions are delineated on the following page.

IC Matrix - Class of Precautions: Construction Project by Patient Risk

	Construction Project Type			
Patient Risk Group	**TYPE A**	**TYPE B**	**TYPE C**	**TYPE D**
LOW Risk Group	I	II	II	III/IV
MEDIUM Risk Group	I	II	III	IV
HIGH Risk Group	I	II	III/IV	IV
HIGHEST Risk Group	II	III/IV	III/IV	IV

Note: Infection Control approval will be required when the Construction Activity and Risk Level indicate that Class III or Class IV control procedures are necessary.

Step 3____

Steps 1-3 Adapted with permission V Kennedy, B Barnard, St Luke Episcopal Hospital, Houston TX ; C Fine, CA
Steps 4-14 Adapted with permission Fairview University Medical Center, Minneapolis MN by ECSI Inc 2001
Forms modified and provided courtesy of J Bartley, ECSI Inc 2002

Description of Required Infection Control Precautions by Class

	During Construction Project	Upon Completion of Project
CLASS I	1. Execute work by methods to minimize raising dust from construction operations. 2. Immediately replace a ceiling tile displaced for visual inspection	
CLASS II	1. Provide active means to prevent airborne dust from dispersing into atmosphere. 2. Water mist work surfaces to control dust while cutting. 3. Seal unused doors with duct tape. 4. Block off and seal air vents. 5. Place dust mat at entrance and exit of work area 6. Remove or isolate HVAC system in areas where work is being performed.	1. Wipe work surfaces with disinfectant. 2. Contain construction waste before transport in tightly covered containers. 3. Wet mop and/or vacuum with HEPA filtered vacuum before leaving work area. 4. Remove isolation of HVAC system in areas where work is being performed.
CLASS III	1. Remove or Isolate HVAC system in area where work is being done to prevent contamination of duct system. 2. Complete all critical barriers i.e. sheetrock, plywood, plastic, to seal area from non work area or implement control cube method (cart with plastic covering and sealed connection to work site with HEPA vacuum for vacuuming prior to exit) before construction begins. 3. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units. 4. Contain construction waste before transport in tightly covered containers. 5. Cover transport receptacles or carts. Tape covering unless solid lid.	1. Do not remove barriers from work area until completed project is inspected by the owner's Safety Department and Infection Control Department and thoroughly cleaned by the owner's Environmental Services Department. 2. Remove barrier materials carefully to minimize spreading of dirt and debris associated with construction. 3. Vacuum work area with HEPA filtered vacuums. 4. Wet mop area with disinfectant. 5. Remove isolation of HVAC system in areas where work is being performed.
CLASS IV	1. Isolate HVAC system in area where work is being done to prevent contamination of duct system. 2. Complete all critical barriers i.e. sheetrock, plywood, plastic, to seal area from non work area or implement control cube method (cart with plastic covering and sealed connection to work site with HEPA vacuum for vacuuming prior to exit) before construction begins. 3. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units. 4. Seal holes, pipes, conduits, and punctures appropriately. 5. Construct anteroom and require all personnel to pass through this room so they can be vacuumed using a HEPA vacuum cleaner before leaving work site or they can wear cloth or paper coveralls that are removed each time they leave the work site. 6. All personnel entering work site are required to wear shoe covers. Shoe covers must be changed each time the worker exits the work area. 7. Do not remove barriers from work area until completed project is inspected by the owner's Safety Department and Infection Control Department and thoroughly cleaned by the owner's Environmental Services Department.	1. Remove barrier material carefully to minimize spreading of dirt and debris associated with construction. 2. Contain construction waste before transport in tightly covered containers. 3. Cover transport receptacles or carts. Tape covering unless solid lid 4. Vacuum work area with HEPA filtered vacuums. 5. Wet mop area with disinfectant. 6. Remove isolation of HVAC system in areas where work is being performed.

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Steps 4-14 Adapted with permission Fairview University Medical Center, Minneapolis MN by ECSI Inc 2001
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Step 4. **Identify the areas surrounding the project area, assessing potential impact**

Unit Below	Unit Above	Lateral	Lateral	Behind	Front
Risk Group	Risk Group	Risk Group	Risk Group	Risk Group	Risk Group

Step 5. **Identify specific site of activity eg, patient rooms, medication room, etc.**

Step 6. **Identify issues related to: ventilation, plumbing, electrical in terms of the occurrence of probable outages.**

Step 7. **Identify containment measures, using prior assessment. What types of barriers? (Eg, solids wall barriers); Will HEPA filtration be required?**

(Note: Renovation/construction area shall be isolated from the occupied areas during construction and shall be negative with respect to surrounding areas)

Step 8. **Consider potential risk of water damage. Is there a risk due to compromising structural integrity? (eg, wall, ceiling, roof)**

Step 9. **Work hours: Can or will the work be done during non-patient care hours?**

Sep 10. **Do plans allow for adequate number of isolation/negative airflow rooms?**

Step 11. **Do the plans allow for the required number & type of handwashing sinks?**

Step 12. **Does the infection control staff agree with the minimum number of sinks for this project?**
(Verify against AIA Guidelines for types and area)

Step 13. **Does the infection control staff agree with the plans relative to clean and soiled utility rooms?**

Step 14. **Plan to discuss the following containment issues with the project team. Eg, traffic flow, housekeeping, debris removal (how and when)**

Appendix: Identify and communicate the responsibility for project monitoring that includes infection control concerns and risks. The ICRA may be modified throughout the project. Revisions must be communicated to the Project Manager.

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Infection Control Construction Permit

	Permit No:
Location of Construction:	Project Start Date:
Project Coordinator:	Estimated Duration:
Contractor Performing Work	Permit Expiration Date:
Supervisor:	Telephone:

YES	NO	CONSTRUCTION ACTIVITY	YES	NO	INFECTION CONTROL RISK GROUP
		TYPE A: Inspection, non-invasive activity			GROUP 1: Low Risk
		TYPE B: Small scale, short duration, moderate to high levels			GROUP 2: Medium Risk
		TYPE C: Activity generates moderate to high levels of dust, requires greater 1 work shift for completion			GROUP 3: Medium/High Risk
		TYPE D: Major duration and construction activities Requiring consecutive work shifts			GROUP 4: Highest Risk

CLASS I	1. Execute work by methods to minimize raising dust from construction operations. 2. Immediately replace any ceiling tile displaced for visual inspection.	3. Minor Demolition for Remodeling
CLASS II	1. Provides active means to prevent air-borne dust from dispersing into atmosphere 2. Water mist work surfaces to control dust while cutting. 3. Seal unused doors with duct tape. 4. Block off and seal air vents. 5. Wipe surfaces with disinfectant.	6. Contain construction waste before transport in tightly covered containers. 7. Wet mop and/or vacuum with HEPA filtered vacuum before leaving work area. 8. Place dust mat at entrance and exit of work area. 9. Remove or isolate HVAC system in areas where work is being performed.
CLASS III **Date** **Initial**	1. Obtain infection control permit before construction begins. 2. Isolate HVAC system in area where work is being done to prevent contamination of the duct system. 3. Complete all critical barriers or implement control cube method before construction begins. 4. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units. 5. Do not remove barriers from work area until complete project is thoroughly cleaned by Env. Services Dept.	6. Vacuum work with HEPA filtered vacuums. 7. Wet mop with disinfectant 8. Remove barrier materials carefully to minimize spreading of dirt and debris associated with construction. 9. Contain construction waste before transport in tightly covered containers. 10. Cover transport receptacles or carts. Tape covering. 11. Remove or isolate HVAC system in areas where work is being performed/
Class IV **Date** **Initial**	1. Obtain infection control permit before construction begins. 2. Isolate HVAC system in area where work is being done to prevent contamination of duct system. 3. Complete all critical barriers or implement control cube method before construction begins. 4. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units. 5. Seal holes, pipes, conduits, and punctures appropriately. 6. Construct anteroom and require all personnel to pass through this room so they can be vacuumed using a HEPA vacuum cleaner before leaving work site or they can wear cloth or paper coveralls that are removed each time they leave the work site.	7. All personnel entering work site are required to wear shoe covers 8. Do not remove barriers from work area until completed project is thoroughly cleaned by the Environmental Service Dept. 9. Vacuum work area with HEPA filtered vacuums. 10. Wet mop with disinfectant. 11. Remove barrier materials carefully to minimize spreading of dirt and debris associated with construction. 12. Contain construction waste before transport in tightly covered containers. 13. Cover transport receptacles or carts. Tape covering. 14. Remove or isolate HVAC system in areas where is being done.

Additional Requirements:	
Date Initials	___________Exceptions/Additions to this permit Date Initials are noted by attached memoranda
Permit Request By:	Permit Authorized By:
Date:	Date:

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UV Savings at 20% Fouling

AHU Info

Desig.	Space	Airflow (cfm)	Cooling Coil Leaving Air Temp (F)	Coiling Coil Pressure Drop, clean (in.w.g.)	Coiling Coil Pressure Drop, fouled (in.w.g.)	COP	Annual Hours of Cooling	Cooling Load, clean (Btu/h)	Cooling Load, fouled (Btu/h)	Capacity loss due to fouling (btu/h)
AHU-1	Laboratory	44,000	53	0.82	0.984	4.1	8760	2,600,000	3,120,000	520,000
AHU-2	Laboratory	44,000	53	0.82	0.984	4.1	8760	2,600,000	3,120,000	520,000
AHU-3	Laboratory	44,000	53	0.82	0.984	4.1	8760	2,600,000	3,120,000	520,000
AHU-4	Laboratory	44,000	53	0.82	0.984	4.1	8760	2,600,000	3,120,000	520,000
AHU-5	Clinical	44,000	48	0.97	1.164	4.1	8760	3,027,000	3,632,400	605,400
AHU-6	Redundant	44,000	48	0.97	1.164	4.1	8760	3,027,000	3,632,400	605,400
AHU-7	Office	50,000	51	1.53	1.836	4.1	8760	3,526,000	4,231,200	705,200
Totals								*19,980,000*	*23,976,000*	*3,996,000*

Fan Energy Savings

Desig.	Fan Energy, clean (kW)	Fan Energy, fouled (kW)	Fan Energy Savings (kW)	Fan Energy Cost, clean ($)	Fan Energy Cost, fouled ($)	Fan Energy Savings ($)	Cost per kWh ($)
AHU-1	7.43	8.92	1.49	$7,413	$8,895	$1,483	$0.1139
AHU-2	7.43	8.92	1.49	$7,413	$8,895	$1,483	$0.1139
AHU-3	7.43	8.92	1.49	$7,413	$8,895	$1,483	$0.1139
AHU-4	7.43	8.92	1.49	$7,413	$8,895	$1,483	$0.1139
AHU-5	8.79	10.55	1.76	$8,769	$10,523	$1,754	$0.1139
AHU-6	8.79	10.55	1.76	$8,769	$10,523	$1,754	$0.1139
AHU-7	15.75	18.90	3.15	$15,717	$18,861	$3,143	$0.1139
Totals	*63*	*76*	*13*	*$62,906*	*$75,487*	*$12,581*	

Cooling Energy Savings

Desig.	Cooling Energy, clean (kW)	Cooling Energy, fouled (kW)	Cooling Energy Savings (kW)	Cooling Energy Cost, clean ($)	Cooling Energy Cost, fouled ($)	Cooling Energy Savings ($)	Total Energy Savings ($)
AHU-1	185.86	223.03	37.17	$185,442	$222,531	$37,088	$38,571
AHU-2	185.86	223.03	37.17	$185,442	$222,531	$37,088	$38,571
AHU-3	185.86	223.03	37.17	$185,442	$222,531	$37,088	$38,571
AHU-4	185.86	223.03	37.17	$185,442	$222,531	$37,088	$38,571
AHU-5	216.38	259.66	43.28	$215,897	$259,077	$43,179	$44,933
AHU-6	216.38	259.66	43.28	$215,897	$259,077	$43,179	$44,933
AHU-7	252.05	302.46	50.41	$251,488	$301,786	$50,298	$53,441
Totals	*1,428*	*1,714*	*286*	*$1,425,051*	*$1,710,061*	*$285,010*	*$297,591*

UV Info

Desig.	UV wattage (W)	UV Lamp Fixture First Cost ($)	UV Lamp Installation Cost ($)	UV Lamp Replacement Bulb Cost ($)	UV Operating Cost ($)
AHU-1	1080	$8,250	$2,240	$540	$1,078
AHU-2	1080	$8,250	$2,240	$540	$1,078
AHU-3	1080	$8,250	$2,240	$540	$1,078
AHU-4	1080	$8,250	$2,240	$540	$1,078
AHU-5	1080	$8,250	$2,240	$540	$1,078
AHU-6	1080	$8,250	$2,240	$540	$1,078
AHU-7	1080	$8,250	$2,240	$540	$1,078
Totals	*7,560*	*$57,750*	*$15,680*	*$3,780*	*$7,543*

Maintenance Info

Desig.	Maintenance Cost before UV ($)	Maintenance Cost after UV ($)	Maintenance Cost Savings ($)
AHU-1	$1,000	$0	$1,000
AHU-2	$1,000	$0	$1,000
AHU-3	$1,000	$0	$1,000
AHU-4	$1,000	$0	$1,000
AHU-5	$1,000	$0	$1,000
AHU-6	$1,000	$0	$1,000
AHU-7	$1,000	$0	$1,000
Totals	*$7,000*	*$0*	*$7,000*

Payback Period

Total Initial Cost ($)	Total Annual Savings ($)	Payback Period (yrs)
11030	$37,953	0.29062
11030	$37,953	0.29062
11030	$37,953	0.29062
11030	$37,953	0.29062
11030	$44,316	0.2489
11030	$44,316	0.2489
11030	$52,823	0.20881
$77,210	*$293,268*	*0.263*

UV Savings at 10% Fouling

AHU Info

Desig.	Space	Airflow (cfm)	Cooling Coil Leaving Air Temp (F)	Coiling Coil Pressure Drop, clean (in.w.g.)	Coiling Coil Pressure Drop, fouled (in.w.g.)	COP	Annual Hours of Cooling	Cooling Load, clean (Btu/h)	Cooling Load, fouled (Btu/h)	Capacity loss due to fouling (btu/h)
AHU-1	Laboratory	44,000	53	0.82	0.902	4.1	8760	2,600,000	2,860,000	260,000
AHU-2	Laboratory	44,000	53	0.82	0.902	4.1	8760	2,600,000	2,860,000	260,000
AHU-3	Laboratory	44,000	53	0.82	0.902	4.1	8760	2,600,000	2,860,000	260,000
AHU-4	Laboratory	44,000	53	0.82	0.902	4.1	8760	2,600,000	2,860,000	260,000
AHU-5	Clinical	44,000	48	0.97	1.067	4.1	8760	3,027,000	3,329,700	302,700
AHU-6	Redundant	44,000	48	0.97	1.067	4.1	8760	3,027,000	3,329,700	302,700
AHU-7	Office	50,000	51	1.53	1.683	4.1	8760	3,526,000	3,878,600	352,600
Totals								*19,980,000*	*21,978,000*	*1,998,000*

Fan Energy Savings

Desig.	Fan Energy, clean (kW)	Fan Energy, fouled (kW)	Fan Energy Savings (kW)	Fan Energy Cost, clean ($)	Fan Energy Cost, fouled ($)	Fan Energy Savings ($)	Cost per kWh ($)
AHU-1	7.43	8.17	0.74	$7,413	$8,154	$741	$0.1139
AHU-2	7.43	8.17	0.74	$7,413	$8,154	$741	$0.1139
AHU-3	7.43	8.17	0.74	$7,413	$8,154	$741	$0.1139
AHU-4	7.43	8.17	0.74	$7,413	$8,154	$741	$0.1139
AHU-5	8.79	9.67	0.88	$8,769	$9,646	$877	$0.1139
AHU-6	8.79	9.67	0.88	$8,769	$9,646	$877	$0.1139
AHU-7	15.75	17.33	1.58	$15,717	$17,289	$1,572	$0.1139
Totals	*63*	*69*	*6*	*$62,906*	*$69,196*	*$6,291*	

Cooling Energy Savings

Desig.	Cooling Energy, clean (kW)	Cooling Energy, fouled (kW)	Cooling Energy Savings (kW)	Cooling Energy Cost, clean ($)	Cooling Energy Cost, fouled ($)	Cooling Energy Savings ($)	Total Energy Savings ($)
AHU-1	185.86	204.44	18.59	$185,442	$203,986	$18,544	$19,285
AHU-2	185.86	204.44	18.59	$185,442	$203,986	$18,544	$19,285
AHU-3	185.86	204.44	18.59	$185,442	$203,986	$18,544	$19,285
AHU-4	185.86	204.44	18.59	$185,442	$203,986	$18,544	$19,285
AHU-5	216.38	238.02	21.64	$215,897	$237,487	$21,590	$22,467
AHU-6	216.38	238.02	21.64	$215,897	$237,487	$21,590	$22,467
AHU-7	252.05	277.26	25.21	$251,488	$276,637	$25,149	$26,721
Totals	*1,428*	*1,571*	*143*	*$1,425,051*	*$1,567,556*	*$142,505*	*$148,796*

UV Info

Desig.	UV wattage (W)	UV Lamp Fixture First Cost ($)	UV Lamp Installation Cost ($)	UV Lamp Replacement Bulb Cost ($)	UV Operating Cost ($)
AHU-1	1080	$8,250	$2,240	$540	$1,078
AHU-2	1080	$8,250	$2,240	$540	$1,078
AHU-3	1080	$8,250	$2,240	$540	$1,078
AHU-4	1080	$8,250	$2,240	$540	$1,078
AHU-5	1080	$8,250	$2,240	$540	$1,078
AHU-6	1080	$8,250	$2,240	$540	$1,078
AHU-7	1080	$8,250	$2,240	$540	$1,078
Totals	*7,560*	*$57,750*	*$15,680*	*$3,780*	*$7,543*

Maintenance Info

Desig.	Maintenance Cost before UV ($)	Maintenance Cost after UV ($)	Maintenance Cost Savings ($)
AHU-1	$1,000	$0	$1,000
AHU-2	$1,000	$0	$1,000
AHU-3	$1,000	$0	$1,000
AHU-4	$1,000	$0	$1,000
AHU-5	$1,000	$0	$1,000
AHU-6	$1,000	$0	$1,000
AHU-7	$1,000	$0	$1,000
Totals	*$7,000*	*$0*	*$7,000*

Payback Period

Total Initial Cost ($)	Total Annual Savings ($)	Payback Period (yrs)
11030	$18,668	0.590854
11030	$18,668	0.590854
11030	$18,668	0.590854
11030	$18,668	0.590854
11030	$21,849	0.504828
11030	$21,849	0.504828
11030	$26,103	0.422558
$77,210	*$144,473*	*0.5344*

