*Wellington Condominiums*

***Exton, PA***

**Senior Thesis Final Report**

# BUILDING FOR THE FUTURE


**Sean Flynn - Construction Management**

**Dr. John Messner – Faculty Advisor**

# Wellington Condominiums

Exton PA

Extraordinary Residences Exceptional Lifestyle

Wellington

## Design and Construction Team:

**Owner:** The Hankin Group
**General Contractor:** Wellington Commercial Construction
**Construction Manager:** Wellington Commercial Construction
**Architects:** Minno & Wasko Architects and Planner
**Engineers:** Liberty Engineering

## General Scope:

**Size:** 147,069 S.F. 4 Story luxury condominiums w/ Parking Garage
**Building Cost:** $18.1 million
**Schedule:** September 2005 thru May 2007
**Project Delivery:** CM @ Risk

## Architecture:

-Designed in the tradition of grand estate homes
-Situated at Eagleview community town center
-8 designs with a choice of décor being “traditional” or “contemporary”
-Designated areas for concerts, shopping, dining and fun
-Building surrounded by landscaped parks and native woods
-Stylish brick and cast stone exterior veneer
-Composite slate roof and membrane roof w/ copper eave drip edge

## M.E.P. Systems:

-Fire protection system includes sprinklers, fire alarms and smoke detectors throughout each residence and public areas
-Building access communication system, telephone, cable and internet ready
-HVAC is an all air gas fired furnace supplying each condominium residence
-Main Electrical Distribution switch board is 1600 Amp, 3 phase, 120/208 V
-The main electrical distribution connects to 4 meter banks which are then broken down to each individual apartments

## Construction and Structural:

-Being built in a very developed commercial neighborhood
-Geotech report indicated site had variance in quality of soils
-Installed permanent dewatering system before actual construction
-Delay in Permits and architectural approvals pushed façade construction to winter
-Foundation utilizes 18” strip and column footings w/ 5” slab on grade
-First floor makes use of a 12” heavily reinforced two way flat plate concrete slab
-Other floors use innovative Hambros Joist 3” slab on deck composite system

## Wellington Features:

-48 unique floor plans up to 2,300 S.F.
-Great views from large bay windows
-Hardwood floors in all living areas
-Polished Granite Countertops
-Elegant lobby entry

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Design and Fabrication
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Sean Flynn
Construction Management
www.arche.psu.edu/thesis/eportfolio/2007/portfolios/SRF163/



# Contents



## A.1 Executive Summary

The Wellington Condominiums Project was investigated to identify areas of a project that were good candidates for further research in: alternative methods of construction, value engineering, and schedule compression.

The main body of research that was conducted concerning the construction industry is: What are the decisions that industry members make in providing and utilizing new formwork products? Who makes the decision to use a new formwork product and when? What process of action can manufactures and suppliers do to promote new formwork products? Who takes the responsibilities and risks? Can a process and procedure be created and implemented to help aid the construction industry? These questions and more are further explored in greater detail in the following sections to come.

The Hambros Joist Composite Deck System Analysis builds off the main research as taking a project level look to determine whether or not this system was correctly selected for the Wellington Condominiums Project. Many problems have resulted because of this system and further research as to alternative methods and means is examined. An acoustical breadth is provided here to investigate the claims of the manufacturer and supplier as stating the 2.5” deck slab to the Hambros Joist Composite Deck System is very good to industry standards for minimal vibration and sound transfer.

The third analysis is a foundation redesign which targets where a majority of the delays and change orders to the project resulted. This is of great interest to the project team due to the tremendous amount of resources that had to be applied to correct the problem. Another area of concern is that the foundation system required a large amount of time and cost to the project which pushed back the façade construction to the winter months. The foundations system would be challenged by redesigning the system to a mat slab foundation. Many reasons as to why a mat slab foundation would be preferred are detailed in the following sections. The structural breadth will take a deeper look as to whether or not a mat slab foundation system would be of greater value to the project.

The final analysis builds off the early delays that occurred on the construction of the foundation system. Since the schedule was pushed back, the façade construction would not begin until the winter months. This creates a need for the project team to think of alternative ways of constructing the building. The first floor consists of pre cast panels and follows with typical masonry construction up to the 4$^{th}$ floor. An analysis is performed on the comparison between utilizing pre-cast for the entire structure and rather than just for the first floor. Caution will be used when changing the building composition of the building façade by utilizing renders of the project.

## A.2 Credits and Acknowledgements


*~ I would like to personally thank the Architectural Engineering Department here at the Pennsylvania State University, Hankin Group, and all the industry personnel for their dedicated support of the completion of this thesis research paper. It is they who instilled the knowledge that made all this possible.*

*~I would also like to thank my family and friends for their support through this time and helping me persevere to attaining my lifelong goals.*

*~A main theme that I would like introduce into the report is "Building for the Future." As construction managers our future is about building tomorrow today. We have to understand that our basic responsibilities are in the actual construction and management of a building project. This is only a fraction of our responsibilities of what is more vital: the building of communication, trust, and respect with other people in the industry. Our future depends on building respect and taking team work and ethics to a new higher standard. With project delivery methods more frequently utilizing better team work arrangements like design-build, it is up to us whether or not the future of the building construction industry will respect that evolving philosophy.*



## A.3 Project Background

A project background has been assembled in order to understand the research methodology behind the Wellington Condominiums Project. The following sections that will detail the Wellington Condominiums Project Background are as followed:

## A.3.1 General Building Data

**Building Name:** Wellington Condominiums

**Location and Site:** 614 Wharton Boulevard Exton, PA 19341 at the Eagleview Town Square

**Building Occupant Name:** Wellington Condominiums

**Occupancy:** Separated Mixed Use Groups of R-2 Residential (Specifically 48 Luxury Condominiums) and S-2 Parking Garage

**Size:** 147,069 SF (Including Parking Garage)

**Number of stories above grade/ total levels:** 4 Stories / 5 Levels w/ Parking Garage

**Primary Project Team:**

| | |
|---|---|
| **Owner:** | ***The Hankin Group*** |
| **General Contractor:** | ***Wellington Commercial Construction*** |
| **Construction Manager:** | ***Wellington Commercial Construction*** |
| **Architect:** | ***Minno & Wasko Architects and Planner*** |
| **Engineers:** | ***Liberty Engineering*** |



***Chester Valley Engineers***

***Earth Engineering Inc.***

***Swirnow Structures LLC***

***American Panel Tec***

**Dates of Construction:**
**Start: 9/26/05**
**Finish: 5/04/07**

**Actual Cost:** $18,105,952 (Overall Project Cost w/ General Conditions. Not including costs of consultants/services/designs for Architectural/Structural, Civil, Geotechnical, and MEP of the Project.)

**Project Delivery Method:** Design-Build

**Major National Codes:**
2003 International Building Code
2003 International Mechanical Code
2003 International Fuel Gas Code
2002 National Electric Code
2003 National Standard Plumbing Code
National Fire Protection Agency (NFPA 13, NFPA 13R)
Americans with Disabilities Accessibility Guidelines (ADDAG)

**Residential Zoning Requirements:** Uwchlan Township Zoning Ordinance 12 of 1997:

***Maximum Building Height: 65 feet***
Actual Building Height: 58 feet 4 inches

***Building Coverage: 50%***

***Maximum Building Length: 300 feet***
Actual Building Length: 267 feet

***Building Setbacks: 25 feet***

***Maximum Occupant Load: 735 persons***

***Parking Requirements: 120 peak demand (2.5 / unit)***

***Maximum Allowable Residential Egress Travel Distance: 250 feet***
Actual Maximum Residential Egress Travel Distance: 160 feet

***Accessible Means of Stair Egress Capacity: 240 people***

***Maximum Allowable Garage Egress Travel Distance: 400 feet***
Actual Maximum Allowable Garage Egress Travel Distance: 164 feet

## A.3.2 Architecture

**"Extraordinary Residences Exceptional Lifestyle"** is the quote that architects tried to convey and bring to life in the design of the Wellington Condominiums Project. Wellington Condominiums or Wellington Estates is a 4 story luxury condominium located at the heart of the award winning community town center of Eagleview. Wellington is a limited collection of extraordinary condominium homes styled to give the effect of a grand estate homestead. The condominiums have 48 residences which can be up to 2300 square feet in each living space. The 8 designs Willow, Sequoia, Juniper, Cypress, Aspen, Magnolia, Palmetto, and Holy are the floor plans that future homeowners have to choose from with a choice of décor being "traditional" or "contemporary."

The architectural style and philosophy took into account the surrounding nature and environments that encompasses the building. As the name of the eight floor plan designs suggest, Wellington tries to connect nature by introducing huge windows and private balconies to view the luscious forests and strategically laid out parks to the condominiums. This natural and environmental connection with the building and its surroundings was so important to the design that the mechanical units at the last minute were redesigned to be on top of the roof so that future homeowners would encapsulate the entire atmosphere that the owner wanted.



The architectural design also focused on the location and amenities that Wellington Condominiums would offer to the home owners. Being that Wellington was located right at Wellington Square Park, home owners have access to many areas of recreation, concerts, shopping, dining and entertaining right at their door step. No need to drive to go to the mall or stores because everything is within 10 – 15 minutes of casual walking distance. In order to ensure full customer satisfaction, the amenities that where architecturally designed with serious consideration were the underground and indoor parking, building controls and security, and recycling and trash receptions on each floor.

## A.3.3 Building System Summary

| Building Systems Summary | | |
|---|---|---|
| Yes | No | Work Scope |
| | X | Demolition Required |
| X | | Cast in Place Concrete |
| X | | Structural Steel |
| | X | Precast Concrete |
| X | | Mechanical System |
| X | | Electrical System |
| X | | Masonry |
| X | | Curtain Wall |
| X | | Support of Excavation |

**Figure 1:** Building Systems Summary

### A.3.3.1 Cast in Place Concrete

The foundation and first floor consists of a large part of the cast in place concrete that was done on the construction site. The structural engineer has specified in the construction documents that all concrete work except the slab on grade shall have a minimum compressive strength of 6,000 PSI. The type of horizontal and vertical formworks and concrete placement methods of the foundation and first floor elements are described in more detail as followed:



**Footings:**

- Normal weight concrete with a minimum compressive strength of 6,000 PSI at 28 days
- Reinforcing will consist of A615, Grade 60
- Average size of column footing 15’L X 15’W X 18”D
- Minimum of 3 feet below finished surface where exposed to frost
- Minimum allowable bearing pressure of 3,500 PSF

**Slab on Grade:**

- 5 inches of normal weight concrete with a minimum compressive strength of 3,000 PSI at 28 days
- Reinforced with 6 X 6 – W2.1 X W2.1 welded wire fabric, over a 14 inch crushed stone sub base and vapor barrier

**Foundation Bearing and Shear Wall Construction**: (includes exterior and stair and tower walls)

- 8” and 12” normal weight reinforced concrete with a minimum compressive strength of 6,000 PSI at 28 days

**First Floor:**

- 12” of normal weight reinforced concrete with a minimum compressive strength of 6,000 PSI at 28 days

Since the soil at the time had enough cohesion to stay in place, the foundation strip and column footings did not require any horizontal or vertical formwork. The only task left was to situate the footing rebar and place the concrete with a concrete pump at the locations required. Once the footings were to the strength required, the foundation’s exterior walls and columns took form with large gang forms. These large forms took shape very quickly with a 120 ton AmQuip crane tipping up each one into position. The formwork was connected and reinforced into place with lateral bracing. After the formwork was set and properly supported, the rebar was placed in the foundation walls and columns. Following inspection from the project management team, the concrete was placed with a concrete pump and allowed time to gain strength.

After pouring the slab on grade with the concrete pump the next focus was on the first floor. The first floor would be the first encounter and need for horizontal formwork. The formwork consisted of setting up metal shores, stringers, and joists with plywood as the sheathing. The first floor’s vertical formwork would also make use of plywood as the ease of handling and construction. The rebar and roughins were situated and the concrete was placed using the concrete pump truck.

## A.3.3.2 Structural Steel

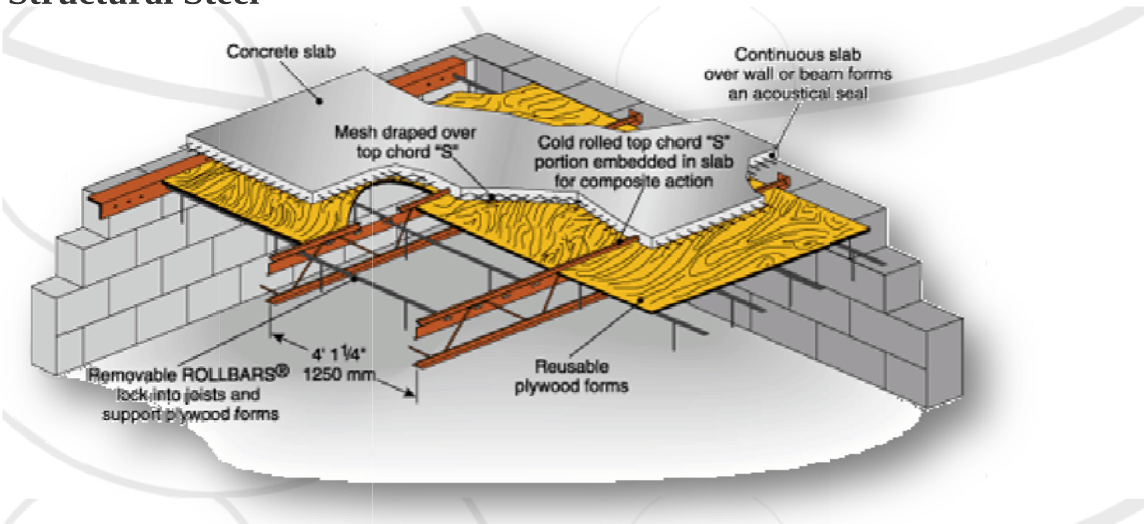



**Figure 2:** Typical Usage of Hambros Joist System Prescribed by Manufacturer
Reference: www.swirnow.com

The Wellington Condominiums Project did not make use of large structural steel components but is using a very innovative system called the Hambro's joist 3" slab on deck composite system. The second, third, and penthouse floor make use of this system. This floor's bearing and shear wall components were designed into the Wellington Condominiums project by the stud engineer and made use of 4" and 6" metal stud walls at 16" o.c. These walls are capable of carrying the loads directly and therefore make it very easy to lay up this composite system. The general steps with advantages to this system are laid out as prescribed by the manufacturer Swirnow Structures.

1. **Spreading Joists:** Spread Hambro joist at 4'-1 ¼" on load bearing walls
2. **Placing Roll bars:** Roll bars are to keep uniform spacing while providing lateral and tensional stability
3. **Installing Plywood Forms:** Installing the plywood creates a working surface and forms a rigid diaphragm during construction
4. **Mesh In Place:** Mesh over top chord of joist creates a way of reinforcing concrete
5. **Pouring Concrete:** No shoring is required with this system when pouring concrete. The minimum thickness requirement is 2 ½". The Wellington Condominiums project makes use of 3" slab thickness.
6. **Stripping Formwork:** When concrete reaches strength of 500 PSI (usually the day after the pour) the plywood forms can be taken out. When the concrete



reaches strength of 1000 PSI (usually within 48 hours) the deck is ready for other trades and the formwork can be removed for future re-use.

The 150 ton AmQuip mobile crane utilized on the project will work around the building as required. The crane after placement of all floors/ceilings will then continue to be of service when the metal roof trusses are installed. With road access to all sides of the building structure there is no great danger of conflicts when the concrete trucks and cranes are working simultaneously.

### A.3.3.3 Mechanical Systems

There are no mechanical rooms to the condominiums but many mechanical closets. On the garage level there are two mechanical closets centrally located in the garage. The other mechanical closets are located in each condo and supply air for that particular condo. The system is an all air and distributes the air through insulated metal ductworks.

In a little more detail, the garage HVAC systems primary concern is air flow with car pollutants. Proper ventilation is critical when the comfort and safety of homeowners is on the line. The designers from Liberty Engineering have specified that 2 main intake lovers 162 X 30 NCA Model XAD – 6 –GL with motor operated control be installed on the north and south side of the garage. On the east face of the building 6 9300 CFM Jenco fans model FSWE – 302A remove the containments that are entered into the building. Two mechanical closets centrally located in the garage each holding a Renzor CAUA indoor gas fired heating units. The heating units are then connected to 18” diameter fabric ductwork that can supply 2200 CFM. This ductwork is attached to the slab above and run the lengthways of the structure. Two gas meters on the building's south east side supplies natural gas to the heating units and other parts of the building where needed.

Other rooms worth mentioning of systems involved are the electric/telephone/cable room, sprinkler room, and elevator rooms. Each room has a 24 X 8 transfer duct that sends in 500 CFM of air directly from the space. The electric/telecommunications/cable and sprinkler rooms have a Q Mark electric unit heater. This unit heater would take the intake air and mix to the temperature required for that space. A 500 CFM Jenko Fan model FDWE – 123A on opposite sides of the room exhaust return air back into the space. The two centrally located elevator rooms also contain a 24 X 8 transfer duct that brings in air from the garage space. These rooms contain a Carrier packaged terminal air conditioning unit which has a capacity of 350 CFM. No electric unit heaters are located in these rooms but they do contain a 500 CFM Jenko Fan model FDWE – 123A to exhaust the return air back into the garage space. Four carbon monoxide detectors are spread across the entire footprint of the garage to detect any large levels of carbon monoxide present from the fumes of cars.



The stairways only contain a Q Mark electric wall heater model AHW - 44083 on the garage floor level. No other return air or supply air acts in the stairways. All refuse rooms from the garage floor up to the penthouse are connected by a main vertical ductwork for return air. This return air is then sent to a 900 CFM Jenko Fan model LPX 120A that is located on the roof. The typical air distribution for the main hallways are two 630 CFM Trane split – system heat pump units with a Metalaire V400 mixing chamber. The fresh air supplied to this system come directly from the roof's Metalaire 5000 air inlet and Trane Condensing Units. This air inlet is fed through a vertical shaft closet to each floor level. No return air distribution system is installed in the main hallways and corridors. It is assumed that the return air is lost through opening of doors, stairs, and elevator shaft. Also a buildup of high pressure is recommended during a fire. Most likely area for a fire is in the condos and if high pressure is built up in the hallway the less likely smoke will occur in the hallway.

The condominiums HVAC systems begin in their own separate mechanical rooms. Each mechanical room is connected to its own Trane condensing unit located on the roof and contains a Trane cooling coil and gas fired furnace. This is then connected into the mixing chamber and then supplied by air ducts off to each room in the condo. There is only one return air duct that is centrally installed into the condos for reuse of air in the mixing chamber. Ductworks from bathroom exhaust air outlets connect back at the mechanical room and are supplied up to the roof to a Jenco Fan. Also typical on the condos façade is a dryer and range hood vent and a gas and fireplace flue. On the roof there is also roof and elevator relief vents for to balance the buildings inner environment conditions.



### A.3.3.4 Fire Protection

The life safety operations of the building are all hardwired to the emergency control panel of the building. The sprinkler piping main line comes into the north side of the building and connects to the sprinkler system in the sprinkler room. The sprinkler pipes are then distributed to each floor level where the main piping is branched off into smaller circuits for diffusion. The sprinkler heads used for fire protection are dry type sprinkler heads. This system is also powered and controlled by the fire alarm panel.

### A.3.3.5 Electrical

The incoming primary electrical duct bank runs along the west side of the building and into two step down transformers. The primary duct bank has six 4" schedule 40 PVC conduits which 2 will be used for service. The incoming cable duct bank has four 4" schedule 40 PVC conduits which all four will be used. From the transformers the primary duct bank goes into a secondary duct bank and into the building's electrical/telecommunications/cable room main distribution switch board (MDSB). The secondary duct bank encases eight 4" schedule 40 PVC conduits which 5 are used. The main service feed for the MDSB is 1600 ampere, 3 phase, 120/208 V, 38 KAIC rated. The physical size of the MDSB is estimated to be 90"H X 102"W X 28" D. The MDSB feeds into Meter Bank's A, B, C, and D, and the House Distribution Panel (HDP). The four meter bank serves all functions that the condos require in the building. Two meter banks share each feeder run up to their proper level. From there each condo gets fed a service of 125 ampere, single phase, 3 wire, and 120/208 V into their own panel board. The HDP services the elevator motor #1 and #2, HVAC, lighting and receptacles for all floors (other than the condos). The fire alarm panel is fed separately and controls the main sprinkler, elevator control panel, remote enunciator, and all life safety functions of the building. Overall the electrical engineers have designed this system to allow for some redundancy by having the primary duct bank only utilizing two out of the six 4" schedule 40 PVC conduits, the secondary duct bank only utilizing five out of eight 4" schedule 40 PVC conduits, and extra space and spares left on the circuit boards of emergency panels and condos. It is very important to do this because of the ever increasing growth of technology. If a building is able to expand and grow with technology the better able the building is to adapting to an ever constantly changing world.



### A.3.3.6 Masonry

To achieve such high standards, the architects and planners first decided on what exterior material to use that was equally appealing and durable at the same time. After much contemplation, the architects and planners determined that the Wellington Condominium's building façade was to consist of predominately a stylish brick and elegant cast stone exterior veneer**.** The transitions of façade materials are central to creating a pleasing environment with future homeowners. The cast stone veneer is primarily situated on the first floor building façade, is utilized around windows and doors as pre cast headers, and serves as a pre cast band and trim linking the transitions of façade materials. From the first floor to the upper floors the elegantly placed cast stone veneer serenely evolves into a modish and colorful brick. The brick façade continues up to the roof line where it is met by a 1 x 12 Azek Trim Board with Fypon BKT8X8x4 décor. Also scattered across the building façade is pre cast medallions and ornamentation to give the condominiums a refined and polished look.

The type of connection for the masonry is typical among the construction industry. The system that holds the façade and interior walls together is 22 gauge galvanized metal ties. The specifications call for the following list of items to be completed for the correct installation of anchoring masonry veneers:

1) Insert slip-in anchors in metal studs as sheathing is installed. Provide one anchor at each stud in each horizontal joint between sheathing boards.
2) Embed tie sections in masonry joints. Provide not less than 2 inches of air space between back of masonry veneer and face of sheathing.
3) Locate anchor sections to allow maximum vertical differential movement of ties up and down.
4) Space anchors by no more than 16" o.c. vertically and 24" o.c. horizontally with not less than 1 anchor for each 2.67 sq. ft. of wall area. Install additional anchors within 12" of openings and at intervals, not exceeding 36", around perimeter.

With all the early delays on the project it has pushed construction of the building façade to the winter months of 2006. This creates logistical issues on how to construct the building façade and keep on schedule. Sometimes the winter months can be harsh in Pennsylvania therefore proper weather days accounted for cannot be overlooked. With that in mind, the scaffolding at this current time is through the use of a typical metal modular frame scaffolding system. This system is very easy to assemble and light to handle. This system if done in the winter would have to be protected from the winter elements and provide a proper work place for all construction workers. Decreased productivity will result if the scaffolding operation is not properly planned for in the winter months.



## A.3.3.7 Curtain Wall

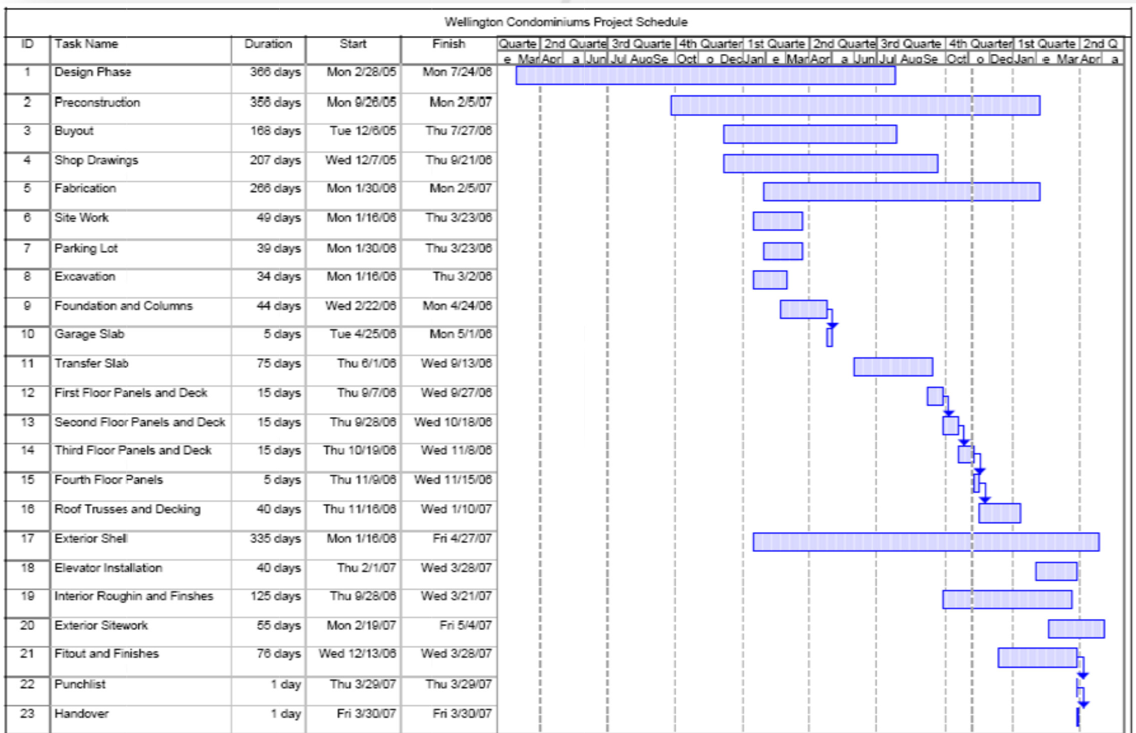
The composition of the 1 hour fire rated exterior wall section of the first through the fourth floor starting from the exterior to the interior are as follows: brick/stone veneer, metal ties, 1 ½” minimum air space, 15” building felt, 5/8” dens glass gold sheathing, 6” metal studs, R-19 batt insulation, vapor barrier, and 5/8” type ‘X’ G.W.B. The foundation wall which encloses the parking garage has architecturally exposed concrete and is composed of with the following: a fluid applied waterproofing membrane extended to cover footing, a bituthene liquid member joint sealant, and a 12” concrete foundation wall.

The construction methods in producing a sustainable curtain wall starts with having a solid foundation. Once the foundation is constructed the shell of the building structure can be built. For the Wellington Condominiums the base utilizes a concrete floor and walls while the upper levels consist of composite decking with metal stud wall framing. Once the main framing of the exterior is complete the curtain wall can then begin construction. Starting from the base and working your way up with scaffolding placing stone and brick veneer at the locations the drawing documents require. The construction of the building curtain wall will take a little more time due to the fact that is being constructed in the winter but the schedule has taken into the account of possible weather day occurrences. The design responsibility falls directly on the structural engineer in specifying the ties and loads present. The contractor is responsible for the correct placement of the curtain wall elements and is to make sure construction is up to code requirements. For example the contractor is responsible that all concrete masonry units be ASTM C90 grade N and have a minimum compressive strength of 1900 PSI, provide temporary bracing for masonry walls during entire erection of walls until adequate strength is developed (usually 7 days or longer), all 8” masonry walls be reinforced with #5 @ 32” vertical minimum, and fill masonry wall cores containing reinforcing with coarse grout.

# A.3.4 Project Schedule

The following sections will give an overview and detailed breakdown of the Wellington Condominiums Project Schedule. With the owner as a developer and early delays on the project, time is a major factor for the project team and is outlined as followed:

## A.3.4.1 Project Schedule Overview



Wellington Condominiums Project Schedule

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | Design Phase | 366 days | Mon 2/28/05 | Mon 7/24/06 |
| 2 | Preconstruction | 356 days | Mon 9/26/05 | Mon 2/5/07 |
| 3 | Buyout | 168 days | Tue 12/6/05 | Thu 7/27/06 |
| 4 | Shop Drawings | 207 days | Wed 12/7/05 | Thu 9/21/06 |
| 5 | Fabrication | 266 days | Mon 1/30/06 | Mon 2/5/07 |
| 6 | Site Work | 49 days | Mon 1/16/06 | Thu 3/23/06 |
| 7 | Parking Lot | 39 days | Mon 1/30/06 | Thu 3/23/06 |
| 8 | Excavation | 34 days | Mon 1/16/06 | Thu 3/2/06 |
| 9 | Foundation and Columns | 44 days | Wed 2/22/06 | Mon 4/24/06 |
| 10 | Garage Slab | 5 days | Tue 4/25/06 | Mon 5/1/06 |
| 11 | Transfer Slab | 75 days | Thu 6/1/06 | Wed 9/13/06 |
| 12 | First Floor Panels and Deck | 15 days | Thu 9/7/06 | Wed 9/27/06 |
| 13 | Second Floor Panels and Deck | 15 days | Thu 9/28/06 | Wed 10/18/06 |
| 14 | Third Floor Panels and Deck | 15 days | Thu 10/19/06 | Wed 11/8/06 |
| 15 | Fourth Floor Panels | 5 days | Thu 11/9/06 | Wed 11/15/06 |
| 16 | Roof Trusses and Decking | 40 days | Thu 11/16/06 | Wed 1/10/07 |
| 17 | Exterior Shell | 335 days | Mon 1/16/06 | Fri 4/27/07 |
| 18 | Elevator Installation | 40 days | Thu 2/1/07 | Wed 3/28/07 |
| 19 | Interior Roughin and Finshes | 125 days | Thu 9/28/06 | Wed 3/21/07 |
| 20 | Exterior Sitework | 55 days | Mon 2/19/07 | Fri 5/4/07 |
| 21 | Fitout and Finishes | 76 days | Wed 12/13/06 | Wed 3/28/07 |
| 22 | Punchlist | 1 day | Thu 3/29/07 | Thu 3/29/07 |
| 23 | Handover | 1 day | Fri 3/30/07 | Fri 3/30/07 |

**Figure 3:** Project Schedule Overview

As the project schedule shows, the preparation for the construction site took a lot of time before the foundation system could be installed. Being that the project was fast tracked; the team had to communicate effectively on the issues of poor quality subsurface conditions. This took a lot of time and reorganization of how the structure would be built but once the permanent dewatering system and soil compaction was completed the actual construction of the foundation footers, walls, columns, and slab could begin. The most critical part of the schedule came when the 12” transfer slab was being constructed. This took by itself 75 days to complete and was very critical to the project being completed on time. Once the transfer slab was completed, the rest of the structure was erected with the



innovative composite deck system. Some of the disadvantages to the schedule are installing the final decking and roof trusses in the middle of winter. For that reason shingles cannot be installed until the following spring when the temperature reaches at least 40 degree Fahrenheit.

Another point worth mentioning is that the building envelope is continually being worked on from the start for installing waterproofing, membranes, etc. and trying to enclose the building as soon as possible. Brickwork is not scheduled to start until January 8, 2007. This creates a longer duration of 80 workdays to lay the brickwork due to the fact of weather days and decreased productivity. The rough in and finish sequences follow very closely to the structural sequence since the project utilizes a new composite deck system. This is where the schedule saves time and allows for the finish trades to get started earlier than usual. To the developers and owners on the project any way the project team can save time but not necessarily money is of great value. The sooner the project can reach the handover date the sooner the revenue can come in.

### A.3.4.2 Detailed Project Schedule

A detailed project schedule was developed for Wellington Condominiums to provide a breakdown of the construction phasing and sequencing. The project schedule begins with preconstruction on September 26, 2005 and ends on May 4, 2007 with exterior landscaping. A highlight breakdown of the project schedule is as followed:

- **Preconstruction:** *355 Days Scheduled From Sept. 26,2005 thru Feb. 5, 2007*
  - Project Management
  - Buyout
  - Shop Drawings
  - Fabrication

- **Construction:** *340 Days Scheduled From Jan. 16,2006 thru May 4, 2007*
  - Exterior
    - Site Work
    - Parking Lot
  - Substructure
    - Foundations & Columns
    - Garage Slab
    - Transfer Slab
  - Superstructure
    - Wall Panels & Hambros Composite Deck System
    - Roof Trusses and Decking

- ♦ Arriscraft & Brickwork
- Interior Shell
  - ♦ Non-load Bearing Partitions
  - ♦ MEP Rough-in and Distribution
  - ♦ Drywall & Finishes
- Fit out
  - ♦ Phase 1
  - ♦ Phase 2

*~See the Attached Appendix for the Detailed Project Schedule~*

## A.3.4.2.A Brief Analysis

### A.3.4.2.A.a Critical Point in Schedule

The detailed project schedule breaks down how the project will flow throughout construction. The transfer slab is a key transition point to the flow and sequence of the project. It takes the project team 65 days to complete the 12” thick 6,000 PSI strength concrete pour versus only spending 60 days to complete the entire foundation systems. If a schedule reduction or acceleration is needed on this project the transfer slab would be the first sequence that should be looked at. After the completion of the foundation and transfer slab sequence, the 4 story superstructure takes 172 days to complete.

### A.3.4.2.A.b Phase 1 and 2

Near the end of completion before handover, a phase 1 and phase 2 are established on the project schedule. Phase 1 and 2 include final framing, rough-in, finishes, and punch list. After the main load bearing walls and MEP rough-in and distributions are installed these phases are then utilized. As seen in the diagram below, the structure is cut into two work zones named phase 1 and phase 2. Phase 1 begins trades on the first floor and then moves floor to floor completing condominiums only in the area highlighted. Phase 2 is scheduled to start and finish 28 days after phase 1. The project team decided to do this to speed up the time for handover and make one of the condominiums a show room for potential home owners. Caution must be taken when trying to accelerate the schedule and setting up phases like this. Home owners will be moving and living in phase 1 potentially while construction is in the process of phase 2. How a worker enters the space and how is each room and floor sequenced are questions that the project team must pay attention to when constructing.

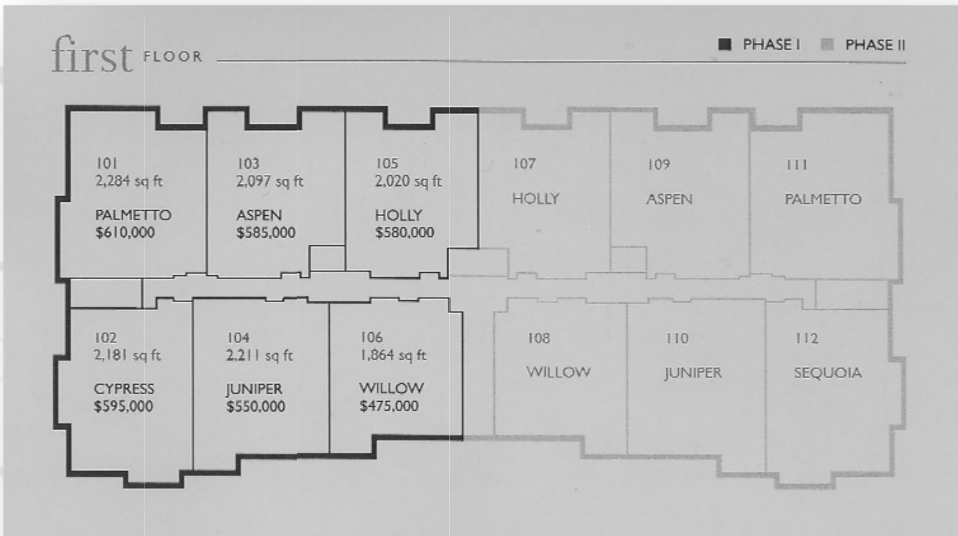



**Figure 4:** First Floor Phase 1 and 2 – Wellington Commercial Construction

**A.3.4.2.A.c Project Delays**

The project schedule attached is an updated best case scenario for the project to be completed. The project team has faced many challenges and has delayed the schedule numerous times. Some of the reasons why the schedule has been delayed are as followed:

- Poor Subsurface Conditions
- Architect and Local Township Approvals
- Change Orders by Owner
- Learning curve to installing new Hambros Joist Composite Deck System



## A.3.5 Project Cost Evaluation

The Wellington Condominiums Project Cost Evaluation has been broken down to compare with industry standards utilizing D4 Cost Estimate and RS Means. An assemblies and detailed estimate have been compiled in the following sections of the building envelope and structural system respectively. Also a General Conditions for the Wellington Condominiums Project have been attached for project estimating reference.

### A.3.5.1 Actual Building Cost

**Actual Building Cost:**
- $17,818,947
- At 147, 069 SF – $121.16/SF

**Total Project Cost:**
- $18,105,952
- At 147,069 SF - $123.11/SF

**Building System Costs:**

- Mechanical: $1,137,000 - $7.73/SF
- Electrical: $1,541,212 – $10.48/SF
- Structural: $3,257,291 - $22.15/SF
- Site work: $776,348 – $5.28/SF
- Plumbing: $890,000 - $6.05/SF
- Fire Protection: $270,000 - $1.84/SF

### A.3.5.2 D4 Cost Estimate

*~See the Attached Appendix for the D4 Cost Estimate~*

### A.3.5.3 R.S. Means Building Cost

| 2006 RS Means Square Foot Costs | | | |
|---|---|---|---|
| UsedSection M.020 Apartment, 4-7 Story, 100,000 SF | | | |
| **General Estimate** | **Quantity** | **Unit Price** | **Amount** |
| Face Brick w/ Concrete Frame | 116349 SF | $130.70/SF | $15,206,814.30 |
| *Added Revisions* | | | |
| Garage | 30,720 | $27.30/SF | $838,656.00 |
| Elevators | 2 | $127,300/Unit | $254,600 |
| Emergency Lighting | 50 | $259/Unit | $12,950 |
| Smoke Detectors | 250 | $164/Unit | $41,000 |
| Ovens | 48 | $1000/Unit | $48,000 |
| Trash Compactors | 1 | $600/Unit | $600 |
| Garbage Disposal | 48 | $200/Unit | $9,600 |
| Hood Vents | 48 | $500/Unit | $24,000 |
| **Assumptions:** | | **Total:** | $16,436,220.30 |
| Based Calcultions on RS Means Max Data of 100,000 SF | | | x 1.02 location factor (Allentown, PA) |
| (Wellington Condominiums 116,349 SF) | | | |
| Used mid to high unit prices for added revisions | | | **$16,764,944.71** |
| Assumed Brick and concrete frame structure | | | |

**Figure 5:** R.S. Means Estimates

### A.3.5.4 Discussion

**Actual Building Cost:**

- **$17,818,947**

**D4 Estimate Building Cost:**

- **$17,460,844**

**R.S. Means Building Cost:**

- **$16,764,944.71**

From the information provided the estimates and actual building costs are very good. The methods performed for the two estimates were done in very dissimilar manners therefore differences are to be expected. The RS Means data goes by the average project cost in the United States today. The Wellington Condominiums Project is not an average apartment complex but has a higher level of quality demanded. Also Wellington Condominiums project is a little higher square footage then the 100,000 square foot industry project average. Therefore being that RS Means bases its calculations off an industry average and lower square footage estimate the estimate should be a little low as shown.

The D4 estimate made use of two closely related residential projects of similar characteristics to the Wellington Condominiums. One project called Eola South Residential Condominium is a four story complex of the same structure system but has a smaller cost and square footage footprint. The Convent and High School project was very similar in size and cost but has some different structural systems to the project. Therefore to gain a better cost estimate of the project the two projects were averaged to get the results shown. The D4 Estimate Program recommends that if one project is to be manipulated then the analysis should stay within 20%. The Eola South Residential Condominium as mentioned had a sizeable difference in square footage and therefore the averaging system was utilized for the best results possible. The D4 estimate was very accurate for what is to be expected for a project of this size and style. One of the major reasons for the difference in the D4 estimate and actual building cost data is that the actual building costs includes change orders. Most of the change orders are from bad soil conditions that were encountered on the project and added just by itself over $160,000. There were other change orders that added to this amount and made the actual building cost higher than the estimates. Also the Wellington Condominiums are utilizing very expensive materials like granite countertops and add additional costs to the project.

## A.3.5.5 Assemblies Estimate

An assembly’s estimate was created for the building envelope system. The estimate includes the concrete foundation, brick/cast stone façade, doors and windows, and roof skin composition. The estimate was broken down with reference to 2006 RS Means Assemblies Estimating Guide. A location factor was applied to the estimate for Allentown, PA for each category as listed in the attached assemblies estimate.

*~See the Attached Appendix for the Assemblies Estimate~*

### A.3.5.5.A Brief Analysis

#### A.3.5.5.A.a Assumptions

A list of the following assumptions has been made for the attached assemblies estimate and is as followed:

- Doors and Windows are similar in size and composition
- The building is rectangular in form with no other façade protrusions
- All material and equipment needed for installation are included
- Concrete walls are 12’ and not 8’ in height

- Metal stud walls are 22 gage not 20 gage in composition
- Copper Gutters are 6” half round not 5” half round

#### A.3.5.5.A.b Comparison of Assemblies Estimate v. Actual Project Estimate

The total amount for the assemblies and actual estimates are listed as followed:

- Assemblies Estimate: $1,966,198.55 = $13.37 / SF
- Actual Project Estimate: $1,958,226.00 = $13.32 / SF
- Estimate Difference: $7,972.55 = 0.41%

### A.3.5.6 Detailed Structural Systems Estimate

An estimate for the cost of the entire superstructure was analyzed for the structural systems. To calculate more accurately the amount of formwork, rebar, and concrete utilized on the substructure a program called RAM Concept was utilized. A 3D model of the structural system was developed to calculate more accurately the system. Below are figures of the RAM Concept program utilized for the detailed structural systems estimate. The superstructure of the building was calculated manually with the guide of 2005 Cost Works software.

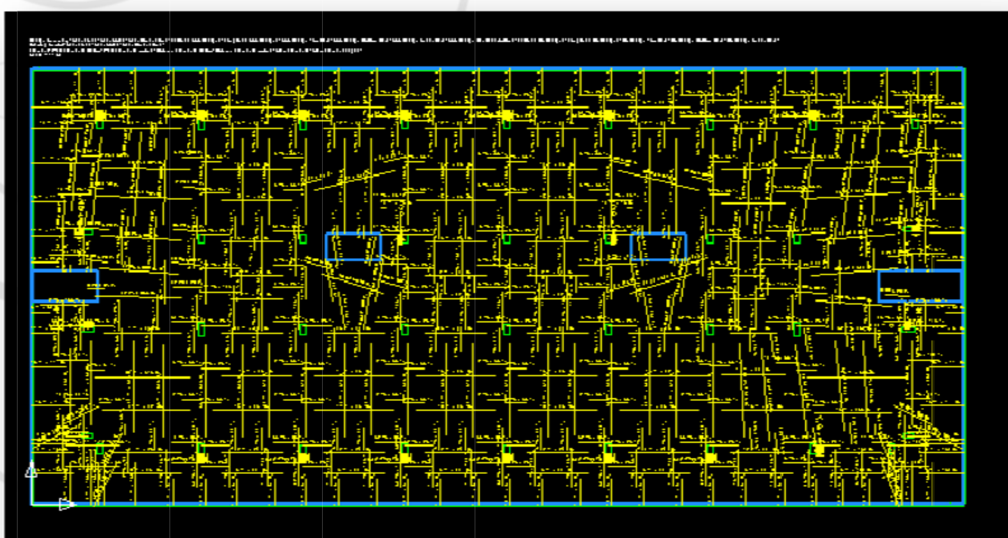


**Figure 6:** Transfer Slab Rebar Placement – RAM

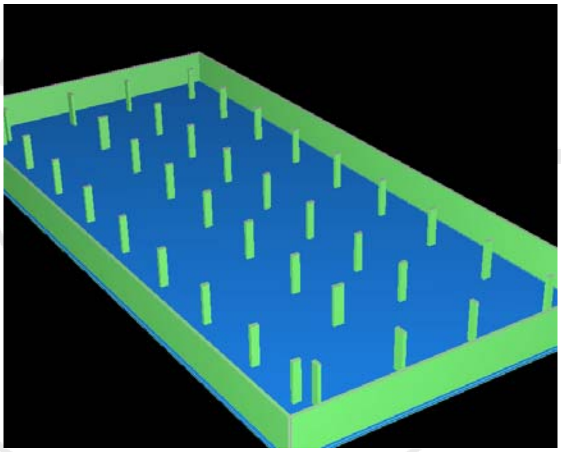


**Figure 7:** Foundation – RAM

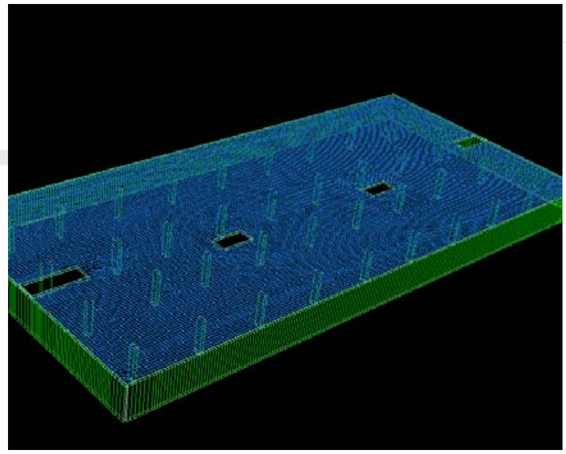


**Figure 8:** Transfer Slab – RAM

*~See the Attached Appendix for the Detailed Structural Systems Estimate~*

## A.3.5.6.A Brief Analysis

### A.3.5.6.A.a Assumptions

A list of the following assumptions has been made for the attached structural estimate and is as followed:

- Concrete is 6000 PSI strength not 5000 PSI strength
- No vapor barriers/insulation/waterproofing/non load bearing walls
- No stairways or elevators
- Foundation wall forms include temporary shoring
- No expansion joints, inserts, sleeves, chases, splicing
- No metal roof framing – design and built by specialty company
- Accessories/tools found in general conditions
- No Waste was included in calculations
- Balcony reinforcing similar to other parts of composite deck
- Not including steel W members assume part of metal stud framing
- The second, third, and forth floor the same
- No detail connections required for joist members
- Footings on the same grade and reinforcing

### A.3.5.6.A.b Comparison of Detailed Estimate v. Actual Project Estimate

The total amount for the detailed and actual estimates are listed as followed:

- Detailed Estimate: $1,966,198.55 = $13.37 / SF
- Actual Project Estimate: $2,530,307.00 = $17.20 / SF
- Estimate Difference: $564,108.45 = 3.12%



The results are different due to the fact the detailed estimate performed did not take into consideration waste or the need of such things like detailed connections or splices. The detailed estimate is a near perfect representation of everything performing up to expectations without delays or problems. Just the structural miscellaneous metals on the project were alone budgeted for $200,000.00. To compare more accurately the estimates, if add a factor of 20% for waste, detailed connections, and miscellaneous metals the totals are as followed:

- Detailed Estimate: $2,359,438.26 = $16.04 / SF
- Actual Project Estimate: $2,530,307.00 = $17.20 / SF
- Estimate Difference: $170,868.74 = 0.94%

## A.3.5.7 General Conditions Estimate

An estimate for the general conditions was assembled for the Wellington Condominiums Project. Part of the estimate includes the following costs: management team, inspections, permits, temporary signs, temporary utilities, construction trailers, tools, and punch list. What are not included in the general conditions are consultants and geotechnical services. These costs are paid for by the owner of the project and not on the general conditions.

*~See the Attached Appendix for the General Conditions Estimate~*

### A.3.5.7.A Brief Analysis

#### A.3.5.7.A.a Comparison of General Conditions Estimate v. Industry Standards

The total general condition cost for the Wellington Condominium project is $692,725.00. The percentage of the total construction dedicated to the general conditions is 3.83%. The 3.83% of total construction cost that the general conditions accumulate are low in today's construction industry.

# A.3.6 Site Plan of Existing Conditions

Two Site Plans have been assembled for the Wellington Condominiums Project. A General Site Plan of the Utilities and a Superstructure Phased Site Plan are outlined in the following sections:

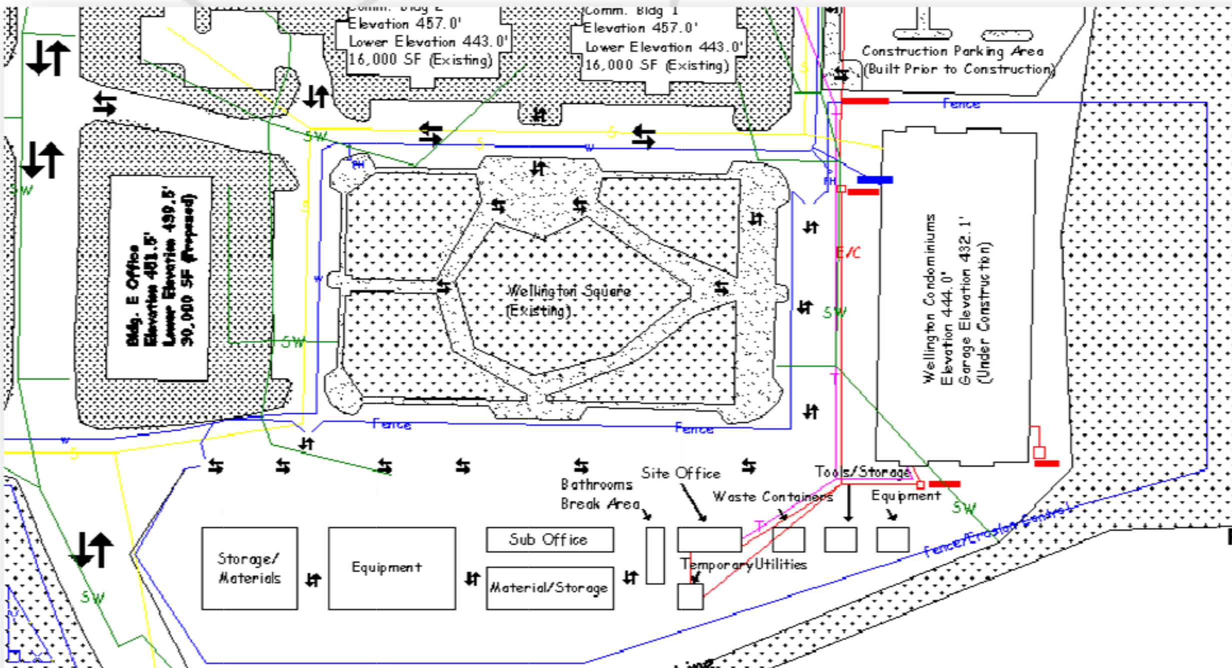



**Figure 9:** Wellington Condominium Site Plan

*~See the Attached Appendix for the Enlarged Site Plan~*

## A.3.6.1 Superstructure Phased Site Plan

A more in depth study of the superstructure phase was utilized through the use of a site plan. The critical phase of the Wellington Condominium project is the construction of the first floor transfer slab and installation of a repeated load bearing stud walls and Hambros joist composite deck system. Sixty five days is spent constructing the transfer slab and the project has before been delayed numerous times. At that current time it was imperative for the project team to be efficient and accelerate the schedule to get back on track. A good way of proper site planning and organization is to sequence the work through the use of a site plan.



*~See the Attached Appendix for the Superstructure Phased Site Plan~*

## A.3.6.1.A Brief Analysis

### A.3.6.1.A.a Key Site Project Zones

The superstructure phased site plan has three main zones named: the unloading and traffic vehicle zone, the storage/equipment/office zone, and the construction zone. These zones offer different functions to the job site for safety and organization. The proper layout of material/equipment/vehicle pathways and sequencing of work is critical to the success of accelerating productivity on the project site. Needed equipment, tools, and material are placed in each zone by the management team to ensure that crews do not have to travel from one side of the site to the other. All other materials that are not needed are secured in designated storage areas.

### A.3.6.1.A.b Superstructure Sequence

The superstructure phase can be broken down to three main stages of construction. The first stage is doing the floor pour. A concrete pump is used around the entire structure pouring the 4 bays. The concrete pours work in a counterclockwise fashion from the north east corner of the construction zone. The concrete pump and trucks work around the site as noted in the site layout plan until all pours have been completed. Once the concrete pour is completed a 120 ton crane is then positioned on the north side of the building structure to place load bearing metal stud walls. The walls are sequenced and placed so that the crane can easily pick them up and bolted/welded into place without wasting time. The flow of work in placing the metal studs and future construction work will go from the north to the south side of the structure. After the metal studs are in place the Hambros joist composite deck system can be installed as detailed in the site layout plan. This work flow sequence of concrete pours, stud wall placement, and composite deck system will continue right through to the fourth floor. Initially a learning curve for the crew is to be expected with the new composite deck system and work sequence. As construction continues the project team expects productivity to increase and schedule time savings.

### A.3.6.1.A.c Critique of Contractor Layout

The site layout utilized by the contractor at this current stage has worked fairly well. When at the project site the delivery truck drivers and construction workers felt that the site layout did the job. Delivery Trucks come from the north end entrance and get unloaded at the construction zone or the designated unloading and vehicle traffic zone. Once the truck is unloaded they proceed to exit out the west side of the site without having to turn around. Construction workers did not have a problem when it came to parking. Ample parking spaces surround the construction site allowing the flexibility of



workers to park wherever they see fit. The project management team reorganized the schedule to build the parking lot before construction started. By many construction workers this had made work on the construction site much more productive.

Some of the areas that I can see improvements in are accessibility to floor work zones and waste removal. As noted in the attached site layout plan, there are only two ladder access points for workers to reach above grade levels. Both ladders being on the south east side of the structure. There should be more ways of easily moving up and down floors while construction is underway. Workers trying to hall equipment back and forth everyday can create issues and lost productivity time. By placing material hoists or more ladders around the structure will create more productivity and worker morale. Another issue is waste removal on the project site. The waste containers are located on the south side of the project site. This means that any waste must be hauled to this location for removal. If these waste containers are put on either end of the job site less hauling would have to be required by equipment.

## A.3.7 Local Conditions

The Wellington Condominiums Project is located in Exton, Pennsylvania, where to the project team's knowledge the area does not any preferences to what method of construction have is presented to them. The most important thing to the project team is not whether or not it is a steel or concrete building rather what is the fastest and best way to constructing the building. The condominiums project features a new composite deck system which saves time and money for the developer. It makes use of steel and concrete and at first takes longer to install then scheduled due to the learning curve involved in constructing the composite decks. But once an established repetition is put into motion the faster the crews get as they go up floor by floor. Also the Chester County Local District doesn't establish rules or regulations on whether union or non union labor forces are required for this area. This gives the project team some flexibility in picking who they would want on the job and take out the factor if or if not they is union laborers.

The project also features the construction of a new parking area for the Wellington Condominiums before the building footprint ever takes rise. In the original design the parking lot was supposed to be the stockpile of excavated material that would be used at a later time. The project team decided that a parking lot would be preferred due to the lack of space during construction. During the site work phase of the schedule, the material was shipped elsewhere so that the parking area could be built at the time of excavation. This proved to be a great decision in that it gave extra parking for not only the people on the construction site but other local business as well. This was one way to give some positive reception to the community's patience for when trucks and huge equipment were digging, creating noise and dust, and creating what might look like a sizeable hole in the ground to local residences.

The project makes use of recycling and proper disposal of waste at the south side of the construction site. This project is not going for a LEED rating but the developers and owners of the project have experience in LEED rated buildings. The fee for disposing of waste will run you $500 per dumpster in Chester County. It is expected on the construction site to go through about 60 dumpsters totaling $30,000 in getting rid of waste for the project duration. Also simple things like reusing plywood for forms are a big thing on the Wellington Condominiums Project. With the use of the new composite deck system, plywood forms can be used many times without having to throw them away. This is just one of the many ways that the project team has thought of for recycling and disposing of materials.

The subsoil conditions on the construction site as specified in the geotechnical report from Earth Engineering was not very good and that a good portion of the sub grade soils would have to be removed and replaced with structural fill. This material as specified by the specifications and recommendations of the geotechnical engineers was that if the structural fill was placed and properly rolled or vibrated that the subsoil would be able to properly distribute the loads from the building’s foundation. Another cause for alert to the project team in the geotechnical report was that the foundation floor grade was under the groundwater level. If the design was to stay as planned the whole bottom third of the foundation would be underwater. The geotechnical engineers offered two solutions to the problem in both raising the foundation up to where the Uwchlan Township zoning would specify or permanent dewatering systems and waterproofing would have to be instituted to the design. The architects and designers felt that it was best to proceed with installing permanent dewatering systems with waterproofing.

Another problem with continuing the original design is substantial excavations below the existing grade would have to be done to achieve the proper amount of required structural fill. This would result in having to rock excavate and use equipment like hydraulic hammering, splitting, or other rock removal techniques. Blasting was not recommended therefore a rock crusher and other equipment would have to be brought on to do the job. All these added expenses can be seen in the estimate to how much it costs the developer and owner. The total expenses just for poor subsurface conditions not including the dewatering and waterproofing systems was well over $160,000. This also delayed the construction and handover date for the project. Other means and methods would be achieved to try to accelerate the schedule as best as possible and try to make up for lost time from having to deal with poor subsurface conditions.

## A.3.8 Client Information

The owner of the project is the Hankin Group and is a development company that owns a large portion of the land in the area. Hankin Group has its roots in being a family owned company that has been developing real estate and communities for a long period of time. Hankin group is recognized as a leader in developing high quality homes and communities in the construction industry. In the recent years the company has developed commercial and industrial parks that well suit the residential areas. The company takes great pride and devotion to how the communities are organized and how to develop the land for future use. The company is very sound in commitment to the communities that they developed and have very strong company values and ethics in doing good business with and for others.

One of the main reasons that Hankin Group went forth with the Wellington Condominiums was that the building would offer home owners a luxury style home right at the center of the local community town square. The ease and convenience of walking out your door and being walking distance to shops and offices was something of great demand. Also with the boom of the residential market in that area for the past few years the opportunity presented itself and Hankin Group then gave the project the green light to start construction. The expectation's from the owner's perspective is only the very best in quality. Top of the line materials and construction are utilized in order to attract the higher cliental. Granite countertops, wooden floors, walk in closets, large bay windows, private balconies, etc. are some of the things that Hankin group has pushed for in the design of the condominiums. Safety is something else that the developers take seriously and is their number one issue when it came time to constructing the project. The project team enforces to all subcontractors of the proper ways of construction so that it is safe to not only to them but future home owners as well. The schedule is another important issue to Hankin Group. The faster the project is constructed, the faster people will want to move in. Future buyers even with the nicest of renders do not want to buy something of great value without ever seeing a building. Once the building takes form, future home owners can see progress made and make the decision to buy a condo. It is up to the project team's best interest to construct the most efficient way possible and still keep the quality of the project at high standards. The cost even though it is not the largest concern is still something that they pay very close attention to. Hankin Group is a business and in order to stay in business it has to make money. If the costs are in check and the quality and schedule is up to par then the Hankin Group is very content with how the project performs.

The main sequencing issues that are of interest to the owner are when it is time for people to move into the condos. The sooner the future home owners can move in, the faster the owner can get their money. During construction the owner is most concerned with getting out of the ground and seeing a structure being developed. The transfer slab is the big stepping point for the project and once that is complete the rest of the structure will go up very quickly. Once the building starts taking form the building can start being enclosed and initiate the selling of condos.

Some of the keys to completing the project to the owner's satisfaction are to produce a high quality project on time and if possible stay as close to the budget. The owner wants to use the very best in materials and results in the budget continuing to rise. It is the project team's goal and responsibility to keep the owner involved and voices an opinion on decisions. Some things like granite countertops or the fancier brick façade is what the owner expects and wants to see. Most of the time if present the information correctly to the owner of what the situation is, the owner is satisfied with having to pay a little more for what they really want. But in the end to construct a successful project the communication line between the project team and owner is critical when doing a project of this size and magnitude.

## A.3.9 Project Delivery System

The project delivery method that was used on the Wellington Condominiums project was a fast-tracked CM @ Risk. The owner and developer Hankin Group wanted to be very flexible in the design and coordination of the project but not take on the bulk of contractual risk. Time is essential on the project and a systematic approach design-bid-build delivery method would not be very effective. Hankin Group's major goal is to deliver the highest quality building at the fastest time possible.

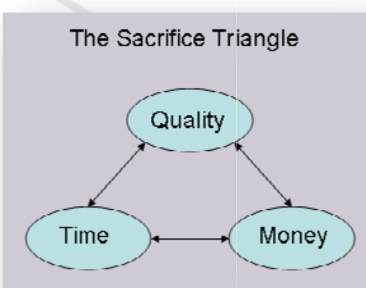



**Figure 4**: The Sacrifice Triangle
- Reference: Fundamentals of Construction Management

To help explain this concept of the sacrifices an owner has to make is by looking at the sacrifice triangle. For example the Hankin Group on this project wanted high quality as fast as possible. This leaves the owner to make the sacrifice of money. More money would have to be done to fulfill the owner's needs and requirements. This chart also works with any other two systems of sacrifice. For example if an owner wants the lowest cost and highest quality then the owner must accept that the project will take longer to be built. If the owner wants the lowest cost and shortest time to complete a project then quality should not be the main issue for the owner. These things must be understood and analyzed by the owner in order for the project to be successful. Feasibility studies and analysis on the Wellington Condominiums was conducted by Hankin Group and was found that the sooner the condominium would be built the greater



the potential profits would be. With this in mind Hankin group then proceeded to go with a fast-tracked CM @ Risk rather than a traditional project delivery system.

The contractual relationships for the Wellington Condominiums are very straight forward in that the owner Hankin Group has contracts with the GC/CM, Architect, land surveyor, and geotechnical engineer. The surveyor and geotechnical engineer have a lump sum contractual arrangement, the GC/CM on the project has a GMP, and architect utilizes a cost plus fee arrangement.

Another interesting point is that “Wellington Commercial Construction” is really part of the developers firm. For protection reasons the developer creates a company for that particular project and acts like its own separate entity from the firm. Even though the project manager has an office at Hankin Group under a GMP contract, legally he works for Wellington Commercial Construction. The architect’s job by contract is to manage the design team on the project while the GC/CM is fully responsible for the management of contractors and construction of the project. The architect and GC/CM work very closely together on the project in any changes that are requested from the owner. Every other day a call from the owner is issued to the project team and this request from the owner is put on the project team’s table. The team then gets together and meets with consultants on the conditions of the order and sees if it is possible to do within reason. The architects are then in charge of the consultants to change the design and GC/CM is in charge of the contractors to see that those changes are constructed. All the consultants and contractors contracts go by a lump sum to each party on the project.

The selection process for the Wellington Project is based on trust and previous relationships with the owner. The architect, civil engineer and land surveyor, geotechnical engineer and owner have in past worked very closely with other projects and therefore got the job. By doing many development projects over the years the owner starts to develop a relationship with someone they can get along with and function well. Again time is money and the less introducing to a new system or format the quicker it is to get a project completed. The GC/CM is in reality part of the owners company but for legality reasons is seen as its own entity. The contractors on the job were either selected due to trust and previous experience or had the most economical and value adding to the project. These decisions were made by the GC/CM and then passed onto the owner for final approval.
With bonding and insurance, the GC/CM holds much of the responsibility and not the owner. Since the owner and GC/CM are of the same company the owner tends to shed most of that responsibility to the GC/CM on the project so that the owner is free from any legal stance. The owner is only going to do what is necessary to protect themselves and let the GC/CM do as they see fit to protect themselves during the project. The contractors on the project are expected to have their own insurance and liabilities when working on the construction site.

The contract types and delivery systems for the project are a good selection for a developer for the very reason time is money. If an owner has to wait for the project to be designed, bid and built in a systematic way the opportunity for larger profitability is over. Therefore flexibility in design and construction, easy paths of communication with many parties, and ways of protection for the owner are the major reasons for why the project was setup this way. Risk is a big factor to play in being a developer and by shedding responsibility to another entity in the company for that project and working with familiar faces is critical to whether or not this project is successful.

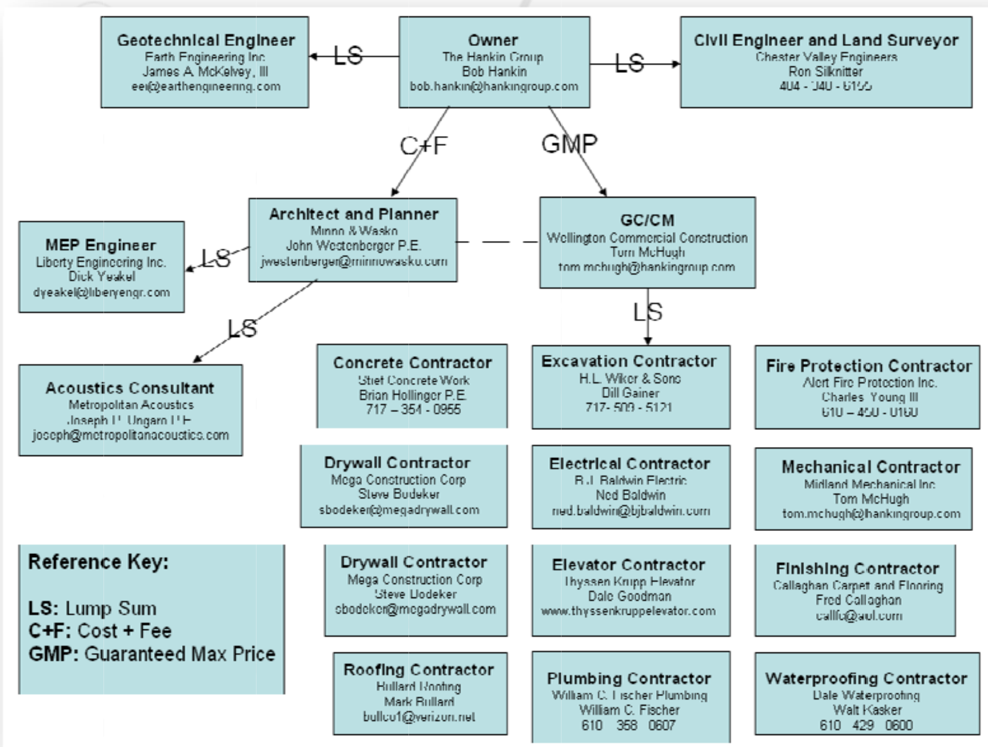



**Figure 10:** Project Delivery of Wellington Condominiums



## A.3.10 Staffing Plan

First and foremost Bob Hankin; president from Hankin Group oversees all projects including Wellington Commercial Construction which is run by Tom McHugh; director of construction. Even though technically by contract Bob Hankin has nothing associated with the company he still has authority and control over what the GC/CM dose on the project. Bob Hankin is primarily concerned over the big picture of the project and leaves the details to Tom McHugh. Tom McHugh's primary responsibility is to manage the everyday issues on this particular project and is the key link between the owner and GC/CM on the project. The senior project manager Ray Winch organizes and manages what happens on the construction site. The rest of the staff answer in the same fashion one way or another to Ray Winch and predominately are on the construction site full time managing the crews and production of the project. The staff from working on many other projects is very close and knows from experience what to expect from each other. Everyone has their role to play and have been very successful up to this date.

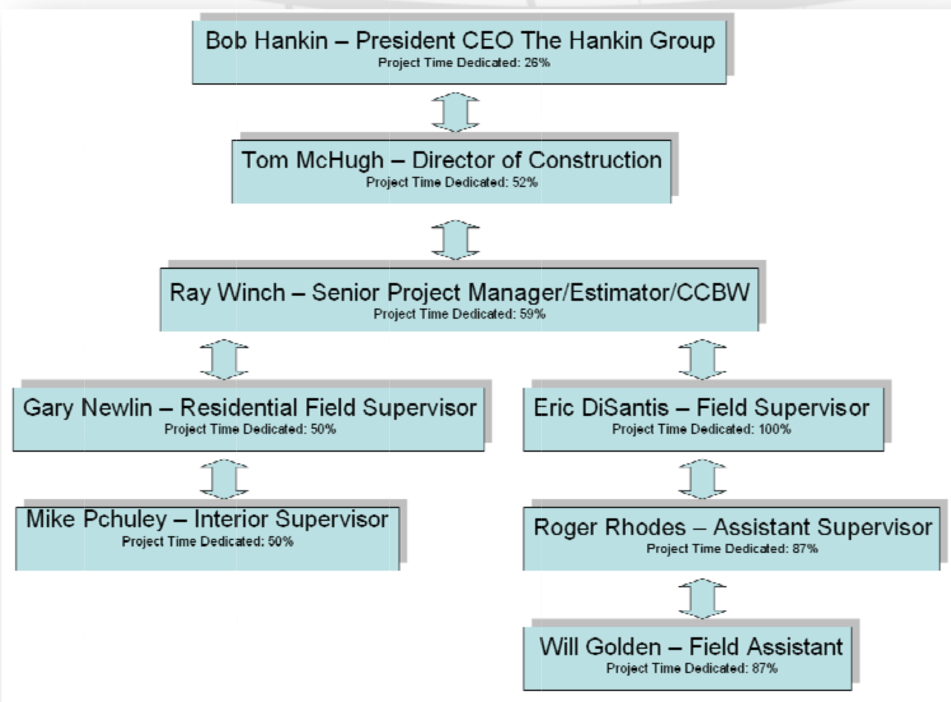



**Figure 11:** Staffing Chart of Wellington Commercial Construction



# B. Critical Issue Research

## B.1 Introduction to Critical Issue

A critical issue that is to be pursued further in research is the decisions that industry members make in providing and utilizing new products regarding formwork systems. Who makes the decision to use a new formwork product and when? Who takes the responsibilities and risks of new formwork system? Can a process and procedure be created and implemented to help aid the construction industry? What process of action can manufactures and suppliers do to promote new products effectively? These questions are going to be researched and analyzed in the construction industry in hope of providing real solutions to real world problems.

The theme of the report as to building respect in the industry goes much farther. “Building for the Future” and gaining respect with other industry members in communicating efficiently is a step towards a better working environment for all. Building respect will lead to building a brighter future for not only students but for everyone who works in and out of the construction industry.

The main research will explore the decision making methodology of new formwork products with the exemplary utilization of the Hambros Joist Composite Deck System. The Hambros Joist Composite Deck System is an innovative product to the construction industry. On a micro level, the Hambros Joist Composite Deck System on the Wellington Condominiums Project will be analyzed in a technical investigation by asking the question: ‘Was the Hambros Joist Composite Deck System a correct decision to be utilized on the Wellington Condominiums Project? Also where would this product be best utilized and the rational process for selecting this product?’ As part of the main research and analysis, the research goal is to define the decision process rational that industry members do in the adoption of new formwork products. It is in the hope of this research to solve some common issues that could be readily fixed and help alleviate common problems that the construction industry is having in the adoption of new formwork products.



## B.2 Main Research and Analysis Overview

The main research and analysis overview for the Critical Issue Research has been broken down into the following sections:

- **B.2.1 Problem Identification**
- **B.2.2 Proposed Solution**
- **B.2.3 Research Steps**
- **B.2.4 Research Outcomes**

### B.2.1 Problem Identification

The critical issue that has been identified and will be further researched is: the decisions that industry members make in providing and utilizing new products regarding formwork systems. Who makes the decision to use a new formwork product and when? Who takes the responsibilities and risks of new formwork system? Can a process and procedure be created and implemented to help aid the construction industry? What process of action can manufactures and suppliers do to promote new products effectively? These questions are going to be researched and analyzed in the construction industry in hope of providing real solutions to real world problems.

### B.2.2 Proposed Solution

Many case studies have been researched through the implementation of new products in the construction industry. One product is the Hambros Joist Composite Deck System and its use in the construction industry. Setting a path and a step by step procedure as to how to present and initiate new products in the construction industry is a key stepping stone towards improving the adaptation of new products. Also if a set path for manufacturers and suppliers are established; better supply management chains and communication lines can be established. As the industries move towards more team work initiatives the greater the need for set processes and communication lines.

### B.2.3 Research Steps

The procedure to investigating the decisions that industry members make in providing and utilizing new formwork products are as followed:

1. Background research as to what current information has been researched regarding the decisions behind formwork systems.
2. Conduct interviews with a wide range of industry personal to gain a perspective as the decisions made behind formwork selection.
3. Based on the gathered research create a process of the current generic formwork decision process, the formwork decision process at the Wellington



Condominiums Project, and the most ideal decision process for selecting formwork systems.

4. Analyze the formwork decision processes created and answer questions as to how this can be implemented and utilized for the construction industry.

The sources of outside information that will be required to fulfill these research steps are as followed:

1. Information from supply chain managers in the manufacturing and construction industry through research and interviews.
2. Connections with owners and design professionals (in particular the Wellington Condominiums Project) on their input of a process of utilizing new products.
3. Research documents in the areas of formwork products and its diffusion into the industry.

### B.2.4 Research Outcomes

The research outcomes are to create a logical and systematic approach as to how the construction industry can improve the supply chain management of utilizing new formwork products. The implementation of this process can be immediately utilized by any company and can be a way in improving the flow of ideas and communication between both industries. This process and procedure is the key to opening the door between industries and in hope of benefiting all parties involved.

I feel that all parties of the construction and manufacturing industry would benefit and have interest in the process and procedure of introducing new products into the construction industry. Having a process that all industry members can follow may lead to having a more productive and respectful working environment.



## B.3 Data Collection Tool

A questionnaire was created to gain an in depth knowledge as to industry member's method, procedure, or process when considering the usage of a new formwork product. This questionnaire was utilized through personal and phone interviews with industry members. A total of five interviews were conducted with a wide range of people in many construction related areas as to gain a perspective of the whole construction industry. The data collection questionnaire for the interviews conducted is outlined below.

**Interview Questionnaire Outline:**

**~Introduction:** Thank interviewee for their time and cooperation.

**~Overview:** Basically what I am trying to do is create a decision tree by mapping out the process industry members make when a new product comes out regarding formwork systems.

**~ Question 1:** My focus is on the method, process, or procedure you conduct when considering the usage of new formwork products.

Not focused on if you prefer flying truss versus conventional wood systems or the advantages and disadvantages of a system; rather on a deeper behind the scenes outtake on the following:

Who do you talk to?
Who makes the decisions?
Do you have an established procedure you must do when considering new formwork systems or in general new products?

**~Discussion 1:** 10 minute discussion on this subject with interviewee.

**~Question 2:** As far as the legalities of formwork design during construction; who has the risks and responsibilities?