UV Savings at 5% Fouling

AHU Info

Desig.	Space	Airflow (cfm)	Cooling Coil Leaving Air Temp (F)	Coiling Coil Pressure Drop, clean (in.w.g.)	Coiling Coil Pressure Drop, fouled (in.w.g.)	COP	Annual Hours of Cooling	Cooling Load, clean (Btu/h)	Cooling Load, fouled (Btu/h)	Capacity loss due to fouling (btu/h)
AHU-1	Laboratory	44,000	53	0.82	0.861	4.1	8760	2,600,000	2,730,000	130,000
AHU-2	Laboratory	44,000	53	0.82	0.861	4.1	8760	2,600,000	2,730,000	130,000
AHU-3	Laboratory	44,000	53	0.82	0.861	4.1	8760	2,600,000	2,730,000	130,000
AHU-4	Laboratory	44,000	53	0.82	0.861	4.1	8760	2,600,000	2,730,000	130,000
AHU-5	Clinical	44,000	48	0.97	1.0185	4.1	8760	3,027,000	3,178,350	151,350
AHU-6	Redundant	44,000	48	0.97	1.0185	4.1	8760	3,027,000	3,178,350	151,350
AHU-7	Office	50,000	51	1.53	1.6065	4.1	8760	3,526,000	3,702,300	176,300
Totals								*19,980,000*	*20,979,000*	*999,000*

Fan Energy Savings

Desig.	Fan Energy, clean (kW)	Fan Energy, fouled (kW)	Fan Energy Savings (kW)	Fan Energy Cost, clean ($)	Fan Energy Cost, fouled ($)	Fan Energy Savings ($)	Cost per kWh ($)
AHU-1	7.43	7.80	0.37	$7,413	$7,783	$371	$0.1139
AHU-2	7.43	7.80	0.37	$7,413	$7,783	$371	$0.1139
AHU-3	7.43	7.80	0.37	$7,413	$7,783	$371	$0.1139
AHU-4	7.43	7.80	0.37	$7,413	$7,783	$371	$0.1139
AHU-5	8.79	9.23	0.44	$8,769	$9,207	$438	$0.1139
AHU-6	8.79	9.23	0.44	$8,769	$9,207	$438	$0.1139
AHU-7	15.75	16.54	0.79	$15,717	$16,503	$786	$0.1139
Totals	*63*	*66*	*3*	*$62,906*	*$66,051*	*$3,145*	

Cooling Energy Savings

Desig.	Cooling Energy, clean (kW)	Cooling Energy, fouled (kW)	Cooling Energy Savings (kW)	Cooling Energy Cost, clean ($)	Cooling Energy Cost, fouled ($)	Cooling Energy Savings ($)	Total Energy Savings ($)
AHU-1	185.86	195.15	9.29	$185,442	$194,714	$9,272	$9,643
AHU-2	185.86	195.15	9.29	$185,442	$194,714	$9,272	$9,643
AHU-3	185.86	195.15	9.29	$185,442	$194,714	$9,272	$9,643
AHU-4	185.86	195.15	9.29	$185,442	$194,714	$9,272	$9,643
AHU-5	216.38	227.20	10.82	$215,897	$226,692	$10,795	$11,233
AHU-6	216.38	227.20	10.82	$215,897	$226,692	$10,795	$11,233
AHU-7	252.05	264.65	12.60	$251,488	$264,062	$12,574	$13,360
Totals	*1,428*	*1,500*	*71*	*$1,425,051*	*$1,496,304*	*$71,253*	*$74,398*

UV Info

Desig.	UV wattage (W)	UV Lamp Fixture First Cost ($)	UV Lamp Installation Cost ($)	UV Lamp Replacement Bulb Cost ($)	UV Operating Cost ($)
AHU-1	1080	$8,250	$2,240	$540	$1,078
AHU-2	1080	$8,250	$2,240	$540	$1,078
AHU-3	1080	$8,250	$2,240	$540	$1,078
AHU-4	1080	$8,250	$2,240	$540	$1,078
AHU-5	1080	$8,250	$2,240	$540	$1,078
AHU-6	1080	$8,250	$2,240	$540	$1,078
AHU-7	1080	$8,250	$2,240	$540	$1,078
Totals	*7,560*	*$57,750*	*$15,680*	*$3,780*	*$7,543*

Maintenance Info / *Payback Period*

Desig.	Maintenance Cost before UV ($)	Maintenance Cost after UV ($)	Maintenance Cost Savings ($)	Total Initial Cost ($)	Total Annual Savings ($)	Payback Period (yrs)
AHU-1	$1,000	$0	$1,000	11030	$9,025	1.22214
AHU-2	$1,000	$0	$1,000	11030	$9,025	1.22214
AHU-3	$1,000	$0	$1,000	11030	$9,025	1.22214
AHU-4	$1,000	$0	$1,000	11030	$9,025	1.22214
AHU-5	$1,000	$0	$1,000	11030	$10,616	1.03902
AHU-6	$1,000	$0	$1,000	11030	$10,616	1.03902
AHU-7	$1,000	$0	$1,000	11030	$12,743	0.8656
Totals	*$7,000*	*$0*	*$7,000*	*$77,210*	*$70,075*	*1.102*

UV Savings at 2% Fouling

AHU Info

Desig.	Space	Airflow (cfm)	Cooling Coil Leaving Air Temp (F)	Coiling Coil Pressure Drop, clean (in.w.g.)	Coiling Coil Pressure Drop, fouled (in.w.g.)	COP	Annual Hours of Cooling	Cooling Load, clean (Btu/h)	Cooling Load, fouled (Btu/h)	Capacity loss due to fouling (btu/h)
AHU-1	Laboratory	44,000	53	0.82	0.8364	4.1	8760	2,600,000	2,652,000	52,000
AHU-2	Laboratory	44,000	53	0.82	0.8364	4.1	8760	2,600,000	2,652,000	52,000
AHU-3	Laboratory	44,000	53	0.82	0.8364	4.1	8760	2,600,000	2,652,000	52,000
AHU-4	Laboratory	44,000	53	0.82	0.8364	4.1	8760	2,600,000	2,652,000	52,000
AHU-5	Clinical	44,000	48	0.97	0.9894	4.1	8760	3,027,000	3,087,540	60,540
AHU-6	Redundant	44,000	48	0.97	0.9894	4.1	8760	3,027,000	3,087,540	60,540
AHU-7	Office	50,000	51	1.53	1.5606	4.1	8760	3,526,000	3,596,520	70,520
Totals								*19,980,000*	*20,379,600*	*399,600*

Fan Energy Savings

Desig.	Fan Energy, clean (kW)	Fan Energy, fouled (kW)	Fan Energy Savings (kW)	Fan Energy Cost, clean ($)	Fan Energy Cost, fouled ($)	Fan Energy Savings ($)	Cost per kWh ($)
AHU-1	7.43	7.58	0.15	$7,413	$7,561	$148	$0.1139
AHU-2	7.43	7.58	0.15	$7,413	$7,561	$148	$0.1139
AHU-3	7.43	7.58	0.15	$7,413	$7,561	$148	$0.1139
AHU-4	7.43	7.58	0.15	$7,413	$7,561	$148	$0.1139
AHU-5	8.79	8.96	0.18	$8,769	$8,944	$175	$0.1139
AHU-6	8.79	8.96	0.18	$8,769	$8,944	$175	$0.1139
AHU-7	15.75	16.07	0.32	$15,717	$16,032	$314	$0.1139
Totals	*63*	*64*	*1*	*$62,906*	*$64,164*	*$1,258*	

Cooling Energy Savings

Desig.	Cooling Energy, clean (kW)	Cooling Energy, fouled (kW)	Cooling Energy Savings (kW)	Cooling Energy Cost, clean ($)	Cooling Energy Cost, fouled ($)	Cooling Energy Savings ($)	Total Energy Savings ($)
AHU-1	185.86	189.57	3.72	$185,442	$189,151	$3,709	$3,857
AHU-2	185.86	189.57	3.72	$185,442	$189,151	$3,709	$3,857
AHU-3	185.86	189.57	3.72	$185,442	$189,151	$3,709	$3,857
AHU-4	185.86	189.57	3.72	$185,442	$189,151	$3,709	$3,857
AHU-5	216.38	220.71	4.33	$215,897	$220,215	$4,318	$4,493
AHU-6	216.38	220.71	4.33	$215,897	$220,215	$4,318	$4,493
AHU-7	252.05	257.09	5.04	$251,488	$256,518	$5,030	$5,344
Totals	*1,428*	*1,457*	*29*	*$1,425,051*	*$1,453,552*	*$28,501*	*$29,759*

UV Info

Desig.	UV wattage (W)	UV Lamp Fixture First Cost ($)	UV Lamp Installation Cost ($)	UV Lamp Replacement Bulb Cost ($)	UV Operating Cost ($)
AHU-1	1080	$8,250	$2,240	$540	$1,078
AHU-2	1080	$8,250	$2,240	$540	$1,078
AHU-3	1080	$8,250	$2,240	$540	$1,078
AHU-4	1080	$8,250	$2,240	$540	$1,078
AHU-5	1080	$8,250	$2,240	$540	$1,078
AHU-6	1080	$8,250	$2,240	$540	$1,078
AHU-7	1080	$8,250	$2,240	$540	$1,078
Totals	*7,560*	*$57,750*	*$15,680*	*$3,780*	*$7,543*

Maintenance Info

Desig.	Maintenance Cost before UV ($)	Maintenance Cost after UV ($)	Maintenance Cost Savings ($)
AHU-1	$1,000	$0	$1,000
AHU-2	$1,000	$0	$1,000
AHU-3	$1,000	$0	$1,000
AHU-4	$1,000	$0	$1,000
AHU-5	$1,000	$0	$1,000
AHU-6	$1,000	$0	$1,000
AHU-7	$1,000	$0	$1,000
Totals	*$7,000*	*$0*	*$7,000*

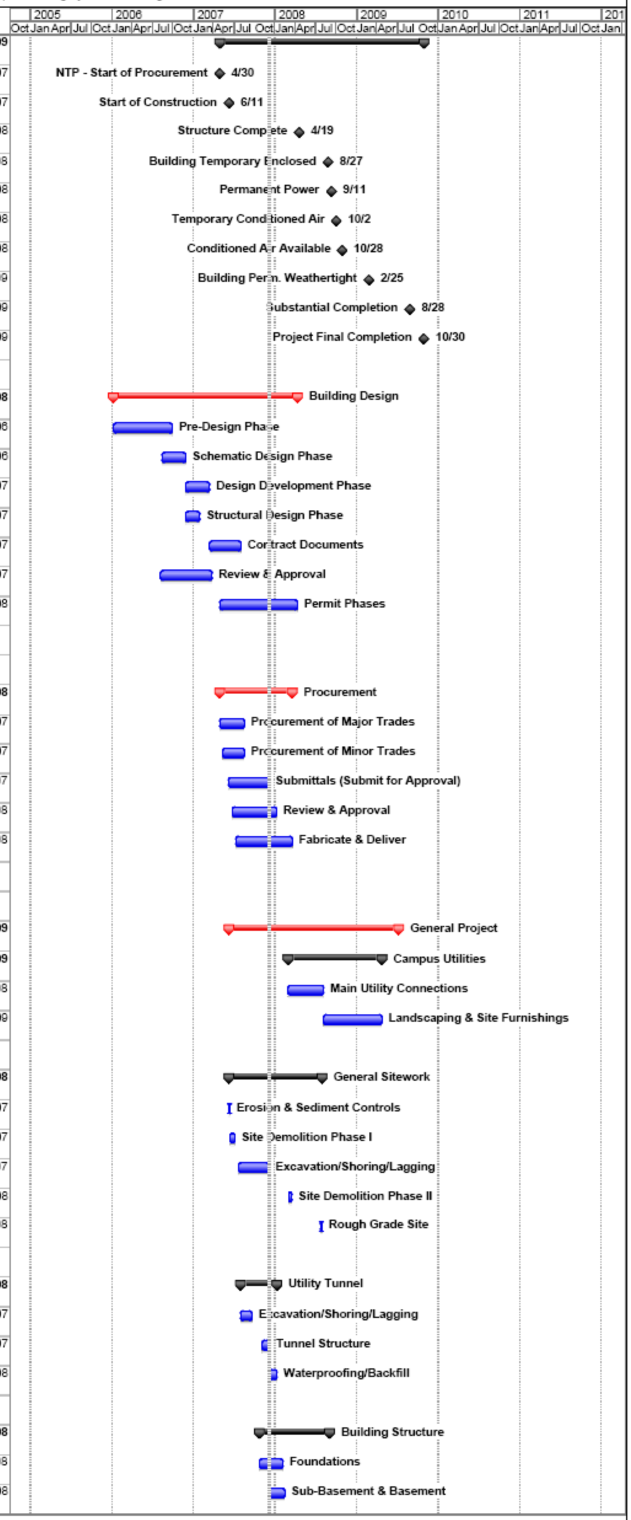
Payback Period

Total Initial Cost ($)	Total Annual Savings ($)	Payback Period (yrs)
11030	$3,240	3.40483
11030	$3,240	3.40483
11030	$3,240	3.40483
11030	$3,240	3.40483
11030	$3,876	2.84591
11030	$3,876	2.84591
11030	$4,727	2.33364
$77,210	*$25,436*	*3.035*

Detailed Project Schedule

The Wilmer Eye Institue Outpatient Surgery & Lab Buidling

ID	Task Name	Duration	Start	Finish
1	**Major Project Milestones**	**658 days**	**Mon 4/30/07**	**Fri 10/30/09**
2	NTP - Start of Procurement	0 days	Mon 4/30/07	Mon 4/30/07
3	Start of Construction	0 days	Mon 6/11/07	Mon 6/11/07
4	Structure Complete	0 days	Sat 4/19/08	Sat 4/19/08
5	Building Temporary Enclosed	0 days	Wed 8/27/08	Wed 8/27/08
6	Permanent Power	0 days	Thu 9/11/08	Thu 9/11/08
7	Temporary Conditioned Air	0 days	Thu 10/2/08	Thu 10/2/08
8	Conditioned Air Available	0 days	Tue 10/28/08	Tue 10/28/08
9	Building Perm. Weathertight	0 days	Wed 2/25/09	Wed 2/25/09
10	Substantial Completion	0 days	Fri 8/28/09	Fri 8/28/09
11	Project Final Completion	0 days	Fri 10/30/09	Fri 10/30/09
12				
13	**Building Design**	**592 days?**	**Mon 1/9/06**	**Fri 4/11/08**
14	Pre-Design Phase	190 days?	Mon 1/9/06	Fri 9/29/06
15	Schematic Design Phase	77 days?	Mon 8/14/06	Tue 11/28/06
16	Design Development Phase	78 days?	Tue 11/28/06	Thu 3/15/07
17	Structural Design Phase	46 days?	Tue 11/28/06	Tue 1/30/07
18	Contract Documents	101 days?	Thu 3/15/07	Thu 8/2/07
19	Review & Approval	165 days?	Tue 8/8/06	Mon 3/26/07
20	Permit Phases	252 days?	Mon 4/30/07	Fri 4/11/08
21				
22				
23	**Procurement**	**235 days?**	**Mon 4/30/07**	**Wed 3/19/08**
24	Procurement of Major Trades	80 days?	Mon 4/30/07	Fri 8/17/07
25	Procurement of Minor Trades	70 days?	Mon 5/14/07	Fri 8/17/07
26	Submittals (Submit for Approval)	129 days?	Fri 6/8/07	Wed 12/5/07
27	Review & Approval	144 days?	Mon 6/25/07	Wed 1/9/08
28	Fabricate & Deliver	183 days?	Wed 7/11/07	Wed 3/19/08
29				
30				
31	**General Project**	**547 days?**	**Mon 6/11/07**	**Thu 7/9/09**
32	**Campus Utilities**	**302 days?**	**Sat 3/1/08**	**Fri 4/24/09**
33	Main Utility Connections	115 days?	Sat 3/1/08	Wed 8/6/08
34	Landscaping & Site Furnishings	187 days?	Thu 8/7/08	Fri 4/24/09
35				
36	**General Sitework**	**301 days?**	**Mon 6/11/07**	**Wed 7/30/08**
37	Erosion & Sediment Controls	4 days?	Mon 6/11/07	Thu 6/14/07
38	Site Demolition Phase I	16 days?	Fri 6/15/07	Fri 7/6/07
39	Excavation/Shoring/Lagging	98 days?	Mon 7/23/07	Wed 12/5/07
40	Site Demolition Phase II	10 days?	Tue 3/4/08	Mon 3/17/08
41	Rough Grade Site	5 days?	Thu 7/24/08	Wed 7/30/08
42				
43	**Utility Tunnel**	**118 days?**	**Wed 8/1/07**	**Thu 1/10/08**
44	Excavation/Shoring/Lagging	37 days?	Wed 8/1/07	Thu 9/20/07
45	Tunnel Structure	25 days?	Tue 11/6/07	Sat 12/8/07
46	Waterproofing/Backfill	24 days?	Mon 12/10/07	Thu 1/10/08
47				
48	**Building Structure**	**227 days?**	**Thu 10/25/07**	**Tue 9/2/08**
49	Foundations	76 days?	Thu 10/25/07	Wed 2/6/08
50	Sub-Basement & Basement	54 days?	Tue 12/4/07	Thu 2/14/08



Project: Wilmer Eye Institute Detailed	Task	Milestone	External Tasks
	Split	Summary	External Milestone
	Progress	Project Summary	Deadline

Detailed Project Schedule

The Wilmer Eye Institue Outpatient Surgery & Lab Buidling

ID	Task Name	Duration	Start	Finish
51	First Floor	55 days?	Fri 2/15/08	Tue 4/29/08
52	Second Floor	54 days?	Tue 3/11/08	Thu 5/22/08
53	Third Floor	50 days?	Thu 4/10/08	Tue 6/17/08
54	Fourth Floor	50 days?	Mon 5/5/08	Fri 7/11/08
55	Fifth Floor	49 days?	Thu 5/29/08	Tue 8/5/08
56	Sixth Floor	33 days?	Mon 6/23/08	Wed 8/6/08
57	Roof	24 days?	Thu 7/17/08	Tue 8/19/08
58	High Roof	16 days?	Tue 8/12/08	Tue 9/2/08
59				
60	**Building Envelope & Temporary Enclosure**	**103 days?**	**Wed 6/18/08**	**Fri 11/7/08**
61	Second Floor	21 days?	Wed 6/18/08	Wed 7/16/08
62	Third Floor	20 days?	Mon 7/14/08	Fri 8/8/08
63	Fourth Floor	21 days?	Wed 8/6/08	Wed 9/3/08
64	Fifth Floor	25 days?	Thu 8/7/08	Wed 9/10/08
65	Sixth Floor	21 days?	Wed 8/20/08	Wed 9/17/08
66	Roof	69 days?	Tue 8/5/08	Fri 11/7/08
67				
68	**Building Skin**	**146 days?**	**Wed 8/27/08**	**Wed 3/18/09**
69	North & NE Elevations	70 days?	Wed 8/27/08	Tue 12/2/08
70	South & SE Elevations	61 days?	Mon 10/20/08	Mon 1/12/09
71	West Elevation	69 days?	Fri 12/12/08	Wed 3/18/09
72				
73	**Interior**	**312 days?**	**Wed 4/30/08**	**Thu 7/9/09**
74	Sub-Basement & Basement	161 days?	Wed 4/30/08	Wed 12/10/08
75	**First Floor**	**216 days?**	**Wed 4/30/08**	**Wed 2/25/09**
76	General Sterile	143 days?	Fri 5/23/08	Tue 12/9/08
77	Operating Rooms	160 days?	Mon 5/19/08	Fri 12/26/08
78	Operating Room Support	157 days?	Thu 6/5/08	Fri 1/9/09
79	Pre/Post Operation	160 days?	Thu 6/12/08	Wed 1/21/09
80	Reception/Entrance	177 days?	Tue 6/17/08	Wed 2/18/09
81	General	28 days?	Mon 1/19/09	Wed 2/25/09
82	Electrical Closet	9 days?	Wed 4/30/08	Mon 5/12/08
83	**Second Floor**	**246 days?**	**Fri 5/23/08**	**Fri 5/1/09**
84	Lab & Lab Support	216 days?	Tue 6/24/08	Tue 4/21/09
85	Office/Atrium	223 days?	Wed 6/18/08	Fri 4/24/09
86	General	53 days?	Wed 2/18/09	Fri 5/1/09
87	Electrical Closet	10 days?	Fri 5/23/08	Thu 6/5/08
88	**Third Floor**	**251 days?**	**Wed 6/18/08**	**Wed 6/3/09**
89	Lab & Lab Support	228 days?	Mon 7/14/08	Wed 5/27/09
90	Office/Atrium	225 days?	Mon 7/14/08	Fri 5/22/09
91	General	61 days?	Wed 3/11/09	Wed 6/3/09
92	Electrical Closet	9 days?	Wed 6/18/08	Mon 6/30/08
93	**Third Floor**	**277 days?**	**Wed 6/18/08**	**Thu 7/9/09**
94	Lab & Lab Support	236 days?	Wed 8/6/08	Wed 7/1/09
95	Office/Atrium	229 days?	Wed 8/6/08	Mon 6/22/09
96	General	72 days?	Wed 4/1/09	Thu 7/9/09
97	Electrical Closet	9 days?	Wed 6/18/08	Mon 6/30/08
98	**Fifth Floor**	**145 days?**	**Thu 8/7/08**	**Wed 2/25/09**
99	General	145 days?	Thu 8/7/08	Wed 2/25/09
100	Electrical Closet	9 days?	Thu 8/7/08	Tue 8/19/08

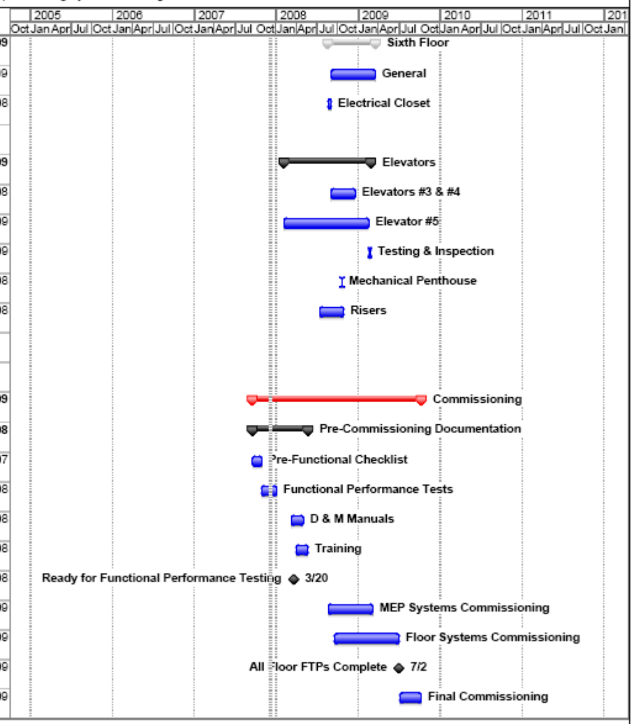
Project: Wilmer Eye Institute Detailed

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Detailed Project Schedule

The Wilmer Eye Institue Outpatient Surgery & Lab Buidling

ID	Task Name	Duration	Start	Finish
101	**Sixth Floor**	**151 days?**	**Wed 8/20/08**	**Wed 3/18/09**
102	General	141 days?	Wed 9/3/08	Wed 3/18/09
103	Electrical Closet	10 days?	Wed 8/20/08	Tue 9/2/08
104				
105	**Elevators**	**279 days?**	**Wed 2/6/08**	**Thu 2/26/09**
106	Elevators #3 & #4	78 days?	Wed 9/3/08	Fri 12/19/08
107	Elevator #5	272 days?	Wed 2/6/08	Tue 2/17/09
108	Testing & Inspection	7 days?	Wed 2/18/09	Thu 2/26/09
109	Mechanical Penthouse	1 day?	Tue 10/21/08	Tue 10/21/08
110	Risers	77 days?	Mon 7/14/08	Tue 10/28/08
111				
112				
113	**Commissioning**	**542 days?**	**Tue 9/18/07**	**Fri 10/9/09**
114	**Pre-Commissioning Documentation**	**181 days?**	**Tue 9/18/07**	**Thu 5/22/08**
115	Pre-Functional Checklist	30 days?	Tue 9/18/07	Mon 10/29/07
116	Functional Performance Tests	50 days?	Mon 10/29/07	Thu 1/3/08
117	D & M Manuals	40 days?	Mon 3/10/08	Thu 5/1/08
118	Training	40 days?	Mon 3/31/08	Thu 5/22/08
119	Ready for Functional Performance Testing	0 days	Thu 3/20/08	Thu 3/20/08
120	MEP Systems Commissioning	142 days?	Thu 8/21/08	Fri 3/6/09
121	Floor Systems Commissioning	207 days?	Wed 9/17/08	Thu 7/2/09
122	All Floor FTPs Complete	0 days	Thu 7/2/09	Thu 7/2/09
123	Final Commissioning	70 days?	Mon 7/6/09	Fri 10/9/09



Project: Wilmer Eye Institute Detailed

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Exterior Building Enclosure Estimate

The Wilmer Eye Institute Outpatient Surgery and Laboratory Building

Quick Building Stats: $65M Cost of Construction
7 Storeys, 202,000 SF

Material Description	Quantity	Units	Material	Installation	Total	Material	Installation	Total
East Elevation								
Brick Face Cavity Wall Standard face brick, 8" conc. block backup Polystyrene cavity insulation	6620	S.F.	10.30	18.95	29.25	68,186	125,449	193,635
Tubular Aluminum Framing For 1/4" glass, one intermediate horizontal	9830	S.F.	13.90	13.05	26.95	136,637	128,282	264,919
Curtain Wall Panels Glazing panel, insulating, 1/2" thick, 2 lites	9830	S.F.	9.15	9.50	18.65	89,945	93,385	183,330
South Elevation								
Brick Face Cavity Wall Standard face brick, 8" conc. block backup Polystyrene cavity insulation	5790	S.F.	10.30	18.95	29.25	59,637	109,721	169,358
Tubular Aluminum Framing For 1/4" glass, one intermediate horizontal	4280	S.F.	13.90	13.05	26.95	59,492	55,854	115,346
Curtain Wall Panels Glazing panel, insulating, 1/2" thick, 2 lites	4280	S.F.	9.15	9.50	18.65	39,162	40,660	79,822
West Elevation								
Brick Face Cavity Wall Standard face brick, 8" conc. block backup Polystyrene cavity insulation	16855	S.F.	10.30	18.95	29.25	173,607	319,402	493,009
Tubular Aluminum Framing For 1/4" glass, one intermediate horizontal	3435	S.F.	13.90	13.05	26.95	47,747	44,827	92,573
Curtain Wall Panels Glazing panel, insulating, 1/2" thick, 2 lites	3435	S.F.	9.15	9.50	18.65	31,430	32,633	64,063
North Elevation								
Brick Face Cavity Wall Standard face brick, 8" conc. block backup Polystyrene cavity insulation	7570	S.F.	10.30	18.95	29.25	77,971	143,452	221,423
Tubular Aluminum Framing For 1/4" glass, one intermediate horizontal	2910	S.F.	13.90	13.05	26.95	40,449	37,976	78,425
Curtain Wall Panels Glazing panel, insulating, 1/2" thick, 2 lites	2910	S.F.	9.15	9.50	18.65	26,627	27,645	54,272
					Totals:	Material	Installation	Total
						$850,888	$1,159,284	$2,010,172

*Cavity wall assembly includes brick shelf, ties to the backups and necessary dampproofing, flashing, and control joints every 20'.
*Figures referenced from R.S. Means Assemblies Cost Data 2008

Detailed Structural Systems Estimate

The Wilmer Eye Institute Outpatient Surgery & Lab Building

Quick Building Stats: $65M Cost of Construction
7 Storeys, 202,000 SF

Description	Quantity	Units	Material	Labor	Equipment	Total	Total (O&P)	Material	Labor	Equipment	Total	Total (O&P)
Slab on Grade												
WWF 6 x 6 - W2.1 x 2.1 (8 x 8) 30 lb. per C.S.F	286	CSF	15.40	21.50		36.90	53.50	4,397	6,138	0	10,535	15,274
Normal Weight Concrete, 3,000 psi	440	CY	106.00			106.00	116.00	46,640	0	0	46,640	51,040
Concrete placement, slab on grade, pumped	440	CY		15.30	5.80	21.10	31.50	0	6,732	2,552	9,284	13,860
Slab on grade, incl. troweled finish, not incl. f	28550	SF	2.01	0.72	0.01	2.74	3.37	57,386	20,556	286	78,227	96,214
or reinforcing, over 10,000 S.F., 6" thick										**Subtotal:**	**144,686**	**176,388**
Mat Footings												
Normal Weight Concrete, 3,000 psi	647	CY	104.00			104.00	114.00	67,246	0	0	67,246	73,712
Concrete placement, foundation mats, over 2	647	CY		4.97	1.88	6.85	10.15	0	3,214	1,216	4,429	6,563
Reinforcing steel, footings, #4-#7	9820	lb	0.47	0.31		0.78	1.05	4,615	3,044	0	7,660	10,311
Reinforcing steel, footings, #8-#18	37260	lb	0.47	0.18		0.65	0.82	17,512	6,707	0	24,219	30,553
										Subtotal:	**103,554**	**121,140**
Pile Caps												
Normal Weight Concrete, 5,000 psi	102	CY	114.00			114.00	125.00	11,639	0	0	11,639	12,763
Concrete placement, pile caps, over 10 C.Y., p	102	CY		8.30	3.13	11.43	16.95	0	847	320	1,167	1,731
Reinforcing steel, footings, #8-#18	9960	lb	0.47	0.18		0.65	0.82	4,681	1,793	0	6,474	8,167
										Subtotal:	**19,280**	**22,660**
Column Footings												
Normal Weight Concrete, 8,000 psi	701	CY	212.00			212.00	233.00	148,612	0	0	148,612	163,333
Concrete placement, spread footings, over 5	701	CY		13.25	5.00	18.25	27.00	0	9,288	3,505	12,793	18,927
Reinforcing steel, footings, #8-#18	41300	lb	0.47	0.18		0.65	0.82	19,411	7,434	0	26,845	33,866
										Subtotal:	**188,250**	**216,126**
Wall Footings												
Normal Weight Concrete, 3,000 psi	516	CY	104.00			104.00	114.00	53,664	0	0	53,664	58,824
Concrete placement, footings, continuous, sh	516	CY		13.25	5.00	18.25	27.00	0	6,837	2,580	9,417	13,932
Reinforcing steel, footings, #4-#7	23880	lb	0.47	0.31		0.78	1.05	11,224	7,403	0	18,626	25,074
										Subtotal:	**81,707**	**97,830**
Foundation Walls												
Normal Weight Concrete, 4,000 psi	1506	CY	108.00			108.00	119.00	162,648	0	0	162,648	179,214
Concrete placement, walls, pumped	1506	CY		14.50	0.43	14.93	24.50	0	21,837	648	22,485	36,897
Reinforcing steel, walls, #3-#7	78520	lb	0.47	0.22		0.69	0.89	36,904	17,274	0	54,179	69,883
Reinforcing steel, walls, #8-#18	158460	lb	0.47	0.17		0.64	0.79	74,476	26,938	0	101,414	125,183
										Subtotal:	**340,726**	**411,177**
Interior Basement Walls												
Normal Weight Concrete, 4,000 psi	102	CY	108.00			108.00	119.00	11,016	0	0	11,016	12,138
Concrete placement, walls, pumped	102	CY		14.50	0.43	14.93	24.50	0	1,479	44	1,523	2,499
Reinforcing steel, walls, #3-#7	7400	lb	0.47	0.22		0.69	0.89	3,478	1,628	0	5,106	6,586
CMU Wall, solid, reinforced alternate course:	11570	SF	3.27	3.81		7.08	9.80	37,834	44,082	0	81,916	113,386
										Subtotal:	**99,560**	**134,609**
Shear Walls												
Normal Weight Concrete, 5,000 psi	709	CY	114.00			114.00	125.00	80,826	0	0	80,826	88,625
Concrete placement, walls, pumped	709	CY		14.50	0.43	14.93	24.50	0	10,281	305	10,585	17,371
Reinforcing steel, walls, #3-#7	44000	lb	0.47	0.22		0.69	0.89	20,680	9,680	0	30,360	39,160
Reinforcing steel, walls, #8-#18	60520	lb	0.47	0.17		0.64	0.79	28,444	10,288	0	38,733	47,811
										Subtotal:	**160,504**	**192,966**
Columns												
Normal Weight Concrete, 5,000 psi	1093	CY	114.00			114.00	125.00	124,556	0	0	124,556	136,575
Concrete placement, columns, pumped	1093	CY		21.50	8.15	29.65	44.50	0	23,491	8,905	32,396	48,621
Reinforcing steel, columns, #3-#7	54422	lb	0.47	0.44		0.91	1.26	25,578	23,946	0	49,524	68,572
Reinforcing steel, columns, #8-#18	261446	lb	0.47	0.29		0.76	1.00	122,880	75,819	0	198,699	261,446
										Subtotal:	**405,175**	**515,213**
Elevated Slabs												
Normal Weight Concrete, 3,000 psi	6836	CY	104.00			104.00	114.00	710,944	0	0	710,944	779,304
Concrete placement, slabs over 10" thick, pu	6836	CY		11.05	4.17	15.22	22.50	0	75,538	28,506	104,044	153,810
Reinforcing steel, elevated slabs, #4-#7	578540	lb	0.49	0.23		0.72	0.93	283,485	133,064	0	416,549	538,042
Reinforcing steel, elevated slabs, #8-#18	149380	lb	0.47	0.29		0.76	1.00	70,209	43,320	0	113,529	149,380
										Subtotal:	**1,345,066**	**1,620,536**

Total Material	Total Labor	Total Equip.	Total	Total (O&P)
$2,240,986	$598,658	$48,865	**$4,431,953**	**$5,396,755**

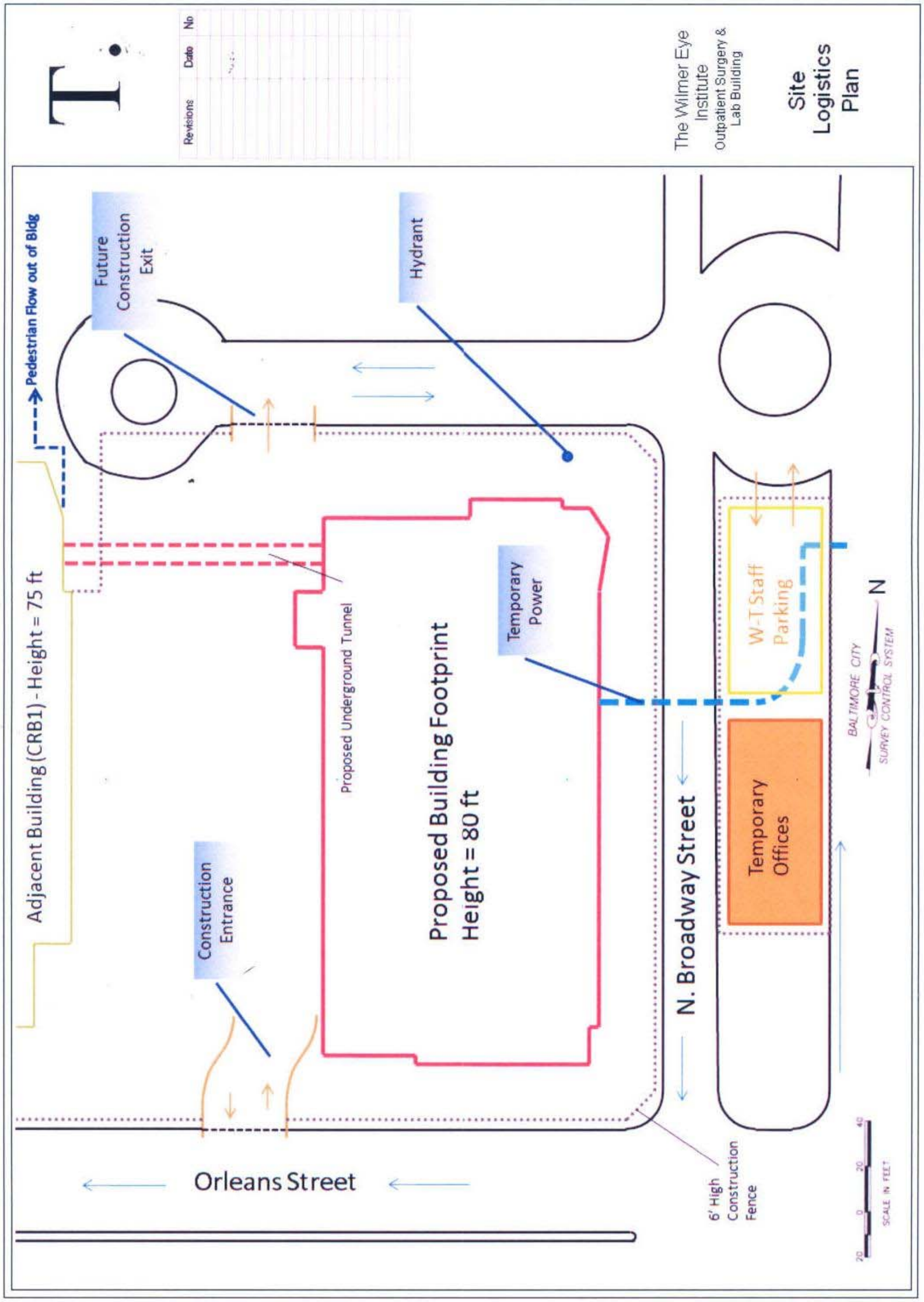
*Assuming area well wall reinforcement is similar to typical foundation wall
*Assuming all foundation walls are 34'-0" due to conflicts in structural and architectural drawings
*Assuming typical dowel length of 4'-0"
*Assuming similar elevated slabs aside from deduction for atrium space
*Assuming all concrete is pumped
*All unit-cost data referenced from R.S. Means Facilities Construction Cost Data 2007, 22nd Annual Edition