**~Discussion 2:** 5 minute discussion on this subject with interviewee.

**~Question 3:** Who takes the risk and responsibilities if the formwork system is integrated with the assembly?



During construction a contractor will not have the ability to decide on whether or not he/she can select to use a particular formwork system. The contractor has no choice but to use the formwork system selected prior.

If the designer then decides for the contractor on the formwork selection, do they take on some of the risk and responsibilities?

**~Discussion 3:** 10 minute discussion on this subject with interviewee. Highlight the Wellington Condominiums Project and the issues surrounding the project team.

**~Question 4:** Who takes the risk and responsibility of the formwork system if problems were to occur on the project in terms of schedule and budget?

Do contractors need to jump in early in the design phase of construction?

Is there a different process in decision making that must take place in the selection of formwork systems?

**~Discussion 4:** 10 minute discussion on this subject with interviewee.

**~Conclusion:** Reiterate by thanking interviewee for their time and cooperation.



## B.4 Critical Issue Research

The procedure to investigating the decisions that industry members make in providing and utilizing new formwork products are as followed:



### B.4.1 Research Background

To analyze the decisions behind formworks systems in as much detail as possible; background research has been conducted. One published work that is worth detailing that has the closest impact to the research detailed in this report is: "*An Interactive Knowledge Based Formwork Selection System for Buildings*," by Awad S. Hanna and Victor E. Sanvido, PSU AE CIC Research Program Technical Report #11, August 1989.

In "*An Interactive Knowledge Based Formwork Selection System for Buildings*," by Awad S. Hanna and Victor E. Sanvido, this body of work has the following concepts and goals:

- Selection and design of formwork systems is influenced by:
  - Building Design
  - Site Constraints
  - Contractor's Experience
  - Availability
- Selection of formwork systems has been identified as one of the major problems which a Contractor encounters.
  - Current practices of rapid placement of concrete have forced the Contractor to search for new or modified systems that can facilitate the construction process.
  - Formwork is selected due to the one that typically gives the most efficient construction sequence.

- Decisions are made by a senior member of a Contractor's organization.
  - Decisions are heavily based on individual's experience.
  - Limited experience may create incorrect decision on the selection of formwork system.
- The report presents tool to assist formwork selector/designer in making decision.
  - Conceptual model created for formwork selection.
  - Computer tool created for designer in the selection of optimum formwork system.

In Figure 1 and 2, details the embodiment of what "*An Interactive Knowledge Based Formwork Selection System for Buildings*," by Awad S. Hanna and Victor E. Sanvido.



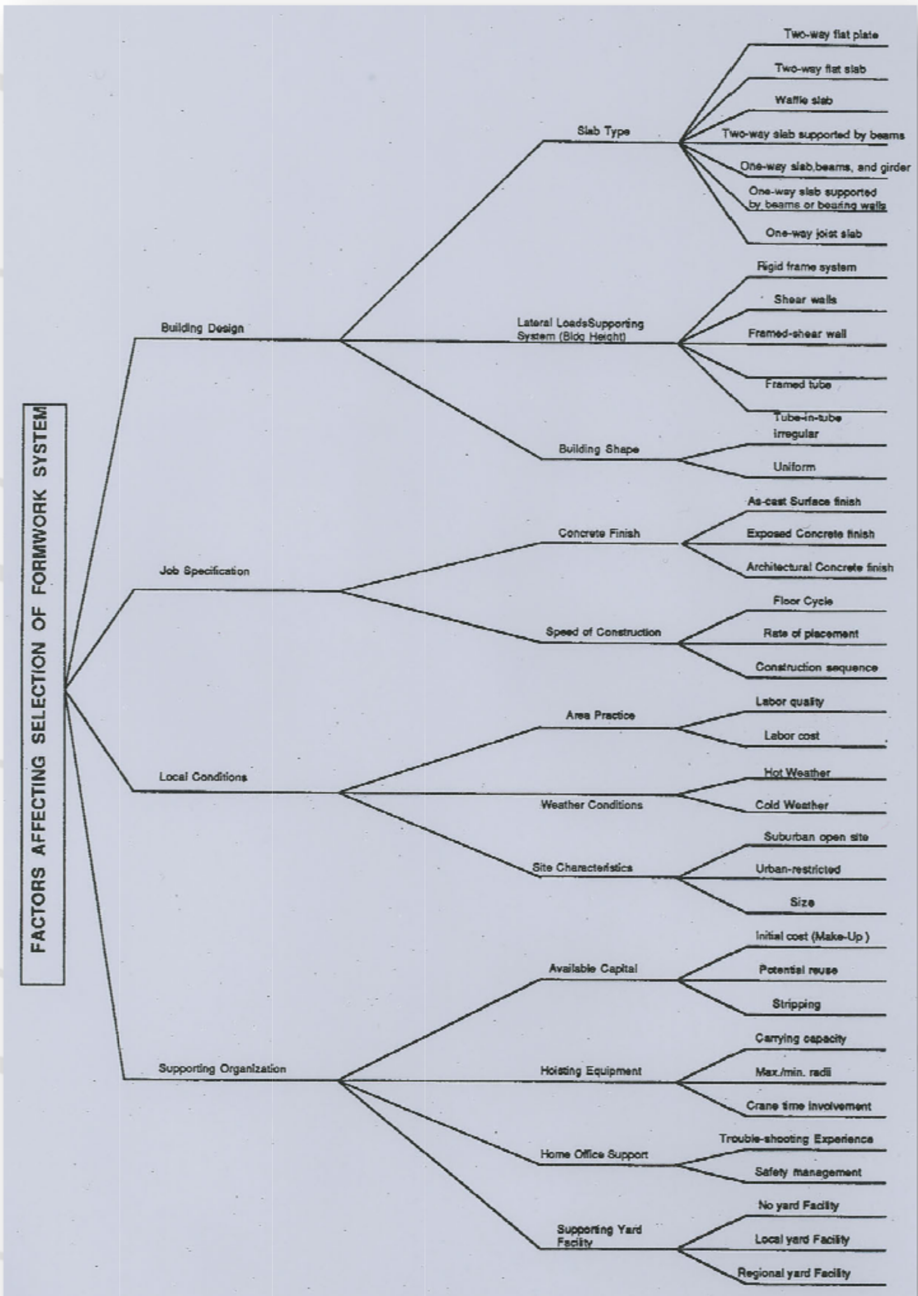



**Figure 1:** Factors Affecting the Selection of Forming Systems from "*An Interactive Knowledge Based Formwork Selection System for Buildings*



| Influence Factor | | | Conventional Wood System | Conventional Metal System | Flying Truss System | Column-Mounted Shoring System | Tunnel Form |
|---|---|---|---|---|---|---|---|
| Building Design | Slab Type | Slab Type | - All slab systems<br>- Most suited for two-way slab supported by beams or one-way slab, beam, girder | | - Two-way: flat plate and flat slab<br>- One-way: slab supported by beams or walls and joist slab (standard or skip-joist) | | - One-way slab supported by walls |
| Building Design | Lateral Support | Compatibility with lateral load supporting system | - Compatible with all lateral load supporting systems | | Generally not suitable for framed tube and tube-in-tube because of the close distance between columns which characterize the tube systems | | - Bearing wall |
| Building Design | Building Shape | Horizontal Uniformity / Irregularity | - System can handle variations in beam size and location<br>- System can handle variations in cantilever shape, size, and location | | - Beams should be of the same size and location or within 20% difference from floor to floor<br>- Cantilever should be of the same size and location or within 20%difference from floor to floor | | - Beams should be of the same size and location<br>- Cantilever balconies should be of the same size and location |
| Building Design | Building Shape | Vertical Uniformity / Irregularity | - System can handle variations of column/wall size and location.<br>- System can handle variations in story height within one floor or from floor to floor. | | - Column/wall should be of the same size and location or within 20% difference from floor to floor<br>- Can handle limited variation (20%) in story height | | - Walls should be of the same size, location, and height from floor to floor |
| Building Design | Building Shape | High Stories (Higher than 14') | -Not suitable for high stories | -More suitable for high stories (light alum. wt.) | - Limited by truss depth ( up to 20') | Height independent system | - Limited height system ( up to 10') |
| Building Design | Miscellaneous | Openings | - System can handle variation in opening size and location | | - Can handle limited variation (20%) in opening size and location | | |
| Building Design | Miscellaneous | Slopes & Cambers | -Slopes and cambers can be accommodated at additional cost | -System must be designed to accommodate slopes and cambers | - Slopes and camber must be identical from floor to floor | | |
| Building Design | Miscellaneous | HVAC | - Can accommodate extensive HVAC | - Can not accommodate extensive HVAC | - HVAC should be minimal and identical from floor to floor | | |
| Building Design | Miscellaneous | Dimension Limitations | -Used for small building size (less than 100,000 sq.ft. ) | -Used for medium building size ( between 100,000 and 200,000 sq. ft. ) | - Used for large size buildings ( more than 200,000 sq. ft.) | | |

**Figure 2:** Factors Affecting the Selection of Horizontal Forming Systems from "*An Interactive Knowledge Based Formwork Selection System for Buildings*

From "*An Interactive Knowledge Based Formwork Selection System for Buildings*," by Awad S. Hanna and Victor E. Sanvido, the research is primarily focused on creating a tool for designers as to what formwork system would be best to utilize on a given project. From Figure 1 and 2, each formwork system is outlined with an influence factor. These influence factors then guide the user as to what formwork system would be best for their project.

The research that is conducted here will build off the information explored by: Awad S. Hanna and Victor E. Sanvido in "*An Interactive Knowledge Based Formwork Selection System for Buildings*," by mapping the decision process construction industry members have to make when selecting a formwork system. This research will not focus on the micro level of whether or not a flying truss system is better over a conventional wood system for a project like the Wellington Condominiums. Rather on a macro level of the process in which construction industry members make when determining what formwork system should be selected. An analogy to this research is illustrated below:



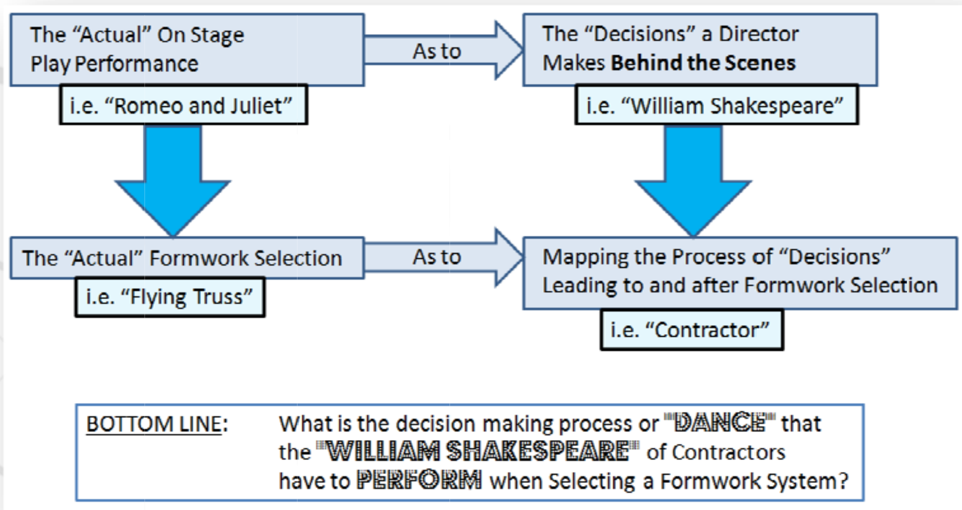



**Figure 3:** Research Analogy

## B.4.2 Industry Perspective

The research analogy illustrates the focus for this investigation and how it will interact with previous research in formwork systems. With the background research outlined and questionnaires completed. The industry perspective can then be explored by conducting interviews with a wide range of industry personnel to gain a view to process of decisions made behind formwork selection. The following construction interviewees that have participated in this research and would like to acknowledge in appreciation are:

- Ray Sowers – Oncore Construction
- Jerry Clayborne – Southland Concrete
- Todd Sody – Sody Concrete Construction
- John Thorsen – Advanced Building Systems
- Randy Green – Southland Concrete

The results of the interviews conducted are summarized and are outlined as followed:

**Note:**

- Bullet points are different views casted by interviewees when asked the same question.
- For instance, if there are two bullet points that would signal a second viewpoint to the same question.



**Interview Questionnaire Results Outline:**

~ **Question 1:** My focus is on the method, process, or procedure you conduct when considering the usage of new formwork products or technologies.

Not focused on if you prefer flying truss versus conventional wood systems or the advantages and disadvantages of a system; rather on a deeper behind the scenes outtake on the following:

Who do you talk to?
Who makes the decisions?
Do you have an established procedure you must do when considering new formwork systems or in general new products?

**~Discussion 1:**

- 
    - Project Manager decides on what system to use.
    - Labor has everything to with formwork selection.
    - European forming systems are ahead of the game.
    - Use Perri Forms to do contract documents for formwork systems.
    - It is up to the contractor to follow contract documents.
- 
    - Experience and labor controls decision.
    - Try new system on smaller scale projects and if works will use on bigger projects with same crew.
    - Use Lumus Design to create formwork/scaffolding shop drawings.
    - The shop drawings must be approved by architect and structural engineer.
    - Once approved it is up to the contractor to follow according to the documents specified.
- 
    - Decisions depend very much on the job, local conditions, and concrete appearance.
    - Cost is also a large factor in deciding on formwork systems.
    - Architects, engineers, or formwork designers create documents for contractors to utilize when constructing a given project.
- 
    - Job superintendent decides on formwork system.
    - Get construction drawings from formwork supplier which then must get an engineer's stamp before contractor can begin construction. Or if have the capability can do it in house and assumes the risk and responsibilities.

- Temporary shoring is contractor’s responsibility and experienced judgment.
- Like to use Perri Forms.
- If have to use a new formwork system the following process would occur:
    - Salesman comes in and gives pitch about formwork system and why it should be utilized on this particular project.
    - Superintendent is there to discuss options with the salesman and then is to decide if this is a viable option.
    - If it is a viable option, the next course of action is to see the formwork in use.
        - Most of the times have to fly to Europe to see latest formwork systems being utilized.
    - See formwork system in action and talk to superintendents and laborers as to what the advantages and disadvantages are to the system.
    - If that goes well the next course of action is to ease the formwork system into a construction project by renting it.
        - Size does not matter.
        - The same crews do not mater but labor is a big part in the success of the formwork system.
    - Get feedback from crews and superintendents as to how the formwork system works.
    - If the system works great then will buy the system for future projects.
    - If the system works okay or if depends greatly on a selective project then will stick to renting the formwork system to whenever needed.
    - If find something that needs improvement will contact the salesman to see if they can update the system for future use.
    - This process and decision making will continue in a cyclical fashion.

**~Discussion 1 Overview:** The decisions for utilizing a new formwork system are made typically by the Superintendent or Project Manager. All interviewees are in agreement that the person who decides must be experienced and knowledgeable towards formwork systems and other related issues. The procedure is in agreement that if you do not have your own in house Formwork Designer; a Formwork Supplier and Manufacturer will create shop drawings based off construction documents, get approved by the Architect and Structural Engineer of record, and then get submitted to the Contractor to be built according to what is specified. The last bullet point goes into detail as to how to implement a new formwork system was of great interest. This will be the basis of focus when mapping the decision process of implementing new formwork systems.



**~Question 2:** As far as the legalities of formwork design during construction; who has the risks and responsibilities?

**~Discussion 2 Overview:**

- All agree that it is the Contractor's responsibility to ensure that he/she follows the construction documents according to what is being specified. The Contractor assumes liability for problems related to construction on the project. If re-shoring is not specified in the construction documents it is up to the contractor to provide a safe environment to all workers during construction.

**~Question 3:** Who takes the risk and responsibilities if the formwork system is integrated with the assembly?

During construction a Contractor will not have the ability to decide on whether or not he/she can select to use a particular formwork system. The Contractor has no choice but to use the formwork system selected prior.

If the Designer then decides for the contractor on the formwork selection, do they take on some of the risk and responsibilities?

**~Discussion 3 Overview:**

- All agree that the Contractor is still responsible for the formwork system in its entirety. Once the Contractor signs the contract with the Owner, it is the Contractor's responsibility as to what is being asked of him to build. Even though the Designer takes away the power of the Contractor to decide what formwork system to use; it is still the Contractor's responsibility to decide on whether or not he/she will build the structure before bidding or signing the contract.

**~Question 4:** Who takes the risk and responsibility of the formwork system if problems were to occur on the project in terms of schedule and budget?

Do Contractors need to jump in early in the design phase of construction?

Is there a different process in decision making that must take place in the selection of formwork systems?

**~Discussion 4 Overview:**

-
    - All agree that the Contractor is responsible due to the formwork system being a part of the construction responsibilities of the Contractor. Even though the decision was made prior without the Contractors input; it is still

the Contractor’s responsibility to build according to what is being specified. Traditionally, the schedule and budget responsibilities also fall onto the construction project team and not onto the design team regarding the Architect or Engineer.

- To medicate this problem for the Wellington Condominiums Project Team it is best for the Contractor to get his/her input early on in the design. This will reduce the risk and make the construction project a lot smoother in transition between design and construction. Also the Contractor should be experienced or is fully prepared to deal with new formwork systems before construction is ever started.
- There is a different process in decision making regarding the selection of new formwork systems. With designs ever becoming more complicated, proper communication between project members is all so crucial to the success of the project.
  - With Design-Build becoming more prevalent in the construction industry it is ever so important to have effective communication lines between all parties involved on a given project.
  - This process change is what will be explored in the next section regarding the mapping of the formwork decision process.

### B.4.3 Mapping the Formwork Decision Process

Based on the gathered research the following formwork decision processes have been modeled:

- **B.4.3.1 Generic Formwork Decision Process Model**
- **B.4.3.2 Wellington Condominiums Formwork Decision Process Model**
- **B.4.3.3 Ideal Decision Process Model for Formwork Systems**

The following **Key** has been assembled to view the following Formwork Decision Process Models:

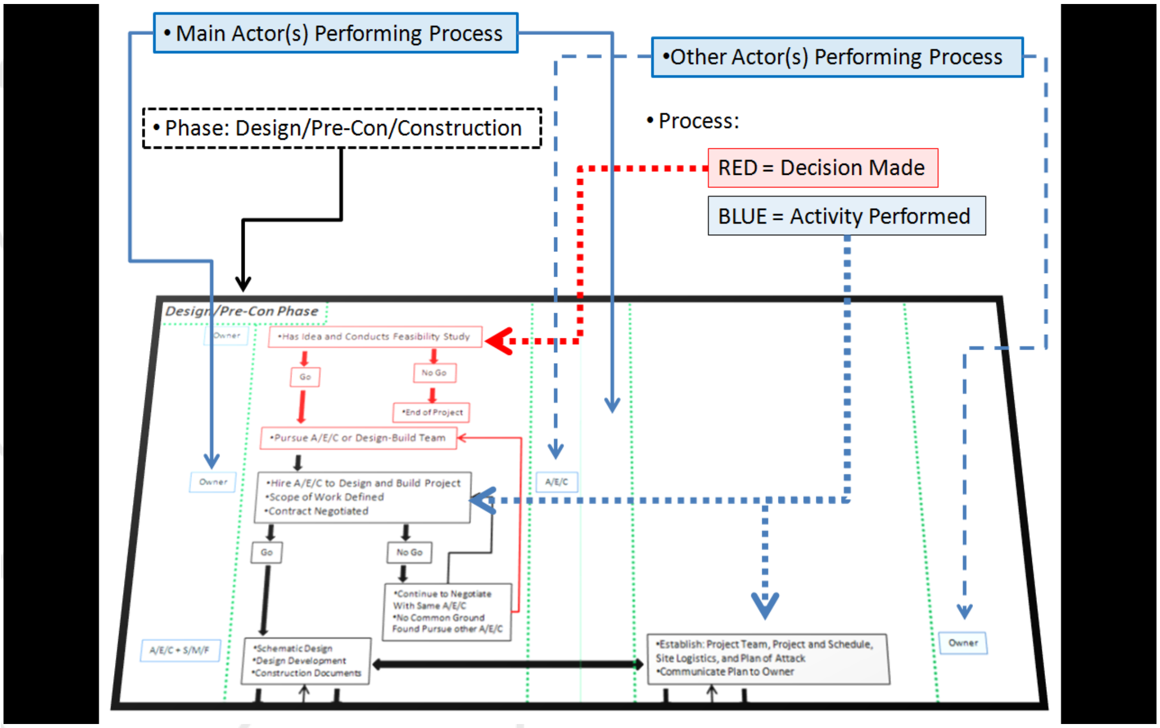


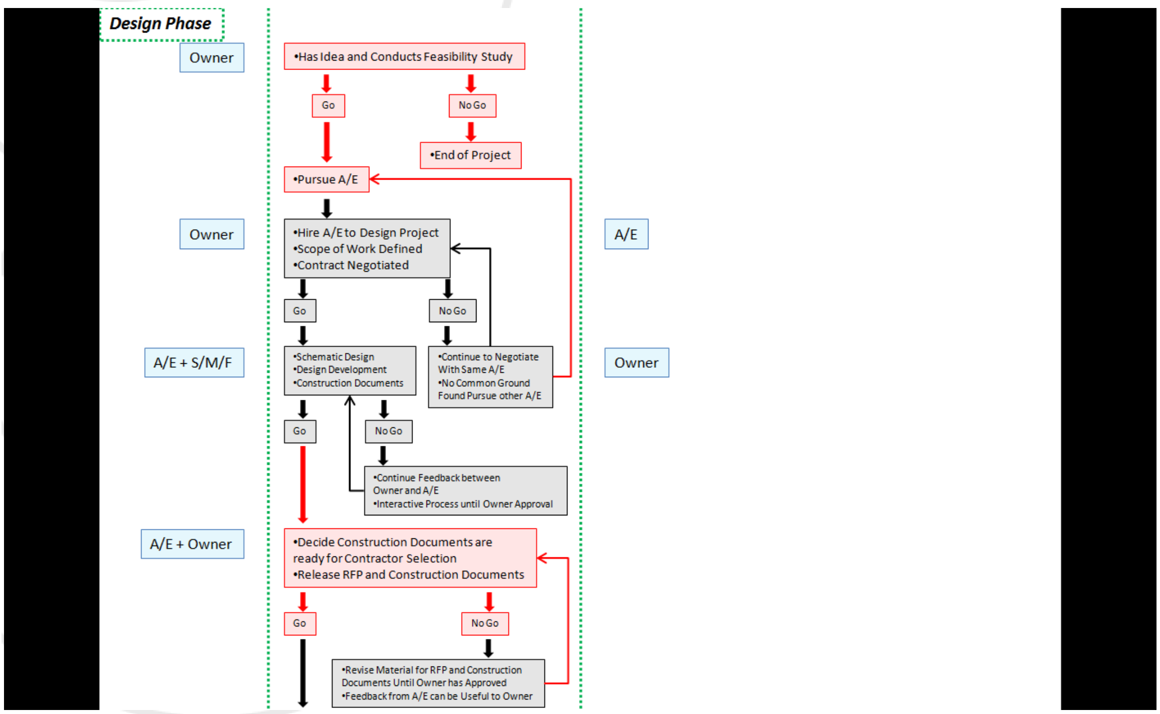

**Figure 4:** Decision Process Model Key

- Key:
  - A/E – Architect/Engineer
  - C – Contractor
  - S/M/F – Supplier/Manufacturer/Fabricator
  - O – Owner
  - D-B – Design-Build
  - Phases:
    - Design
    - Pre-Construction
    - Construction
    - Note: No Operations and Management Phases Have Been Modeled Due to Formwork Being a Temporary Activity for Construction Purposes.

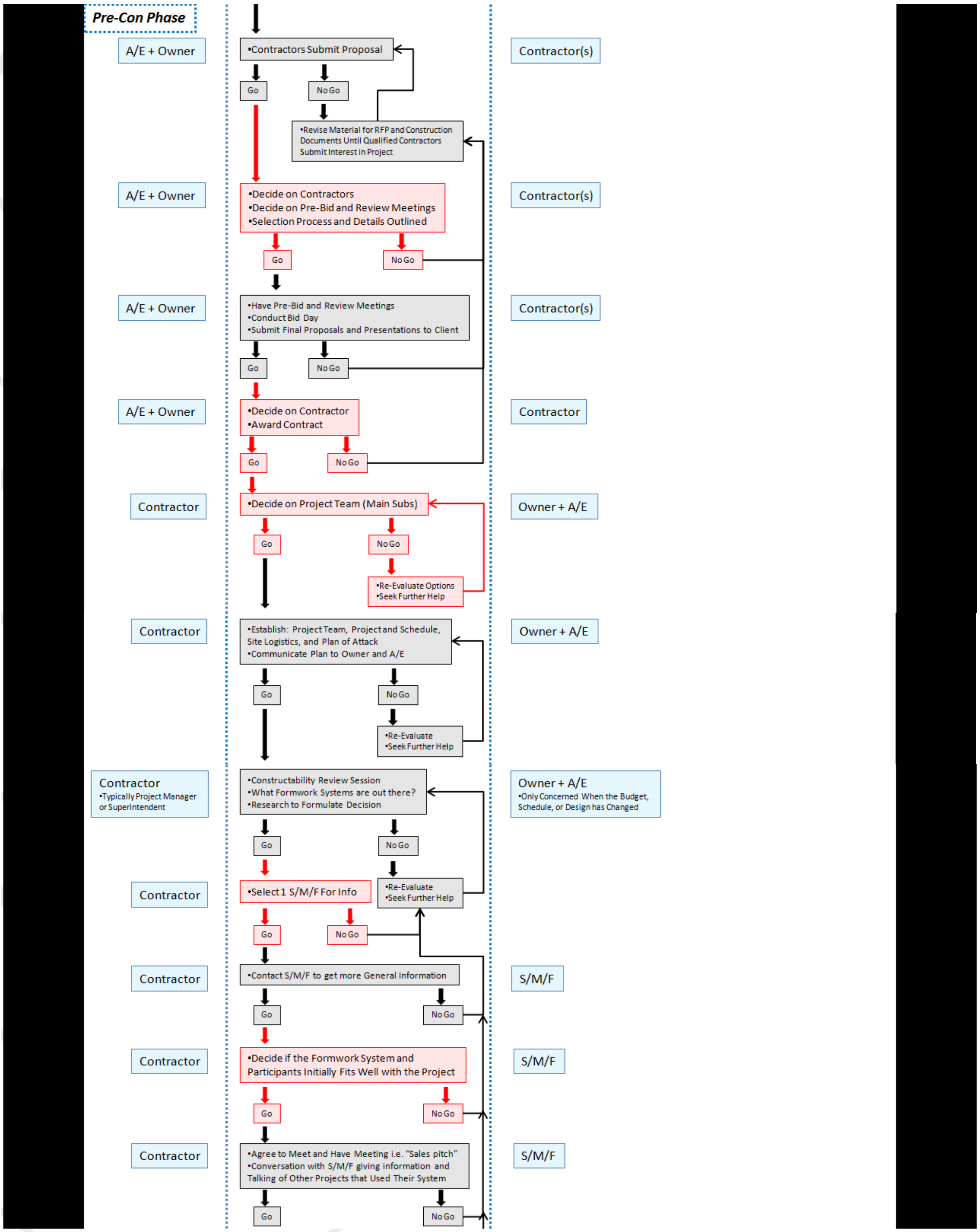


## B.4.3.1 Generic Formwork Decision Process Model

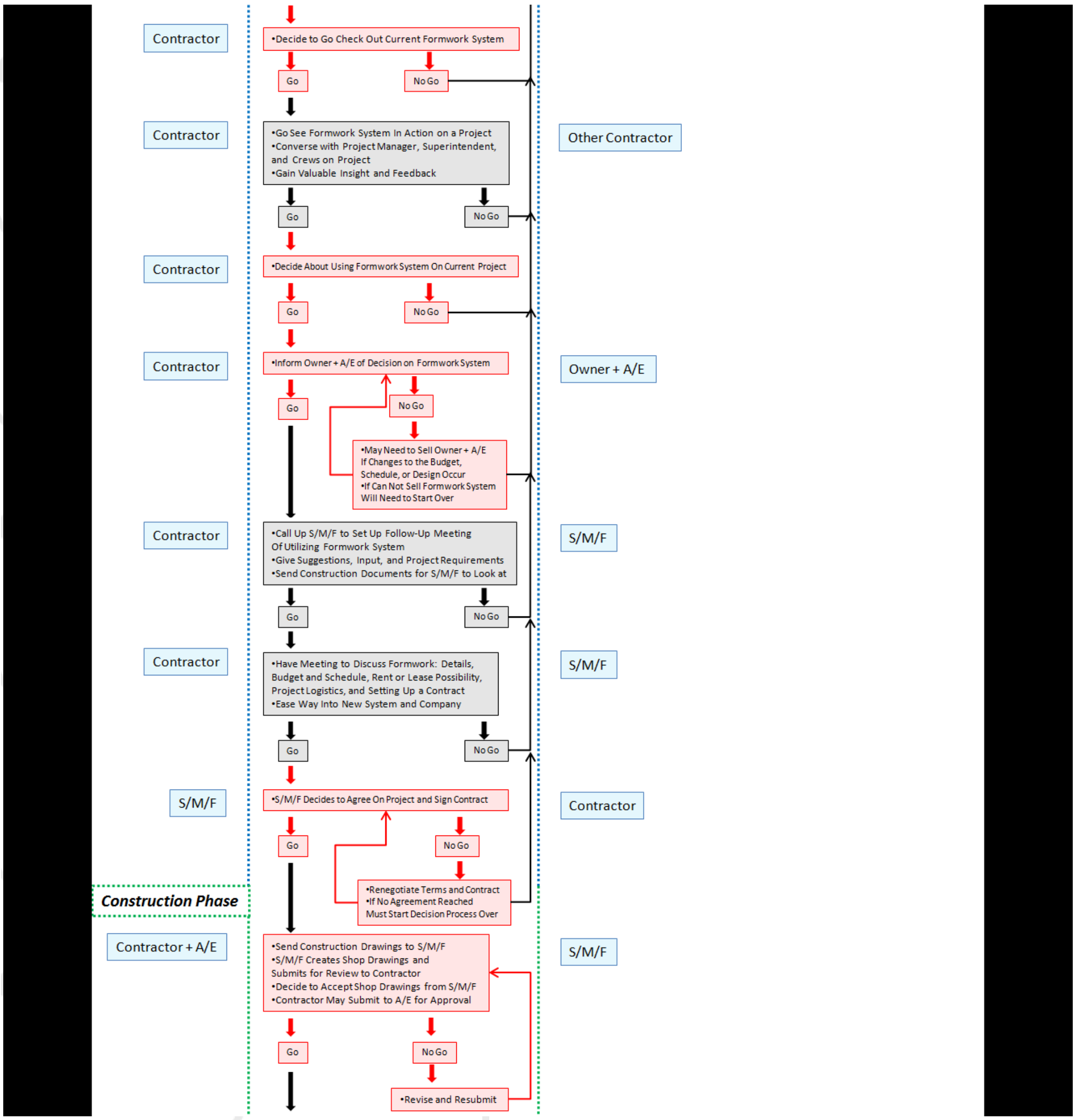
The Generic Process Model for Formwork Decisions is important to understand when analyzing the situation at the Wellington Condominiums Project. The generic model is a representation of what a majority of how construction industry personnel decide on what formwork system would work best for their particular project. All phases surrounding the formwork decision process have been modeled and are duly noted.



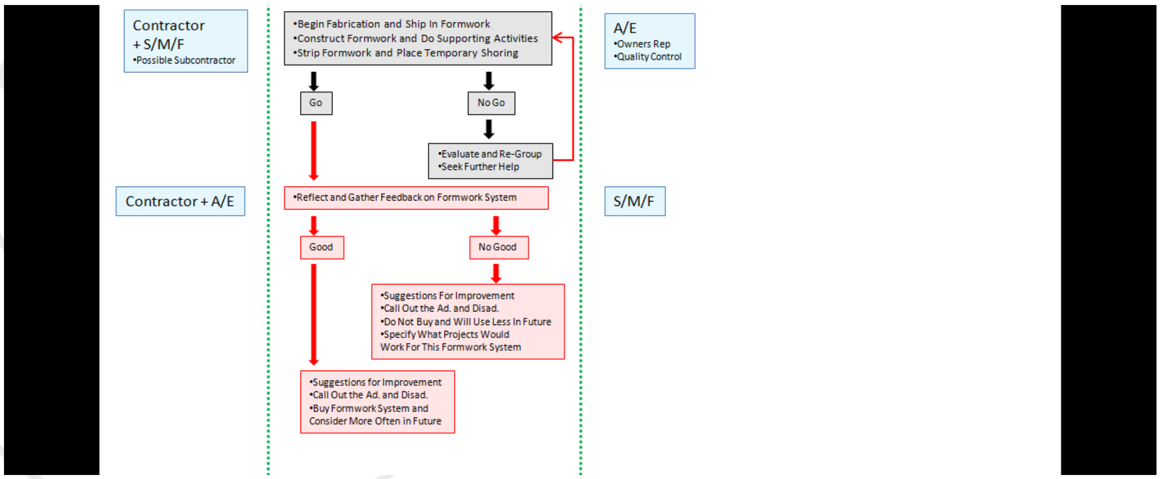



Pre-Con Phase
A/E + Owner
•Contractors Submit Proposal
Contractor(s)
Go
No Go
•Revise Material for RFP and Construction Documents Until Qualified Contractors Submit Interest in Project
A/E + Owner
•Decide on Contractors
•Decide on Pre-Bid and Review Meetings
•Selection Process and Details Outlined
Contractor(s)
Go
No Go
A/E + Owner
•Have Pre-Bid and Review Meetings
•Conduct Bid Day
•Submit Final Proposals and Presentations to Client
Contractor(s)
Go
No Go
A/E + Owner
•Decide on Contractor
•Award Contract
Contractor
Go
No Go
Contractor
•Decide on Project Team (Main Subs)
Owner + A/E
Go
No Go
•Re-Evaluate Options
•Seek Further Help
Contractor
•Establish: Project Team, Project and Schedule, Site Logistics, and Plan of Attack
•Communicate Plan to Owner and A/E
Owner + A/E
Go
No Go
•Re-Evaluate
•Seek Further Help
Contractor
•Typically Project Manager or Superintendent
•Constructability Review Session
•What Formwork Systems are out there?
•Research to Formulate Decision
Owner + A/E
•Only Concerned When the Budget, Schedule, or Design has Changed
Go
No Go
Contractor
•Select 1 S/M/F For Info
•Re-Evaluate
•Seek Further Help
Go
No Go
Contractor
•Contact S/M/F to get more General Information
S/M/F
Go
No Go
Contractor
•Decide if the Formwork System and Participants Initially Fits Well with the Project
S/M/F
Go
No Go
Contractor
•Agree to Meet and Have Meeting i.e. "Sales pitch"
•Conversation with S/M/F giving information and Talking of Other Projects that Used Their System
S/M/F
Go
No Go





Contractor
•Decide to Go Check Out Current Formwork System
Go
No Go
Contractor
•Go See Formwork System In Action on a Project
•Converse with Project Manager, Superintendent, and Crews on Project
•Gain Valuable Insight and Feedback
Other Contractor
Go
No Go
Contractor
•Decide About Using Formwork System On Current Project
Go
No Go
Contractor
•Inform Owner + A/E of Decision on Formwork System
Owner + A/E
Go
No Go
•May Need to Sell Owner + A/E If Changes to the Budget, Schedule, or Design Occur
•If Can Not Sell Formwork System Will Need to Start Over
Contractor
•Call Up S/M/F to Set Up Follow-Up Meeting Of Utilizing Formwork System
•Give Suggestions, Input, and Project Requirements
•Send Construction Documents for S/M/F to Look at
S/M/F
Go
No Go
Contractor
•Have Meeting to Discuss Formwork: Details, Budget and Schedule, Rent or Lease Possibility, Project Logistics, and Setting Up a Contract
•Ease Way Into New System and Company
S/M/F
Go
No Go
S/M/F
•S/M/F Decides to Agree On Project and Sign Contract
Contractor
Go
No Go
•Renegotiate Terms and Contract
•If No Agreement Reached Must Start Decision Process Over
Construction Phase
Contractor + A/E
•Send Construction Drawings to S/M/F
•S/M/F Creates Shop Drawings and Submits for Review to Contractor
•Decide to Accept Shop Drawings from S/M/F
•Contractor May Submit to A/E for Approval
S/M/F
Go
No Go
•Revise and Resubmit




## B.4.3.2 Wellington Condominiums Formwork Decision Process Model

The Wellington Condominiums Project Team ran into some difficulty in budget and schedule and the question is why? Why did the project team run into difficulty? Can the Formwork Decision Process Model show what occurred?

The answer is YES! The difference between what traditionally takes place and what has occurred on the Wellington Condominiums Project is that the decision as to what formwork system was to be utilized was made by the Owner and not the Contractor. In the design phase the Supplier/Manufacturer/Fabricator (S/M/F) presented to the Owner the Hambros Joist Composite Deck System. The Hambros Joist Composite Deck System has integrated its own formwork system that must be utilized with the floor-ceiling assembly. The Owner was sold on the floor-ceiling system and implemented it into the design. As shown in the process, no Contractor input was given into the constructability of the system and therefore the Contractor lost the decision rights on what formwork system should be implemented. When the Contractor was in the constructability review session meetings later on in the pre-construction phase, it was realized that the project team had to utilize the system's formwork or change the entire structural design. Therefore it was decided to stick with the Hambros Joist Composite Deck System and forfeit any rights in formwork decisions that Contractors typically have on a project. This forfeit of decision rights in formwork selection can be seen readily in the model by the decrease in RED ACTIVITIES.