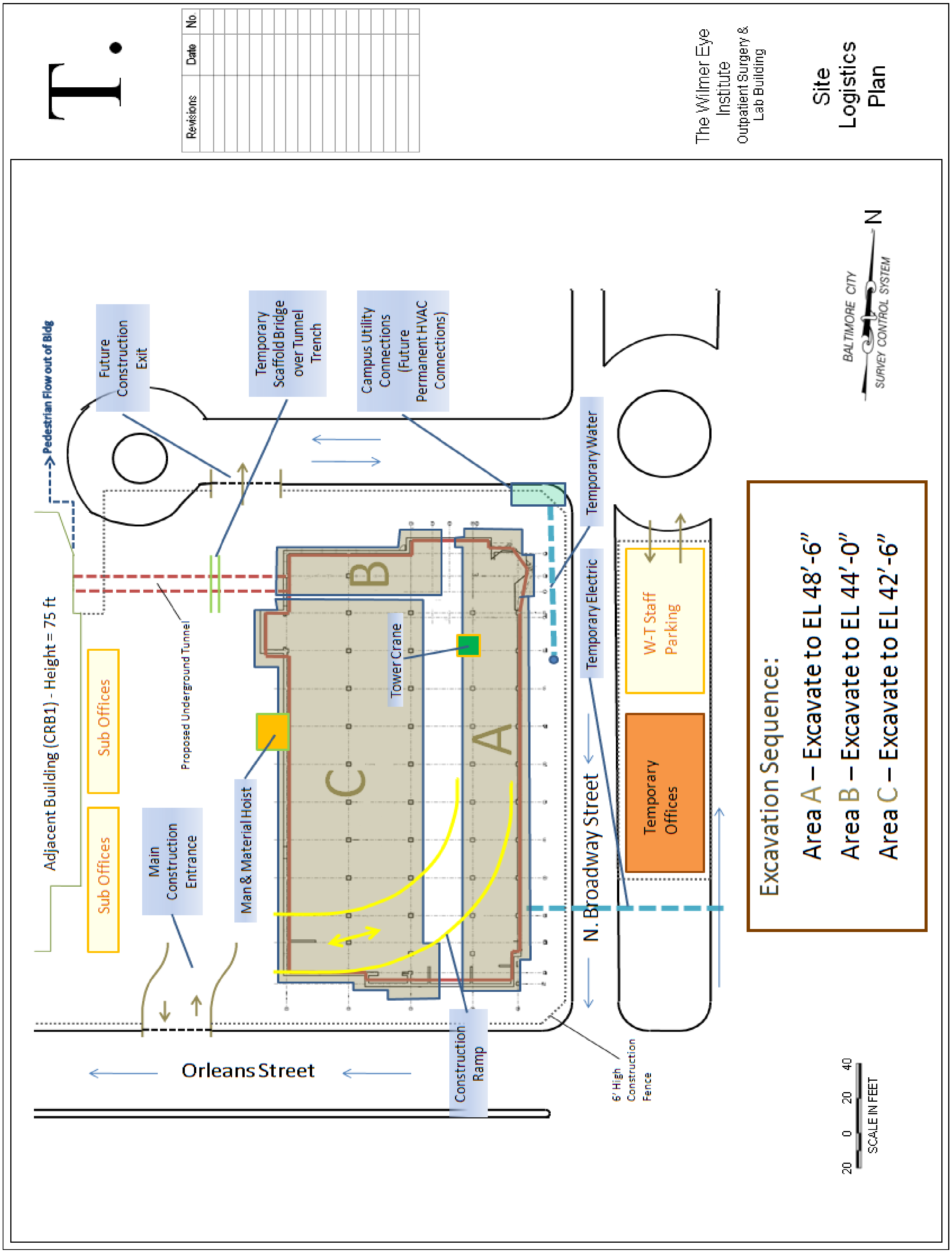
General Conditions Cost Estimate

The Wilmer Eye Institute Outpatient Surgery & Laboratory Building

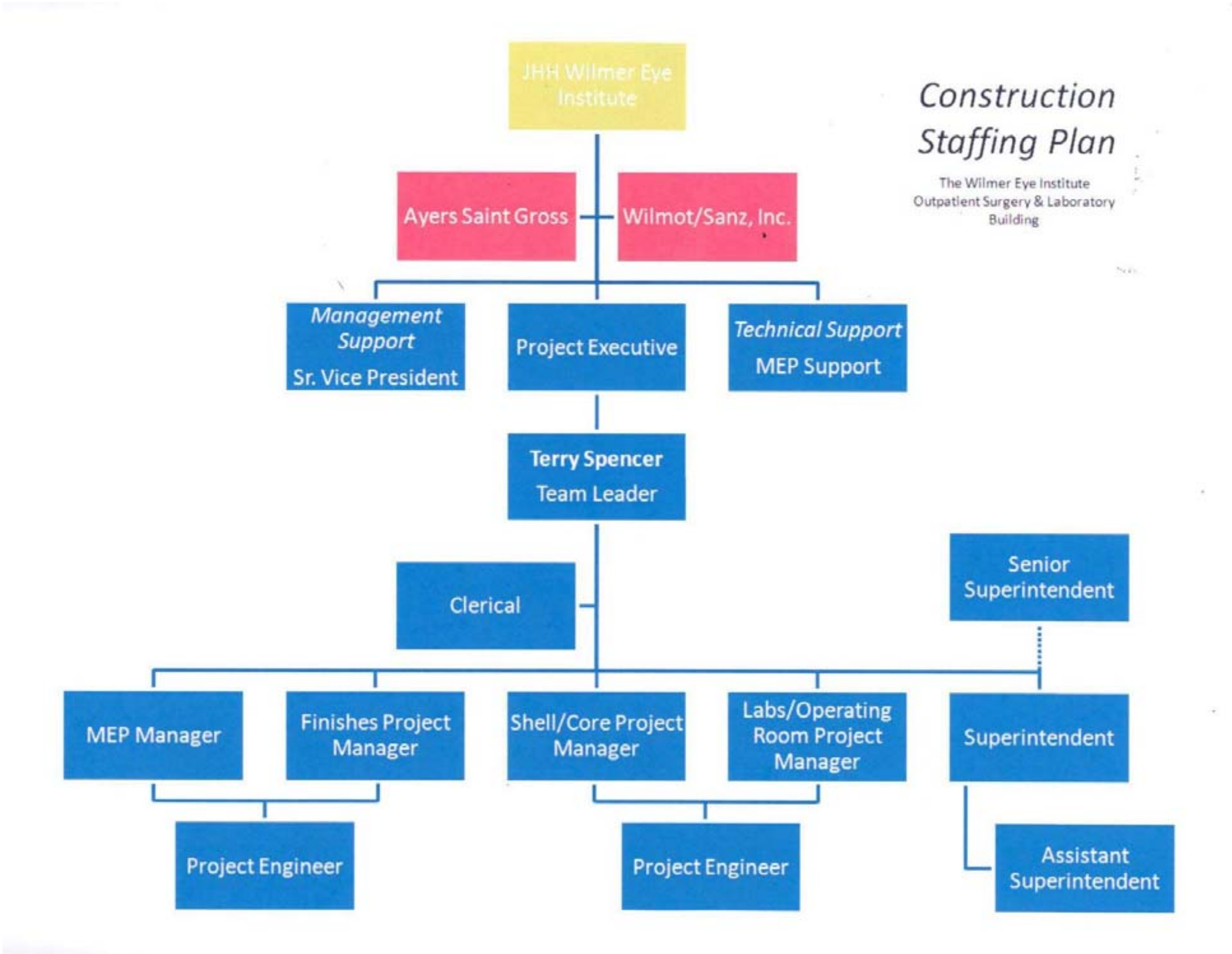
Quick Building Stats: $65M Cost of Construction
7 Storeys, 202,000 SF

Category	Description	$/Unit	Unit	Qty.	Total
Personnel	Project Executive	10000	mo	2	$20,000
	Senior Project Manager	8333	mo	31	$258,323
	Shell/Core PM	7500	mo	17	$127,500
	Finishes PM	7500	mo	14	$105,000
	MEP Manager	7500	mo	15	$112,500
	Labs/OR Manager	7500	mo	14	$105,000
	Senior Superintendent	7500	mo	15	$112,500
	Superintendent	7100	mo	31	$220,100
	Asst. Superintendent	6250	mo	31	$193,750
	Project Engineer	5500	mo	17	$93,500
	Project Engineer	5500	mo	14	$77,000
Office Supplies	General	95	mo	31	$2,945
	Office Elec./HVAC	110	mo	31	$3,410
	Phone Bills	210	mo	31	$6,510
Temporary Offices	Trailer Rental	700	mo	31	$21,700
Temporary Utilities	Water	62	mo	31	$1,922
	Electric	75	mo	31	$2,325
	Lighting	15	CSF	202	$3,030
	Heating	390	mo	6	$2,340
Trash Disposal	Dumpsters	690	wk	140	$96,600
	Trash Chutes	55	LF	80	$4,400
Temporary Facilities	Toilet	685	mo	31	$21,235
Temporary Fencing	Chain link, 11 ga, 6' high	7.15	LF	1120	$8,008
Signage		16.55	SF	20	$331
Scaffold Bridge	Catwalk, 10' span	190	ea	1	$190
Surveying		1200	LS	1	$1,200
Temporary Building Enclosure	Framing over openings	1	SF	63240	$63,240
Photographic Documentation	Photographs	450	set	2	$900
	Cameraman/Film	1375	visit	2	$2,750
Scheduling	CPM Scheduling	15000	LS	1	$15,000
Construction Clean-up		115000	LS	1	$115,000
Man/Material Hoist		6000	LS	1	$6,000
Miscellaneous/Unforseen		6,000	LS	1	$6,000
				Total:	$1,810,209

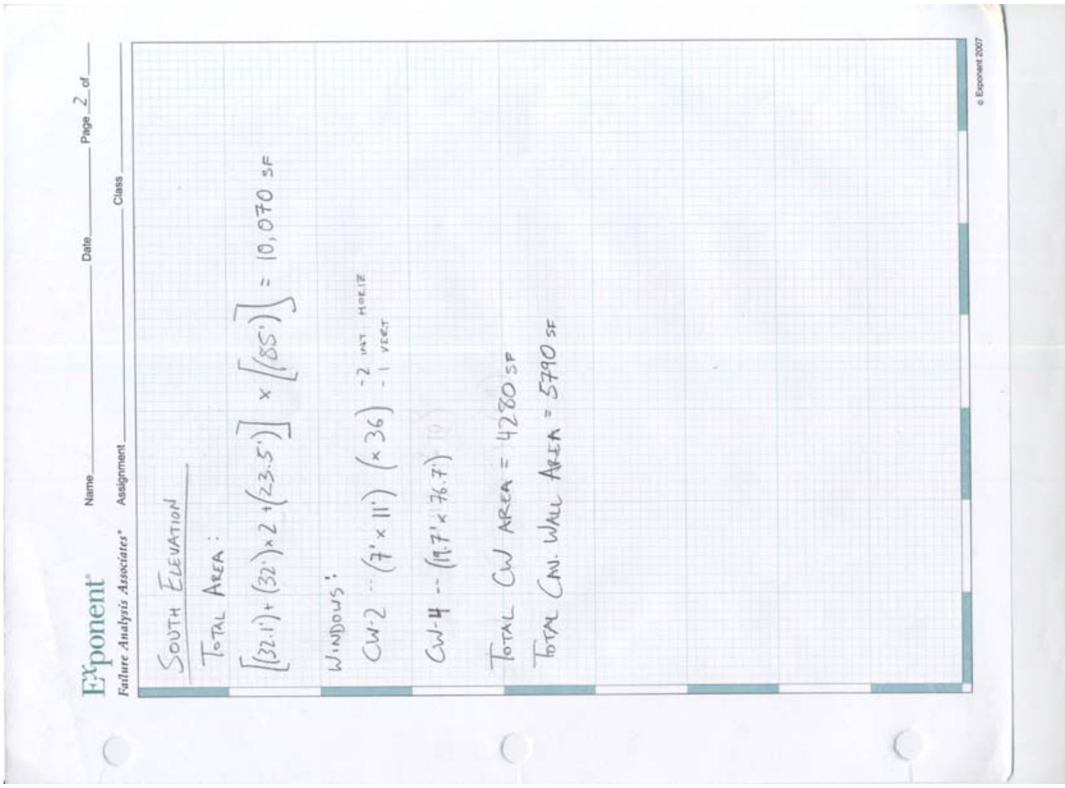

The Wilmer Eye Institute
Outpatient Surgery & Lab Building
Site Logistics Plan
Revisions
Date
No
Pedestrian Flow out of Bldg
Future Construction Exit
Hydrant
Adjacent Building (CRB1) - Height = 75 ft
Proposed Underground Tunnel
Temporary Power
Proposed Building Footprint
Height = 80 ft
Construction Entrance
N. Broadway Street
W-T Staff Parking
Temporary Offices
N
BALTIMORE CITY
SURVEY CONTROL SYSTEM
Orleans Street
6' High Construction Fence
SCALE IN FEET



The Wilmer Eye Institute
Outpatient Surgery & Lab Building
Site Logistics Plan
Revisions
Date
No.
Pedestrian Flow out of Bldg
Adjacent Building (CRB1) - Height = 75 ft
Future Construction Exit
Temporary Scaffold Bridge over Tunnel Trench
Campus Utility Connections (Future Permanent HVAC Connections)
Sub Offices
Sub Offices
Main Construction Entrance
Proposed Underground Tunnel
Man & Material Hoist
Tower Crane
Temporary Water
Temporary Electric
N. Broadway Street
W-T Staff Parking
Temporary Offices
Orleans Street
Construction Ramp
6' High Construction Fence
A
B
C
Excavation Sequence:
Area A – Excavate to EL 48'-6"
Area B – Excavate to EL 44'-0"
Area C – Excavate to EL 42'-6"
BALTIMORE CITY SURVEY CONTROL SYSTEM
N
SCALE IN FEET
20 0 20 40


Construction
Staffing Plan
The Wilmer Eye Institute
Outpatient Surgery & Laboratory
Building
JHH Wilmer Eye
Institute
Ayers Saint Gross
Wilmot/Sanz, Inc.
Management
Support
Sr. Vice President
Project Executive
Technical Support
MEP Support
Terry Spencer
Team Leader
Clerical
Senior
Superintendent
MEP Manager
Finishes Project
Manager
Shell/Core Project
Manager
Labs/Operating
Room Project
Manager
Superintendent
Project Engineer
Project Engineer
Assistant
Superintendent

Exterior Enclosures Estimate Calculations



Exponent® Failure Analysis Associates® — Name — Date — Class — Page 2 of

SOUTH ELEVATION

TOTAL AREA:

[(32.1') + (32')×2 + (23.5')] × [(85')] = 10,070 SF

WINDOWS:

CW-2 -- (7' × 11') (× 36) - 2 INT. HORIZ - 1 VERT

CW-4 -- (19.7' × 76.7')

TOTAL CW AREA = 4280 SF

TOTAL CAV. WALL AREA = 5790 SF

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Exponent® Failure Analysis Associates® — Name TYLER M. SMITH — Date — Assignment EXTERIOR ENCLOSURE EST — Class — Page 1 of

EAST ELEVATION

TOTAL AREA (EXCL. NE CW):

[(6.1') + (10.7') + (6.1') + (14.8') + (21')×8] × [(80')] = 16,450 SF

WINDOWS:

CW-11 -- (7' × 11') (× 80) - 2 INT. HORIZ - 1 INT. VERT

*CW-12 -- (14' × 77.3')

*CW-13 -- (13.8' × 77.3')

*CW-16 (×2) -- (10' × 77.3')/2

*CW-15 -- (19.5' × 77.3')/2

CW-6 -- (7' × 54.5')

TOTAL CW AREA = 9830 SF

TOTAL CAVITY WALL AREA = 6620 SF

* NOT INCL. IN TOTAL AREA

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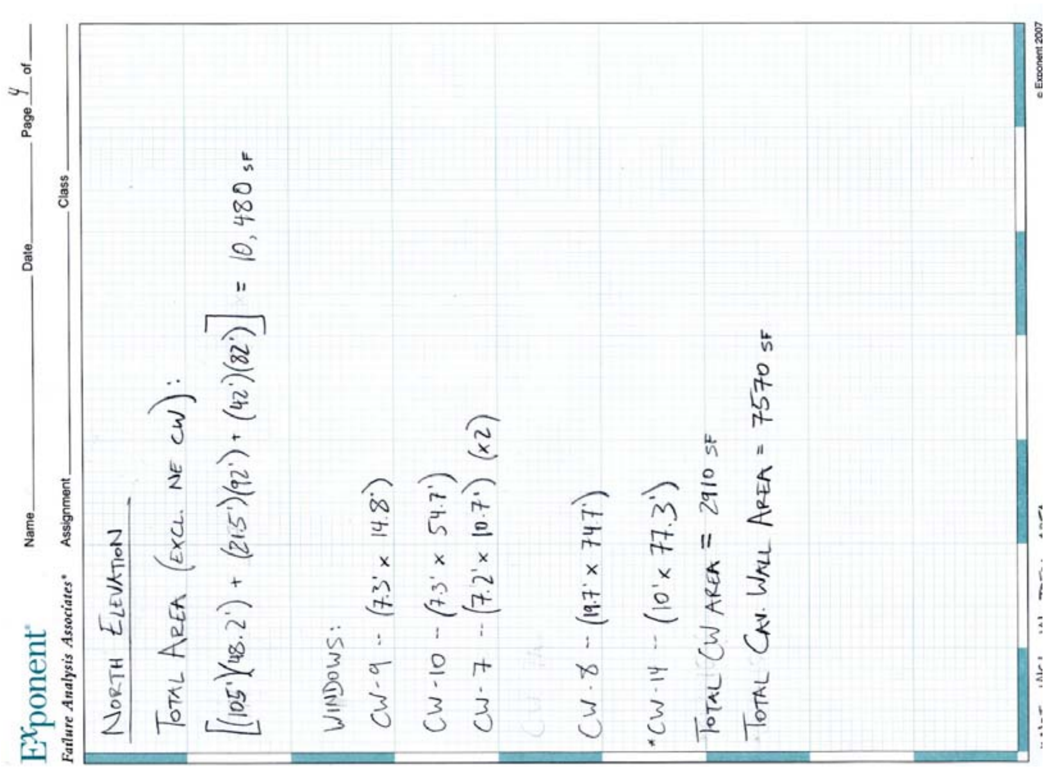
Exterior Enclosures Estimate Calculations



Exponent® Failure Analysis Associates® Name Assignment Date Class Page 4 of

NORTH ELEVATION

TOTAL AREA (EXCL. NE CW):

[(105')(48.2') + (21.5')(92') + (42')(82')] = 10,480 SF

WINDOWS:

CW-9 -- (7.3' × 14.8')

CW-10 -- (7.3' × 54.7')

CW-7 -- (7.2' × 10.7') (×2)

CW-8 -- (19.7' × 74.7')

*CW-14 -- (10' × 77.3')

TOTAL CW AREA = 2910 SF

TOTAL CAV. WALL AREA = 7570 SF

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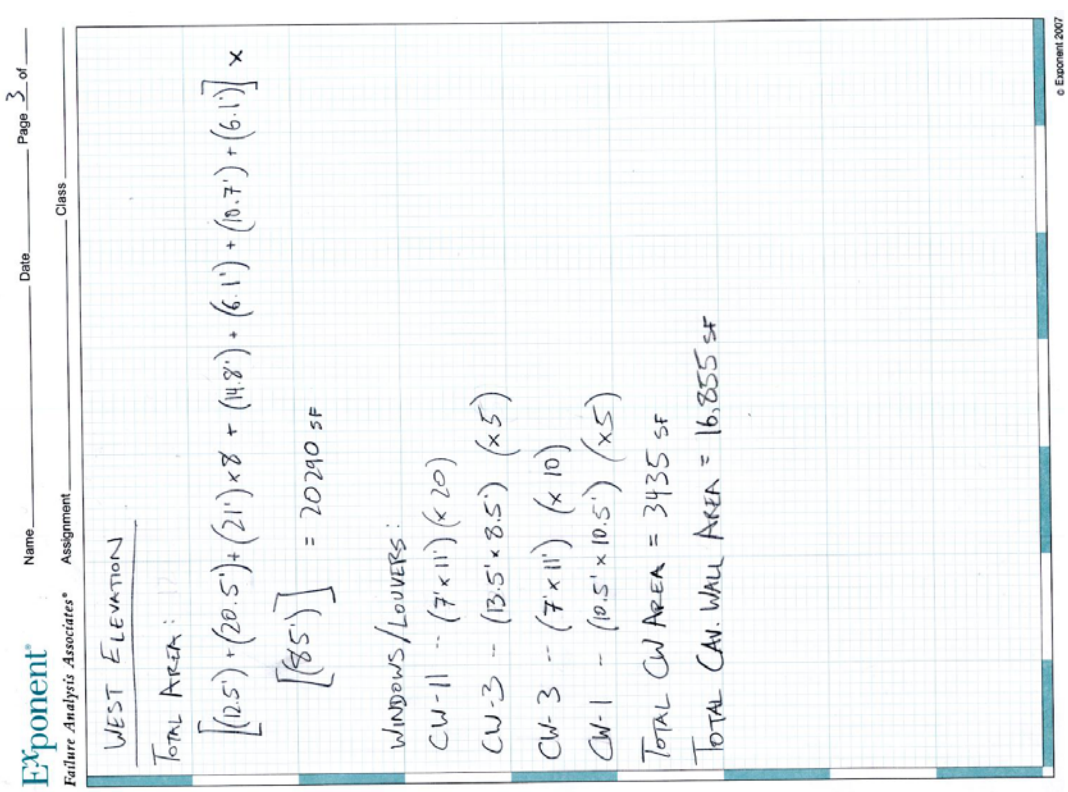

Exponent® Failure Analysis Associates® Name Assignment Date Class Page 3 of

WEST ELEVATION

TOTAL AREA:

[(12.5') + (20.5') + (21') × 8 + (14.8') + (6.1') + (10.7') + (6.1')] ×

[(85')] = 20290 SF

WINDOWS/LOUVERS:

CW-11 -- (7' × 11') (× 20)

CW-3 -- (13.5' × 8.5') (× 5)

CW-3 -- (7' × 11') (× 10)

CW-1 -- (10.5' × 10.5') (× 5)

TOTAL CW AREA = 3435 SF

TOTAL CAV. WALL AREA = 16,855 SF

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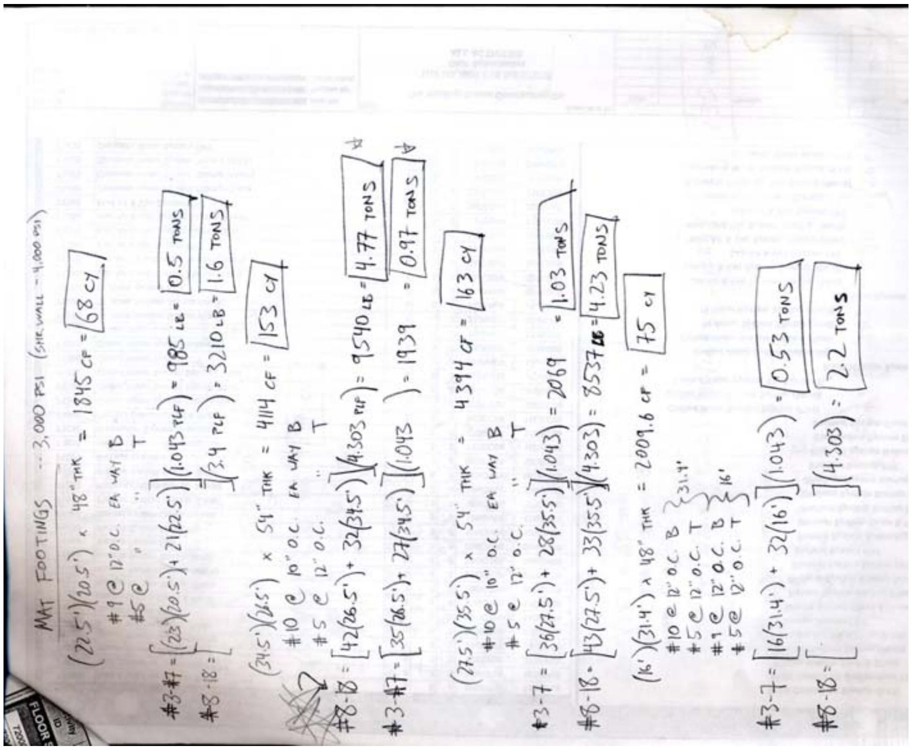
Structural Estimate Calculations



MAT FOOTINGS - 3,000 PSI (SHR. WALL - 4,000 PSI)

(22.5')(20.5') x 48" THK = 1845 CF = 68 CY

#9 @ 12" O.C. EA WAY B

#5 @ " " T

#3-#7 = [(23)(20.5') + 21(22.5')](1.043 PLF) = 985 LB = 0.5 TONS

#8-18 = [ ](3.4 PLF) = 3210 LB = 1.6 TONS

(34.5')(26.5') x 54" THK = 4114 CF = 153 CY

#10 @ 10" O.C. EA WAY B

#5 @ 12" O.C. " T

#8-18 = [42(26.5') + 32(34.5')](4.303 PLF) = 9540 LB = 4.77 TONS

#3-#7 = [35(26.5') + 27(34.5')](1.043) = 1939 = 0.97 TONS

(27.5')(35.5') x 54" THK = 4394 CF = 163 CY

#10 @ 10" O.C. EA WAY B

#5 @ 12" O.C. " T

#3-7 = [36(27.5') + 28(35.5')](1.043) = 2069 = 1.03 TONS

#8-18 = [43(27.5') + 33(35.5')](4.303) = 8537 LB = 4.23 TONS

(16')(31.4') x 48" THK = 2009.6 CF = 75 CY

#10 @ 12" O.C. B } 31.4'

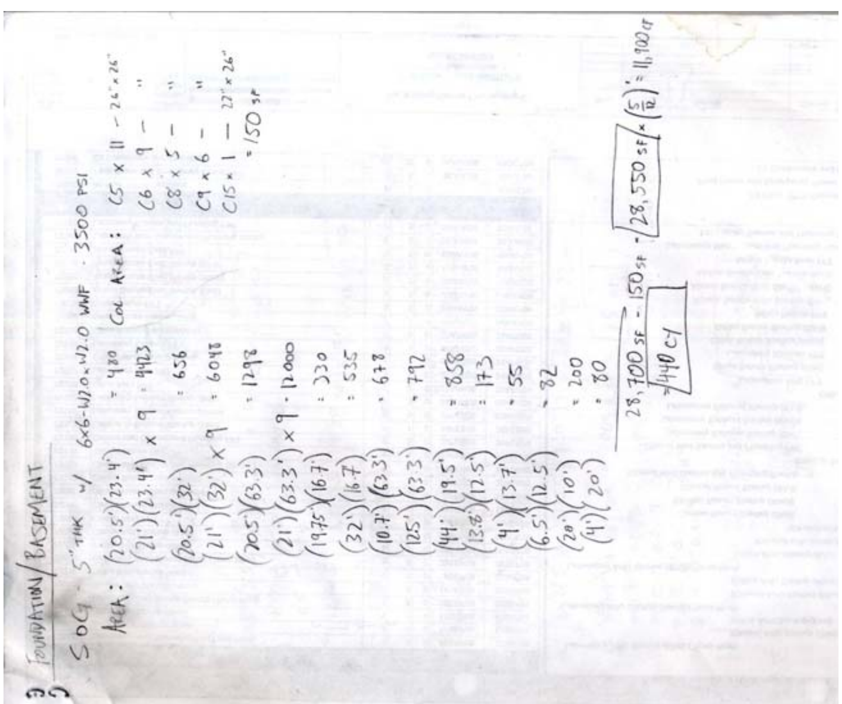
#5 @ 12" O.C. T

#9 @ 12" O.C. B } 16'

#5 @ 12" O.C. T

#3-7 = [16(31.4') + 32(16')](1.043) = 0.53 TONS

#8-18 = [ ](4.303) = 2.2 TONS



FOUNDATION/BASEMENT

SOG 5" THK w/ 6x6-W2.0xW2.0 WWF 3500 PSI

AREA: (20.5')(23.4') = 480 — COL AREA: C5 x 11 — 26" x 26"

(21')(23.4') x 9 = 4423 — C6 x 9 — "

(20.5')(32') = 656 — C8 x 5 — "

(21')(32') x 9 = 6048 — C9 x 6 — "

(20.5')(63.3') = 1298 — C15 x 1 — 22" x 26"

(21')(63.3') x 9 = 12,000 — = 150 SF

(19.75')(16.7') = 330

(32')(16.7') = 535

(10.7')(63.3') = 678

(12.5')(63.3') = 792

(44')(19.5') = 858

(13.8')(12.5') = 173

(4')(13.7') = 55

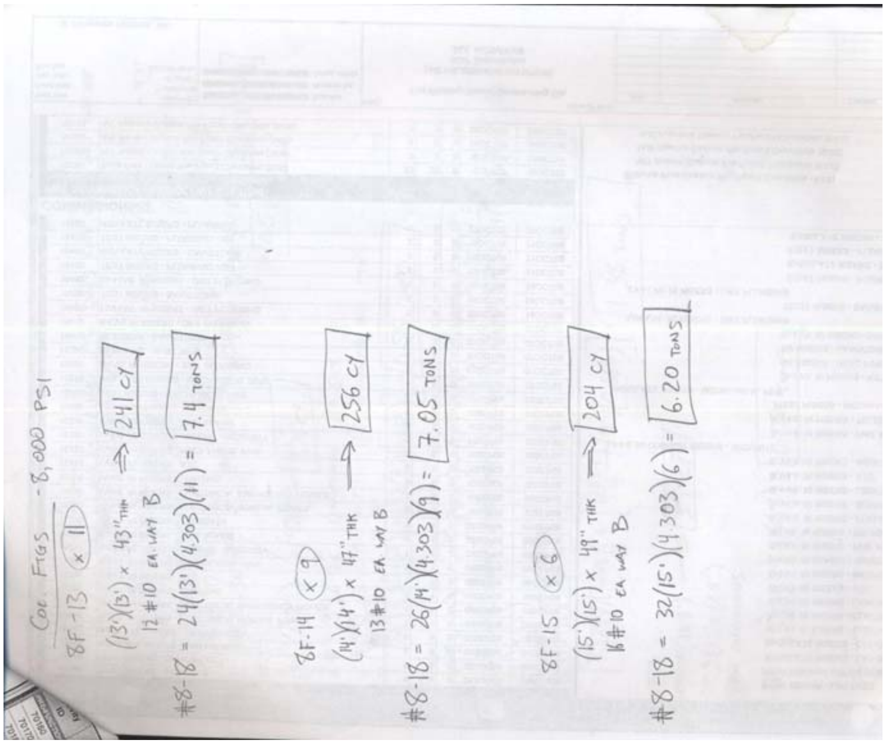
(6.5')(12.5') = 82

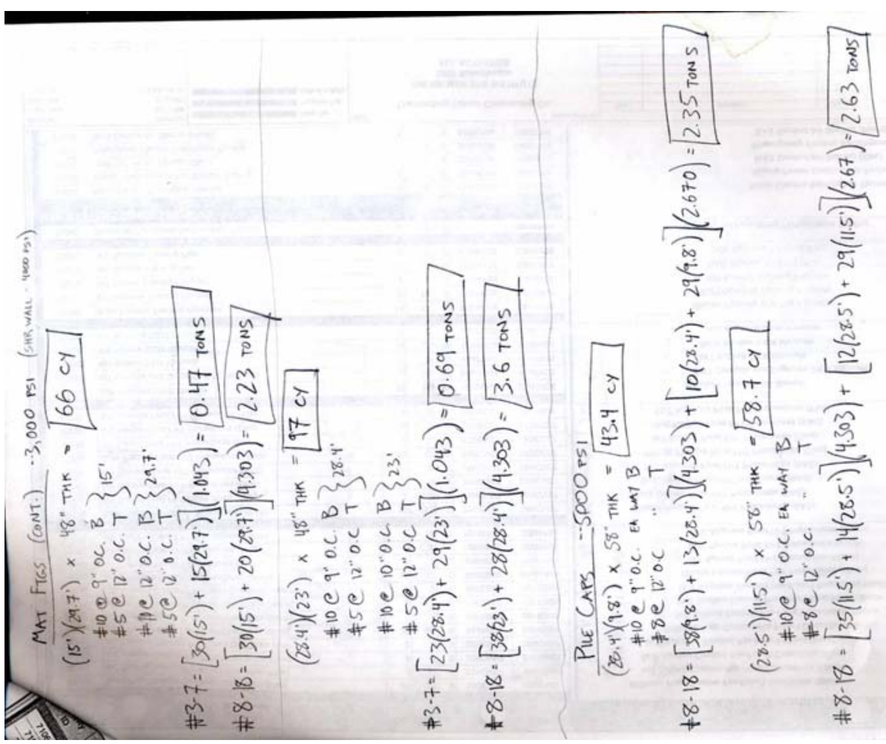
(20')(10') = 200

(4')(20') = 80

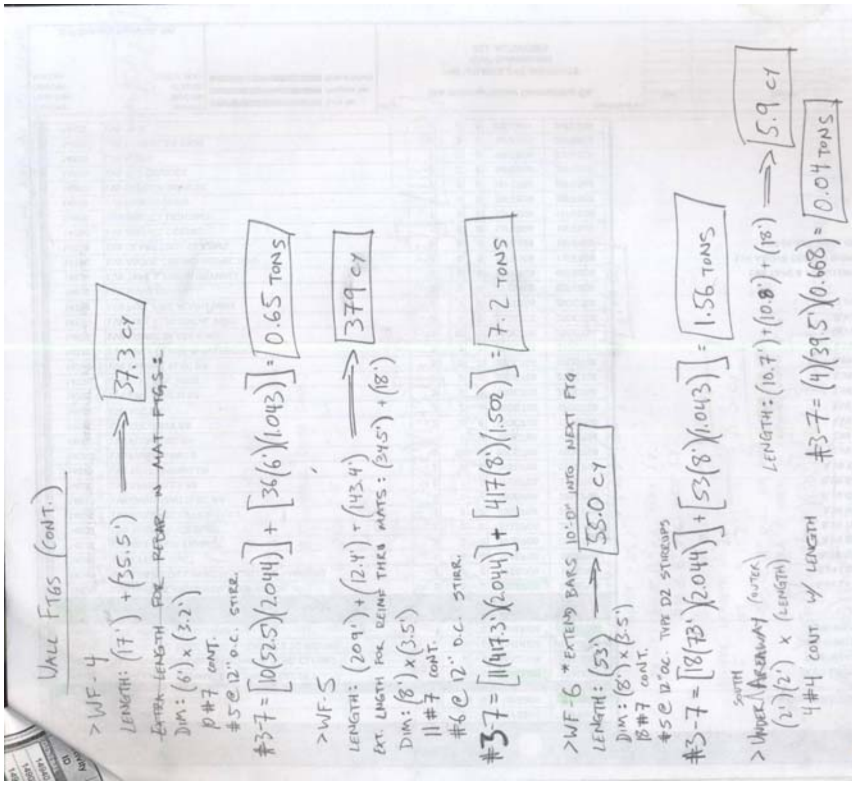
28,700 SF - 150 SF = 28,550 SF x (5/12)' = 11,900 CF = 440 CY

Structural Estimate Calculations





Structural Estimate Calculations



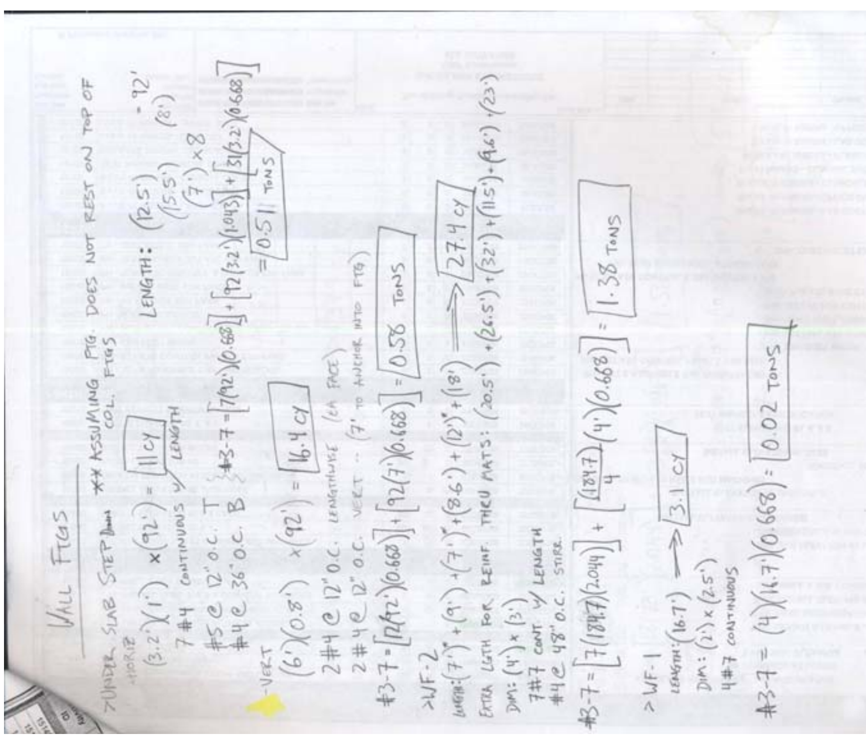
WALL FTGS (CONT.)