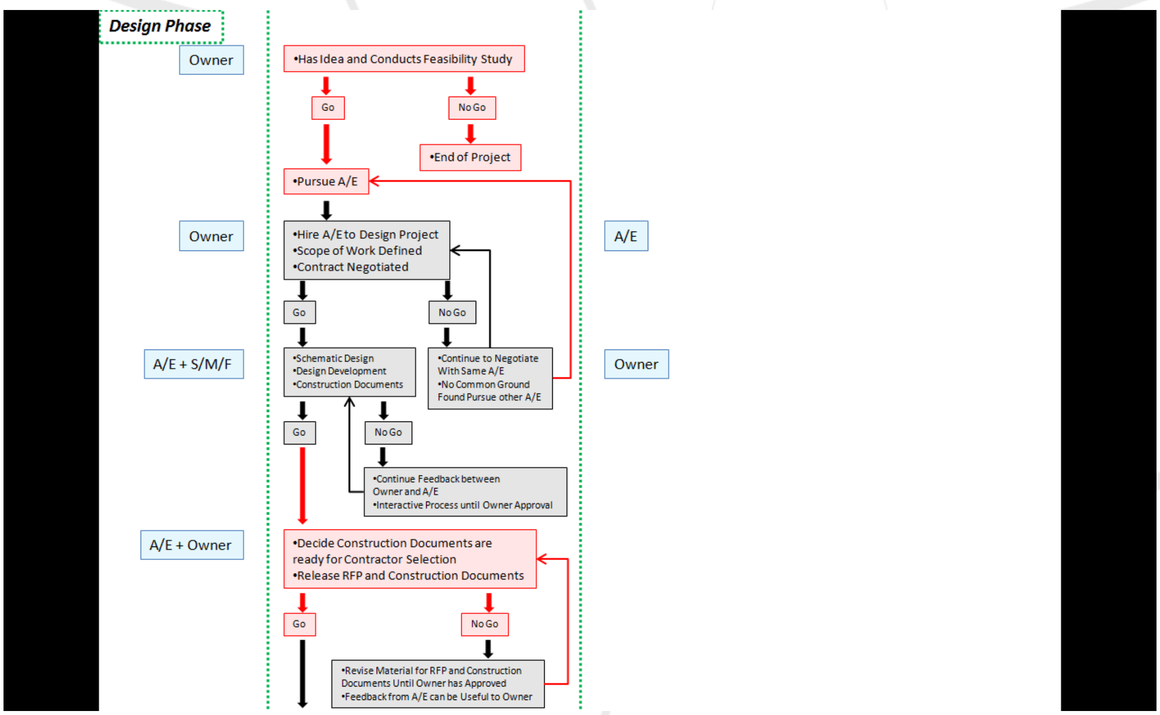
**RULE OF THUMB:** LESS RED ACTIVITIES = LESS DECISIONS MADE

From this decision process model we can determine that due to the project teams inexperience with the system and losing the decision rights based on the Owner has set

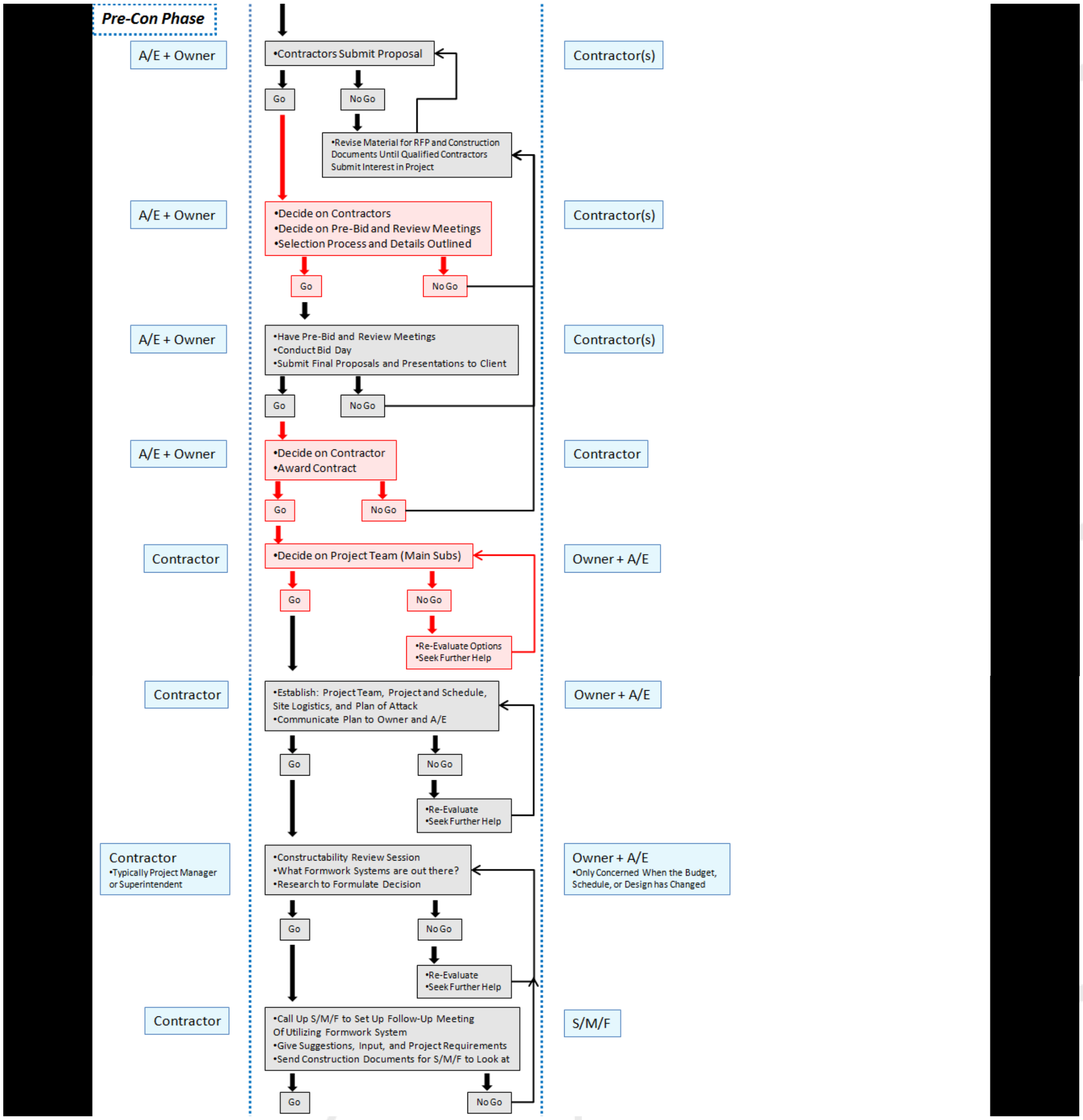


up vulnerability for the project budget and schedule to become inflated. How to solve this problem? The solution is to be answered in the **B.4.4 Results and Recommendations** Section.

**As a side note:** The Contractor selected on the project is really a part of the Owner's company as a whole. Even though the Contractor is a part of the company it still acts as a separate entity and does not collaborate in owner roles and decisions. This puts the Contractor in a tough spot because your work depends on the continual construction of the Owner's developments. By suggesting to the Owner to change the entire design and send mixed signals that the Contractor does not want to construct the project a certain way would create tension between parties. Therefore it was decided by the Contractors to do their best to please the owner in constructing the project as best as they can when utilizing the Hambros Joist Composite Deck System for the very first time. The decision model process shows what minimal options the project team had and which lead to problems in construction and ultimately reflected in the budget and schedule.







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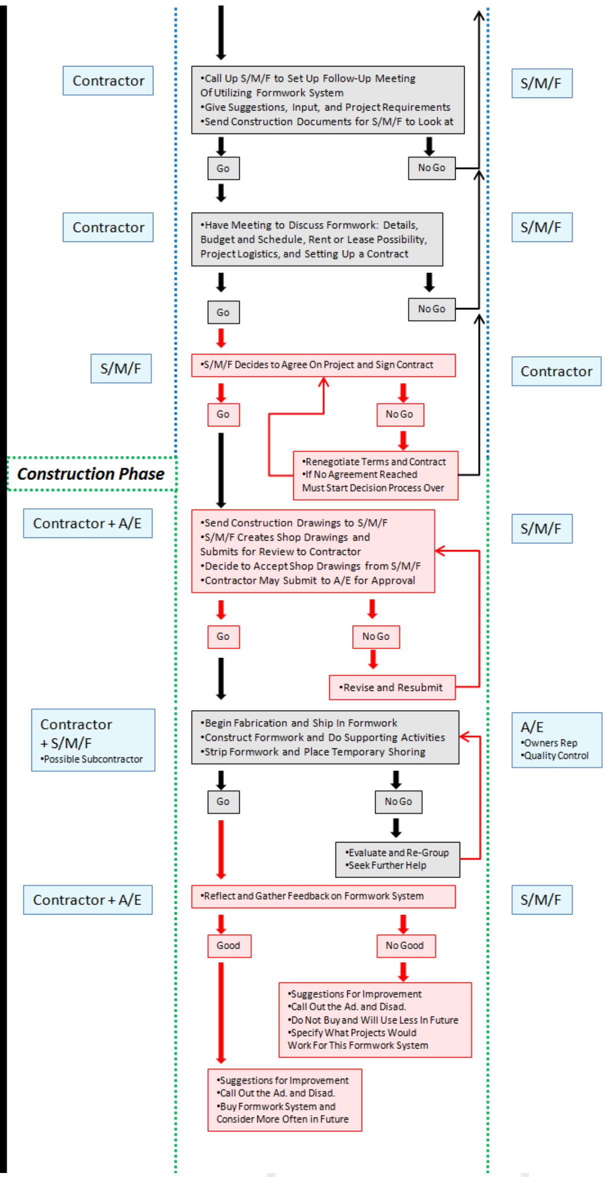
•Decide on Pre-Bid and Review Meetings
•Selection Process and Details Outlined
Contractor(s)
Go
No Go
A/E + Owner
•Have Pre-Bid and Review Meetings
•Conduct Bid Day
•Submit Final Proposals and Presentations to Client
Contractor(s)
Go
No Go
A/E + Owner
•Decide on Contractor
•Award Contract
Contractor
Go
No Go
Contractor
•Decide on Project Team (Main Subs)
Owner + A/E
Go
No Go
•Re-Evaluate Options
•Seek Further Help
Contractor
•Establish: Project Team, Project and Schedule, Site Logistics, and Plan of Attack
•Communicate Plan to Owner and A/E
Owner + A/E
Go
No Go
•Re-Evaluate
•Seek Further Help
Contractor
•Typically Project Manager or Superintendent
•Constructability Review Session
•What Formwork Systems are out there?
•Research to Formulate Decision
Owner + A/E
•Only Concerned When the Budget, Schedule, or Design has Changed
Go
No Go
•Re-Evaluate
•Seek Further Help
Contractor
•Call Up S/M/F to Set Up Follow-Up Meeting Of Utilizing Formwork System
•Give Suggestions, Input, and Project Requirements
•Send Construction Documents for S/M/F to Look at
S/M/F
Go
No Go



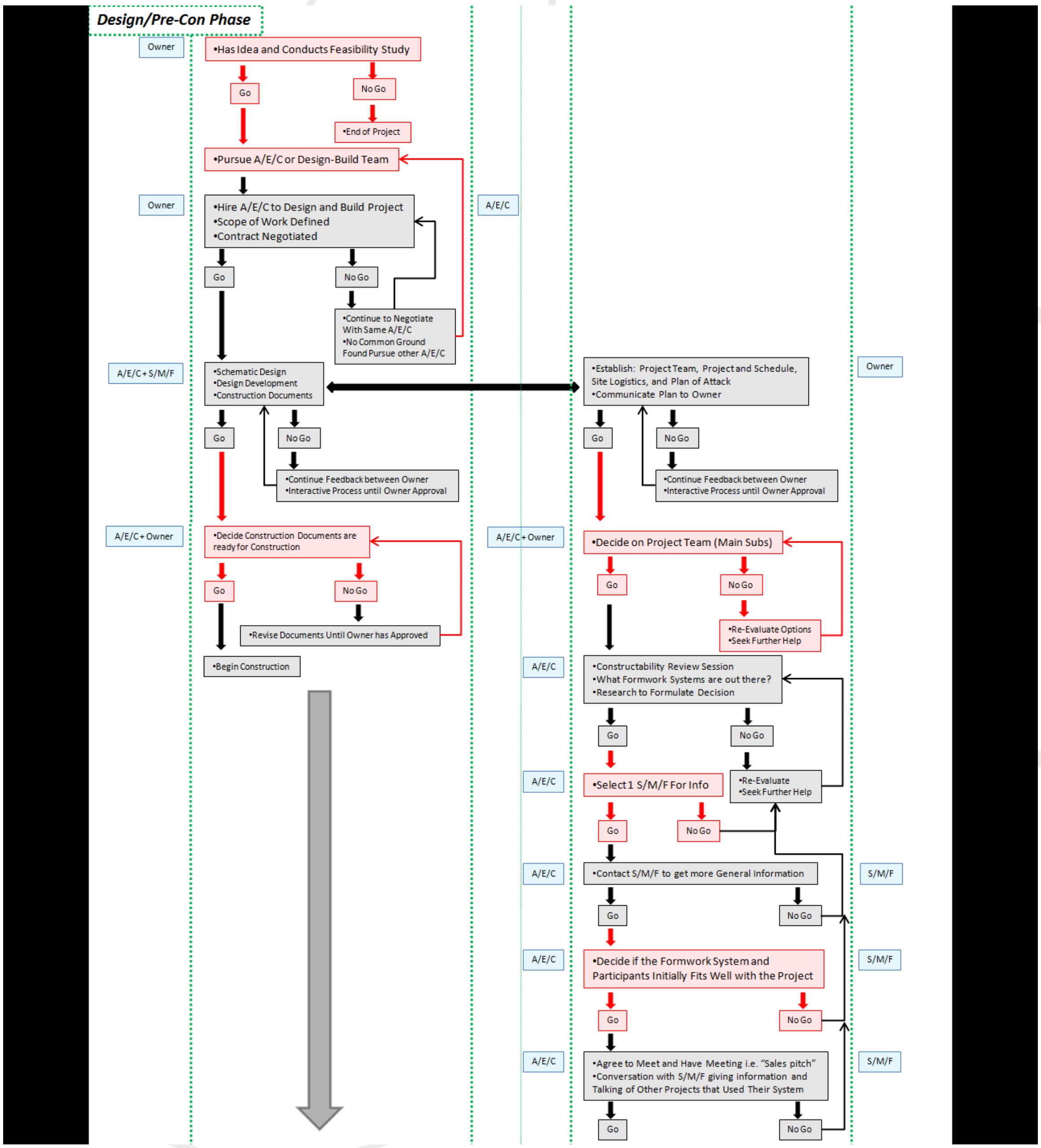



## B.4.3.2 Ideal Decision Process Model for Formwork Systems

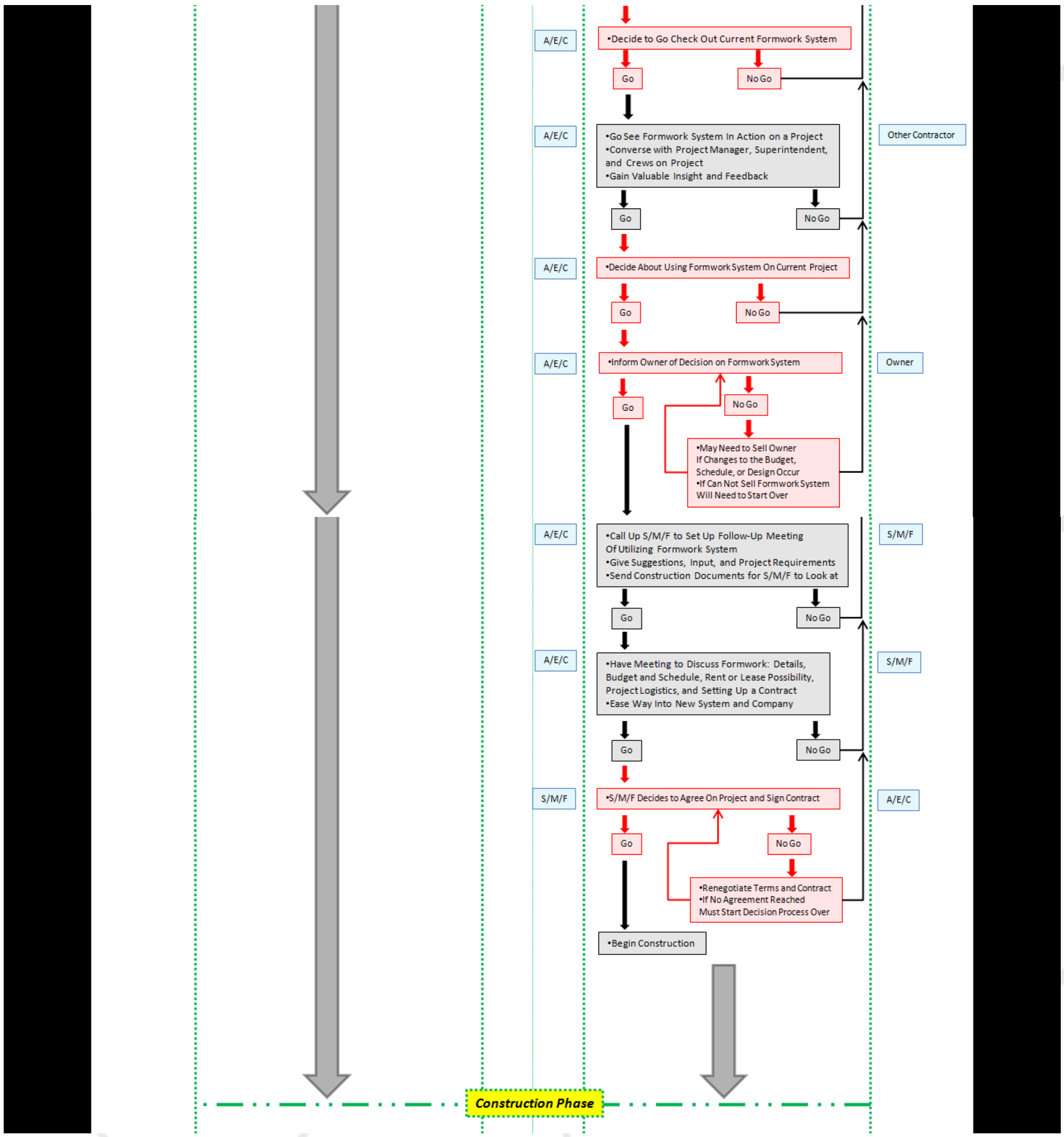
The ideal decision process has been identified for formwork systems as a Design-Build contractual relationship. With Design-Build, task and activities can be eliminated that are deemed wasteful. This also moves the Contractor early on into design decision making process and at that time perform decisions that would normally occur later on in the pre-construction phase. Doing this will ensure that the correct S/M/F will be on the project and keep the formwork decision process in the hands of the Contractor and not the



Owner. The main process of construction or even the formwork decision process does not change from the generic formwork decision process model; rather the design and pre-construction phases get "fused" together and opens a more fluid communication line between all parties. This leads to speedier construction, more efficient decision process between all parties, and more $$$ in the owners pocket.

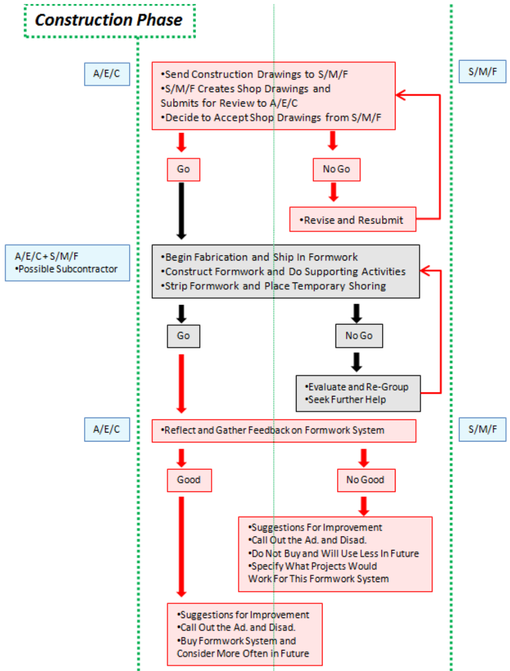






A/E/C
•Decide to Go Check Out Current Formwork System
Go
No Go
A/E/C
•Go See Formwork System In Action on a Project
•Converse with Project Manager, Superintendent, and Crews on Project
•Gain Valuable Insight and Feedback
Other Contractor
Go
No Go
A/E/C
•Decide About Using Formwork System On Current Project
Go
No Go
A/E/C
•Inform Owner of Decision on Formwork System
Owner
Go
No Go
•May Need to Sell Owner If Changes to the Budget, Schedule, or Design Occur
•If Can Not Sell Formwork System Will Need to Start Over
A/E/C
•Call Up S/M/F to Set Up Follow-Up Meeting Of Utilizing Formwork System
•Give Suggestions, Input, and Project Requirements
•Send Construction Documents for S/M/F to Look at
S/M/F
Go
No Go
A/E/C
•Have Meeting to Discuss Formwork: Details, Budget and Schedule, Rent or Lease Possibility, Project Logistics, and Setting Up a Contract
•Ease Way Into New System and Company
S/M/F
Go
No Go
S/M/F
•S/M/F Decides to Agree On Project and Sign Contract
A/E/C
Go
No Go
•Renegotiate Terms and Contract
•If No Agreement Reached Must Start Decision Process Over
•Begin Construction
Construction Phase






## B.4.4 Results and Recommendations

The results and recommendations as to the formwork process modeling for the Wellington Condominiums and ideal process based off the generic model are outlined in the following sections:

- **B.4.4.1 Wellington Condominiums Formwork Decision Process Model**
- **B.4.4.2 Ideal Decision Process Model for Formwork Systems**

### B.4.4.1 Wellington Condominiums Formwork Decision Process Model

The following sections detail what results occurred on the Wellington Condominiums Project and the recommendations of what could be done based off the Wellington Condominiums Formwork Decision Process Model.

#### B.4.4.1.A Wellington Condominiums Formwork Decision Process Model Results

The following key results that lead to problems for the Wellington Condominiums Project Team are outlined as followed:



- Design Phase:
    - S/M/F convinced Owner of their product would be best for the project.
    - Owner liked the idea of cost and schedule savings and had it implemented into the design.
    - This occurred during the continual feedback design period between Owner and A/E.
    - The ultimate decision rests on the Owner and not the A/E as to what systems will be used in the design. This can be seen where the Owner has the "Go/No Go" decision for if the design is ready for contract documents for contractors to bid on.
    - In this model the Owner can keep sending back the design until satisfied.
    - At this stage the decision has already been made and it is too late for the contractor to give input.
- Pre-Construction Phase
    - Process begins similarly to generic model.
    - Contractor sets budget and schedule
        - No Experience with Hambro but does not look hard to construct based off S/M/F feedback.
        - Approved by Owner
    - Site Logistics and Plan of Attack laid out
        - Approved By Owner
    - Constructability Review Meetings
        - Had two options with formwork
            - Use Hambro's formwork system
            - Change Entire Design
        - Final Decision to use Hambro
            - Would create delays and Owner would not like.
        - No Crews available with experience
            - S/M/F will not be subcontracted to perform work.
            - Had to do themselves for first time
        - Decision made easy for contractor
            - Select 1 contact and set up contract agreement with Hambro.
            - All decision power gone!
- Construction Phase
    - Construction Documents submitted for shop drawings.
    - Large learning curve with system and formwork style.
        - Extra cost and schedule implications on contractor
    - Due to concrete leakage on formwork had to have a special crew to come back to clean.
        - Extra cost and schedule implications on contractor



**B.4.4.1.B Wellington Condominiums Decision Process Model Recommendations**

The major problem identified in the results is that the entire Contractor's decision making process is eliminated due to the M/F/S in the continual feedback design process between the Owner and A/E. This is where a majority of the incorrect formwork system selections occur in the formwork decision process. Correct formwork system selection most always occurs at the completion of the Contractor's formwork decision process. This is due to the checks in place and gaining feedback from outsides sources. This leads to a rational decision which will benefit all parties involved on the project.

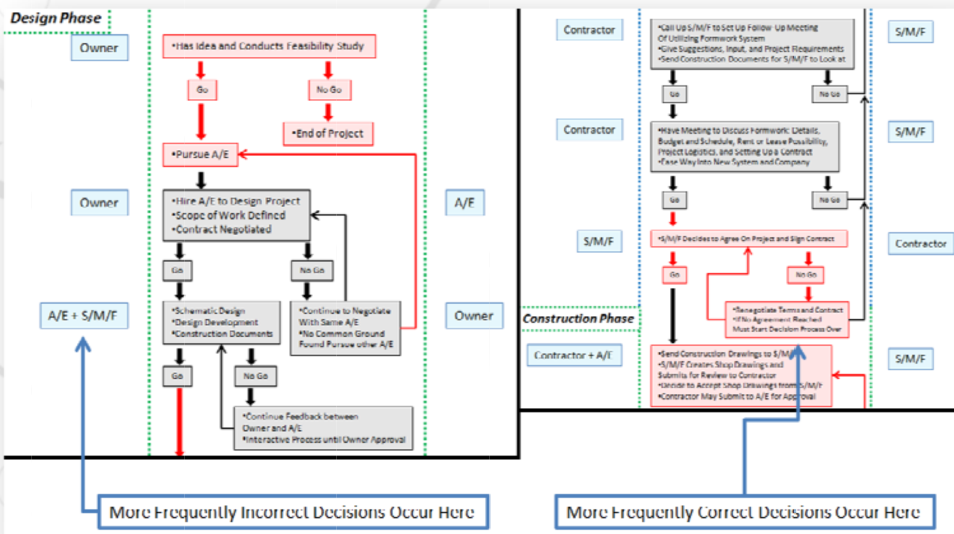



**Figure 5:** Incorrect and Correct Decision Occurrences

**Question:** How do we fix or prevent the occurrence on the Wellington Condominiums Project?

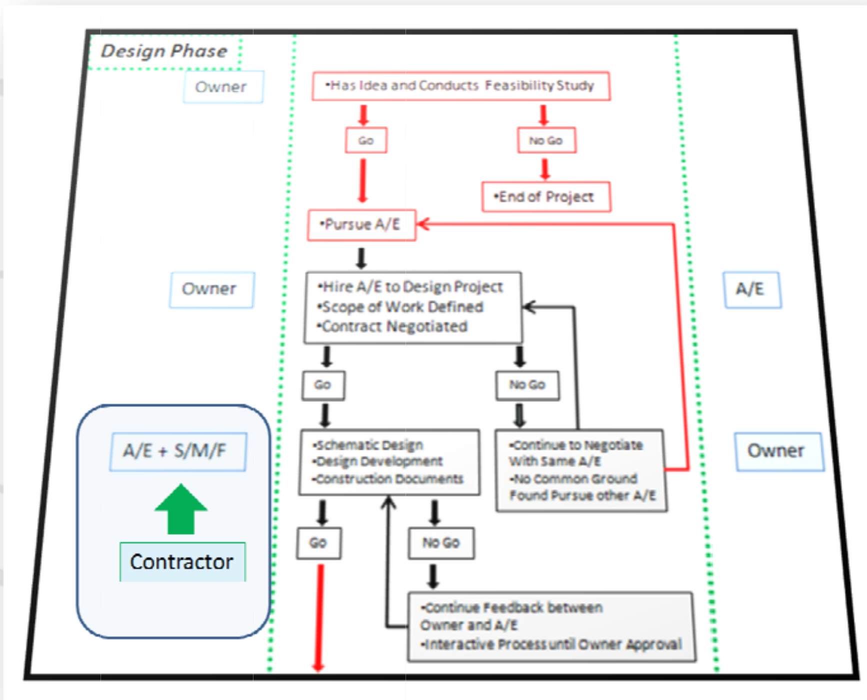



**Figure 6:** Problem fixed i.e. Insert Contractor into the Process

**Answer:** Get the Contractor on board early on when the S/M/F comes into the design phase. Employ the services of a CM Agent in the design and pre-construction phases. At a bare minimum, have someone who is knowledgeable on construction to give sound judgment as far as a constructability perspective.

Having input early on can prevent the occurrence on the Wellington Condominiums Project from happening. Having a CM Agent early on will allow the contractor to go through the proper channels of decisions and checks in the pre-construction phase.



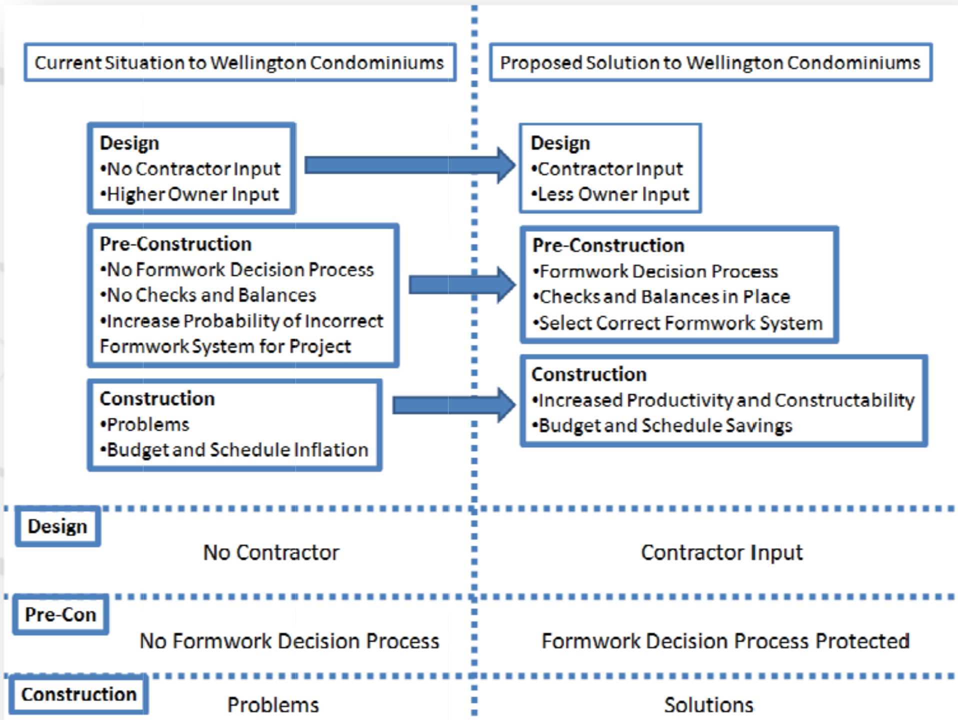



**Figure 7:** Current versus Proposed Solution to the Wellington Condominiums Project

## B.4.4.2 Ideal Decision Process Model for Formwork Systems

The following sections detail what results occurred on researching the Ideal Decision Process Model and the recommendations of what could be done based off the Ideal Decision Process Model.

### B.4.4.2.A Ideal Decision Process Model for Formwork Systems Results

The following key results that lead to the creation for the Ideal Decision Process are outlined as followed:

- Design/Pre-Construction
  - The Design-Build contract structure allows the design and pre-construction phases to combine and start construction at an earlier date.
    - This is one of the main reasons for decrease in project budget and schedule.
  - Owner has idea, conducts feasibility study, and hires A/E/C or Design-Build Team.



- Design and Pre-Construction Services to Owner
- While design is taking place, the contractor can talk to the S/M/F and not the Owner.
  - Contractor can provide educated and experienced input into decision of design regarding constructability.
- Once the design has gathered enough level of detail the construction team can begin the formwork decision process.

- Construction
  - Once construction documents and an S/M/F have been selected, shop drawings can then be created.
  - Formwork can then be fabricated and shipped in for construction purposes.

**B.4.4.2.B Ideal Decision Process Model for Formwork Systems Recommendations**

This decision process model is the most ideal to a project team because it saves time and money, dramatic improvement in communication lines between project participants, less owner involvement in constructability decisions, and S/M/F held in check throughout decision process by experienced industry personnel. Some of the reasons why these statements are true are listed as followed:

- With modeling step by step the Design-Build Decision Process for Formwork Systems, the following selected participants and process are unnecessary and have been eliminated:
  - Participants Eliminated During Specific Process and Decision Activities:
    - Contractor
    - Contractors
    - Owner + A/E (3)
  - **Total: 5 Participants Eliminated**
  - Processes Eliminated During Specific Times
    - Activities Eliminated
      - The need of RFP and Contractor submitting proposal
      - Have pre-bid and other related meetings
      - Submit final proposals and presentations
    - Decisions Eliminated
      - Decide on Contractors
      - Decide on pre-bid and other related meetings
      - Selection process
      - Decide on Contractor and award contract
      - Decide to release design for contractor selection
      - Decide to release RFP and construction documents
  - **Total: 9 Processes Eliminated**

With 5 participants and 9 processes eliminated, it is clear and is proven statically why a Design-Build contract succeeds over a traditional format. Wasteful processes have been taken out of the equation, better communication lines between project participants, and earlier involvement of all project participants leads to success. The Owner will also benefit due to a faster and more productive working environment with the project team. This reduces friction and creates a decrease in budget and schedule.

The only disadvantage is that this will have a little more upfront cost due to the Contractor's early input. It has been proven time and time again that it is well worth the investment of having good feedback, better communication lines, and working relationships. Also due to having the formwork decision process, Contractors are encouraged to explore new formwork products and become educated as to the latest most productive systems on the market today. From the ideal decision process model for formwork systems, an interesting ideology transpires: Wherever a S/M/F enters into the scene; a Contractor is always there in the selected process. This is due to the fact that if an Owner and A/E are not experienced, it will lead to a possible loss in the Contractor's ability to learn and make rational constructability decisions and create an increased vulnerability in the project budget and schedule. Therefore the following rule from this research hypothesizes the following statement:

- For increased project success, a Contractor should be implemented if an S/M/F is to enter a formwork decision process.
- The correct products for a construction project enter under the influence of a Contractor. While the probability of incorrect products for a construction project enters without the influence of a Contractor.

This hypothesis has been proven by the Wellington Condominiums Project and can be served very useful to all construction industry personnel.

**Question:** What process of action can S/M/F do to promote new products effectively?

**Answer:** Depends on the decision process! Generic and ideal promote different ways for S/M/F to conduct business. Savvy S/M/F knows this and benefit greatly from it!

Under the Generic Decision Process:

- The generic decision process is what is commonly found in traditional way of construction projects. A step by step method in which the contractor is brought onto the project at a later date.



- The Savvy S/M/F knows this and therefore attacks early on in the design phase with the Owner and A/E. It is a great place for S/M/F to get into a project and have the designs utilize their products.
- By the time the Contractors step into the picture, the design is already completed and is too late for S/M/F to participate in the project.
- The more the S/M/F can offer to the Owner and A/E, the more business and profits the S/M/F will create!
    - Design becomes more of a factor to the decision process.

Under the Ideal Decision Process:

- The ideal decision process is generally referenced to the new style of construction of design-build.
- In design-build the Contractor has more say in the design and constructability of the project.
- Owners tend to play less of a role and A/E relies more heavily on the Contractor's decision as to what systems or products would be best.
- Therefore it is the Contractor that savvy S/M/F now attacks for business and working relationships. The more S/M/F can do for the contractor the better!
    - Subcontracting work become more of a factor to the decision process.

**Question:** How can this information be utilized in a more readily fashion to construction industry personnel?

**Answer:** An interactive web tool called: "Formwork Decision Process Model" has been created that any construction industry personnel can interact with to gain a sense of the complicated decisions that go into utilizing a new formwork product.

This tool uses the process models created in this report in an easily viewable web format. The tool can guide any user step by step until the project has reached an end to the decision making process of formwork systems. You can access this interactive web tool on the Pennsylvania State University Architectural Engineering Senior Thesis Website @ www.arche.psu.edu/thesis.



# C. Core Investigation Areas

## C.1 Introduction

Detailed analyses of technical building systems and construction methods have been selected and investigated. The three main challenging areas on the Wellington Condominiums Project are detailed in the following sections below.

## C.2 Hambros Joist Composite Deck System ~ *Acoustical Breadth*

**Figure 1:** First Floor Hambros Joist Composite Deck System

The Hambros Joist Composite Deck System for the Wellington Condominiums has been analyzed and is broken down as followed:





## C.2.1 Problem Statement

Is the Hambros Joist Composite Deck System a correct decision to be utilized on the Wellington Condominiums Project? Would a traditional composite deck system be a better alternative to the Wellington Condominiums Project? What type of construction project would best benefit from using the Hambros Joist Composite Deck System?

## C.2.2 Proposed Solution

Analyze and compare the Hambros Joist Composite Deck System to other typical composite deck systems. The main breath will look at the acoustical properties of both systems and see what system would be recommended through a design and constructability perspective. The acoustics is mostly of concern due to the fact that the Hambros Joist Composite Deck System can be as thin as 2.5". Being that thin of a deck and having high end condominiums, the vibration and sound transfer between floors become of great interest and importance. Manufacturers and Suppliers have promoted the fact that this system is excellent by industry standards for minimal vibration and sound transfer. It is up to this research to examine if this claim is true and if any parts of the system, i.e. the acoustical properties, are not as expected then recommendations would be provided to correct the problem.



## C.2.3 Analysis Steps

1. Learn in more detail how the project team selected the use of the Hambros Joist Composite Deck System. What are the initial advantages and disadvantages of this system on the Wellington Condominiums Project?
2. Perform an acoustical analysis to determine if the Hambros Joist Composite Deck System performs up to typical composite systems.
3. Compare and contrast each system and come up with a logical rational as to decide if the Hambros Joist Composite Deck System was the correct choice for this project.
4. If areas of the Hambros Joist Composite Deck System are seen to cause problems what can be done to improve the system during the construction phase.
5. Make recommendations as to where this system would be best utilized for a given project. Identify some key areas that a project team must focus on when deciding to use this product.

## C.2.4 Analysis Result Overview

The research results concluded that the Hambros Joist Composite Deck System has its advantages; but it might not be what is suitable for the Wellington Condominiums Project. The Hambros Joist Composite Deck System is a new product that has been a problem for the project team during construction. Issues have risen to the surface and questions have been researched about whether or not this system fits well with the Wellington Condominiums Project. It is through this investigation, as detailed in the following sections, to create a logical and systematic approach as to see if this system was the correct decision to be utilized on this project.

**C.2.4.1.A Overview of the Hambros Joist Composite Deck System**

The Hambros Joist Composite Deck System was utilized on the Wellington Condominiums Project to provide a new means of floor-ceiling assembly construction.

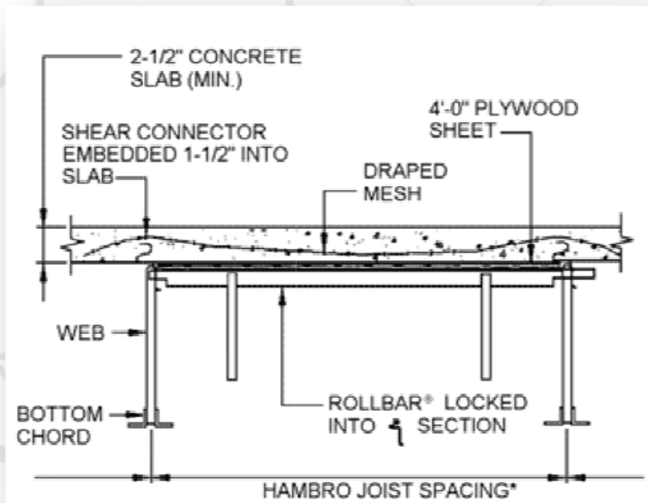



**Figure 2:** Hambros Joist Composite Deck Section

The system, as shown in Figure 2, utilizes a concrete slab through the support of 4'-1/4" spaced Hambro Joists. Some of the unique features of utilizing this floor-ceiling assembly are: the concrete slab can be as thin as 2-1/2", utilize minimum reinforcing through the application of welded wire mesh, 4'-0" plywood sheets can be removed the day after a concrete pour, and no shoring/re-shoring is required for this system.

The process at which to utilize this system is very straight forward and is outlined as followed:

1. **Spreading Joists:** Spread Hambro joist at 4'-1 ¼" on load bearing walls
2. **Placing Roll bars:** Roll bars are to keep uniform spacing while providing lateral and tensional stability
3. **Installing Plywood Forms:** Installing the plywood forms a working surface and forms a rigid diaphragm during construction
4. **Mesh In Place:** Mesh over top chord of joist creates a way of reinforcing concrete
5. **Pouring Concrete:** No shoring is required with this system when pouring concrete. The minimum thickness requirement is 2 ½". The Wellington Condominium project makes use of 3" slab thickness.



6. **Stripping Formwork:** When concrete reaches strength of 500 PSI (usually the day after the pour) the plywood forms can be taken out. When the concrete reaches strength of 1000 PSI (usually within 48 hours) the deck is ready for other trades and the formwork can be removed for future re-use.

**C.2.4.1.B Advantages and Disadvantages of the Hambros Joist Composite Deck System**

Through the experience of the project team on the Wellington Condominiums Project and manufacturer's specifications, a list of the advantages and disadvantages have been compiled as followed:

**Advantages**

**Fire Ratings:** U.L. Fire Ratings for 1, 2 and 3 hours and can eliminate the need for fire dampers.

**Composite Design:** Provides a floor that is 2-3 times more rigid, with 1/3 the deflection of a typical bar joist assembly. Hambro also provides 4' joist spacing without bridging and bracing. Typical bar joist assemblies are spaced at 2' or 2'-6" on center and require bridging, bracing, and a metal deck.

**Cost Savings:** No Shoring or Re-shoring required. Less concrete and reinforcing are needed which decreases material cost. Overall the Hambro Composite Deck System is in the same price range as other floor-ceiling assemblies.

**Slab Penetrations:** Is relatively simple using sleeves, Styrofoam, or wood blocking prior to concreting. No tendons and fewer joists offer flexibility. Slender 3,000 PSI slab makes coring simple, if necessary.

**Schedule Savings:** Typically after one or two days the formwork can be stripped and work can begin on the next level without the need of shoring or re-shoring. Total construction per floor can reach levels of less than 5 days with experienced crew members.

**Mechanical Interfacing:** Features open web configuration, no bridging and 4' to 6' joist spacing accommodates mechanical distribution within the joist plenum. Hambro permits full-length ducts and pipes, and virtually eliminates dropped ceilings and sofits.

**Disadvantages**

**Acoustical Properties:** Hambro has an STC 52 and IIC 26 for a 2 ½" slab and 1 layer of ½" drywall. The IIC rating is very low due to the composite systems thin concrete slab.



Special consideration to what floor material is applied to the system must be carefully analyzed.

**Bearing Systems:** Hambro works well for a variety of bearing systems. One of the biggest problems with this system through the utilization of load bearing metal stud walls is that it is dependent on a flat concrete surface for panel bearing. If there are any bumps or high spots in the concrete where the panels bear on the slab, then the panel needs to be shimmed, and that area of the building gets taller. If the panels stacked on top of each other and the slab butt into the side of the panel (perhaps bearing on an angle or recess in the panel), then the concrete flatness and accuracy would be less of an issue.

**Labor Intensive:** Only two or three companies specialize in the installation of this system professionally in the eastern United States. The system tends to be very labor intensive due to moving the Hambro Joists into place. A lot of time is spent by crews stripping the formwork from the joist assembly for the next floor level.

**Installation:** Increase in schedule and budget can result if not familiar with the system and its components. System is unlike other floor-ceiling assemblies and requires different planning during construction.

**Versatility:** Hambro is well-suited to a variety of projects but is very difficult to use when walls are not repetitious and linear.

**Quality Control:** Measures must be in place to control any seepage of concrete from the formwork system during pouring. After stripping the formwork, a special crew may be needed to come back through to properly finish the surface of the concrete assembly. Additional costs to the contractor may be inherited due to this situation.

**C.2.4.1.C Project Team Selection of the Hambros Joist Composite Deck System**

The Wellington Condominiums Project Team selected the Hambros Joist Composite Deck System by the design team to initially speed up the construction process. Through consultation of the manufacturers and engineers, the project team was able to then utilize the Hambros Joist Composite Deck system on the Wellington Condominiums Project.



## C.2.4.1.D Original Estimate and Schedule

The Wellington Condominium's original composite deck system estimate and schedule are detailed as followed:

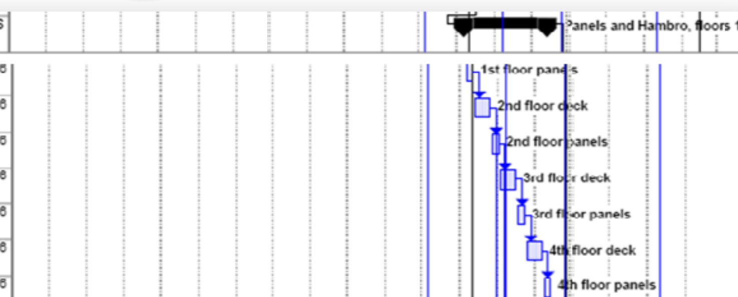
**Original Estimate:**

| Hambro Joist System and Components | | | | Superstructure | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total |
| Division 5 Metals | | | | | | | | | | |
| 25526.54 | 54204100550 | Floor joist, galv CF steel, 12 ga x 12" D, incl jois | | | | L.F. | 153,159.24 | 0.00 | 0.00 | 153,159.24 |
| 2,700.000 | 54204101550 | Floor joist, galv CF steel, 12 ga x 12" D, incl fas | 2 Carp | 30 | 0.533 | Ea. | 0.00 | 46,305.00 | 0.00 | 46,305.00 |
| | | Totals | | | | | $153,159.24 | $46,305.00 | $0.00 | $199,464.24 |
| | | | | ENR Building Cost Index Inflation from 2005 to 2006<br>Allentown, PA Location Factor already in calculations | | | | | (3.9% Total Cost Escalation) | $207,243.35 |

*~See Attached Appendix for Detailed Structural Takeoff~*

**Original Schedule:**

| | | | |
|---|---|---|---|
| Panels and Hambro, floors 1-4 | 50 days | Mon 8/7/06 | Fri 10/13/06 |
| 1st floor panels | 5 days | Mon 8/7/06 | Fri 8/11/06 |
| 2nd floor deck | 10 days | Mon 8/14/06 | Fri 8/25/06 |
| 2nd floor panels | 5 days | Mon 8/28/06 | Fri 9/1/06 |
| 3rd floor deck | 10 days | Mon 9/4/06 | Fri 9/15/06 |
| 3rd floor panels | 5 days | Mon 9/18/06 | Fri 9/22/06 |
| 4th floor deck | 10 days | Mon 9/25/06 | Fri 10/6/06 |
| 4th floor panels | 5 days | Mon 10/9/06 | Fri 10/13/06 |




**Total:** **50 Work Days = 10 Weeks**
**Mon 8/7/06 – Fri 10/13/06**

*~See Attached Appendix for Full Schedule~*

**C.2.4.2.A Architectural Acoustical Breadth Analysis of the Hambros Assembly**

An acoustical analysis was performed to determine if the Hambros Joist Composite Deck System performs up to other conventional steel joist and deck systems. This breadth analysis will explore:

1. What acoustical properties are used to rate a floor-ceiling assembly? How is a floor-ceiling assembly created?
2. The manufacturer Swirnow Building System's claim that the Hambro D500 acoustical properties are excellent as compared to other floor-ceiling assemblies.
3. Identify areas of the Hambro Joist Composite Deck System that are of need of further improvement based on the Wellington Condominiums Project specifications.
4. Suggestions for acoustical performance improvement on the Wellington Condominiums Project.
5. Recommendation of what floor-ceiling assembly should be utilized on a project based on acoustical properties.

**C.2.4.2.B Architectural Acoustical Background Information and Example Calculation**

The main acoustical properties that are used to rate floor/ceiling assemblies are the sound transmission class (STC) and impact isolation class (IIC).

STC, according to *Architectural Acoustics* by David Egan, is defined as: a single-number rating of airborne sound transmission loss (TL) performance of a construction measured at standard one-third octave band frequencies. The higher the STC rating, the more efficient the construction will be in reducing sound transmission within the frequency of range of the test.

The STC rating method and procedures are specified in the American Society for Testing Materials (ASTM) annual book of standards. The following floor-ceiling assembly was utilized as an example to the steps required in calculating the STC value:

❖ Conventional Steel Joist & Metal Deck with 1 5/8" Concrete and 5/8" Gypboard

**Step 1:** Calculate or look up TL data based on the floor-ceiling assembly chosen.

| Building Construction | Transmission Loss (dB) 125 Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz | STC Rating | IIC Rating† |
|---|---|---|---|---|---|---|---|---|
| 31. Construction no. 30 with 5/8-in gypsum board screwed to resilient channels spaced 24 in oc perpendicular to joists | 30 | 35 | 44 | 50 | 54 | 60 | 47 | 39 |
| 32. Construction no. 31 with 3-in glass-fiber insulation in cavity | 36 | 40 | 45 | 52 | 58 | 64 | 49 | 46 |
| 33. 4-in reinforced concrete slab (54 lb/ft²) | 48 | 42 | 45 | 56 | 57 | 66 | 44 | 25 |
| 34. 14-in precast concrete tees with 2-in concrete topping on 2-in slab (75 lb/ft²) | 39 | 45 | 50 | 52 | 60 | 68 | 54 | 24 |
| 35. 6-in reinforced concrete slab (75 lb/ft²) | 38 | 43 | 52 | 59 | 67 | 72 | 55 | 34 |
| 36. 6-in reinforced concrete slab with 3/4-in T&G wood flooring on 1 1/2 by 2 wooden battens floated on 1-in glass fiber (83 lb/ft²) | 38 | 44 | 52 | 55 | 60 | 65 | 55 | 57 |
| 37. 18-in steel joists 16 in oc with 1 5/8-in concrete on 5/8-in plywood under heavy carpet laid on pad, and 5/8-in gypsum board attached to joists on ceiling side (20 lb/ft²) | 27 | 37 | 45 | 54 | 60 | 65 | 47 | 62 |

**Figure 3:** Transmission Loss Data for Common Building Elements

**Step 2:** Plot the measured TL values against the frequencies ranging from 125 to 4000 Hz.

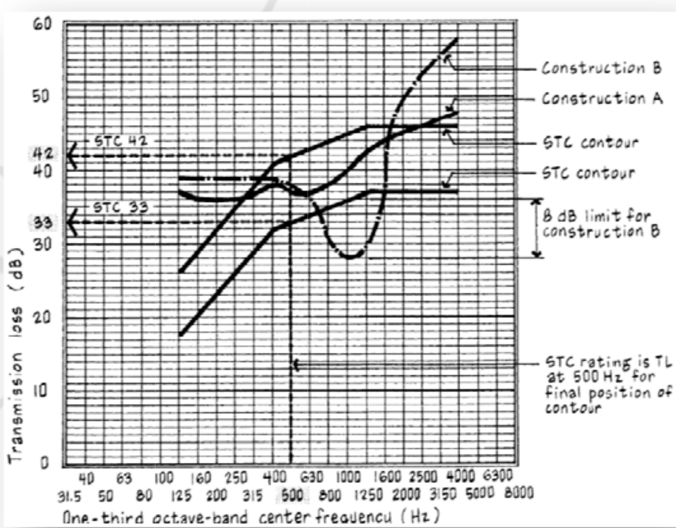



**Figure 4:** Example of Plotted Transmission Loss with STC Contour

**Step 3:** The STC rating, as shown in Figure 4, can be graphically determined by using a transparent overlay on which the STC contour is reproduced. The STC contour, as defined by ASTM, is shifted vertically relative to the plotted curve of test data to as high a final position possible according to the following limiting criteria:

- The maximum deviation of the test curve below the contour at any single test frequency shall not exceed 8 dB.
- The sum of the deviations below the contour at all 16 frequencies of the test curve shall not exceed 32 dB.

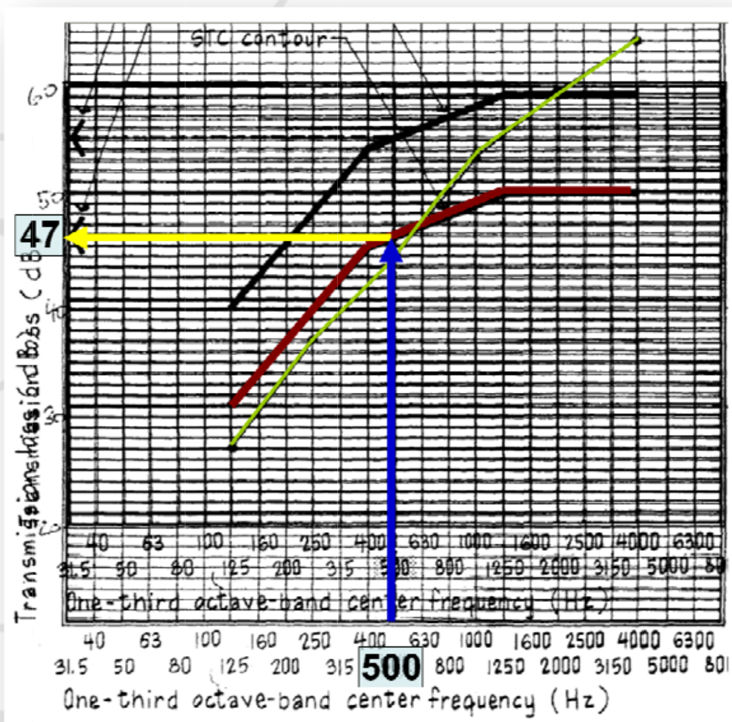



**Figure 5:** Conventional Steel Joist & Metal Deck Overlay

**Step 4:** Once the criteria has been met as shown in Figure 5, a vertical line is drawn from the 500 Hz frequency to the STC contour and then horizontally to the TL scale. The number read from the TL scale is the STC for that assembly. For this example, a conventional steel joist & metal deck overlay has an STC rating of 47.

**Note:** STC 50 is the minimum required for apartments and condominiums and must be in accordance with ASTM-E336 and ASTM-E90-70. If STC 50 is not reached further noise control parameters must be done.



IIC, according to *Architectural Acoustics* by David Egan, is defined as: a single-number rating of the sound transmission loss performance of a floor-ceiling construction measured at standard one-third octave band frequencies. The higher the IIC rating, the more efficient the construction will be in reading impact sound transmission within the frequency range of the test.

In the United States, the IIC rating method is recommended by the Federal Housing Administration (FHA) as a rating of impact sound isolation effectiveness for floor-ceiling assemblies. The same procedure used for calculating STC is applied for IIC. The only differences are listed as followed:

- ❖ Instead of measuring TL data, the Impact sound pressure level is measured in relation to the floor-ceiling assemblies.
- ❖ The Impact sound pressure level is plotted against the frequencies ranging from 100 to 3150 Hz. The IIC contour is applied utilizing the ASTM criteria as described in the STC procedure.
- ❖ The IIC rating is read off in similar fashion as shown in Figure 6 below.

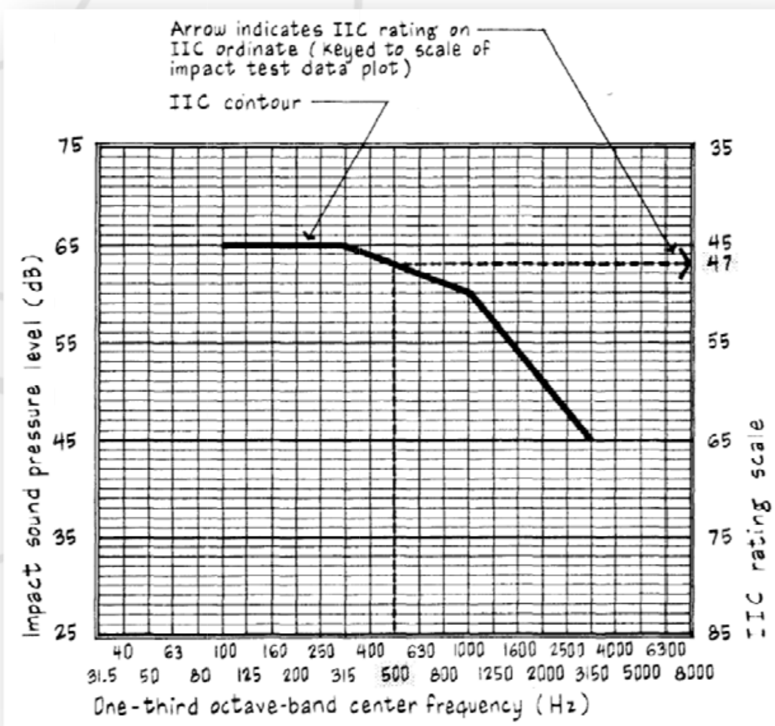



**Figure 6:** Example of IIC Rating Graph

The STC and IIC ASTM rating procedure has been performed numerous times and administrations like the California Department of Health Services have compiled a catalog of accepted STC and IIC ratings for Wall and Floor-Ceiling Assemblies. An example of what you would find in the catalog of STC and IIC Ratings for Wall and Floor-Ceiling Assemblies is as followed:

California Office of Noise Control 153 1980

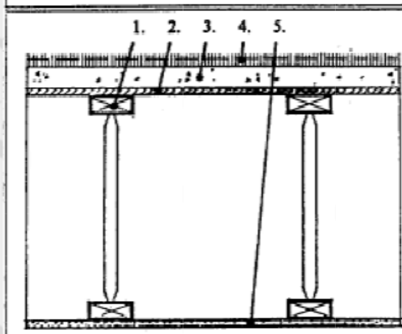
| Sketch | Brief Description | ... | Laboratory Test Number Year Frequencies Tested Source of Data | STC<br>IIC | Section Number |
|---|---|---|---|---|---|
|  | 1. 18" deep open-web joists, 16"o.c.<br>2. 5/8" plywood nailed to joists.<br>3. 1 5/8" lightweight concrete.<br>4. 44 oz. carpet on 40 oz. hair pad.<br>5. 5/8" gypsum board. | ... | Kodaras Acoustical Labs.<br>224-38-65<br>224-37-65<br>1965<br>11f<br>16f<br>American Plywood Assn. | 46<br>62 | 2.2.4.1.2.1 |



**Figure 7:** Catalog of STC and IIC Ratings for Conventional Steel Joist & Metal Deck

**Important Observation:** From the following information provided, you can see that the STC and IIC data are consistent for Conventional Steel Joist & Metal Deck:

**Figure 3:** TL Data for Common Building Elements
- ❖ STC: 47
- ❖ IIC: 62

**Figure 5:** Conventional Steel Joist & Metal Deck Overlay
- ❖ STC: 47

**Figure 7:** Catalog of STC and IIC Ratings for Conventional Steel Joist & Metal Deck
- ❖ STC: 46
- ❖ IIC: 62



### C.2.4.2.C The Manufacturer's Claim

The manufacturer Swirnow Building systems have made the claim that the Hambro D500 has the acoustical properties of reaching an STC 57 and IIC 30. The manufacturers have provided a chart below to show the relationship between the Hambro D500 and other floor-ceiling assemblies.

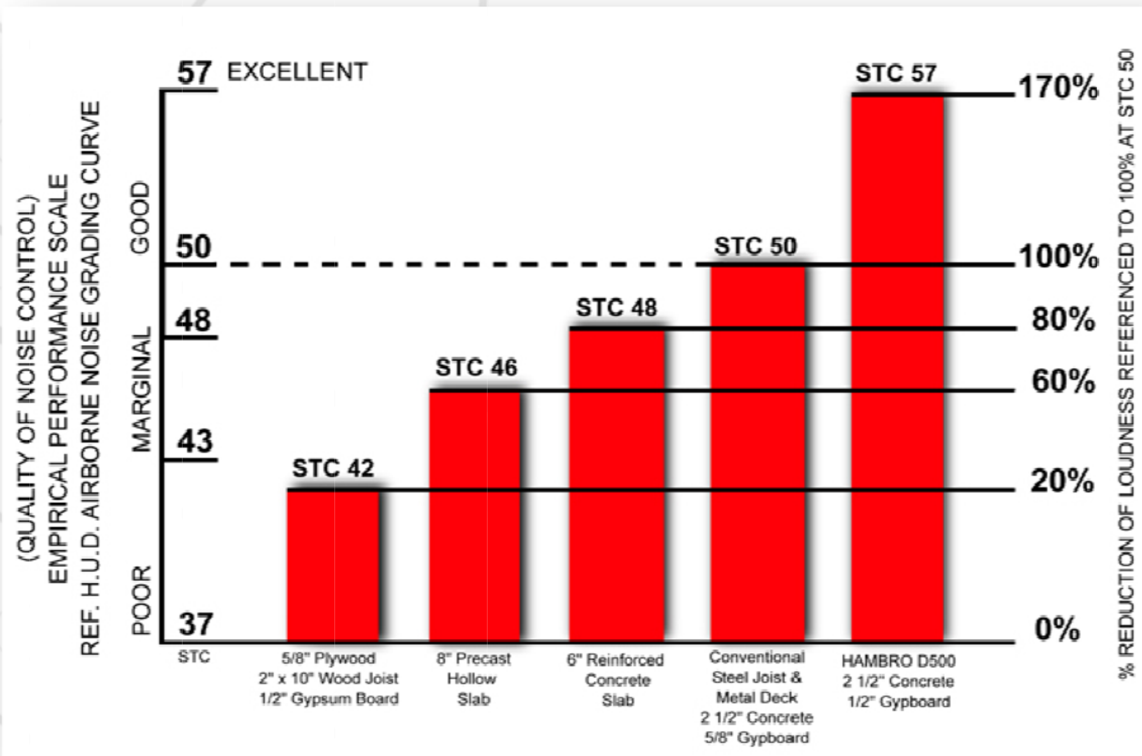



**Figure 8:** Manufacturer Swirnow Building Systems Comparison Chart

This chart as shown in Figure 8 shows that the Hambro D500 has a STC 57 and is considered excellent to the quality of noise control. Other floor-ceiling assemblies are compared as listed in the chart. But further investigation into this chart and other data reveals that this data is misleading to the normal viewer.

## HAMBRO SOUND INFORMATION

| Hambro Assemblies | STC | IIC |
|---|---|---|
| 2 1/2" slab, 1 layer 1/2" drywall | 52 | 26 |
| 3" slab, 1 layer 1/2" drywall | 57 | 30 |
| 4" slab, 1 layer 1/2" drywall | 58 | 32 |
| 4" slab, 2 layer 1/2" drywall | 60 | 36 |

Figure 9: Acoustical Property Specifications for the Hambro Assemblies

From Figure 9 we can see that the Hambro Assembly with a 2 ½" slab has a STC 52 and not STC 57 as specified in Figure 8.

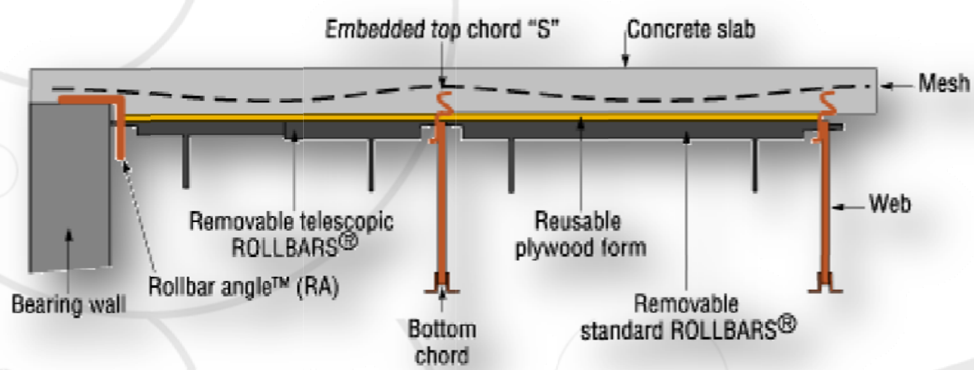
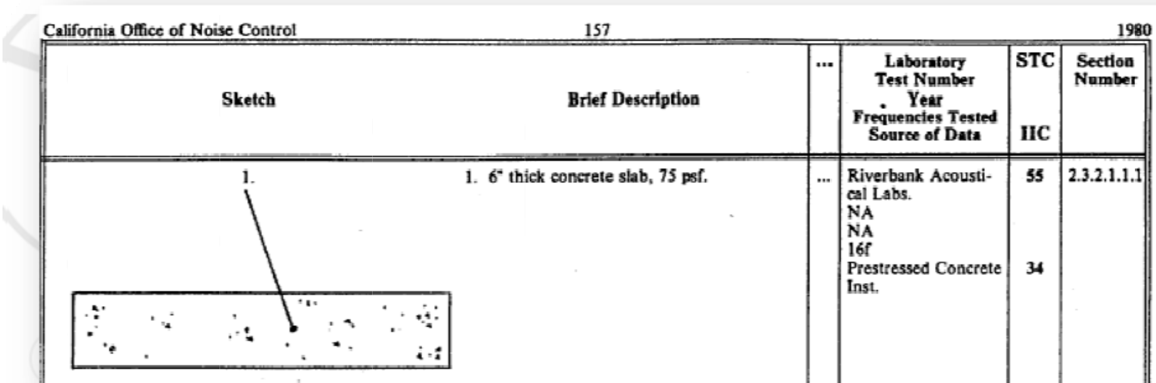



**Figure 10:** Hambro D500 Floor-Ceiling Assembly

From the above "Important Observation" it was concluded that Conventional Steel Joist & Metal Deck reached a maximum value of STC 47. In Figure 8, the manufacturers specify an STC 50.

In Figure 11 below; for 6" thick concrete slab a STC 55 is achieved. The manufacturers specify that 6" thick concrete slab achieves a STC 48.

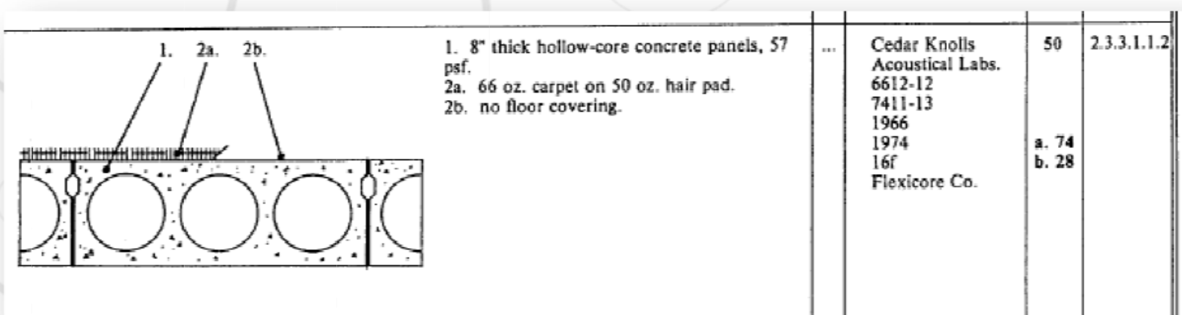


California Office of Noise Control 157 1980

| Sketch | Brief Description | ... | Laboratory Test Number • Year Frequencies Tested Source of Data | STC / IIC | Section Number |
|---|---|---|---|---|---|
| 1. | 1. 6" thick concrete slab, 75 psf. | ... | Riverbank Acoustical Labs. NA NA 16f Prestressed Concrete Inst. | 55 / 34 | 2.3.2.1.1.1 |

**Figure 11:** STC and IIC Ratings for 6" Thick Concrete Slab

Figure 12 below indicates that for 8" thick hollow slab a STC 50 is achieved. The manufacturers specify that 8" thick hollow slab achieves a STC 46.

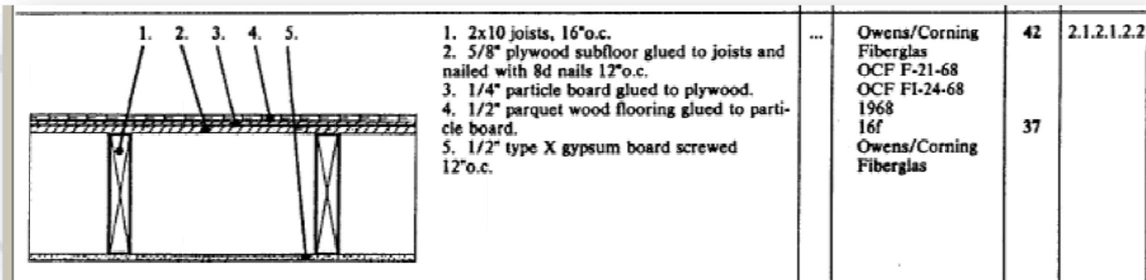


| | | | | | |
|---|---|---|---|---|---|
| 1. 2a. 2b. | 1. 8" thick hollow-core concrete panels, 57 psf. 2a. 66 oz. carpet on 50 oz. hair pad. 2b. no floor covering. | ... | Cedar Knolls Acoustical Labs. 6612-12 7411-13 1966 1974 16f Flexicore Co. | 50 / a. 74 b. 28 | 2.3.3.1.1.2 |

**Figure 12:** STC and IIC Ratings for 8" Hollow Slab

For a 2 x 10 Wood Joist Floor-Ceiling Assembly an STC 42 is achieved by the California Department of Health Services as indicated in Figure 13. The manufacturers Swirnow Building Systems have claimed that an STC 42 is achievable.





| | | | | | |
|---|---|---|---|---|---|
| 1. 2. 3. 4. 5. | 1. 2x10 joists, 16"o.c. 2. 5/8" plywood subfloor glued to joists and nailed with 8d nails 12"o.c. 3. 1/4" particle board glued to plywood. 4. 1/2" parquet wood flooring glued to particle board. 5. 1/2" type X gypsum board screwed 12"o.c. | ... | Owens/Corning Fiberglas OCF F-21-68 OCF FI-24-68 1968 16f Owens/Corning Fiberglas | 42 37 | 2.1.2.1.2.2 |

**Figure 13:** STC and IIC Ratings for 2 x 10 Wood Joist Floor-Ceiling Assembly

With all that information at hand updated versions of the floor-ceiling assemblies STC ratings have been compiled in Figure 14.

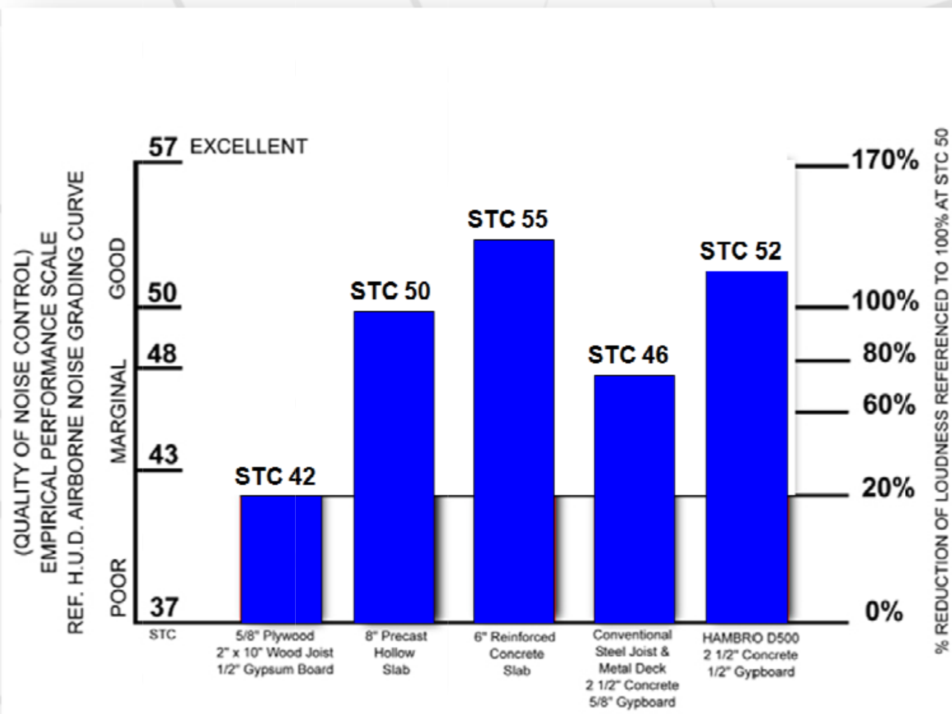



**Figure 14:** Updated Chart for STC Ratings for Floor-Ceiling Assemblies

Figure 14 now represents a clear picture of what floor-ceiling systems should be recommended based on STC rating. As it currently stands the 6" reinforced concrete slab achieves the highest rating for reducing apparent loudness of transmitted airborne noise such as speech, radio, TV, and music.

**STC RATINGS: WHAT THEY MEAN**

| STC Rating | Practical Guidelines |
|---|---|
| 25 | Normal speech easily understood |
| 30 | Normal speech audible, but not intelligible |
| 35 | Loud speech audible, fairly understandable |
| 40 | Loud speech audible, but not intelligible |
| 45 | Loud speech barely audible |
| 50 | Shouting barely audible |
| 55 | Shouting Inaudible |

**Figure 15:** What Does It All Mean?

By having a STC 52 for the Hambro D500 System this indicates that if shouting were to occur in an apartment or condominium above the sound would transfer through the floor-ceiling assembly.



**C.2.4.2.D Further Improvements to the Assembly**

Therefore on the Wellington Condominiums Project adjustments were made to minimize the sound and vibration transfer between floor-ceiling assemblies. Figure 16 is a floor-ceiling assembly detail that illustrates what the project team did to improve on architectural acoustics.