>WF-4
LENGTH: (17') + (35.5') → 37.3 CY
EXTRA LENGTH FOR REBAR IN MAT FTGS:
DIM: (6') x (3.2')
8 #7 CONT.
#5 @ 12" O.C. STIR.
#3-7 = [10(52.5')(2.044)] + [36(6')(1.043)] = 0.65 TONS

>WF-5
LENGTH: (209') + (12.4') + (143.4') → 37.9 CY
EXT. LENGTH FOR REINF THRU MATS: (34.5') + (18')
DIM: (8') x (3.5')
11 #7 CONT.
#6 @ 12" O.C. STIR.
#3-7 = [11(417.3')(2.044)] + [417(8')(1.502)] = 7.2 TONS

>WF-6 *EXTEND BARS 10'-0" INTO NEXT FTG
LENGTH: (53') → 55.0 CY
DIM: (8') x (3.5')
18 #7 CONT.
#5 @ 12" O.C. TYPE D2 STIRRUPS
#3-7 = [18(73')(2.044)] + [53(8')(1.043)] = 1.56 TONS

> UNDER SOUTH AREAWAY (OUTER)
(2')(2') x (LENGTH)
LENGTH: (10.7') + (10.8') + (18') → 5.9 CY
4 #4 CONT W/ LENGTH
#3-7 = (4)(39.5')(0.668) = 0.04 TONS



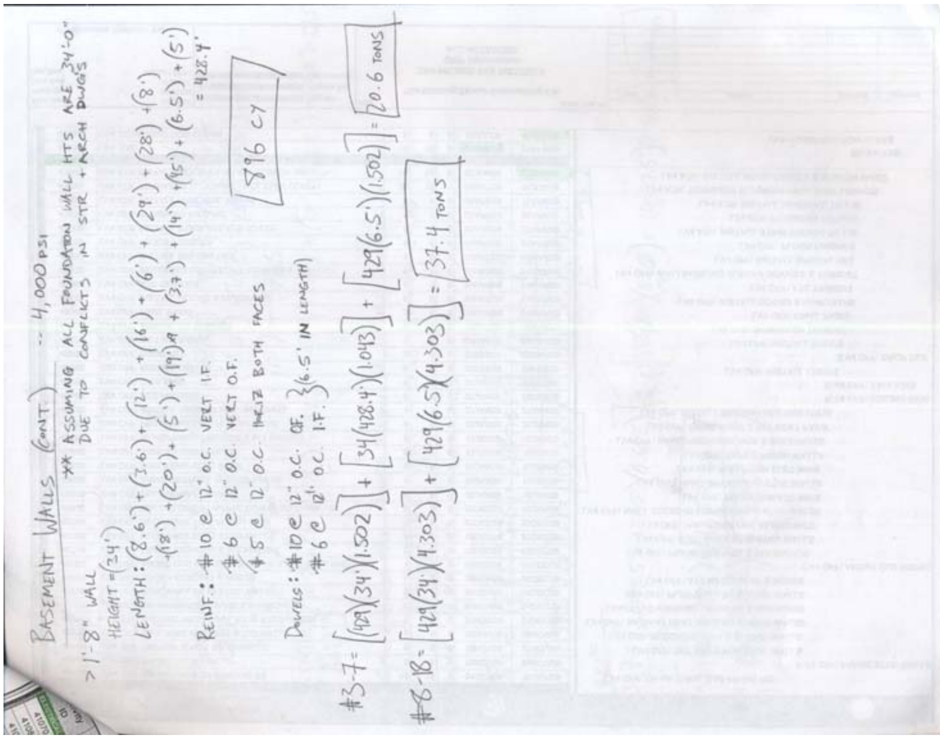
WALL FTGS

>UNDER SLAB STEP DOWN ** ASSUMING FTG. DOES NOT REST ON TOP OF COL. FTGS
-HORIZ
(3.2')(1') x (92') = 11 CY
LENGTH: (12.5') (15.5') (7') x 8 (8') = 92'
7 #4 CONTINUOUS W/ LENGTH
#5 @ 12" O.C. T
#4 @ 36" O.C. B
#3-7 = [7(92')(0.668)] + [92(3.2')(1.043)] + [31(3.2')(0.668)] = 0.51 TONS
-VERT
(6')(0.8') x (92') = 16.4 CY
2 #4 @ 12" O.C. LENGTHWISE (EA FACE)
2 #4 @ 12" O.C. VERT → (7' TO ANCHOR INTO FTG)
#3-7 = [2(92')(0.668)] + [92(7')(0.668)] = 0.58 TONS

>WF-2
LENGTH: (7')* + (9') + (7')* + (8.6') + (12')* + (18') → 27.4 CY
EXTRA LGTH FOR REINF. THRU MATS: (20.5') + (26.5') + (32') + (11.5') + (14.6') + (23')
DIM: (4') x (3')
7 #7 CONT. W/ LENGTH
#4 @ 48" O.C. STIR.
#3-7 = [7(189.7)(2.044)] + [(189.7)/4 (4')(0.668)] = 1.38 TONS

> WF-1
LENGTH: (16.7') → 3.1 CY
DIM: (2') x (2.5')
4 #7 CONTINUOUS
#3-7 = (4)(16.7')(0.668) = 0.02 TONS

Structural Estimate Calculations



BASEMENT WALLS (CONT.) -- 4,000 PSI

** ASSUMING ALL FOUNDATION WALL HTS ARE 34'-0" DUE TO CONFLICTS IN STR + ARCH DWG'S

> 1'-8" WALL
HEIGHT = (34')
LENGTH: (8.6') + (3.6') + (12') + (16') + (6') + (29') + (28') + (8') + (18') + (20') + (5') + (19')9 + (3.7') + (14') + (15') + (6.5') + (5') = 428.4'

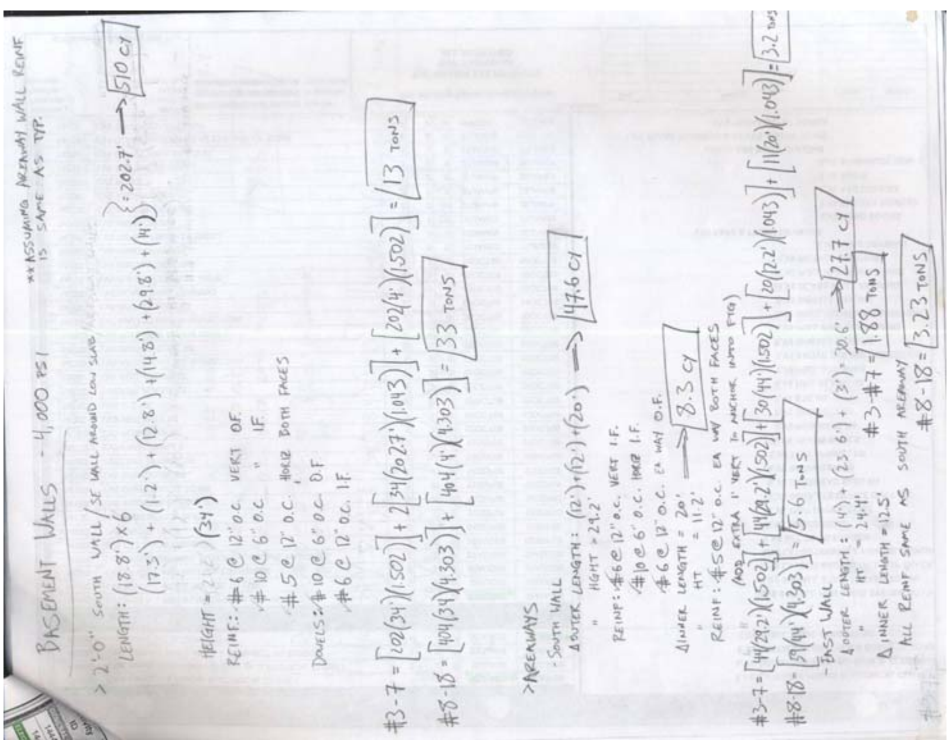
REINF: #10 @ 12" O.C. VERT I.F.
#6 @ 12" O.C. VERT O.F.
#5 @ 12" O.C. HORIZ BOTH FACES

896 CY

DOWELS: #10 @ 12" O.C. OF. / #6 @ 12" O.C. I.F. } (6.5' IN LENGTH)

#3-7 = [(429)(34')(1.502)] + [34(428.4')(1.043)] + [429(6.5')(1.502)] = 20.6 TONS

#8-18 = [429(34')(4.303)] + [429(6.5')(4.303)] = 37.4 TONS



BASEMENT WALLS - 4,000 PSI

**ASSUMING AREAWAY WALL REINF IS SAME AS TYP.

> 2'-0" SOUTH WALL / SE WALL AROUND LOW SLAB
LENGTH: (18.8') × 6
(17.5') + (1.2') + (12.8') + (14.8') + (29.8') + (14') } = 202.7' → 510 CY

HEIGHT = (34')
REINF: #6 @ 12" O.C. VERT OF.
#10 @ 6" O.C. " IF.
#5 @ 12" O.C. HORIZ BOTH FACES
DOWELS: #10 @ 6" O.C. O.F.
#6 @ 12" O.C. I.F.

#3-7 = [202(34')(1.502)] + 2[34(202.7')(1.043)] + [202(4')(1.502)] = 13 TONS

#8-18 = [404(34')(4.303)] + [404(4')(4.303)] = 33 TONS

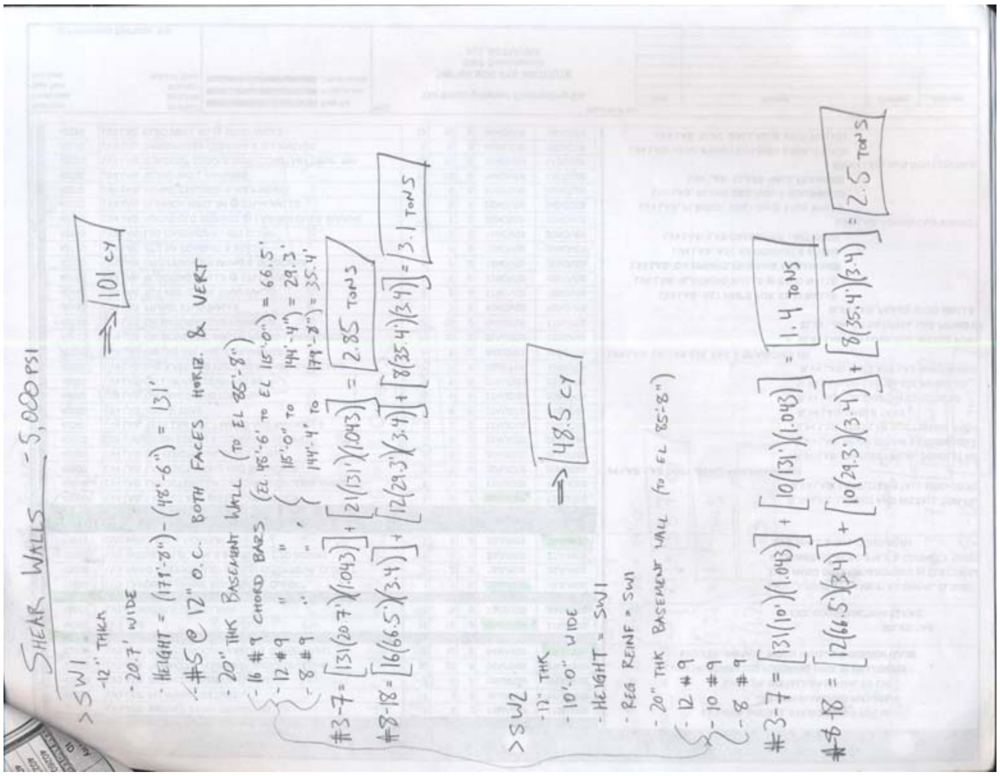
> AREAWAYS
- SOUTH WALL
Δ OUTER LENGTH: (12') + (12') + (20') → 47.6 CY
" HGHT = 29.2'
REINF: #6 @ 12" O.C. VERT I.F.
#10 @ 6" O.C. HORIZ I.F.
#6 @ 12" O.C. EA WAY O.F.
Δ INNER LENGTH = 20' → 8.3 CY
" HT = 11.2'
REINF: #5 @ 12" O.C. EA WAY BOTH FACES
(ADD EXTRA 1' VERT TO ANCHOR INTO FTG)

#3-7 = [44(29.2')(1.502)] + [44(29.2')(.502)] + [30(44')(1.502)] + [20(12.2')(1.043)] + [11(20')(1.043)] = 3.2 TONS

#8-18 = [59(44')(4.303)] = 5.6 TONS

- EAST WALL
Δ OUTER LENGTH: (4') + (23.6') + (3') = 30.6' → 27.7 CY
" HT = 24.4'
Δ INNER LENGTH = 12.5'
#3-#7 = 1.88 TONS
ALL REINF SAME AS SOUTH AREAWAY
#8-18 = 3.23 TONS

Structural Estimate Calculations



SHEAR WALLS – 5,000 PSI

>SW1
- 12" THK
- 20.7' WIDE
- HEIGHT = (179'-8") – (48'-6") = 131' ⟹ 101 CY
- #5 @ 12" O.C. BOTH FACES HORIZ. & VERT
- 20" THK BASEMENT WALL (TO EL 85'-8")
- 16 #9 CHORD BARS (EL 48'-6" TO EL 115'-0") = 66.5'
- 12 #9 " (115'-0" TO 144'-4") = 29.3'
- 8 #9 " (144'-4" TO 179'-8") = 35.4'

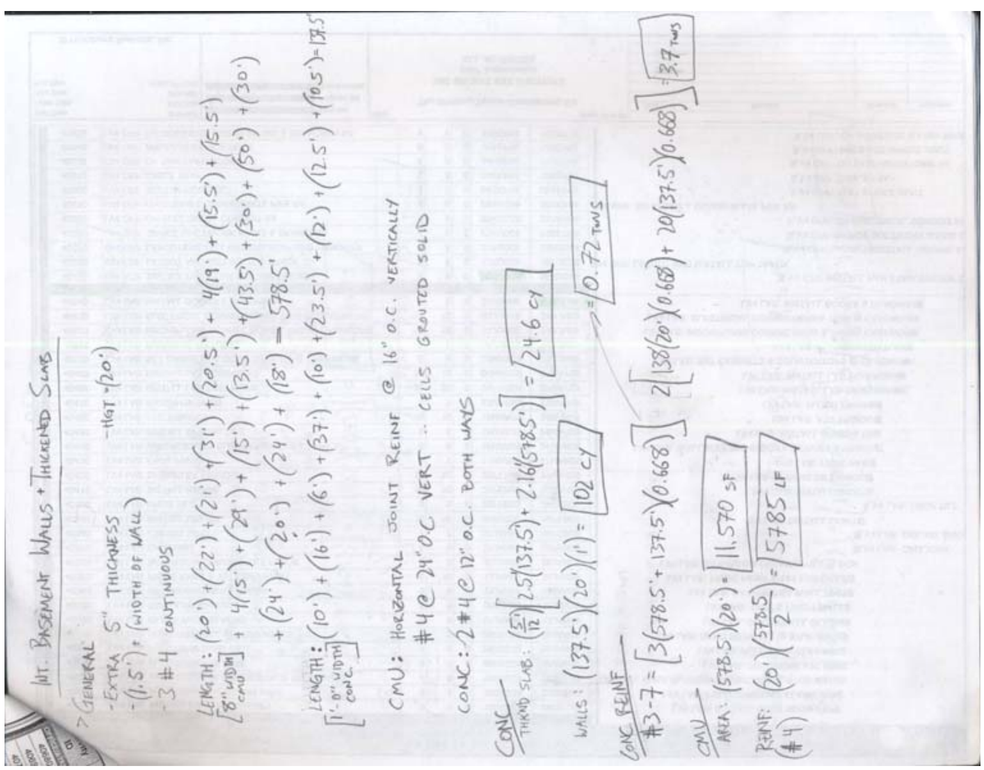
#3-7 = [131(20.7')(1.043)] + [21(131')(1.043)] = 2.85 TONS

#8-18 = [16(66.5')(3.4)] + [12(29.3')(3.4)] + [8(35.4')(3.4)] = 3.1 TONS

>SW2
- 12" THK
- 10'-0" WIDE
- HEIGHT = SW1 ⟹ 48.5 CY
- REG REINF = SW1
- 20" THK BASEMENT WALL (TO EL 85'-8")
- 12 #9
- 10 #9
- 8 #9

#3-7 = [131(10')(1.043)] + [10(131')(1.043)] = 1.4 TONS

#6-18 = [12(66.5')(3.4)] + [10(29.3')(3.4)] + [8(35.4')(3.4)] = 2.5 TONS



INT. BASEMENT WALLS + THICKENED SLAB

> GENERAL
- EXTRA 5" THICKNESS
- (1.5') + (WIDTH OF WALL)
- 3 #4 CONTINUOUS
- HGT (20')

LENGTH: [8" WIDTH CMU] (20') + (22') + (21') + (31') + (20.5') + 4(19') + (15.5') + (15.5') + 4(15') + (29') + (15') + (13.5') + (43.5') + (30') + (50') + (30') + (24') + (20') + (24') + (18') = 578.5'

LENGTH: [1'-0" WIDTH CONC] (10') + (16') + (6') + (37') + (10') + (23.5') + (12') + (12.5') + (10.5') = 137.5'

CMU: HORIZONTAL JOINT REINF @ 16" O.C. VERTICALLY
#4 @ 24" O.C. VERT ∴ CELLS GROUTED SOLID

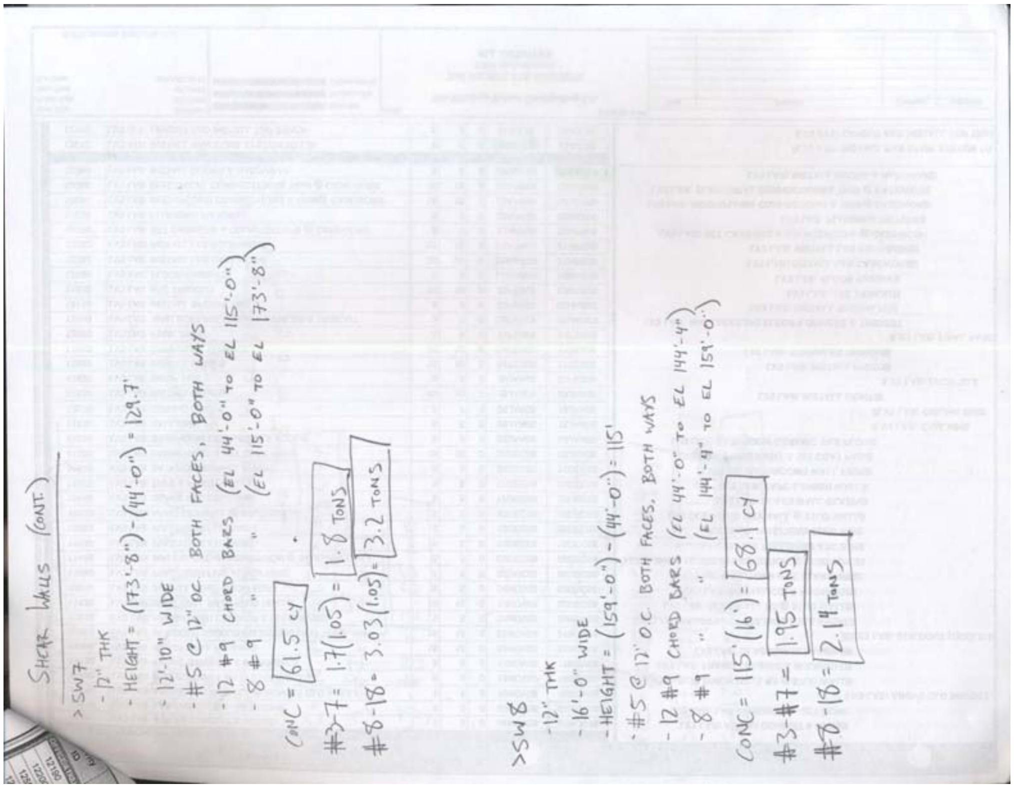
CONC: 2 #4 @ 12" O.C. BOTH WAYS

CONC
THKND SLAB: (5'/12)[2.5(137.5') + 2.16(578.5')] = 24.6 CY
WALLS: (137.5')(20')(1') = 102 CY

CONC REINF
#3-7 = [3(578.5' + 137.5')(0.668)] = 0.72 TONS
2[138(20')(0.668) + 20(137.5')(0.668)] = 3.7 TONS

CMU
AREA: (578.5')(20') = 11,570 SF
REINF: (#4) (20')(578.5/2) = 5785 LF

Structural Estimate Calculations



SHEAR WALLS (CONT.)