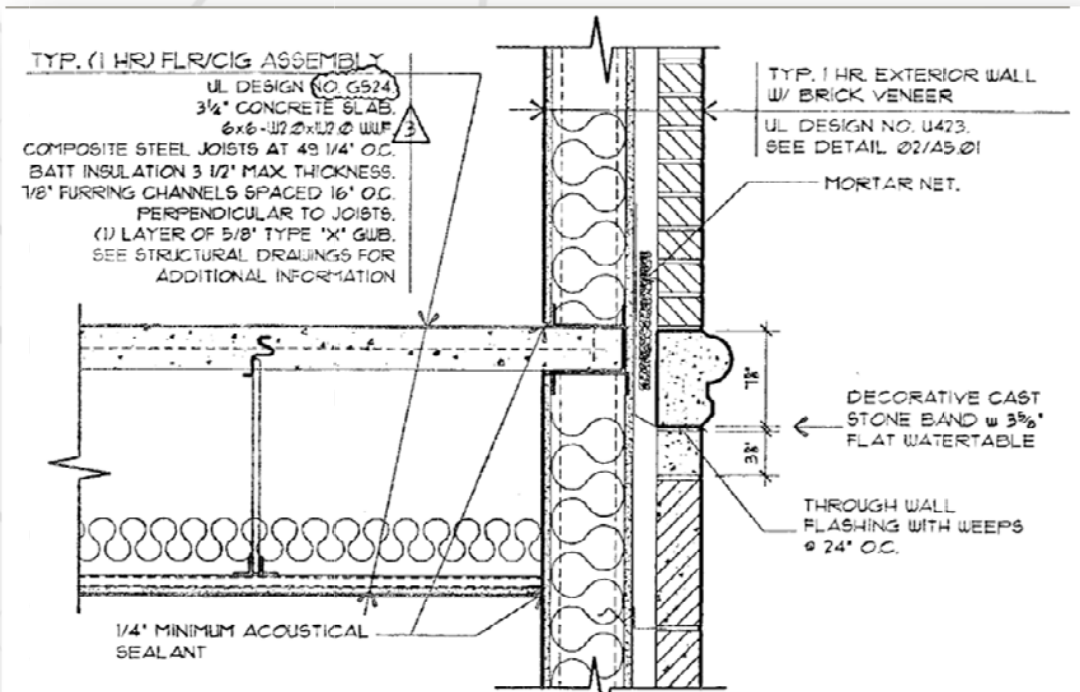



**Figure 16:** Wellington Condominiums Project Floor-Ceiling Assembly Detail

The following initial change that the Wellington Condominiums project team made is as followed:

- ❖ Went with 3 ¼” thick concrete slab

From this information, the Wellington Condominiums Hambro Joist Composite Deck System thru the utilization of the Hambro D500 floor-ceiling deck assembly will have an STC 57 and IIC 30.

The STC 57 achieved through the utilization of the Hambros Joist Composite Deck System meets IBC requirements of having at least STC 50 rating. With an STC 57, it means that all sound transmission will be isolated between floors. Shouting will be inaudible and create an atmosphere that luxury condominiums demand.

| Source room \ Receiving room | Bedroom | Living room | Kitchen | Bathroom | Family room | Corridor |
|---|---|---|---|---|---|---|
| Bedroom | 50 | 50 | 50 | 50 | 50 | 50 |
| Living room | 55 | 50 | 50 | 50 | 50 | 45 |
| Kitchen | 55 | 50 | 45 | 45 | 45 | 40 |
| Bathroom | 55 | 55 | 50 | 50 | 40 | 40 |
| Family room | 55 | 50 | 45 | 45 | 40 | 40 |
| Corridor | 50 | 45 | 40 | 45 | 35 | - |

**Figure 17:** STC Recommendations for Dwellings

Figure 17 indicates the STC level recommendations that should be achieved for a level of comfort for occupants. The highest STC rating achieved for dwellings occurs at STC 55 with a bathroom being the source room and a bedroom being the receiving room. Since an STC 57 is achieved on the Wellington Condominiums Project, no further analysis is needed due to sound transfer.

| Source room (located above) \ Receiving room (located below) | Bedroom | Living room | Kitchen | Bathroom | Family room | Corridor |
|---|---|---|---|---|---|---|
| Bedroom | 52 | 52 | 50 | - | 48 | - |
| Living room | 57 | 52 | 52 | - | 50 | - |
| Kitchen | 62 | 57 | 52 | - | 52 | - |
| Bathroom | - | - | 52 | 50 | - | - |
| Family room | 62 | 60 | 58 | - | - | - |
| Corridor | 62 | 57 | 52 | - | - | 48 |

**Figure 18:** IIC Recommendations for Dwellings

The current IIC 30 rating provided creates an issue when compare ratings to Figure 18. In Figure 18, the recommendations for dwellings are shown to indicate acceptable levels of impact noise between floor-ceiling assemblies.

Improvement must be made to prevent impact noises caused by walking, rolling carts, dropped objects, shuffled furniture, and slammed doors. On the Wellington Condominiums Project the project team did the following to prevent impact noises from transferring between floors:

- Added batt insulation with 3 ½” maximum thickness
- ¼” minimum acoustical sealant



**IIC AND STC IMPROVEMENTS FROM MODIFICATIONS TO FLOOR-CEILING CONSTRUCTIONS**

The table shows modifications to floor-ceiling constructions along with the corresponding estimated improvements in IIC and STC ratings. Floated floors can be more effective when installed on concrete slabs than on wood-joist flooring because concrete slabs provide more rigid support.

| Modifications to Basic Construction | IIC Improvement | STC Improvement |
|---|---|---|
| **Wood Joist** | | |
| Resiliently suspended ceiling | 8 | 10 |
| Floated floor | 8 | 10 |
| Sound-absorbing material in airspace of resiliently suspended ceiling | 7 | 2 to 4 |
| **Concrete Slab** | | |
| Resiliently suspended ceiling | 8 | 10 to 12 |
| Floated floor | 15 to 20 | 10 to 12 |
| Sound-absorbing material in airspace of resiliently suspended ceiling | > 5 | > 3 |
| Wood flooring (≥ 1/2 in thick) set in mastic | 7 | 0 |
| **Wood Joist or Concrete-Slab** | | |
| Vinyl tile | 0 to 5 | 0 |
| Linoleum (3/32 in thick) | 3 to 5 | 0 |
| Carpet on foam rubber underlay (use higher end of IIC range for concrete slab systems) | 20 to 40 | 0 |

**Figure 19:** IIC and STC Improvements to Floor-Ceiling Constructions

Figure 19 indicates that if a sound-absorbing material is added an IIC and STC improvement of 5 and 3 results respectively. Therefore a STC 62 and IIC 33 results due to the improvements listed in Figure 19. With an IIC 33 more improvement is still needed to isolate impact noise between floors.

For the Wellington Condominiums Project to ensure proper impact noise isolation a STC 62 should be reached. Therefore 29 additional points should be achieved to ensure occupants the luxury grandeur of the condominiums promised.



**IMPACT OF FLOOR FINISHES & HAMBRO FLOOR SYSTEM**

| Floor Finishes | Additional IIC Points |
|---|---|
| Carpet and Pad | 24 |
| Homasote 1/2" comfort base under wood laminate **www.homasote.com** | 18 |
| 6 mm cork under engineered hardwood | 21 |
| Dodge Regupol 4010 10 mm underlayment under ceramic tile **www.regupol.com** | 20 |
| Quiet Walk underlayment underlaminate flooring **www.mpglobalproducts.com** | 19 |
| Insulayment under engineered wood **www.mpglobalproducts.com** | 20 |
| 1 1/2" Maxxon gypsum underlayment over Enkasonic sound control mat with quarry tile over Noble Seal SIS **www.maxxon.com** | 28 |
| 1 1/2" Maxxon gypsum underlayment over Enkasonic sound control mat with wood laminate floor over silent step **www.maxxon.com** | 29 |
| 1 1/2" Maxxon gypsum underlayment over Enkasonic sound control mat w/Armstong Commissions Plus Sheet Vinyl **www.maxxon.com** | 27 |

**Figure 20:** Additional IIC Points

Figure 20 indicates additional IIC points that can impact the Hambro floor system. The IIC rating is strongly effected and dependent upon the type of floor finish for its resistance to impact noise transmission. To achieve high ICCs, the use of soft floor surfaces (carpet and pad), suspended ceilings, floated floors, and isolator hangers should be utilized. To gain the additional IIC Points necessary the 1 ½” Maxxon gypsum underlayments over Enkasonic sound control mat with wood laminate floor over silent step should be utilized. The utilization of this product will ensure total impact noise isolation for occupants. Other methods can be done in other areas that would not require such high IIC ratings. For example: The bedroom over bedroom in Figure 16 has an IIC rating recommendation of 52. Utilizing carpet and pad for this area will create an IIC 57 which is acceptable. But caution must be taken when a kitchen is over a bedroom because an IIC 62 is required and if utilize ceramic tile in the kitchen an IIC 53 results. This will create impact noises to the bedroom below and make the room unacceptable to current standards.

**C.2.4.2.E Suggestions for Improvement**

Therefore it is recommended that in order to achieve maximum sound and vibration isolation between floor-ceiling systems an STC 55 and IIC 62 should be achieved. The Hambros Joist Composite Deck System can achieve this if the following is done to the original assembly:

- Increase concrete slab thickness of 3 ¼”
- Add batt insulation with 3 ½” maximum thickness
- Apply ¼” minimum acoustical sealant
- Utilize 1 ½” Maxxon gypsum underlayment over Enkasonic sound control mat with wood laminate floor over silent step (This can be used with other materials but caution must be made.)

**C.2.4.2.F Architectural Acoustical Recommendation**

**Important Observation:** A quick comparison to Conventional Steel Joist & Metal Deck:

STC 47:
- Add floated floor or increase thickness of concrete slab
- Apply ¼” minimum acoustical sealant
- Results in STC 57

IIC 62:
- Already achieves IIC requirements of impact noise

Conventional Steel Joist & Metal Deck require less to improve acoustics of the assembly therefore could be an alternative to the Hambros Joist Composite Deck System.

**C.2.4.3.A Compare and Contrast other Floor-Ceiling Assemblies**

The Hambros Joist Composite Deck System is just one of the many floor-ceiling assemblies that are currently being utilized in the industry today. To fully understand if the Hambros Joist Composite Deck System was the correct choice for the Wellington Condominiums Project, a matrix chart was compiled to compare and contrast three similar systems. The three systems analyzed were: the Hambros Joist Composite Deck System, Conventional Steel Joist and Composite Deck System, and Epicore MSR Composite Floor System. The Hambros Joist Composite Deck System was explored in **Section C.2.4.1** while the other two systems are investigated as detailed below:

**C.2.4.3.B Conventional Steel Joist and Composite Deck System**

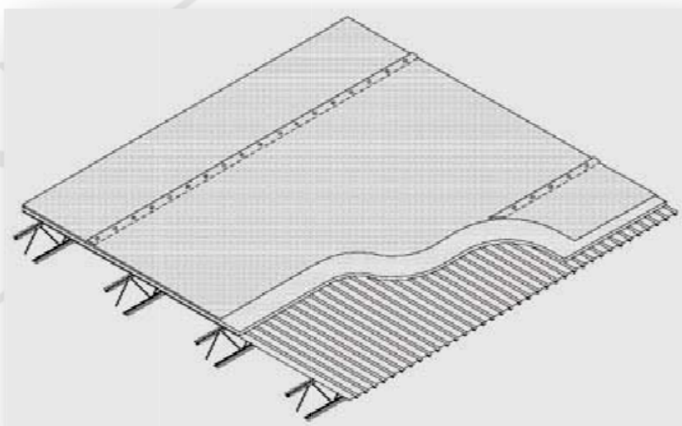


**Figure 21.A:** Conventional Steel Joist and Composite Deck System

As indicated in Figure 21.A, the Conventional Steel Joist and Composite Deck System utilize steel joists, metal deck, and concrete slab to forming the floor-ceiling assembly. The main difference with this system as compared to the Hambros Joist Composite Deck System is that the metal deck replaces the need for formwork. No formwork, shoring or re-shoring is required but bracing may be necessary during construction. Utilizing this system beneficially removes the need to remove any formwork and have an additional crew to finish surfaces.

| UL Design No. | Rating (hr) | Slab Thickness (in.) | Ceiling | Beam Rating |
|---|---|---|---|---|
| G003 | 2 | 2 ½ | Suspended Panel | - |
| G213 | 2 | 3 | Suspended Panel | 2 |
| | 3 | 4 | Suspended Panel | 3 |
| G227 | 2 | 2 ½ | Suspended Panel | 3 |
| G228 | 2 | 3 ¼ | Suspended Panel | 2 |
| G229 | 2 | 3 | Suspended Panel | 2 |
| | 3 | 4 | Suspended Panel | 3 |
| G524 | 2 | 2 ½* | Gypboard ½ | 2 |
| | 3 | 3 ½* | Gypboard ½ | 3 |
| G525 | 3 | 3 ¼ | Gypboard 5/8 | 3 |
| G702 | 1-2-3 | Varies* | Spray On | - |
| G802 | 1-2-3 | Varies* | Spray On | - |

* Note normal and lightweight concrete.

**Figure 21.B:** Conventional Steel Joist and Composite Deck System Fire Ratings (www.ul.com)

In Figure 21.B, the fire rating for a conventional steel joist and composite deck system is shown to indicate a 2 or 3 hour fire rating which exceeds the requirements of 1 hour.

### C.2.4.3.C Epicore MSR Composite Floor System


**Figure 22.A:** Epicore MSR Composite Floor System (www.infinitysystems.com)

Infinity Structural Systems developed a floor-ceiling assembly that is similar in idea to the Conventional Steel Joist and Composite Deck System without metal joists. This system utilizes an Epicore MSR Deck which spans on top of pre-panelized load-bearing metal stud walls. Similar to the Hambros Joist Composite Deck System but requires no formwork due to the Epicore MSR Deck. The only disadvantage to this system as compared to the other systems is that shoring and re-shoring is required. The main advantage to this system is that it saves on formwork and the labor intensive placement of steel joists. It is up to the project team to decide on what system works best for the given situation at hand.

U.L. Fire Ratings
U.L. Design Number D938

| Restrained* Rating Required | Total Slab Depth (Inches) | Type and Weight of Concrete (pcf) |
|---|---|---|
| 1 hour | 4 | RW (147) |
| 1 hour | 3¾ | LW (110) |
| 1½ hour | 4½ | RW (147) |
| 1½ hour | 4 | LW (110) |
| 2 hour | 5 | RW (147) |
| 2 hour | 4¼ | LW (110) |

* For unrestrained rating, refer to Underwriters Laboratories, Inc. Fire Resistance Directory.

NOTES:
RW - regular weight concrete
LW - lightweight concrete

**Figure 22.B:** Epicore MSR Composite Floor System Fire Ratings (www.infinitysystems.com)

Also shown in Figure 22.B are the fire ratings for Epicore MSR Composite Floor System without any other material such as gypboard, spray on, or suspended panels. This has by itself a rating of 1 hour which matches the fire rating for the Wellington Condominiums project requirement.

**C.2.4.3.D Main Comparison and Contrast between Systems**

The main comparison factors are listed as followed between the three systems:

❖ Hambros Joist Composite Deck System:

Joists: Required
Formwork: Required
Shoring and Re-shoring: Not Required

❖ Conventional Steel Joist and Composite Deck System:

Joists: Required



Formwork: Not Required
Shoring and Re-shoring: Not Required

❖ Epicore MSR Composite Floor System:

Joists: Not Required
Formwork: Not Required
Shoring and Re-shoring: Required

Interviews from numerous industry members confirm that one of the controlling factors in the selection of floor systems is labor. Specifically, how much labor is required to construct the system to the project specifications? The most labor intensive systems of the same level of specifications are not highly recommended by most industry members. Therefore by initial comparison of the systems, it can be seen that the Hambros Joist Composite Deck System requires the most labor involvement while the Epicore MSR Composite Floor System requires the least labor involvement. This is primarily due to the labor intensity of joist layout during construction and formwork placement and stripping.

To confirm that the Epicore MSR Composite Floor System may be the best assembly for the project team; each floor-ceiling assembly was broken down into 12 categories of interest and rated on a scale based on how well the system performs for the Wellington Condominiums Project.

**Note:** The schedule and cost estimate for each of these systems are very similar and fluctuate greatly from project to project. When talked to manufacturers the ranges ranged greatly and therefore are not a major comparison factor in the analysis.

*~See the Attached Appendix for Comparison of Systems~*



#### C.2.4.3.E Conclusion

From the analysis we can determine that for the Wellington Condominiums Project the selection of the Epicore MSR Composite Floor System would have been best. Even though the Hambros Joist Composite Deck System scored an “Okay-Good” rating, the Epicore MSR Composite Floor System scored a “Good-Great” rating. One of the reasons for this is due to labor. Labor is a controlling factor and dictates what the schedule and budget will be for a given project. Due to the project team’s inexperience with the Hambros Joist Composite Deck System and its related properties; the Epicore MSR Composite Floor System may have been an overall better solution to the Wellington Condominiums Project.

### C.2.4.4 Improvements when Constructing Hambro

The project team ran into problems that caused delays and change orders. One of the problems project managers were having on the project site was the labor intensity of installing the Hambros Joists. These joists had to be moved into position by hand and then aligned accordingly. If the project team was able to use a crew or brought on a consultant that had experience with the system; delays and change orders would not be a high probability of occurrence. Other improvements such as acoustics should be taken into consideration when constructing a floor-ceiling assembly such as the Hambros Joist Composite Deck System.

### C.2.4.5 Projects Best Suited for Hambros Joist Composite Deck System

From the analysis, it can be determined that for the Wellington Condominiums Project the utilization of the Hambros Joist Composite Deck System could have been better suited for other projects. Some of the issues that have arisen during construction that have made the Hambros Joist Composite Deck System unpractical for the Wellington Condominiums Project are due to: the project team’s inexperience with the system, highly labor intensive system, acoustical demands for the living spaces, constraints of the formwork system selection process, and non-repetitive joist spacing layout.

From industry interviews it was determined that the following points of reference be utilized when considering the implantation of the Hambros Joist Composite Deck System:

- Repetitive Joist Spacing and Uniformity Throughout
- Sound Vibration not a critical factor in the building design
- Have highly skilled labor
- Recommended Use: Factories, Stores, Warehouses, Malls, Airports
- Not Recommended Use: Retirement Homes, Hospitals, Hotels, and Luxury Apartments and Condominiums



# C.3 Foundation Redesign ~ *Structural Breadth*

**Figure 1:** Foundation Excavation

The Current Foundation System for the Wellington Condominiums has been analyzed and is broken down as followed:





## C.3.1 Problem Statement

With poor subsurface conditions prevalent, can the foundation system be redesigned to possibly reduce cost and time spent without interfering with architects or owner needs?

This problem was identified through the geotechnical reports, change orders, and project manager interviews. A lot of money, time, and energy were spent by the project team having to deal with poor subsurface conditions. An analysis communicating some potential solutions is one study of great interest to many on the Wellington Condominiums Project.

## C.3.2 Proposed Solution

A possible solution to the Wellington Condominiums Project is for a structural redesign of the foundation system. A structural breath will be utilized in the analysis of the comparison between the current and proposed systems. The current foundation system makes use of single slab column footings and will be challenged through the redesign of a matt slab foundation. A matt slab foundation system is proposed and will be researched to do the following possibilities:

1. Save time and money by not having to excavate as deep in rock material.
2. If footing depth can be decreased possible savings in the dewatering system could happen.
3. Using a matt slab could reduce the strength needed for foundation concrete and also if designed correctly act as a slab on grade. This could potentially save time and cost to the project.

## C.3.3 Analysis Steps

The procedure to investigating if a matt slab foundation system would be more viable than a traditional single slab column footing is as followed:

1. Learn in more detail and have available the single slab column footing's estimate, schedule, design documentation, specifications, and methods of construction.
2. Redesign the foundation system utilizing a matt slab foundation. Figure out how much material, cost, and time would be spent to construct.
3. Compare the two systems and create a matrix chart based on the owner requirements of which system overall is better for the project.

## C.3.4 Analysis Result Overview

The matt slab foundation system at first seems to be an ironic system to select rather than pouring single slab column footings. When looking at the following items: cost and time spent to rock excavate by rock hammering, putting in a extensive permanent dewatering system and support equipment, weeks of delays that would push back the façade construction to the winter months, and the structural engineer specifying the use of 6,000 PSI concrete for footings. Once you look at all those variables the cost and ease of simply pouring the entire slab may be a better alternative. Also the analysis can be swayed either way by the owners inputs of the foundation system based on a matrix chart.

### C.3.4.1.A Overview of the Current Wellington Condominium's Foundation System

The Wellington Condominium's foundation consists of a large part of the cast in place concrete that was done on the construction site. The type of horizontal and vertical formworks and concrete placement methods of the foundation are described in more detail as followed:

**Footings:**

- Normal weight concrete with a minimum compressive strength of 3,000 PSI at 28 days (This was value engineered due to the CM questioning the specified 6,000 PSI compressive strength in the contract documents by the engineer of record.)
- Reinforcing will consist of A615, Grade 60
- Average size of column footing 15'L X 15'W X 18"D
- Minimum of 3 feet below finished surface where exposed to frost
- Minimum allowable bearing pressure of 3,500 PSF

**Figure 2:** Wellington Condominium's Foundation



**Slab on Grade:**

- 5 inches of normal weight concrete with a minimum compressive strength of 3,000 PSI at 28 days
- Reinforced with 6 X 6 – W2.1 X W2.1 welded wire fabric, over a 14 inch crushed stone sub base and vapor barrier

**Foundation Bearing and Shear Wall Construction**: (includes exterior and stair and tower walls)

- 8” and 12” normal weight reinforced concrete with a minimum compressive strength of 3,000 PSI at 28 days

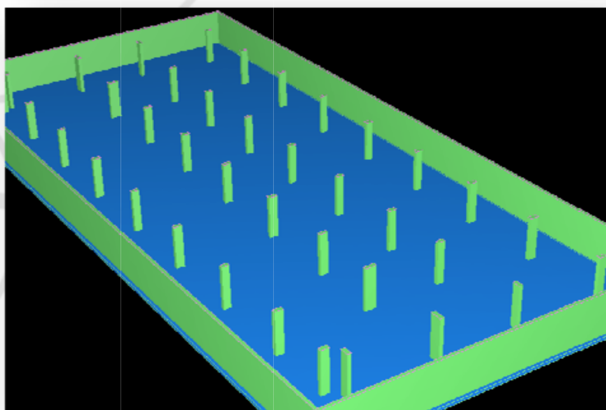


**Figure 3:** Substructure from RAM Concept

Since the soil at the time had enough cohesion to stay in place, the foundation strip and column footings did not require any horizontal or vertical formwork. The only task left was to situate the footing rebar and place the concrete with a concrete pump at the locations required. Once the footings were to the strength required, the foundation’s exterior walls and columns took form with large gang forms. These large forms took shape very quickly with a 120 ton AmQuip crane tipping up each one into position. The formwork was connected and reinforced into place with lateral bracing. After the formwork was set and properly supported, the rebar was placed in the foundation walls and columns. Following inspection from the project management team, the concrete was placed with a concrete pump and allowed time to gain strength.



### C.3.4.1.B Original Estimate and Schedule

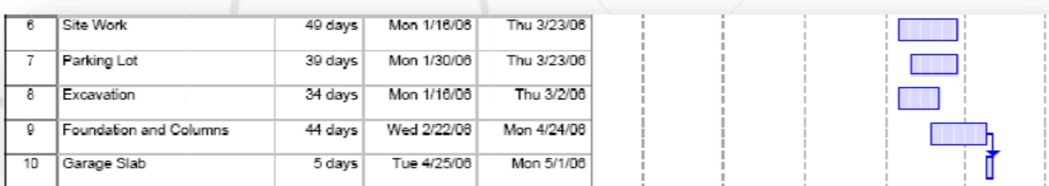
The Wellington Condominium's original foundation system estimate and schedule are detailed as followed:

**Original Estimate:**

| | |
|---|---|
| • Single Slab Column Footings: | $104, 374 |
| • Wall Strip Footings: | $13,070 |
| • Foundation Walls: | $133,139 |
| • Foundation Columns: | $33,488 |
| • Slab on Grade: | $73,048 |
| **Total:** | **$357,119** |

*~See Attached Appendix for Detailed Structural Takeoff~*

**Original Schedule:**



| | | | | |
|---|---|---|---|---|
| 6 | Site Work | 49 days | Mon 1/16/06 | Thu 3/23/06 |
| 7 | Parking Lot | 39 days | Mon 1/30/06 | Thu 3/23/06 |
| 8 | Excavation | 34 days | Mon 1/16/06 | Thu 3/2/06 |
| 9 | Foundation and Columns | 44 days | Wed 2/22/06 | Mon 4/24/06 |
| 10 | Garage Slab | 5 days | Tue 4/25/06 | Mon 5/1/06 |

**Total: 83 Work Days = 17 Weeks**
**Mon 1/16/06 – Mon 5/1/06**

*~See Attached Appendix for Full Schedule~*

### C.3.4.1.C Geotechnical Report Summary

The Wellington Condominium's project team hired on Earth Engineering, a geotechnical engineer and geologist company located in East Norriton PA, to perform a geotechnical investigation for the site conditions at Wellington Condominiums. Fifteen test borings were completed for the investigation from May 23 through May 25, 2005. The borings were conducted by Main Line Drilling Company of Wayne, PA and were field located to the project team's specifications by the surveyor Hopkins and Scott, Inc. A representative of Earth Engineering supervised and monitored the test boring activities.

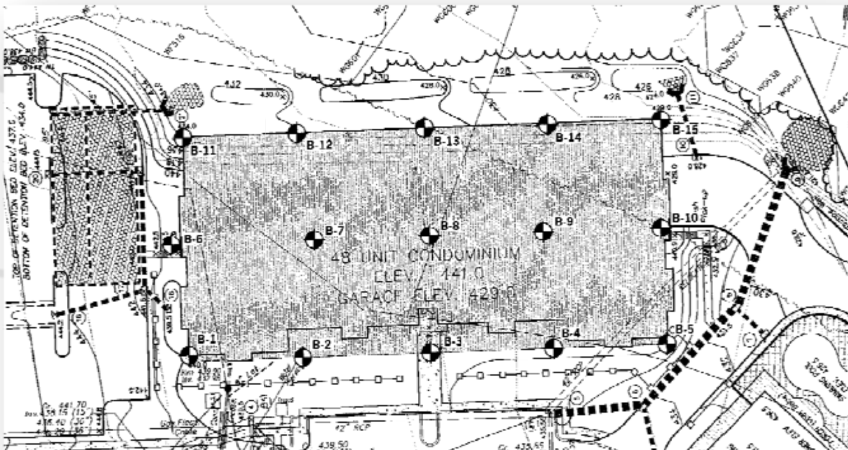



**Figure 4:** Site Boring Investigation

The laboratory results indicated that the soil classification for a majority of the soil according to ASTM specifications was sandy silt. It has a bearing capacity of 4 KSF and a fair drainability record. Groundwater was encountered at all of the boring locations and as much as 5 feet above the proposed finished floor garage. Earth Engineering recommends raising the finished floor grade or providing permanent waterproofing and drainage system to maintain groundwater levels below the proposed finished floor grade. Substantial soil and rock excavations below the existing grade must be done to achieve the correct soil bearing pressure.

*~See Attached Appendix for Test Boring Results~*

**C.3.4.1.D Foundation Construction**

The project team armed with this information knew that soil conditions would be an issue and therefore took the recommendation of Earth Engineering to provide waterproofing and permanent dewatering systems to the foundation system. The architects did not want to raise the finished floor grade due to the parking garage at the foundation level. An increase in elevation would make the parking garage more visible and possibly make the building less architecturally pleasing.  During excavation the project team encountered poor subsurface conditions and had to take extra measures through change orders to ensure a proper foundation design. During the course of excavation the following amounts of change orders had to be conducted to correct the poor subsurface conditions:

| # | Change Orders<br>DESCRIPTION | AMOUNT |
|---|---|---|
| 1 | Site plan topography wrong, and poor soils had to be excavated | $20,000 |
| 2 | Unsuitable soils | $38,487 |
| 3 | Unsuitable soils | $4,709 |
| 4 | Unsuitable soils | $12,942 |
| 5 | Change under slab drainage pipe from SDR35 to SCH40 so it won't get crushed. It wasn't spec'd. | $1,930 |
| 6 | Unsuitable soils | $35,808 |
| 7 | Rock Crusher | $43,000 |
| 8 | Additional cleanouts and floor drains at garage | $1,749 |
| 9 | Footing over-excavation and lean fill | $12,620 |
| 10 | Add'l 3" ID binder | $1,391 |
| 11 | Unsuitable soils | $10,000 |
| 12 | Waterproofing | $80,000 |
| | **TOTAL CHANGES** | **$253,159** |

**Figure 5:** Foundation Change Orders

The total amount for change orders was $253,159 and resulted in a total payout of $610,278. This ended up being a 70% increase in the total budget for the foundations. The encounter of poor subsurface conditions led to delaying the project by more than 3 weeks. This created a domino effect to the entire schedule and was one of the major reasons why the façade construction was pushed to the middle of winter.

### C.3.4.2.A Overview of the Foundation Redesign

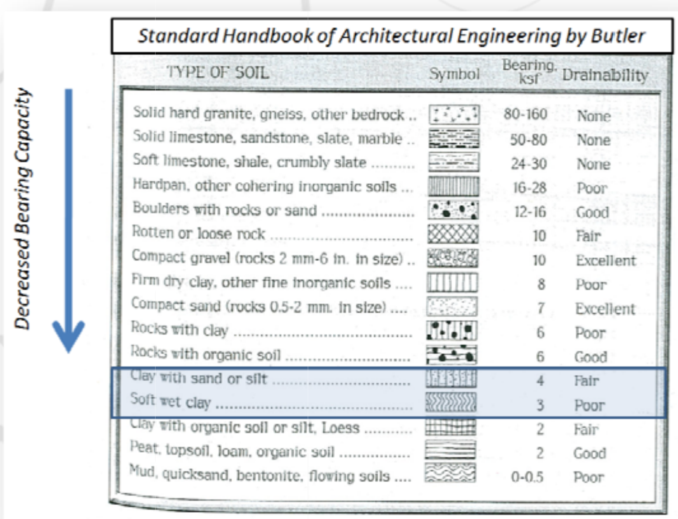
With the encounter of poor subsurface conditions there was an opportunity to investigate whether or not the foundation system should have been changed. It is through this analysis to decide whether or not a redesign of the foundation system would be deemed a viable solution. The selection of a particular foundation was based on a number of factors from the *Building Design and Construction Handbook by Merritt* and is as followed:

1. **Adequate Depth:** Preventing frost damage and undermining by scour.
2. **Bearing Capacity Failure:** Foundation must be safe against failure.
3. **Settlement:** Must not settle to the extent that it damages the structure.
4. **Quality:** Must have adequate quality so that it is not subjected to deterioration.
5. **Adequate Strength:** Must be built to sufficient strength so that it does not fracture or break apart under superstructure loads. The foundation construction must conform to design specifications.
6. **Adverse Soil Changes:** The foundation must be able to resist adverse soil conditions. Expansive soils such as silt and clay could expand or shrink, causing movement of the foundation and damage to the structure.
7. **Seismic Forces:** Foundation must be able to support the structure during an earthquake without excessive settlement or lateral movement.

Footing types other than spread footings are usually used for the following reasons and were used as a guide from the *2007 RS Means Assemblies Data* to the selection of the Wellington Condominiums foundation redesign:

1. Bearing Capacity of soil is very low.
2. Very large footings are required, at a cost disadvantage.
3. Soil under footing is very compressible, with the probability of causing excessive or differential settlement.
4. Good bearing soil is deep.
5. Potential for scour action exists.
6. Varying subsoil conditions within building perimeter.

All these reasons apply to the Wellington Condominium Foundation. The bearing capacity can only be designed to withstand 3500 PSI which is considered fairly low. With varying subsoil conditions within the building perimeter, comes the requirement of utilizing large and deep footings to prevent excessive settlement and have good bearing soil.



*Standard Handbook of Architectural Engineering by Butler*



| TYPE OF SOIL | Symbol | Bearing, ksf | Drainability |
|---|---|---|---|
| Solid hard granite, gneiss, other bedrock | | 80-160 | None |
| Solid limestone, sandstone, slate, marble | | 50-80 | None |
| Soft limestone, shale, crumbly slate | | 24-30 | None |
| Hardpan, other cohering inorganic soils | | 16-28 | Poor |
| Boulders with rocks or sand | | 12-16 | Good |
| Rotten or loose rock | | 10 | Fair |
| Compact gravel (rocks 2 mm-6 in. in size) | | 10 | Excellent |
| Firm dry clay, other fine inorganic soils | | 8 | Poor |
| Compact sand (rocks 0.5-2 mm. in size) | | 7 | Excellent |
| Rocks with clay | | 6 | Poor |
| Rocks with organic soil | | 6 | Good |
| Clay with sand or silt | | 4 | Fair |
| Soft wet clay | | 3 | Poor |
| Clay with organic soil or silt, Loess | | 2 | Fair |
| Peat, topsoil, loam, organic soil | | 2 | Good |
| Mud, quicksand, bentonite, flowing soils | | 0-0.5 | Poor |

**Figure 6:** Properties of Soils

From Figure 6, it can be shown that the bearing capacity for the soils at Wellington Condominiums is poor and that the drainability is between the range of fair and poor. Therefore due to the reasons listed above, it was determined to analyze the redesign of the Wellington Condominiums foundation system by utilizing a mat foundation.

**C.3.4.2.B Mat Foundation Concept Applied to Wellington Condominiums**

According to the *Building Design and Construction Handbook by Merritt,* a mat foundation is defined: as a single combined footing for an entire building unit. It is economical when building loads are relatively heavy and the safe soil pressure is small. Based on economic considerations according to the *Building Design and Construction Handbook by Merritt*, mat foundations are constructed for the following reasons and are judged against the Wellington Condominiums circumstances:

1. **Large Individual Footings:** A mat foundation is often constructed when the sum of individual footing areas exceeds about ½ of the foundation area.

   Wellington Condominiums Calculation:
   - 259’ x 121’ Building Area = 31,339 SQ FT
   - 36 Footings x (20’ x 20’ Max Footing Area) = 14,400 SQ FT
   - (14,400 SQ FT / 31,339 SQ FT) x 100 = 45.95% < 50% SUM

   From the calculation, it can be determined that approximately 46% of the footing area is below the rule of thumb value but is within consideration for mat foundation.
2. **Cavities or Compressible Lenses:** Mat foundation used when subsurface exploration indicates that there will be unequal settlement below the foundation due to small cavities or compressible lenses. A mat foundation would distribute the load more evenly and create better conditions for any possible settlement.

   Wellington Condominiums Analysis Viewpoint:
   - Cavities or Compressible Lenses have not been indicated in the geotechnical reports or have been an issue during construction.
   - Minimal value has been placed on cavities or compressible lenses for this analysis.
3. **Shallow Settlements:** A mat foundation can be recommended when shallow settlements predominate and the mat foundation would minimize differential settlements.

   Wellington Condominiums Analysis Viewpoint:
   - Differential Settlement was identified in the geotechnical report and has been a large concern to the project team.
   - Large consideration has been placed on how the foundation settlements would be with a mat foundation system.
4. **Unequal Distribution of loads:** Large disparity in building loads acting on different areas of the foundation can be subjected to excessive differential settlement with conventional spread footings. Using a mat foundation would tend to distribute the unequal building loads and reduce the differential settlements.

Wellington Condominiums Analysis Viewpoint:

- The column and wall loading varies and therefore different column sizes and spread footings are utilized. The largest spread footings are constructed at the corners and center of the foundation.
- Unequal distribution of loads is something to consider but is not a major focus for the design of the Wellington Condominiums mat foundation redesign analysis. Load distribution will be considered in the analysis for completeness.

5. **Hydrostatic Uplift:** A mat foundation could be used to resist uplift forces due to a high groundwater table.

Wellington Condominiums Analysis Viewpoint:

- Groundwater at the project site is of huge concern to the project team. Extensive groundwater measures had to be in place before construction could ever begin.
- Any reduction in waterproofing or groundwater measures from the utilization of a mat slab would be of great savings in budget and schedule.

**C.3.4.2.C Mat Foundation Design Background**

The design background for a mat foundation tends to be very complicated and requires extensive knowledge and experience. Being said there are many articles and programs that engineers use when considering the design of a mat foundation system. Some of the design criteria outlined in the *Building Design and Construction Handbook by Merritt* are as followed:

1. Weight of soil excavated for the foundation decreases the pressure on the soil under the mat. If excavated soil weighs more than the building, there is a net decrease in pressure at mat level from that prior to excavation.
2. When the mat is rigid, a uniform distribution of soil pressure can be assumed and the design can be based on a statically determinant structure as shown in the Figure 7 below.
3. If the centroid of the factored loads does not coincide with the centroid of the mat area, the resulting nonuniform soil pressure should be used in the strength design of the mat.
4. Strength-design provisions for flexure, one-way and two-way shear, development length, and serviceability should conform to ACI 318 Building Code Requirements.

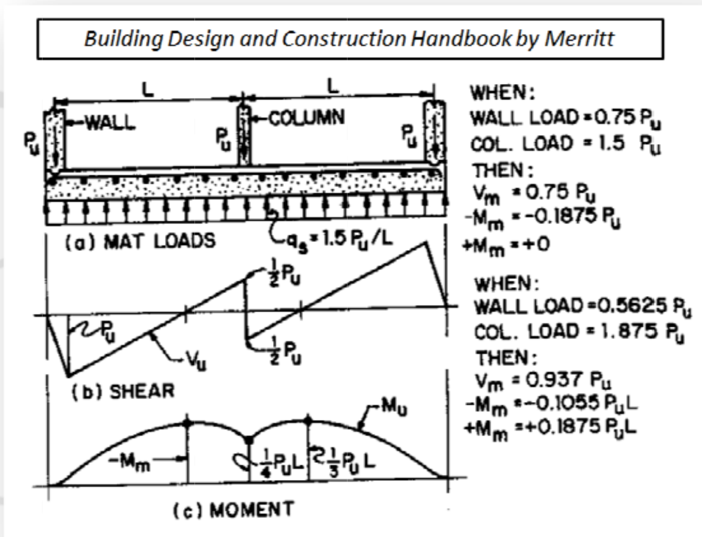



**Figure 7:** Design Conditions for a Rigid Mat Footing

### C.3.4.2.D Mat Foundation Design Input Data and Assumptions

A mat foundation design was created through the utilization of PCA MAT® Software by Structure Point. This software specializes in the complicated design of mat foundations. Before utilizing the software and inputting data, information background about the foundation conditions had to be identified.

- Earth Engineering has assumed and indicated in contract documents that the column loads will not exceed 473 kips, and that the wall loads will not exceed 10 kips per lineal foot. Earth Engineering has assumed that no unbalanced moments or lateral loads are imposed on the columns and walls. Based on these assumptions, Earth Engineering estimated that the total settlement to be less than one inch and the differential settlement to be within tolerable limits.
- Concrete
    - Compression Strength: 3 KSI
    - Unit Weight: 145 PCF
    - Young's Modulus: 3155.92 KSI
    - Poisson's Ratio: 0.15
- Soil
    - Subgrade Modulus: 50 KCF
    - Allowable Pressure: 3.5 KSF
- Steel
    - Yield Strength: 60 KSI

    - Young's Modulus: 29,000 KSI
- Design Parameters
    - Minimum Reinforcing Ratio (% of gross area): 0.18
    - Top and Bottom Reinforcing
        - X-Direction: 3.25 inches
        - Y-Direction: 3.5 inches
- Column Dimensions (from construction documents)
- Slaved Nodes: Rx Degree of Freedom
- Loads and Load Combinations
    - Service
    - Ultimate

### C.3.4.2.E Mat Foundation Design

Once the data has been inputted and assigned to elements in the PCA MAT® Software program, results can be quickly attained. The advantage to this software is analyzing how thick a mat slab has to be to properly support the required loads of the structure. Simply changing the thickness in the input data will update the results for the viewer to see. The goal is to get the thickness of the mat foundation as thin as possible due to the controlling cost of concrete and reinforcement. Also by decreasing the depth of the foundation better control over hydrostatic uplift, load distribution, and settlements will occur.

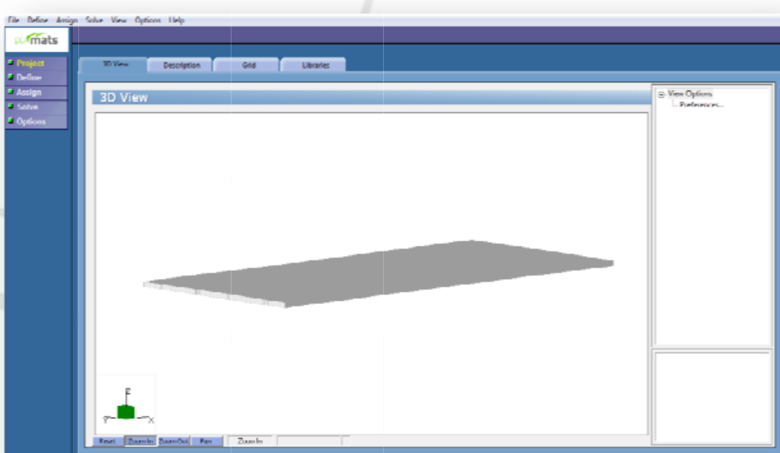
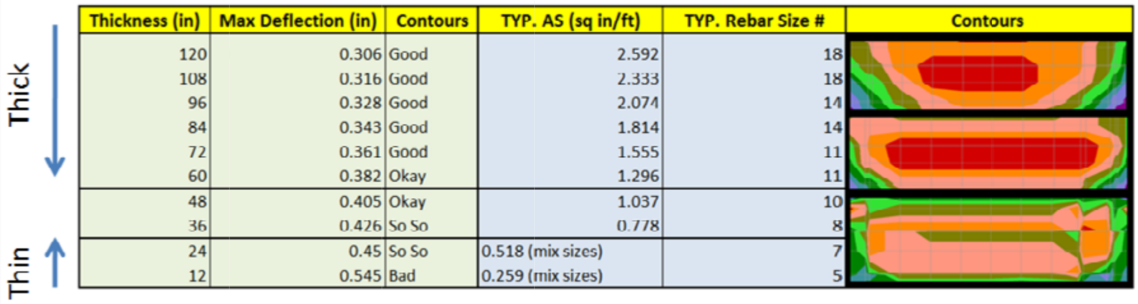



**Figure 8:** PCA MAT® Software

For the design analysis the following thickness will be looked at to determine the most appropriate for the Wellington Condominiums mat foundation system: 120", 108", 96", 84", 72", 60", 48", 36", 24", and 12". With each thickness the amount of reinforcing, deflection settlement, and moment capacity will be determined. The best combination of the three will result in the selected mat foundation thickness. The chart below shows the results of the analysis using the PCA MAT® Software.

PCA MAT® Analysis Results Chart

| Thickness (in) | Max Deflection (in) | Contours | TYP. AS (sq in/ft) | TYP. Rebar Size # |
|---|---|---|---|---|
| 120 | 0.306 | Good | 2.592 | 18 |
| 108 | 0.316 | Good | 2.333 | 18 |
| 96 | 0.328 | Good | 2.074 | 14 |
| 84 | 0.343 | Good | 1.814 | 14 |
| 72 | 0.361 | Good | 1.555 | 11 |
| 60 | 0.382 | Okay | 1.296 | 11 |
| 48 | 0.405 | Okay | 1.037 | 10 |
| 36 | 0.426 | So So | 0.778 | 8 |
| 24 | 0.45 | So So | 0.518 (mix sizes) | 7 |
| 12 | 0.545 | Bad | 0.259 (mix sizes) | 5 |




From the PCA MAT® Chart, it can be shown that the ideal thickness for the mat foundation lies between 48" and 36". Above the results creates large rebar sizes and thick mat slabs which are unnecessary to carry the structural load. Below the results creates mixed rebar sizes and bad settlement contours. Therefore it is recommended that a 48" mat slab be utilized due to the settlement contours and typical rebar sizes that are commonly found in constructing foundations. This value tends to be on the conservative side of the given results.

*~See Attached Appendix for PCA Mat® Contours*
*And Analysis Calculations~*

**C.3.4.2.F Other Mat Foundation Design Considerations**

One of the major concerns addressed on the project site other than poor subsurface conditions was the high water table. As an example in Figure 9, the Boring B-5 Garage Finished Floor Elevation (G.F.F.E.) and groundwater depth is at 429.00 feet and 423.00 feet respectively. With a 4 foot mat foundation there will be an additional 2 feet above the groundwater depth level.

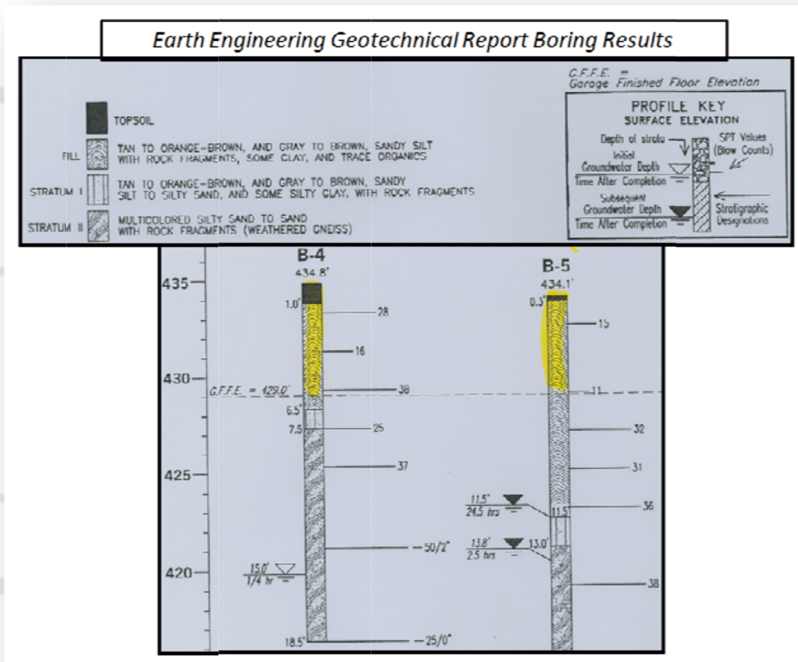



**Figure 9:** Geotechnical Boring Results from Earth Engineering

More concern by the project team was given for the depth of the groundwater table at B-1, B-6, and B-11. The groundwater table was above the G.F.F.E. and something needed to be done. The project team decided at the beginning of the project to install first the dewatering system and an excellent waterproofing system. This proved to pay dividends when constructing the foundation system. Even though the soil was considered poor, construction workers with the dewatering system were provided a dry area to work in. If the permanent dewatering system was not installed prior to foundation construction, delays and productivity decreases could have resulted. It is in this analysis that the project team did an excellent job concerning waterproofing and the design for the mat foundation concerning groundwater depth should remain the same.

The permanent dewatering system utilizes a gravity flow system with an electrical sump pump backup. The current gravity flow system utilizes a 6” DIA perforated drainage PVC under the 5” slab on grade from a starting elevation of 430.75’ to a gravity outfall of 429.71’. The maximum travel distance is approximately 379’ with a 0.03 in/ft drainage piping slope. The drainage piping currently runs between column and footings and it is recommended that the piping system remain the same but be dropped 4’ to accommodate the mat foundation system. Doing so may result in a greater influx of water and create a greater need for the dewatering and waterproofing system. With this increase in demand



for water removal may create a possible backlog of additional hydrostatic pressure that cannot be forgotten about. With a possibility of increased hydrostatic pressure with the utilization of the same drainage system comes to the responsibility of the designer as to what to do. Through advice of structural engineers and contractors it was recommended that once you start constructing your foundation that the dewatering system must be in effect to reduce the possibility of high hydrostatic pressure on the foundation system. With a permanent dewatering system installed prior to construction, it will alleviate any potential risk during construction of hydrostatic pressure. The following calculation is provided as to give a rule of thumb to the structural load interaction of the Wellington Condominiums Project:

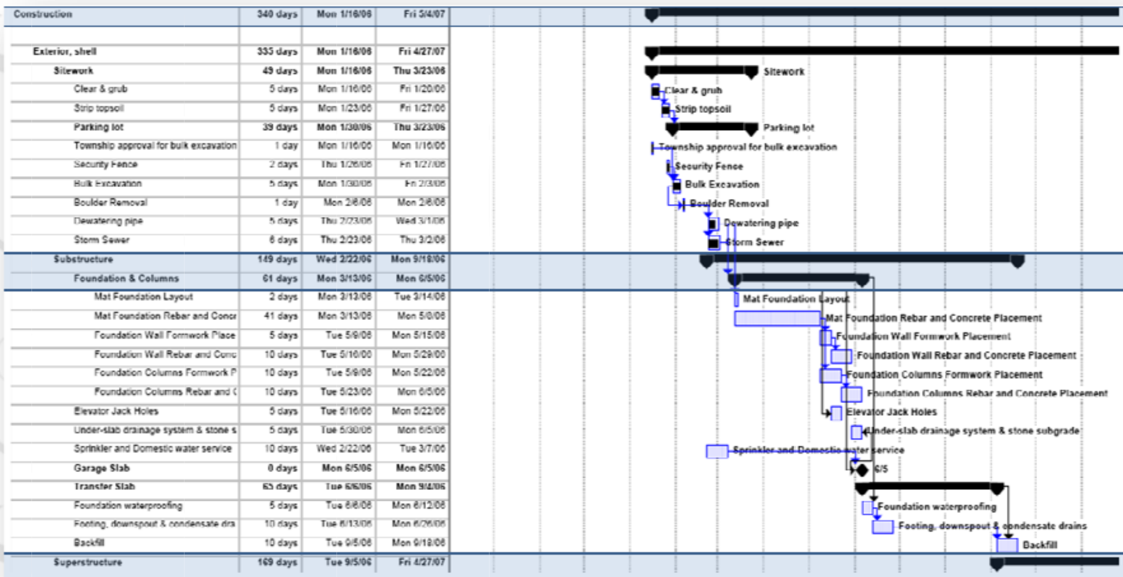
| | |
|---|---|
| Allowable Bearing Pressure of Soil Conditions: | 3.5 KSF |
| Square footage of Mat Foundation: 259' x 121' | 31,339 SF |
| Allowable Total Load Transferred to Soil Conditions: | **109,687 K** |

| | |
|---|---|
| Maximum Column Load: 473 K x 36 Columns | 17,028 K |
| Maximum Wall Load: 10 K/FT x 760 FT | 7600 K |
| Total Mat Foundation Load: | **24,628 K** |

The mat foundation load is less than the allowable mat foundation load; therefore the foundation has enough strength to allow for the prevalent soil conditions. There is a 4.45 safety factor on this analysis which will allow for any additional hydrostatic pressure and uplift from the soil conditions present. With the permanent dewatering system installed prior to foundation construction and continued throughout the project; there is no additional analysis to consider.

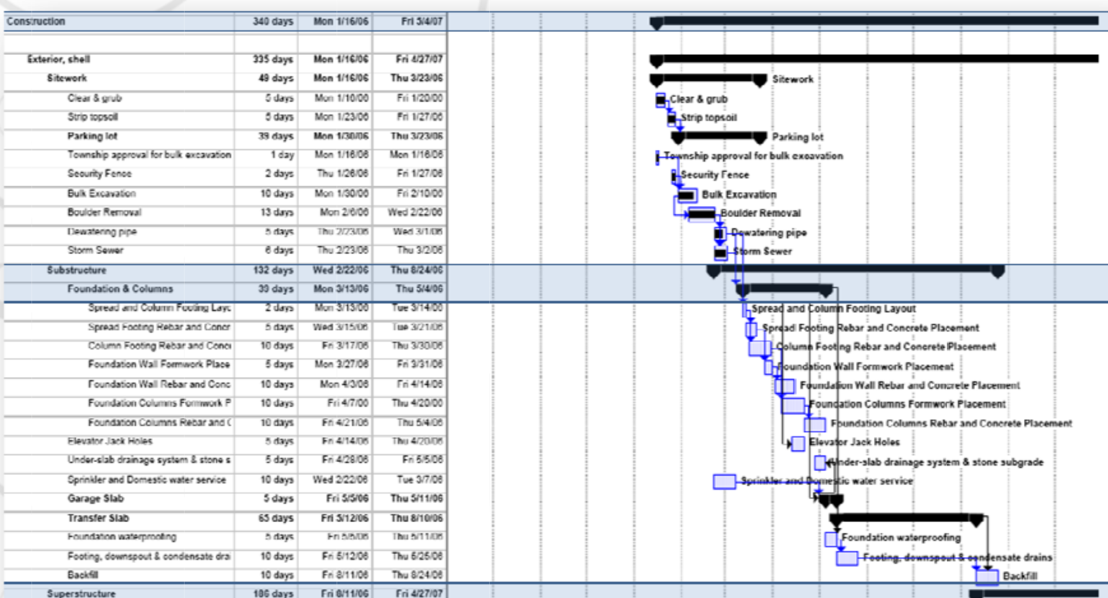
**C.3.4.2.G Mat Foundation Schedule Implications**

The schedule effect to the implementation of the mat foundation system is shown in Figure 10.A along with the original schedule in Figure 10.B.



| Construction | 340 days | Mon 1/16/06 | Fri 5/4/07 |
|---|---|---|---|
| | | | |
| Exterior, shell | 335 days | Mon 1/16/06 | Fri 4/27/07 |
| Sitework | 49 days | Mon 1/16/06 | Thu 3/23/06 |
| Clear & grub | 5 days | Mon 1/16/06 | Fri 1/20/06 |
| Strip topsoil | 5 days | Mon 1/23/06 | Fri 1/27/06 |
| Parking lot | 39 days | Mon 1/30/06 | Thu 3/23/06 |
| Township approval for bulk excavation | 1 day | Mon 1/16/06 | Mon 1/16/06 |
| Security Fence | 2 days | Thu 1/26/06 | Fri 1/27/06 |
| Bulk Excavation | 5 days | Mon 1/30/06 | Fri 2/3/06 |
| Boulder Removal | 1 day | Mon 2/6/06 | Mon 2/6/06 |
| Dewatering pipe | 5 days | Thu 2/23/06 | Wed 3/1/06 |
| Storm Sewer | 6 days | Thu 2/23/06 | Thu 3/2/06 |
| Substructure | 149 days | Wed 2/22/06 | Mon 9/18/06 |
| Foundation & Columns | 61 days | Mon 3/13/06 | Mon 6/5/06 |
| Mat Foundation Layout | 2 days | Mon 3/13/06 | Tue 3/14/06 |
| Mat Foundation Rebar and Concr | 41 days | Mon 3/13/06 | Mon 5/8/06 |
| Foundation Wall Formwork Place | 5 days | Tue 5/9/06 | Mon 5/15/06 |
| Foundation Wall Rebar and Conc | 10 days | Tue 5/16/06 | Mon 5/29/06 |
| Foundation Columns Formwork P | 10 days | Tue 5/9/06 | Mon 5/22/06 |
| Foundation Columns Rebar and ( | 10 days | Tue 5/23/06 | Mon 6/5/06 |
| Elevator Jack Holes | 5 days | Tue 5/16/06 | Mon 5/22/06 |
| Under-slab drainage system & stone s | 5 days | Tue 5/30/06 | Mon 6/5/06 |
| Sprinkler and Domestic water service | 10 days | Wed 2/22/06 | Tue 3/7/06 |
| Garage Slab | 0 days | Mon 6/5/06 | Mon 6/5/06 |
| Transfer Slab | 65 days | Tue 6/6/06 | Mon 9/4/06 |
| Foundation waterproofing | 5 days | Tue 6/6/06 | Mon 6/12/06 |
| Footing, downspout & condensate dra | 10 days | Tue 6/13/06 | Mon 6/26/06 |
| Backfill | 10 days | Tue 9/5/06 | Mon 9/18/06 |
| Superstructure | 169 days | Tue 9/5/06 | Fri 4/27/07 |

**Figure 10.A:** Mat Foundation System Schedule



| Construction | 340 days | Mon 1/16/06 | Fri 5/4/07 |
|---|---|---|---|
| | | | |
| Exterior, shell | 335 days | Mon 1/16/06 | Fri 4/27/07 |
| Sitework | 49 days | Mon 1/16/06 | Thu 3/23/06 |
| Clear & grub | 5 days | Mon 1/16/06 | Fri 1/20/06 |
| Strip topsoil | 5 days | Mon 1/23/06 | Fri 1/27/06 |
| Parking lot | 39 days | Mon 1/30/06 | Thu 3/23/06 |
| Township approval for bulk excavation | 1 day | Mon 1/16/06 | Mon 1/16/06 |
| Security Fence | 2 days | Thu 1/26/06 | Fri 1/27/06 |
| Bulk Excavation | 10 days | Mon 1/30/06 | Fri 2/10/06 |
| Boulder Removal | 13 days | Mon 2/6/06 | Wed 2/22/06 |
| Dewatering pipe | 5 days | Thu 2/23/06 | Wed 3/1/06 |
| Storm Sewer | 6 days | Thu 2/23/06 | Thu 3/2/06 |
| Substructure | 132 days | Wed 2/22/06 | Thu 8/24/06 |
| Foundation & Columns | 39 days | Mon 3/13/06 | Thu 5/4/06 |
| Spread and Column Footing Layc | 2 days | Mon 3/13/06 | Tue 3/14/06 |
| Spread Footing Rebar and Concr | 5 days | Wed 3/15/06 | Tue 3/21/06 |
| Column Footing Rebar and Conc | 10 days | Fri 3/17/06 | Thu 3/30/06 |
| Foundation Wall Formwork Place | 5 days | Mon 3/27/06 | Fri 3/31/06 |
| Foundation Wall Rebar and Conc | 10 days | Mon 4/3/06 | Fri 4/14/06 |
| Foundation Columns Formwork P | 10 days | Fri 4/7/06 | Thu 4/20/06 |
| Foundation Columns Rebar and ( | 10 days | Fri 4/21/06 | Thu 5/4/06 |
| Elevator Jack Holes | 5 days | Fri 4/14/06 | Thu 4/20/06 |
| Under-slab drainage system & stone s | 5 days | Fri 4/28/06 | Fri 5/5/06 |
| Sprinkler and Domestic water service | 10 days | Wed 2/22/06 | Tue 3/7/06 |
| Garage Slab | 5 days | Fri 5/5/06 | Thu 5/11/06 |
| Transfer Slab | 65 days | Fri 5/12/06 | Thu 8/10/06 |
| Foundation waterproofing | 5 days | Fri 5/5/06 | Thu 5/11/06 |
| Footing, downspout & condensate drai | 10 days | Fri 5/12/06 | Thu 5/25/06 |
| Backfill | 10 days | Fri 8/11/06 | Thu 8/24/06 |
| Superstructure | 186 days | Fri 8/11/06 | Fri 4/27/07 |

**Figure 10.B:** Original Foundation System Schedule

*~See Attached Appendix for the Complete Schedule~*



From the schedules the important dates to take notice are highlighted in blue and listed as followed for analysis:

**Mat Foundation System:**

- Construction: 340 Days — Mon 1/16/06 – Fri 5/4/07
- Substructure: 149 Days — Wed 2/22/06 – Mon 9/18/06
- Foundation and Columns: 61 Days — Mon 3/13/06 – Mon 6/5/06
- Superstructure: 169 Days — Tue 9/5/06 – Fri 4/27/07

**Original Foundation System:**

- Construction: 340 Days — Mon 1/16/06 – Fri 5/4/07
- Substructure: 132 Days — Wed 2/22/06 – Thu 8/24/06
- Foundation and Columns: 39 Days — Mon 3/13/06 – Thu 5/4/06
- Superstructure: 186 Days — Fri 8/11/06 – Fri 4/27/07

**Key:** Red – Schedule Push Back    Green – Schedule Pull Back

Some interesting results have occurred that are worth noting for the comparison between schedules. The construction of the mat foundation in comparison to the original foundation system will result in as followed:

- Construction: Entire Construction of the project will be the same start and finish date with no increase or decrease in project schedule.
- Substructure: The construction of the substructure will increase by 17 days. The substructure construction will start on the same day but finish at a later time.
- Foundation and Columns: Foundation and Columns will increase by 22 days. The foundation and column construction will start on the same day but finish at a later time.
- Superstructure: The superstructure will decrease in time of construction by 17 days. The start time will be pushed back but will finish on the same day as the original schedule.

What this data is revealing is that there is float within the schedule and the utilization of a mat foundation system will not delay the overall project. There is an increase in parts of the schedule but due to superstructure float was able to take on those extra days of construction and still finish on time. Therefore based on these observations, more analysis must be conducted further as to whether or not to utilize a mat foundation system for the Wellington Condominiums Project.

### C.3.4.2.H Mat Foundation Budget Implications

The current budget for the Wellington Condominiums Foundation system is based on the following estimates:

**Original Estimate:**

- Single Slab Column Footings: $104, 374
- Wall Strip Footings: $13,070
- Slab on Grade: $73,048
- Change Orders $253,159

**Total: $443,651**

**Mat Foundation Estimate @ 4' Thickness:**

- **2007 RS Means Building Construction Data**
- Cubic Yards of Mat Foundation: 259' x 121' x 4' 4,643 CY
- 2 Crews (C-14C) Totaling:
  - 2 Foreman
  - 12 Carpenters
  - 4 Rodmen (reinf.)
  - 8 Laborers
  - 2 Cement Finishers
  - 2 Gas Engine Vibrators
- Material Cost: $174/CY $807,882
- Labor Cost: $70/CY/Crew x 2 Crews = $140/CY $650,020
- Equipment: $0.38/CY/Crew x 2 Crews = $0.76/CY $3,529

**Total: $1,461,431**

**Mat Foundation Estimate @ 3' Thickness:**

- **2007 RS Means Building Construction Data**
- Cubic Yards of Mat Foundation: 259' x 121' x 3' 3,482 CY
- 2 Crews (C-14C) Totaling:
  - 2 Foreman
  - 12 Carpenters
  - 4 Rodmen (reinf.)
  - 8 Laborers
  - 2 Cement Finishers
  - 2 Gas Engine Vibrators
- Material Cost: $174/CY $605,868
- Labor Cost: $70/CY/Crew x 2 Crews = $140/CY $487,480



- Equipment: $0.38/CY/Crew x 2 Crews = $0.76/CY $2,646

**Total: $1,095,994**

From the estimate analysis, at a minimum 3' mat foundation thickness the cost is 2.5 times over the original foundation estimate. At the preferred 4' mat foundation thickness the cost is 3.3 times over the original foundation estimate. If utilized the 4' mat foundation system, 53% of the total structural system would be put towards the redesign. Also 84% of the original cost would have to be put towards the construction of the mat foundation system.

If the owner were to decide solely on the estimates given here for the project budget as to what system should be utilized. It would not be beneficial to use a mat foundation system based on these estimates.

## C.3.4.3 Comparison of the Two Foundation Systems

The comparison of the two foundation systems have been created through a matrix chart based on the owner requirements of which system overall is better for the project.

| Compare and Contrast Foundation Systems | Orginal Foundation System | | | | | Mat Foundation System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Categories of Interest | Ratings | Total Weight | Weight | Grade | Comment | Ratings | Total Weight | Weight | Grade | Comment |
| Material and Equipment | 11 | 3.83 | 2.87 | 75.00% | Good | 11 | 3.83 | 2.49 | 65.00% | Okay |
| Change Orders | 4 | 10.83 | 5.96 | 55.00% | Poor | 4 | 10.83 | 7.04 | 65.00% | Okay |
| Cost | 1 | 13.83 | 11.76 | 85.00% | Great | 1 | 13.83 | 7.61 | 55.00% | Poor |
| Watertable Interaction | 3 | 11.83 | 7.69 | 65.00% | Okay | 3 | 11.83 | 7.69 | 65.00% | Okay |
| Schedule | 7 | 7.83 | 5.09 | 65.00% | Okay | 7 | 7.83 | 5.09 | 65.00% | Okay |
| Subsurface Interaction | 2 | 12.83 | 7.06 | 55.00% | Poor | 2 | 12.83 | 10.91 | 85.00% | Great |
| Load Distribution | 6 | 8.83 | 5.74 | 65.00% | Okay | 6 | 8.83 | 8.39 | 95.00% | Excellent |
| Drainage System | 5 | 9.83 | 7.37 | 75.00% | Good | 5 | 9.83 | 6.39 | 65.00% | Okay |
| Labor Intensive | 8 | 6.83 | 4.44 | 65.00% | Okay | 8 | 6.83 | 4.44 | 65.00% | Okay |
| Installation | 10 | 4.83 | 3.14 | 65.00% | Okay | 10 | 4.83 | 3.14 | 65.00% | Okay |
| Versatility | 12 | 2.83 | 2.12 | 75.00% | Good | 12 | 2.83 | 1.84 | 65.00% | Okay |
| Quality Control | 9 | 5.83 | 4.37 | 75.00% | Good | 9 | 5.83 | 4.37 | 75.00% | Good |
| TOTAL | | 100.00 | 67.6 | | Okay | | 100.00 | 69.4 | | Okay |
| Average | | | | 70.00% | | | | | 72.50% | |

The comparison and contrast of the two foundation systems have been created through a matrix chart based on what was most important through the owner's perspective on a scale of 1-12. Each system would be graded on how well it performs in each of the 12 categories. For instance, the cost for the original foundation system was deemed as a reasonable price and was commented as being great advantage to the project budget. The mat foundation was deemed as poor due to the high cost imposed onto the project budget.



The results have indicated that a score of 67.6% and 69.4% for the original and mat foundation system respectively. Both are indicated as an okay system but it is the mat foundation which should be selected by the owner. This provides an interesting perspective in that the mat foundation even though cost was a number one concern and was over three times the original foundation system; the mat foundation should be perused if given the correct amount of funding availability. The advantages of the mat foundation in subsurface interaction and load distribution create just enough of an advantage to spend the extra money on the system. If however other variables were to change; it could give the possibility of the original foundation system being preferred over the mat foundation system. But with the current information provided, if the amount of funding is available, the mat foundation system should be selected for the Wellington Condominiums Project.



## C.4 Façade Integration

**Figure 1:** CIP Formwork for Balconies

The Wellington Condominiums Façade has been analyzed and is detailed in the following sections outlined below:



- C.4.4.3.A Research Data and Recommendations
- C.4.4.3.B Structural Implications
- C.4.4.3.C Methods of Construction
- C.4.4.3.D Precast Estimate and Schedule
- C.4.4.3.E Other Impacts
- C.4.4.3.F Comparison of Two Façade Systems

## C.4.1 Problem Statement

With many early problems and delays on the project, is there a way to constructing the building façade, in the winter months of 2007, in a more productive manner? Can this be done without ruining the architectural style and vision of the owner and architect design?

This was one of the first things that was looked at and asked to the project manager when analyzing the project schedule. The schedule at first was not this way but with early delays it has pushed back façade construction to the winter months.

## C.4.2 Proposed Solution

At first glance the answer to this is 'Yes we can change the building façade!' But caution must be in place when wanting to change the architectural style of the building façade. The proposed solution would be to introduce a façade integration of exterior components. This will be done through the use of pre cast throughout the entire façade rather than on the first floor. The first floor mainly consists of cast stone exterior veneer that has to be situated with a crane. Following the construction of the cast stone exterior veneer, the rest of the floors utilize traditional brick masonry construction. One of the major reasons why exterior masonry construction cannot start is the formwork in place for the cantilevered cast-in-place condominium balconies. These balconies require a great deal of time to pour and form. After the fourth floor balconies are poured, they must wait to be at strength before the scaffolding is removed.

This creates huge logistical issues and delays in constructing the façade. If the system components can be preassembled whether they are the balconies or façade, cost and time could be saved to the project.

## C.4.3 Analysis Steps

1. Learn in more detail about the current Wellington Condominiums Project façade and the possibility of the integration of façade components through the use of pre cast or preassemblies in fabrication shops.
2. If pre cast is the main alternative, a rendering should be created to show the owner that there are little if any differences to the architectural style and vision to the project.



3. Do a cost, schedule, and methods of construction comparison analysis of the building façade options.

## C.4.4 Analysis Result Overview

The overview for the façade analysis is very clear before doing the investigation. Typically pre cast will save you cost and time in labor and equipment. During the winter months this becomes greater due to the loss of expected productivity during this time period. With the addition of not being able to start constructing due to the scaffolding in place for the cast-in-place balconies; there is a great demand for alternative means and methods of construction. The architectural style of the project has been rendered in the following research sections to see if the exterior has changed in dramatic or subtle ways. This is a major research step because if the exterior façade changes architecturally, most likely the owner or architect is not going to approve of the changes. But if a rendering can show that minimal changes would occur and substantial cost and schedule savings would result then this could be a good alternative to the Wellington Condominiums Project.

### C.4.4.1.A Overview of the Current Wellington Condominiums Façade

In order for the Wellington Condominiums Project façade to achieve such high standards, the architects and planners first decided on what exterior material to use that was equally appealing and durable at the same time. After much contemplation, the architects and planners determined that the Wellington Condominium's building façade was to consist of predominately a traditional brick and cast stone exterior veneer**.** The cast stone veneer is primarily situated on the first floor building façade, is utilized around windows and doors as pre cast headers, and serves as a pre cast band and trim linking the transitions of façade materials. The brick façade continues up to the roof line where it is met by a 1 x 12 Azek Trim Board with Fypon BKT8X8x4 décor. Also scattered across the building façade is pre cast medallions and ornamentation to give the condominiums a refined and polished look.

The type of connection for the masonry is typical among the construction industry. The system that holds the façade and interior walls together is 22 gauge galvanized metal ties. The specifications call for the following list of items to be completed for the correct installation of anchoring masonry veneers:

5) Insert slip-in anchors in metal studs as sheathing is installed. Provide one anchor at each stud in each horizontal joint between sheathing boards.
6) Embed tie sections in masonry joints. Provide not less than 2 inches of air space between back of masonry veneer and face of sheathing.
7) Locate anchor sections to allow maximum vertical differential movement of ties up and down.



8) Space anchors by no more than 16” o.c. vertically and 24” o.c. horizontally with not less than 1 anchor for each 2.67 sq. ft. of wall area. Install additional anchors within 12” of openings and at intervals, not exceeding 36”, around perimeter.

The composition of the 1 hour fire rated exterior wall section of the first through the fourth floor starting from the exterior to the interior are as follows: brick/stone veneer, metal ties, 1 ½” minimum air space, 15” building felt, 5/8” dens glass gold sheathing, 6” metal studs, R-19 batt insulation, vapor barrier, and 5/8” type ‘X’ G.W.B.

### C.4.4.1.B Original Estimate and Schedule

The Wellington Condominium’s original façade estimate and schedule are detailed as followed:

**Original Estimate:**

| Wellington Condominiums Façade | | | | Systems Costs | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release |
| B20 Exterior Closure | | | | | | | | | |
| 670.910 | B20101023000 | Flt precast conc,4" thick,5x18',smooth gray,low rise | S.F. | 4,193.19 | 2,475.66 | 6,668.85 | 181 | Open | 2006 |
| 8,998.600 | B20101023150 | Flt precast conc,4" thick,12x20',smooth gray,low rise | S.F. | 79,187.68 | 9,898.46 | 89,086.14 | 181 | Open | 2006 |
| 14,588.330 | B20101305200 | Brk vnr/met std bkup,std face,20gax3-5/8"nlb std,16" OC sp,mng bn | S.F. | 86,071.15 | 199,860.12 | 285,931.27 | 181 | Open | 2006 |
| | | Totals | | $169,452.01 | $212,234.24 | $381,686.25 | | | |
| | | | | x | x | x | | | |
| | | Allentown PA location factor multiplier | | 0.90 | 1.074 | 1.027 | | | |
| | | | | $166,062.97 | $227,939.57 | $391,991.79 | | | |

*~See Attached Appendix for Detailed Assemblies Takeoff~*

**Original Schedule:**

| | | | |
|---|---|---|---|
| Arriscraft & Brickwork | 80 days | Mon 1/8/07 | Fri 4/27/07 |
| First Floor Arriscraft & Brickw | 20 days | Mon 1/8/07 | Fri 2/2/07 |
| Second Floor Arriscraft & Bric | 20 days | Mon 2/5/07 | Fri 3/2/07 |
| Third Floor Arriscraft & Brickw | 20 days | Mon 3/6/07 | Fri 3/30/07 |
| Forth Floor Arriscraft & Brickw | 20 days | Mon 4/2/07 | Fri 4/27/07 |


**Total:** **80 Work Days = 16 Weeks**
**Mon 1/8/07 – Mon 4/27/07**

*~See Attached Appendix for Full Schedule~*



### C.4.4.1.C Why GO Pre-Cast?

The Wellington Condominium's original façade schedule indeed shows that construction will start in the winter months of 2007. This creates additional concerns of work area enclosure for the subcontractors during the winter months and who is responsible for the additional costs associated with that? In the original project estimate there was no line item for heating and enclosure for the construction of the building façade. During that time it was assumed that the façade would be enclosed before the winter and that no great influx of additional heating or enclosure was necessary. Therefore this would be the subcontractor's responsibility and digression as how to handle construction of the building façade. In either case a decrease in productivity and an increase in schedule and budget will occur for the project.

The construction of the cast-in-place cantilever balconies is another area of concern for the project team. These balconies are poured at every floor and are supported by a scaffolding system. The scaffolding system cannot be removed until the $4^{th}$ floor balcony has reached full strength. After the $4^{th}$ floor balcony has reached full strength, the scaffolding can then be removed to begin masonry façade construction. Therefore even if the project team wanted to get an early start and avoid winter conditions and pick up time on the schedule; they would not be able to do so until the $4^{th}$ floor balcony has reached full strength.

The project team is now faced with a dilemma…The façade construction cannot start early and in fact will be delayed, façade construction will start in the winter time which will lead to decreased productivity and increased project schedule and budget, a masonry subcontractor that is very difficult to work with, and no general condition line items for temporary shelter and heating. What is the project team to do? Answer: **THIN BRICK PRECAST PANELS.**

### C.4.4.1.D Overview of Façade Integration

The advantages of utilizing thin brick precast panels for the Wellington Condominiums Project are as followed:

- Brick precast panels will be constructed in a manufacturing shop and not on the project site. Therefore the production of brick precast panels can occur when the project team is constructing the structural components to the Wellington Condominiums. This will reduce any further delay in the construction of the building façade.
- With brick precast panels being constructed in a controlled environment, better quality control and craftsmanship can occur.
- No shelter or additional heating cost is necessary to include in the subcontractor or general conditions.