>SW7
- 12" THK
- HEIGHT = (173'-8") - (44'-0") = 129.7'
- 12'-10" WIDE
- #5 @ 12" OC BOTH FACES, BOTH WAYS
- 12 #9 CHORD BARS (EL 44'-0" TO EL 115'-0")
- 8 #9 " " (EL 115'-0" TO EL 173'-8")

CONC = 61.5 CY

#3-#7 = 1.7(1.05) = 1.8 TONS

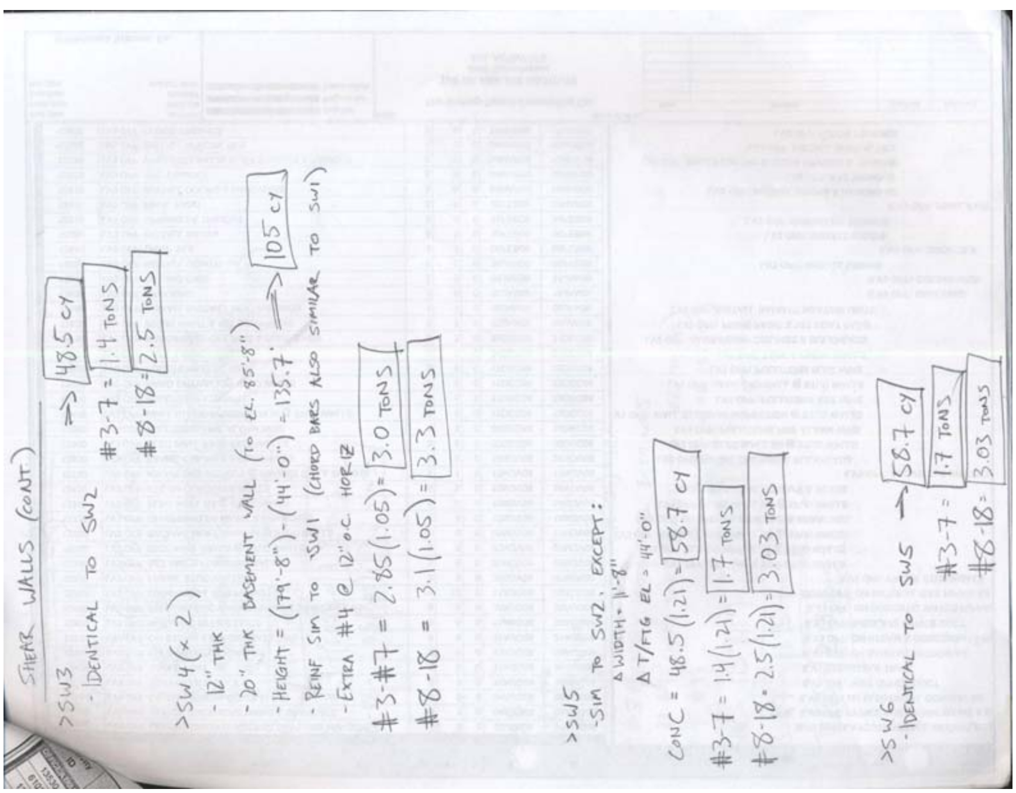
#8-18 = 3.03(1.05) = 3.2 TONS

>SW8
- 12" THK
- 16'-0" WIDE
- HEIGHT = (159'-0") - (44'-0") = 115'
- #5 @ 12" O.C. BOTH FACES, BOTH WAYS
- 12 #9 CHORD BARS (EL 44'-0" TO EL 144'-4")
- 8 #9 " " (EL 144'-4" TO EL 159'-0")

CONC = 115'(16') = 68.1 CY

#3-#7 = 1.95 TONS

#8-18 = 2.14 TONS



SHEAR WALLS (CONT.)

>SW3
- IDENTICAL TO SW2 → 48.5 CY

#3-7 = 1.4 TONS

#8-18 = 2.5 TONS

>SW4 (x 2)
- 12" THK
- 20" THK BASEMENT WALL (TO EL. 85'-8")
- HEIGHT = (179'-8") - (44'-0") = 135.7' → 105 CY
- REINF SIM TO SW1 (CHORD BARS ALSO SIMILAR TO SW1)
- EXTRA #4 @ 12" O.C. HORIZ

#3-#7 = 2.85(1.05) = 3.0 TONS

#8-18 = 3.1(1.05) = 3.3 TONS

>SW5
- SIM TO SW2, EXCEPT:

Δ WIDTH = 11'-8"

Δ T/FTG EL = 44'-0"

CONC = 48.5(1.21) = 58.7 CY

#3-7 = 1.4(1.21) = 1.7 TONS

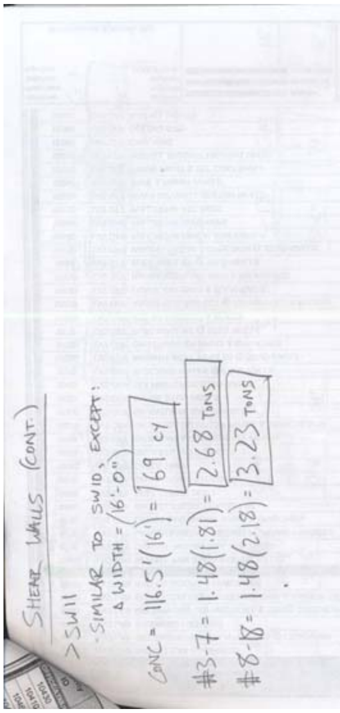
#8-18 = 2.5(1.21) = 3.03 TONS

>SW6
- IDENTICAL TO SW5 → 58.7 CY

#3-7 = 1.7 TONS

#8-18 = 3.03 TONS

Structural Estimate Calculations



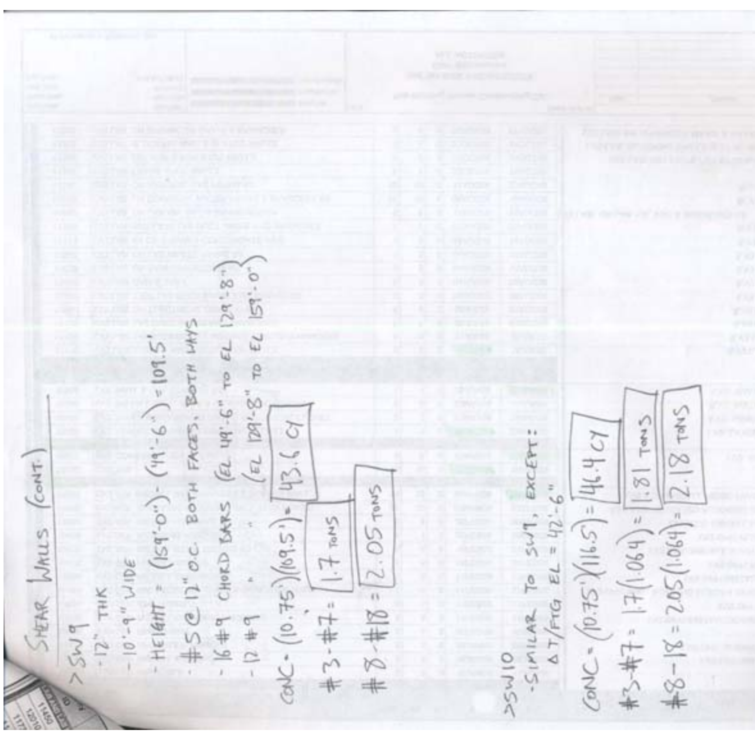
SHEAR WALLS (CONT.)

>SW11
- SIMILAR TO SW10, EXCEPT:
  Δ WIDTH = (16'-0")

CONC = 116.5'(16') = 69 CY

#3-7 = 1.48(1.81) = 2.68 TONS

#8-18 = 1.48(2.18) = 3.23 TONS



SHEAR WALLS (CONT.)

>SW9
- 12" THK
- 10'-9" WIDE
- HEIGHT = (159'-0") - (49'-6") = 109.5'
- #5 @ 12" O.C. BOTH FACES, BOTH WAYS
- 16 #9 CHORD BARS (EL 49'-6" TO EL 129'-8")
- 12 #9 " " (EL 129'-8" TO EL 159'-0")

CONC = (10.75')(109.5') = 43.6 CY

#3-#7 = 1.7 TONS

#8-#18 = 2.05 TONS

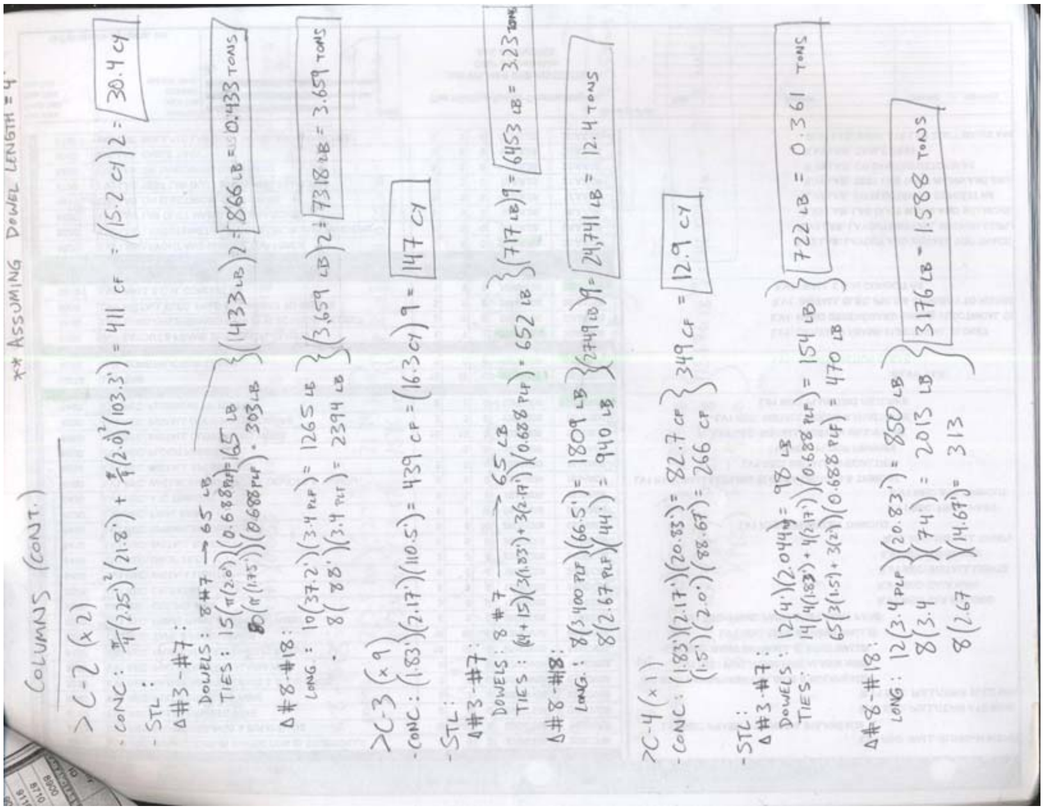
>SW10
- SIMILAR TO SW9, EXCEPT:
  Δ T/FTG EL = 42'-6"

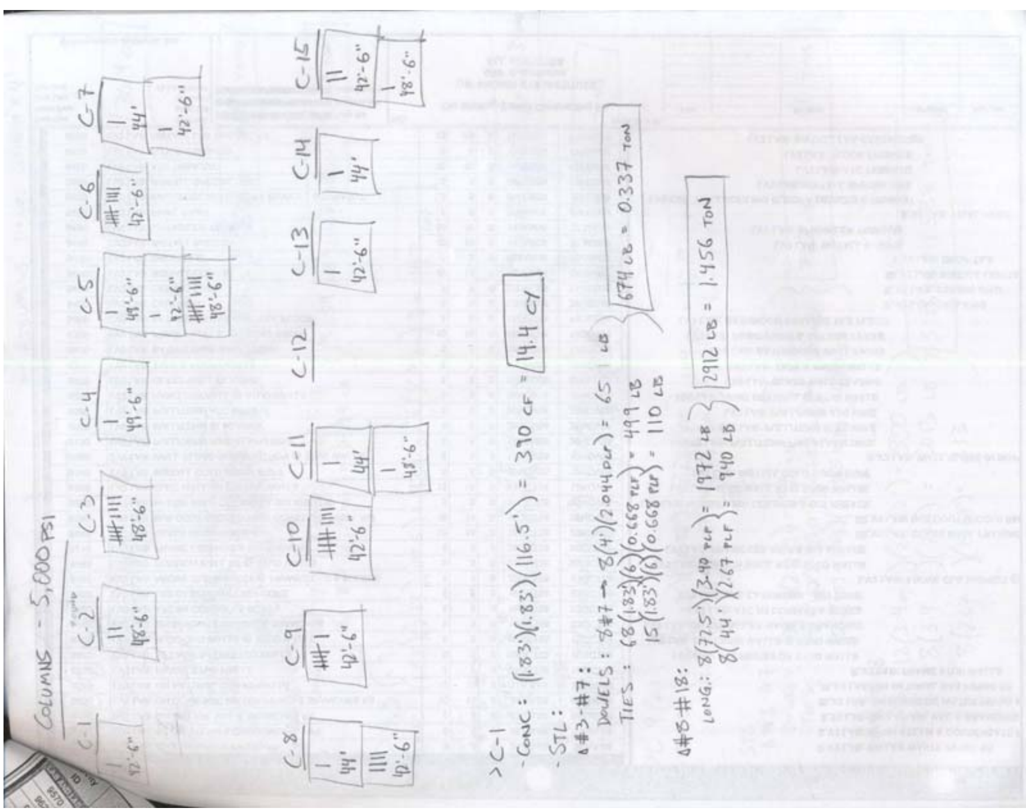
CONC = (10.75')(116.5') = 46.4 CY

#3-#7 = 1.7(1.064) = 1.81 TONS

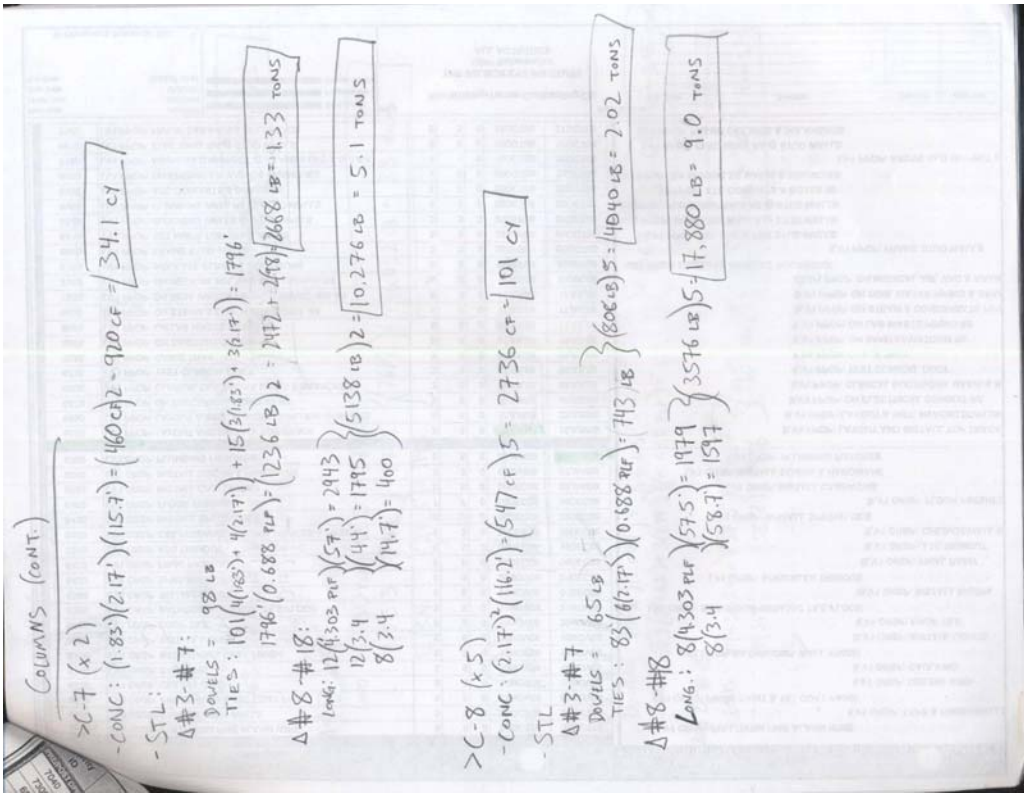
#8-18 = 2.05(1.064) = 2.18 TONS

Structural Estimate Calculations





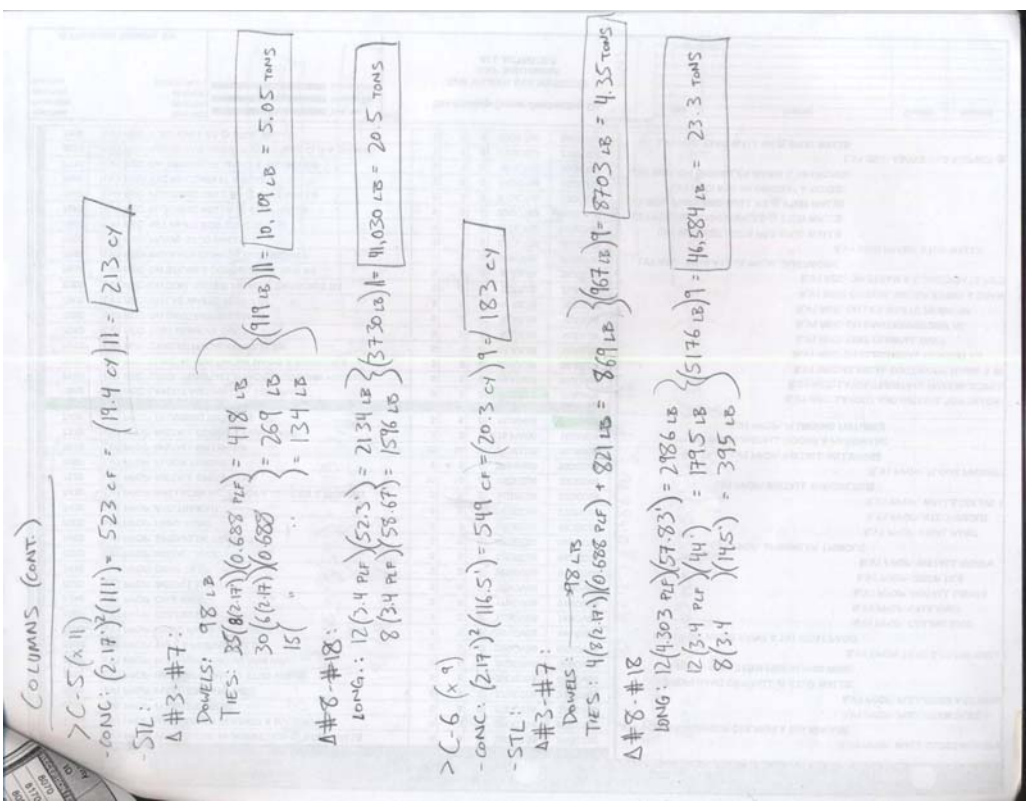
Structural Estimate Calculations



COLUMNS (CONT.)

>C-7 (x 2)
- CONC: (1.83')(2.17')(115.7') = (460 CF)2 = 920 CF = 34.1 CY
- STL:
Δ #3-#7:
DOWELS = 98 LB
TIES: 101(4(1.83') + 4(2.17')) + 15(3(1.83') + 3(2.17')) = 1796'
1796'(0.688 PLF) = (1236 LB)2 = 2472 + 2(98) = 2668 LB = 1.33 TONS
Δ #8-#18:
LONG: 12(4.303 PLF)(57') = 2943
12(3.4)(44') = 1795
8(3.4)(14.7') = 400
(5138 LB)2 = 10,276 LB = 5.1 TONS

>C-8 (x 5)
- CONC: (2.17')²(116.2') = (547 CF)5 = 2736 CF = 101 CY
- STL
Δ #3-#7
DOWELS = 65 LB
TIES: 83(4(2.17'))(0.688 PLF) = 743 LB
(806 LB)5 = 4040 LB = 2.02 TONS
Δ #8-#18
LONG.: 8(4.303 PLF)(57.5') = 1979
8(3.4)(58.7') = 1597
(3576 LB)5 = 17,880 LB = 9.0 TONS

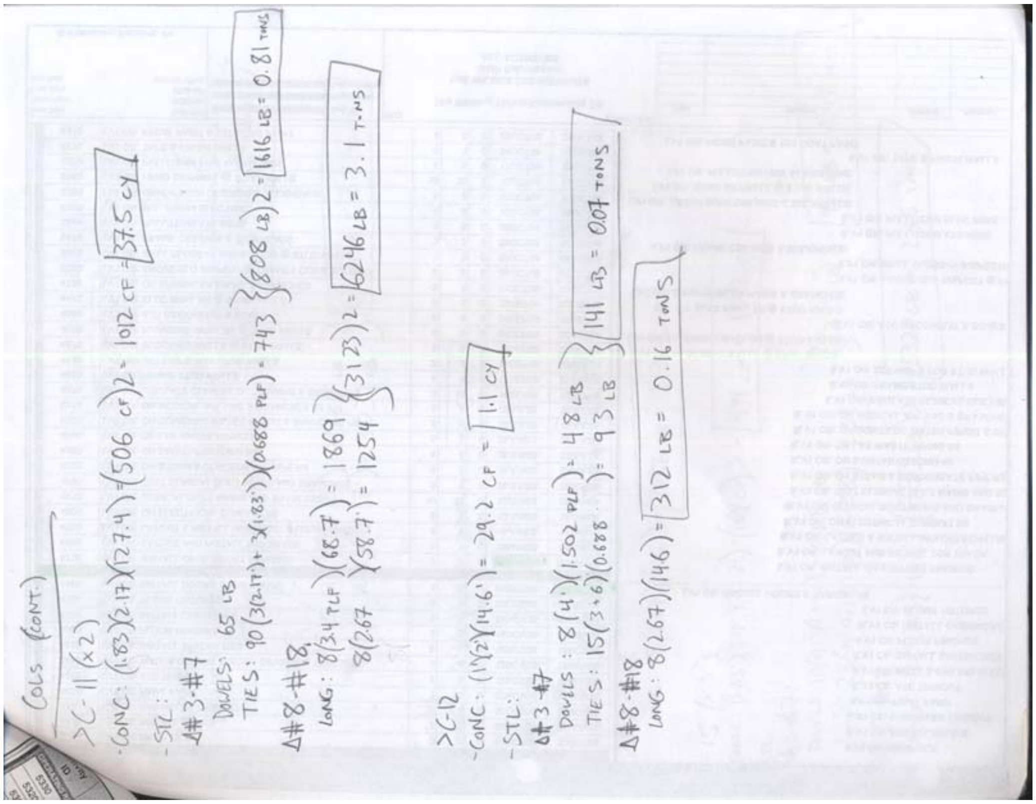


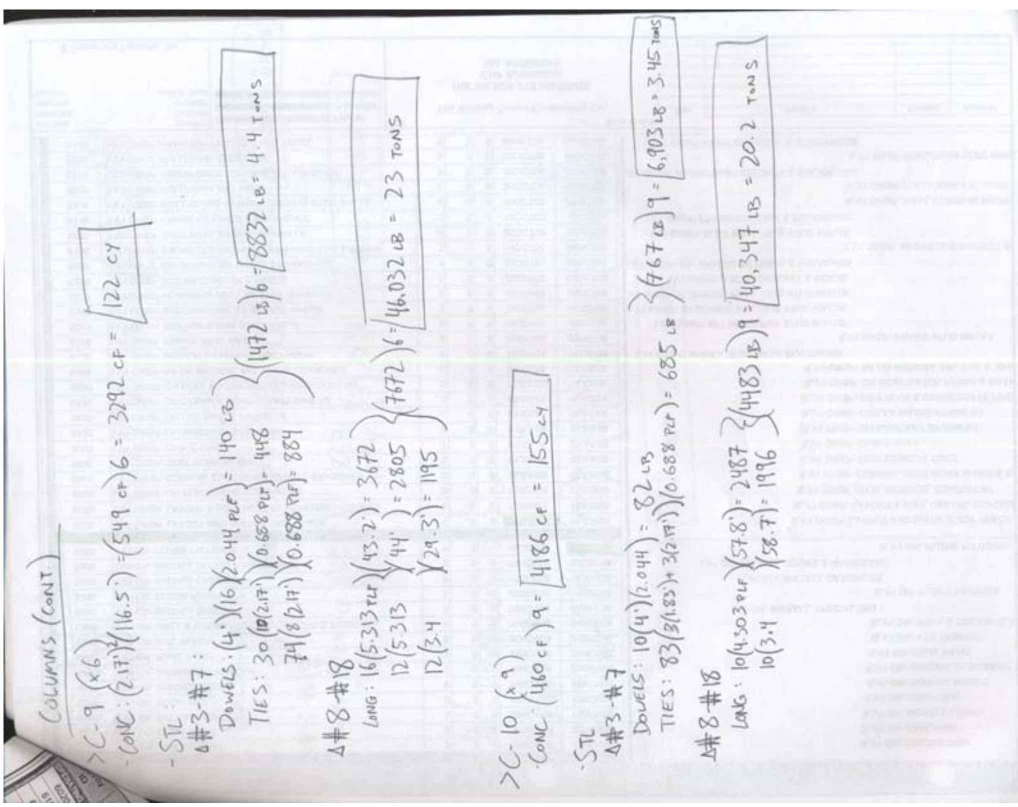
COLUMNS (CONT.)

>C-5 (x 11)
- CONC: (2.17')²(111') = 523 CF = (19.4 CY)11 = 213 CY
- STL:
Δ #3-#7:
DOWELS: 98 LB
TIES: 35(8(2.17'))(0.688 PLF) = 418 LB
30(6(2.17'))(0.688) = 269 LB
15(") = 134 LB
(919 LB)11 = 10,109 LB = 5.05 TONS
Δ #8-#18:
LONG.: 12(3.4 PLF)(52.3') = 2134 LB
8(3.4 PLF)(58.67') = 1596 LB
(3730 LB)11 = 41,030 LB = 20.5 TONS

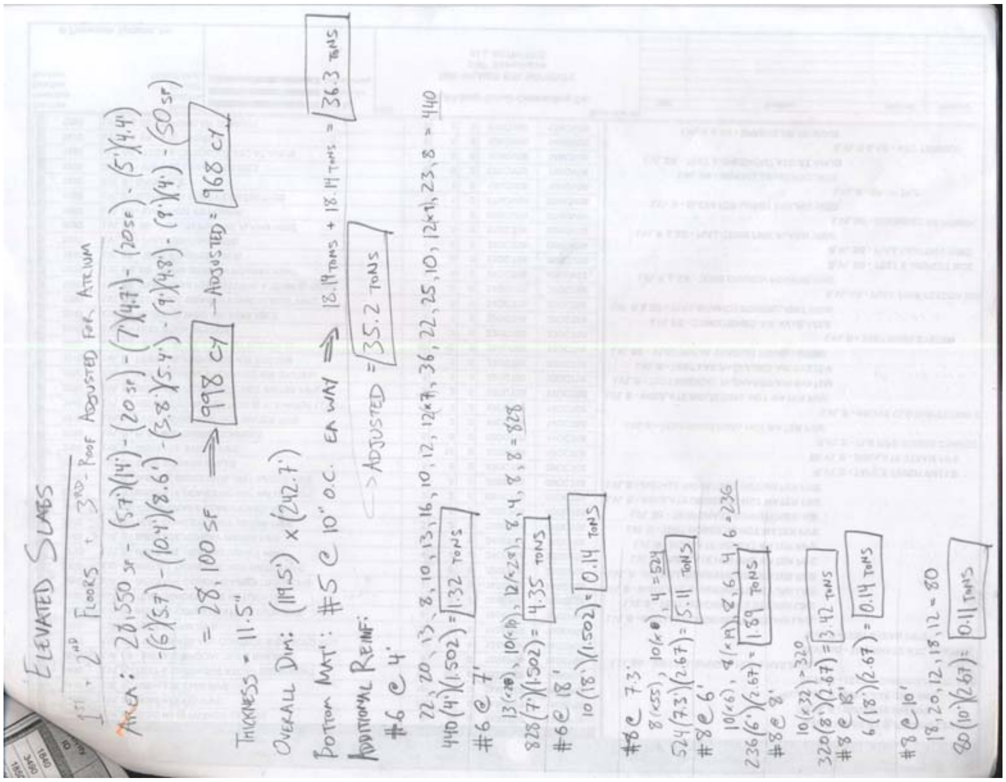
>C-6 (x 9)
- CONC: (2.17')²(116.5') = 549 CF = (20.3 CY)9 = 183 CY
- STL:
Δ #3-#7:
DOWELS: 98 LB
TIES: 4(8(2.17'))(0.688 PLF) + 821 LB = 869 LB
(967 LB)9 = 8703 LB = 4.35 TONS
Δ #8-#18
LONG: 12(4.303 PLF)(57.83') = 2986 LB
12(3.4 PLF)(44') = 1795 LB
8(3.4)(14.5') = 395 LB
(5176 LB)9 = 46,584 LB = 23.3 TONS

Structural Estimate Calculations





Structural Estimate Calculations



ELEVATED SLABS

1ST, 2ND FLOORS + 3RD, ROOF ADJUSTED FOR ATRIUM

AREA: 28,550 SF − (5.7')(14') − (20 SF) − (7')(4.7') − (20 SF) − (5')(4.4') − (6')(5.7') − (10.4')(8.6') − (3.8')(5.4') − (9')(4.8') − (9')(4') − (50 SF)

= 28,100 SF ⟹ 998 CY — ADJUSTED = 968 CY

THICKNESS = 11.5"

OVERALL DIM: (119.5') x (242.7')

BOTTOM MAT: #5 @ 10" O.C. EA WAY ⟹ 18.19 TONS + 18.14 TONS = 36.3 TONS

ADDITIONAL REINF: → ADJUSTED = 35.2 TONS

#6 @ 4'

22, 20, 13, 8, 10, 13, 16, 10, 12, 12(x7), 36, 22, 25, 10, 12(x1), 23, 8 = 440

440(4')(1.502) = 1.32 TONS

#6 @ 7'

13(x28), 10(x10), 12(x29), 8, 4, 8, 8 = 828

828(7')(1.502) = 4.35 TONS

#6 @ 18'

10(18')(1.502) = 0.14 TONS

#8 @ 7.3'

8(x55), 10(x8), 4 = 524

524(7.3')(2.67) = 5.11 TONS

#8 @ 6'

10(x6), 8(x19), 8, 6, 4, 6 = 236

236(6')(2.67) = 1.89 TONS

#8 @ 8'

10(x32) = 320

320(8')(2.67) = 3.42 TONS

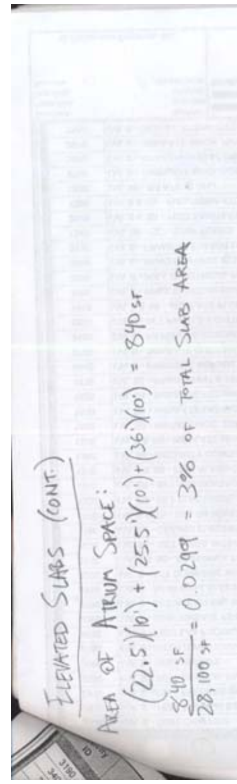
#8 @ 18'

6(18')(2.67) = 0.14 TONS

#8 @ 10'

18, 20, 12, 18, 12 = 80

80(10')(2.67) = 0.11 TONS

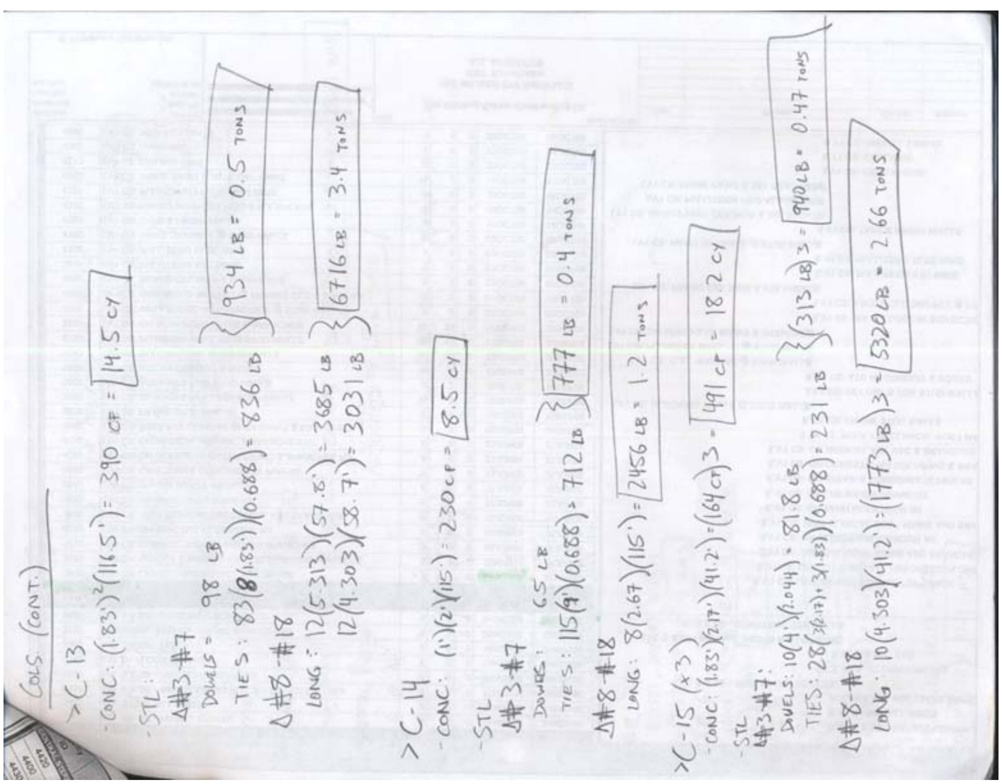


ELEVATED SLABS (CONT.)

AREA OF ATRIUM SPACE:

(22.5')(10') + (25.5')(10') + (36')(10') = 840 SF

840 SF / 28,100 SF = 0.0299 = 3% OF TOTAL SLAB AREA



COLS. (CONT.)

> C-13

- CONC: (1.83')²(116.5') = 390 CF = 14.5 CY

- STL:

Δ#3-#7

DOWELS = 98 LB

TIES: 83(8(1.83'))(0.688) = 836 LB } 934 LB = 0.5 TONS

Δ#8-#18

LONG: 12(5.313)(57.8') = 3685 LB

12(4.303)(58.7') = 3031 LB } 6716 LB = 3.4 TONS

> C-14

- CONC: (1')(2')(115') = 230 CF = 8.5 CY

- STL

Δ#3-#7

DOWELS: 65 LB

TIES: 115(9')(0.688) = 712 LB } 777 LB = 0.4 TONS

Δ#8-#18

LONG: 8(2.67)(115') = 2456 LB = 1.2 TONS

> C-15 (x3)

- CONC: (1.83')(2.17')(41.2') = (164 CF)3 = 491 CF = 18.2 CY

- STL

Δ#3-#7:

DOWELS: 10(4')(2.044) = 81.8 LB

TIES: 28(3(2.17) + 3(1.83))(0.688) = 231 LB } (313 LB)3 = 940 LB = 0.47 TONS

Δ#8-#18

LONG: 10(4.303)(41.2') = (1773 LB)3 = 5320 LB = 2.66 TONS