- Increased productivity in the installation of brick precast panels will result due to less subcontractor masonry need on the project site.
- A crane is already being used for the first floor construction of cast stone exterior veneer and can then be used for the installation of brick precast panels.
- Savings in schedule will significantly increase and enclose the building quickly during the winter months. This will help promote an increase in productivity to other subcontractor trades at the project site.
- Safety will increase on the project site with less influx of needed crews to construct the building façade.
- Local precast companies nearby project site for easy shipping and handling of panels.
- Panels can be engineered like standard precast panels and therefore makes the structural integrity of a brick wall no longer a concern.
- Visual quality of the façade is considered good and can be more appealing to architects and owners if designed and constructed correctly.

**Figure 2:** Thin Brick Precast Panel (API Manufacturer: www.apiprecast.com)

With all these advantages to using thin brick precast panels, it is something that the project team should look at if given enough lead time. Due to the poor subsurface conditions encountered early on in the project, it is still realistic for the project team to utilize a thin brick precast panel instead of traditional brick construction.

The company that can provide thin brick precast panels within the local area is a manufacturer called Architectural Precast Inc. (API).


**Figure 3:** API Website: www.apiprecast.com

API is located in Middleburg, PA about 2 hours away from the Wellington Condominiums project site. As discussed by a representative of API; the process is as followed for the production of thin brick precast panels:

1. API will produce precast elevation drawings or 'E drawings' from the Architect contract drawings.
2. After approval from the Architect, API will then begin production of precast panels.
3. The 'E drawings' are used to create individual precast piece details so that a carpenter can construct the negative mold.
4. A crew will assemble the mold, caulk all the joints, and apply a release agent to the mold in order to release concrete adhesion.
5. Steel reinforcing is constructed in the steel shop and then placed into the molds along with any connections or details that the panels may require. This follows accordance with PCI standards.
6. Molds are cleaned and checked for quality before being released to pour.
7. Form liners are manufactured to the architects design in order to control the placement of brick and to also control the concrete from leaking in front of the brick. Also the back of bricks has a keyway to ensure proper bondage to the concrete.
8. After the precast has cured, the liner is removed and the brick face is revealed.

This process is fairly typical for most projects and if pursued early enough, is deemed very feasible for the Wellington Condominiums Project.

### C.4.4.2.A Façade Rendering Analysis

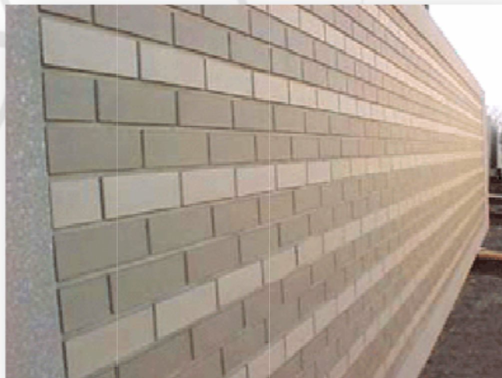


**Figure 4:** Thin Brick Precast Panel (API Manufacturer: www.apiprecast.com)

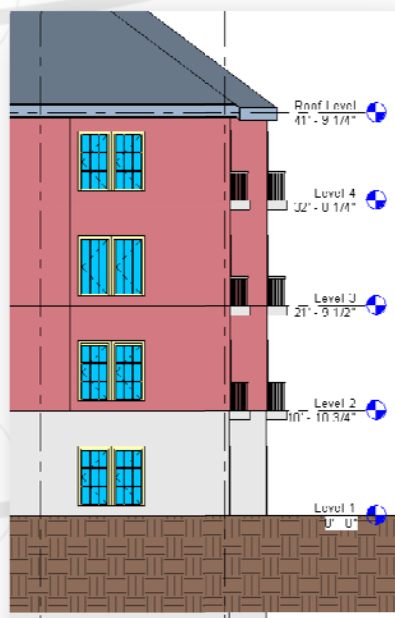



**Figure 5:** Elevation

With thin brick precast being the main alternative, a rendering is created  of wall sections to show the owner that there are little if any differences to the architectural style and vision to the project. The analysis will focus on the brick façade on Level 2, 3, and 4 as indicated in Figure 5.

The following renders will show the differences between what is currently being utilized versus what could be utilized with precast. With these renders an Architect can make a better judgment on utilizing precast without changing the style and environment for the Wellington Condominiums.

The program that was used to create these renders for this analysis was Autodesk Revit® and is shown in the following subcategories:

- Current Façade Renderings
- Traditional v. Precast Brick Façade Comparison
- Rendering Analysis Conclusions



### C.4.4.2.B Current Façade Renderings of Wellington Condominiums

**Figure 6:** West Building Render of Traditional Brick Veneer Façade

**Figure 7:** West Building Render of Traditional Brick Veneer Façade



**Figure 8:** North-West Building Render of Traditional Brick Veneer Façade

**Figure 9:** Detail of Traditional Brick Veneer Façade Render Utilizing Autodesk Revit®

**C.4.4.2.C Traditional v. Precast Brick Façade Comparison Renderings**

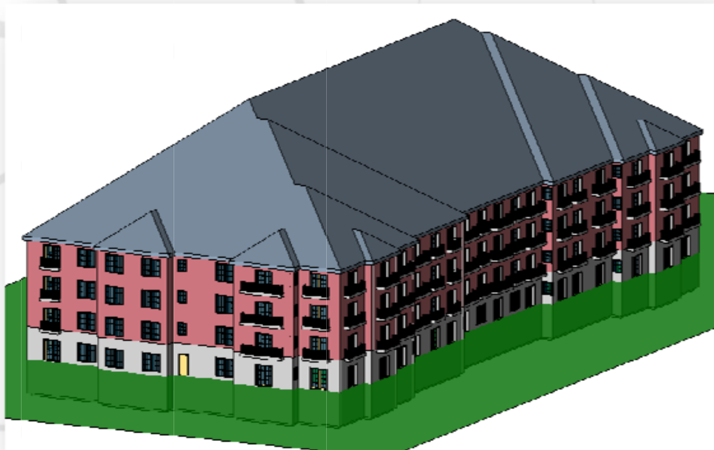


**Figure 10A:** Traditional Brick Veneer Façade Render Utilizing Autodesk Revit®

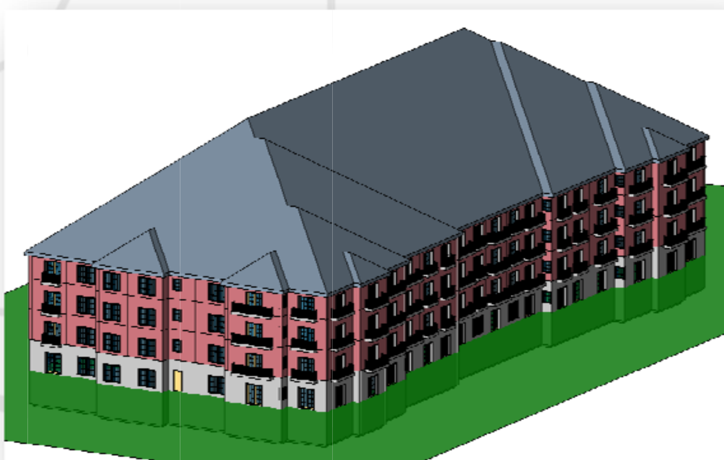


**Figure 10B:** Thin Brick Precast Panel Façade Render Utilizing Autodesk Revit®



**Figure 11A:** West Building Outline of Traditional Brick Veneer Façade

**Figure 11B:** West Building Outline of Thin Brick Precast Panel Façade



**Figure 12A:** West Building Close-up Render of Traditional Brick Veneer Façade

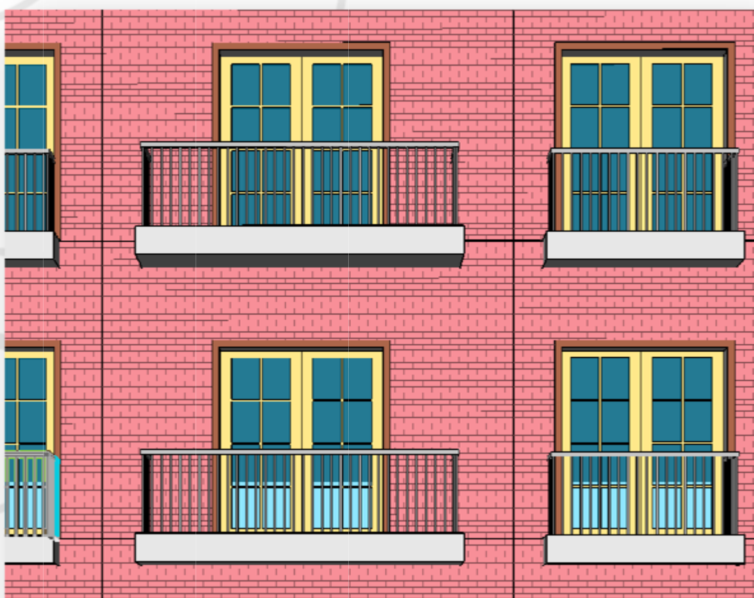


**Figure 12B:** West Building Close-up Render of Thin Brick Precast Panel Façade

**Figure 13A:** North-West Building Outline of Traditional Brick Veneer Façade

**Figure 13B:** North-West Building Outline of Thin Brick Precast Panel Façade

**Figure 14A:** North-West Building Close-up Render of Traditional Brick Veneer Façade

**Figure 14B:** North-West Building Close-up Render of Thin Brick Precast Panel Façade

**C.4.4.2.D Rendering Analysis Conclusions**

With thin brick precast being the main alternative, the renderings is of the wall sections shows the owner that there are little differences to the architectural style and vision to the project. The worst case scenario was modeled for the Wellington Condominiums project being one story height panels of up to an average of 15'- 20'length. It is in this analysis recommendation that the building façade if designed accordingly will look very similar and will not oppose any differences to the architectural style and vision to the project.

**C.4.4.3.A Research Data and Recommendations**

In order to decide on whether or not the Wellington Condominiums project team should implement a thin brick precast façade system the following main areas will be explored: structural implications, methods of construction, estimate, and schedule. Other considerations such as fire wall ratings and mechanical loads will be explored but will not be the major focus of the analysis.

**C.4.4.3.B Structural Implications**

The current structural system utilizes a Hambros Joist Composite Deck System which rest on load bearing metal stud walls with structural steel column tubing throughout. These loads are then transferred floor by floor to the foundation system located on the garage level. The current traditional brick veneer façade is a 3 story continuous load bearing wall that has very few places for tie-ins along the main structural system. A detail of the current façade is detailed in Figure 15.

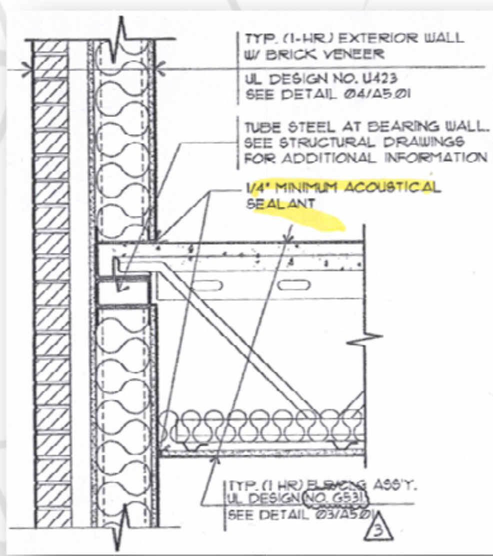



**Figure 15:** Typical 1- HR Exterior Wall with Brick Veneer

When consulted with one of the local head directors at API Manufacturing, the discussion of the current structural system became of concern when wanting to use a precast façade. Precast panels typically fall into the range of 150 lbs./ft^3. With a 7" thick panel spanning 10' in unsupported height, a value of 875 lbs./ft becomes a concern. The current load bearing metal stud walls will not have enough structural integrity to withstand the loading of the precast panels. Therefore other means and methods must be done to implement a precast façade.



The current structural system grid with structural steel column tubing without load bearing metal stud walls are depicted in Figure 16 and 17.

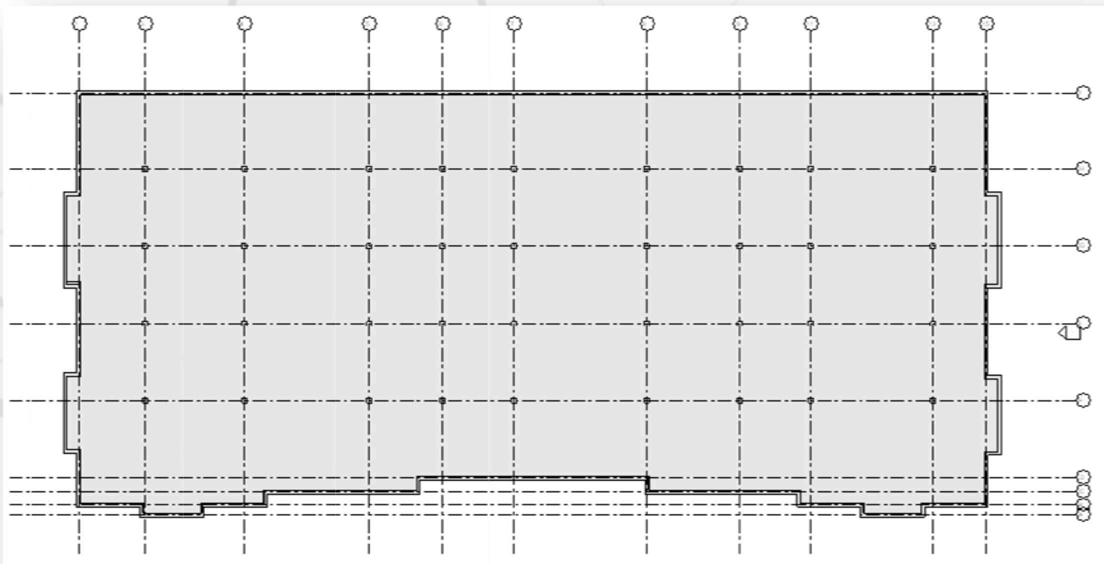


**Figure 16:** Current Structural System Grid with Structural Steel Column Tubing

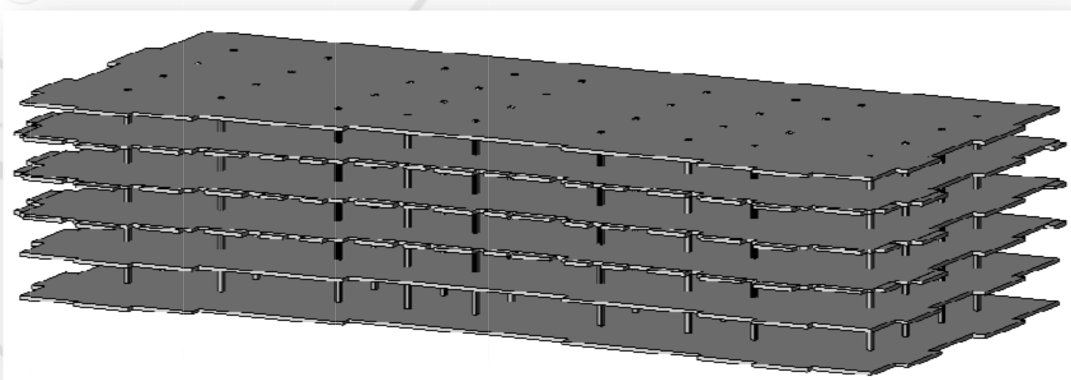


**Figure 17:** Current Structural System with Structural Steel Column Tubing

As shown in Figure 16 and 17, the connections for the precast would be very difficult due to the thin concrete deck and load bearing metal stud walls. Therefore two options have been discussed and are proposed:



1. **Scrap and Go Methodology:** Change the Hambros Joist Composite Deck System to another structural system that is in more in line with precast assemblies.
2. **Modify Methodology:** Utilize the Hambros Joist Composite Deck system but introduce more structural steel column tubing and steel reinforcement around the exterior building footprint to support the precast panels.

The first idea would be a viable solution to the Wellington Condominiums project team if implanted early enough in the design. From the Hambros Joist Composite Deck System Analysis was identified two other systems that may be in more favor of an alternative structural system that can support precast panels.

The second idea of utilizing more structural steel tubing and steel reinforcement would be a viable solution for the Wellington Condominium project team during the early phases of construction. Due to early problems with subsurface conditions and schedule of great concern due to construction of the façade in the winter months; this idea could be implemented. Therefore this analysis will explore idea #2 with the utilization of the current structural system with modifications made.

It was determined that in order to provide proper connection support to the precast façade, 45 structural steel column tubing and steel reinforcement be placed around the exterior building footprint. These columns would span an unsupported and total height (4 stories) of on average 10’ and 40’ respectively. This reinforcing would have to be designed to carry the loading conditions and be properly distributed to the foundation system by a licensed structural engineer. Figures 18 thru 22 shows a possible view of what this structural modification would look like imposed onto the Wellington Condominiums.

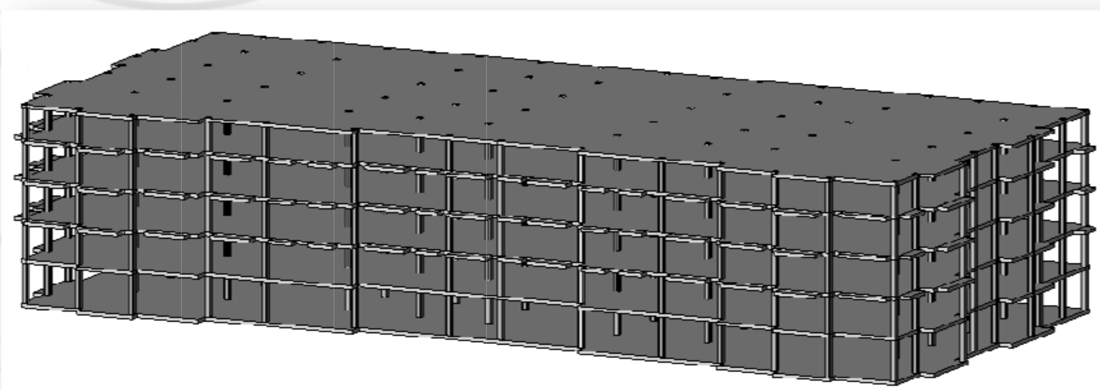


**Figure 18:** Modified Structural System with Structural Steel Column Tubing



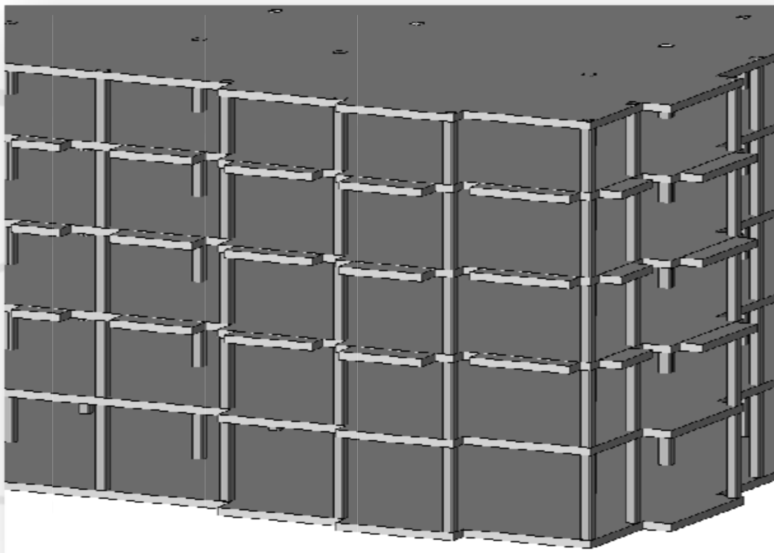


**Figure 19:** Modified Structural System Close-up

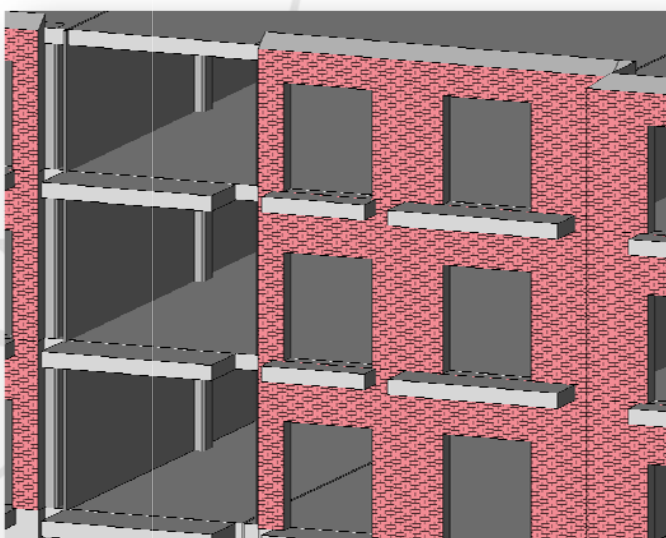


**Figure 20:** Modified Structural System Interaction Close-Up



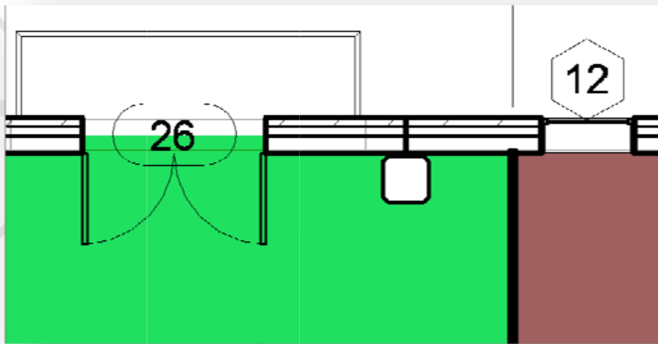



**Figure 21:** Modified Structural System Interaction Floor Plan

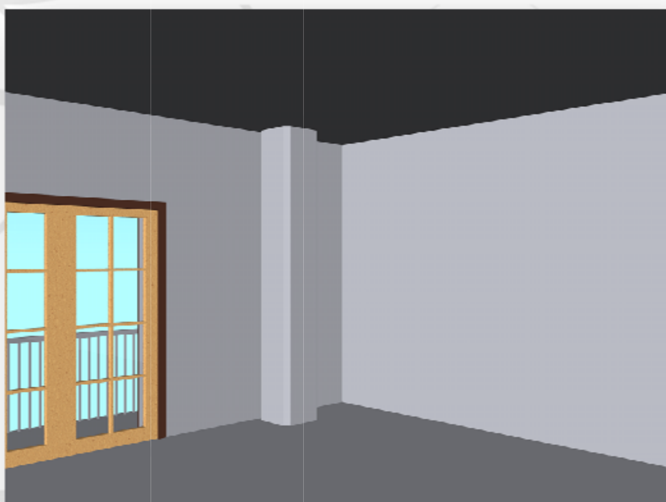


**Figure 22:** Modified Structural System Living Space Implications

The structural connection between the precast panel and modified structural system with structural steel column tubing is shown in Figure 23.



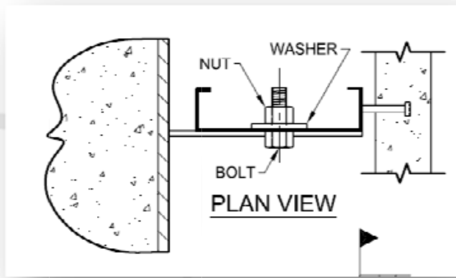



**Figure 23:** Modified Precast Structural Connection Detail (www.slenderwall.com)

With the installation of structural steel column tubing and steel reinforcement, the connection can then be made properly between both systems. With proper design and installation techniques this can be seen as structurally feasible to the Wellington Condominiums project team. To check with this design methodology, Mark Taylor from Nitterhouse was consulted as to if this would be structurally feasible. From conversations with Mark Taylor, this would be deemed a viable option to the project team at Wellington Condominiums.

**C.4.4.3.C Methods of Construction**

Once the structural system has been analyzed and deemed feasible to the Wellington Condominiums project team; a methods of construction of the precast assembly can then be investigated.

With the utilization of API, the entire erection will be done under API subcontracting crew and will not need Wellington Condominiums project subcontracting crews. Therefore this saves the logistics of crane and trucking of material onto the responsibility of API. When consulting with API, the specifications of typical thin brick precast panels are as followed:

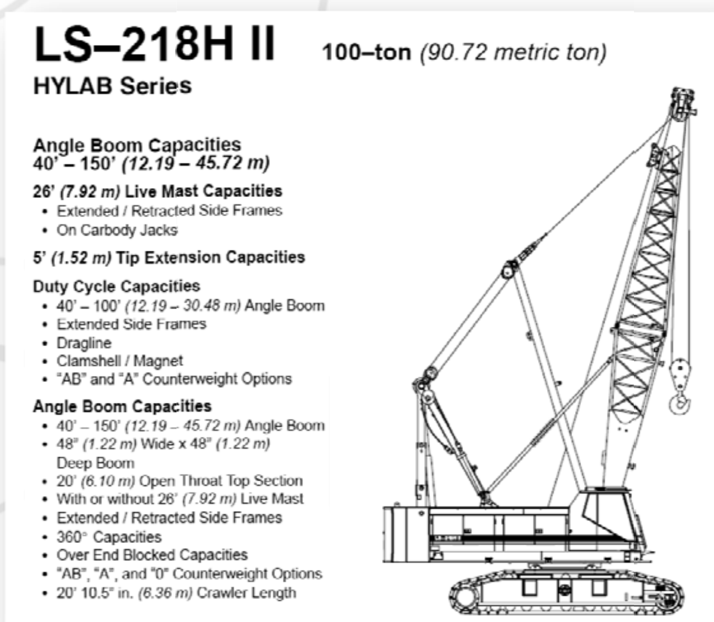
- Dimensions
  - Length: 15’ typical (up to 60’ +)
  - Height: 7’ typical (up to 14’)
  - Thickness: 7” typical
  - Wellington Condominiums (20’ x 10’ x 7”)
- Weight (20’x 10’ x 7”)
  - 150 lbs./ft^3
  - 875 lbs./ft
  - 17,500 lbs./panel ~ 8.75 tons/panel
- Productivity
  - 40 man hours/panel
  - 8-15 pieces/day



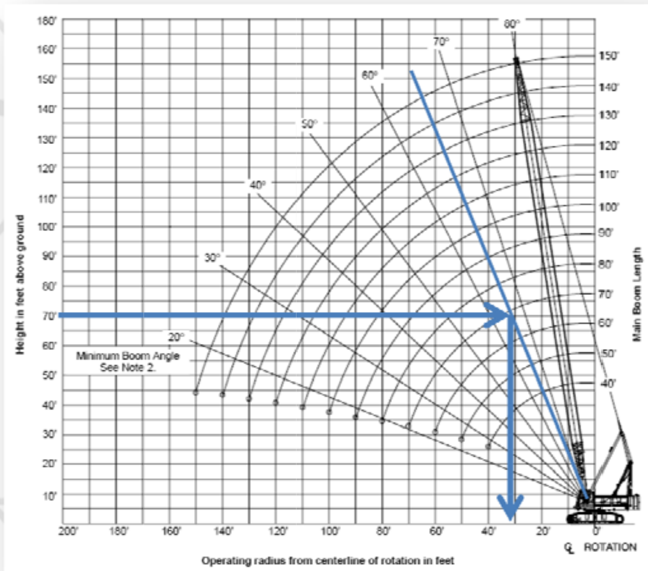
- Cost
  - $30 - $35 / panel
  - Includes:
    - Consultation and Shop Drawings
    - Fabricated Products and Connections
    - Shipping and Handling
    - Installation Crew and Equipment (crane)
  - Not included:
    - Calking
- Time Frame (typical):
  - Shop Drawings: 6 Weeks
  - Owner Changes and Approval: 4 Weeks
  - Fabrication Before Construction Starts: 2 Weeks
  - Erection: 5 Weeks
  - **Total: 17 Weeks**

With this information, the crane size and selection can then be done. The highest and most weight a construction crane would be required to pick is: 60' @ 10 tons/panel.

**Crane Data Sheet:** Amquip Lattice Boom Crawler Crane








| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 16 | 81.8 | 154,900 | 154,900 | 134,300 | 88,700 | 76,000 | 45,700 |
| 17 | 81.1 | 146,200 | 146,200 | 119,800 | 78,900 | 69,400 | 41,600 |
| 18 | 80.4 | 138,400 | 138,400 | 108,100 | 71,000 | 63,800 | 38,100 |
| 19 | 79.6 | 131,300 | 131,300 | 98,300 | 64,400 | 59,000 | 35,100 |
| 20 | 78.9 | 124,800 | 123,900 | 90,100 | 58,900 | 54,800 | 32,400 |
| 25 | 75.2 | 99,900 | 87,200 | 63,000 | 40,700 | 40,000 | 23,200 |
| 30 | 71.5 | 80,500 | 66,800 | 47,900 | 30,500 | 31,000 | 17,500 |
| 35 | 67.7 | 64,100 | 53,700 | 38,300 | 24,000 | 25,000 | 13,800 |
| 40 | 63.7 | 52,900 | 44,700 | 31,600 | 19,500 | 20,700 | 11,100 |
| 50 | 55.4 | 38,700 | 32,900 | 22,900 | 13,700 | 15,000 | 7,400 |
| 60 | 46.2 | 30,100 | 25,600 | 17,500 | 10,000 | 11,200 | 5,100 |
| 70 | 35.2 | 24,200 | 20,600 | 13,800 | 7,500 | 8,600 | 3,400 |
| 80 | 19.5 | 19,900 | 16,900 | 11,000 | 5,600 | 6,700 | 2,100 |


*~See Attached Appendix for Full Crane Specifications~*


From the graphs we can see that at a load radius of 35’ and a boom angle of 67.7 degrees will result in a maximum pick of 64,100 lbs. Our requirement is no more than 20,000 lbs. at a load radius of 35’ and a boom angle of 67.7 degrees. Therefore this crane will work and can easily and safely assemble the precast panels.



**Figure 24:** Construction Crane (75' @ 65 degrees)

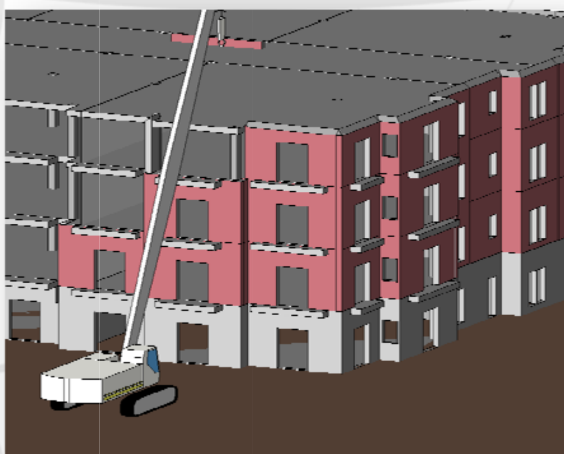


**Figure 25:** Construction Crane (75' @ 65 degrees)

To construct the façade it was recommended by API to construct one façade area at a time rather than enclosing floor by floor. The assembly and installation of the precast panels would start on the south-west building end and continue to move the crane in a clockwise manner around the building footprint.

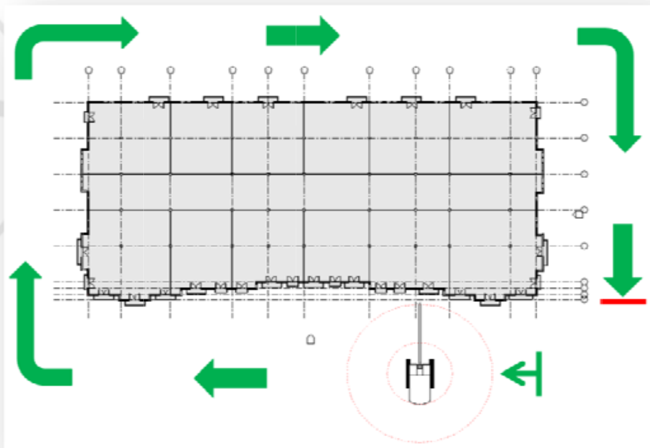


**Figure 26:** Construction Crane Site Movement

An example of one section of the precast panel installation is as followed:

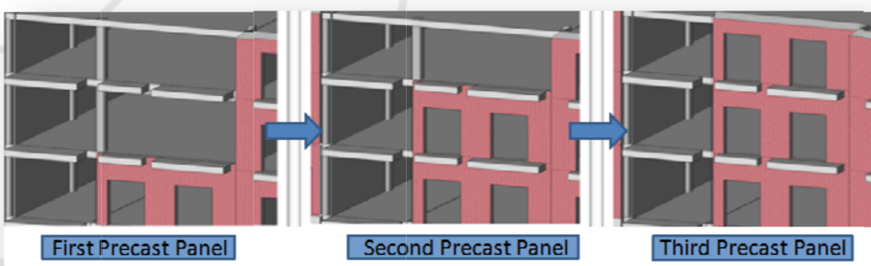



**Figure 27:** Precast Panel Installation



### C.4.4.3.D Precast Estimate and Schedule

The Wellington Condominium's precast façade estimate and schedule are detailed as followed:

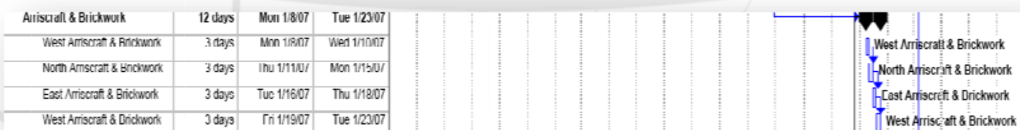
**Original Estimate:** **Total: $391,992**

**Original Schedule:** **80 Work Days = 16 Weeks**
**Mon 1/8/07 – Mon 4/27/07**

**Precast Estimate:** $30/SF x 22,800 SF = $684,000
$35.40/VLF x 40' x 45 Steel Column Tubing = $63,720
(2006 RS Means 1.027 Location Factor Applied)
**Total: $767,909 ($375,917)**

**~ 1.96 Times the Original Cost**

**Precast Schedule:** 1 day/15 precast panels x 45 Precast Panels x 4 floors = 12 days




*~See Attached Appendix for Full Schedule~*

**12 Work Days = 2.4 Weeks**
**Mon 1/8/07 – Tue 1/23/07**

**Note:** First floor Stone Veneer Precast will be supplied by another manufacturer and therefore not in the estimate of the Precast Façade. The Precast schedule on the other hand includes the first floor. Most likely the subcontracting crew that is installing 2nd, 3rd, and 4th floor precast brick panels can install 1st floor precast stone veneer panels.

**Results:** By utilizing a precast façade in its entirety the following results occur:

- Estimate/Budget Increase: **$375,917**
- Schedule Decrease: **68 Work Days**
- Total Schedule Compression: **24 Work Days (4.8 Weeks Saved)**
- Revenue/Cash Flow Brought in for Weeks Saved:
  - $280/Week/Condominium x 4.8 Weeks x 48 Condominiums = **$64,512**
  - General Conditions: **$47,640**



| GENERAL CONDITIONS | | DIVISION TOTAL -------------------------> | | | $47,640 |
|---|---|---|---|---|---|
| SR. PROJECT MANAGER | 4.8 | WKS | $3,500.00 | $16,800 | |
| SUPERINTENDENT | 4.8 | WKS | $3,000.00 | $14,400 | |
| LABORER | 4.8 | WKS | $800.00 | $3,840 | |
| ASSISTANT SUPERINTENDENT | 4.8 | WKS | $2,500.00 | $12,000 | |
| CONSTRUCTION TRAILERS | 1.2 | MTH | $300.00 | $360 | |
| MATERIALS & SUPPLIES | 1.2 | MTH | $200.00 | $240 | |

- Other impact factors: Sell off condominiums faster by putting façade on building and owners can move in at an earlier date. Service is improved to clients and will affect other locally owned business. Increase owner's usage of facilities supporting the condominiums. (I.e. Banks, stores, restaurants, YMCA, and others.)
- Surrounding area is owned and operated by owner/developer and must look at the entire picture rather than just the condominium's impact. Even if a project were to lose money, a developer in the long run may benefit due to the services and quality of life within the community.
  - Food Example
    - 48 Condominiums
    - 3 people/Condominium
    - $50/Person/Day
    - 4.8 weeks additional time of buying food from owner's stores and restaurants
    - Generate: **$241,920**
  - Living Cost Example
    - Pharmacy, furniture, local clothing stores, miscellaneous
    - Assume $100/Week/Person
    - Generate: **$69,120**
- Revised Estimate/Budget SAVINGS: **$47,275**

### C.4.4.3.E Other Impacts

Other impacts that may affect the selection of whether or not to use traditional versus precast brick façade are as followed:

- Mechanical Loading
- Fire Rating

For this analysis, the mechanical impacts are considered the same due to API's insulated precast system. This increases the precast R-value for the system to a level that is acceptable in the construction industry.

Fire rating for the exterior wall system is 1 hour and therefore is achievable by both systems. No further analysis is required.



### C.4.4.3.F Comparison of Two Façade Systems

The comparison of the two façade systems have been created through a matrix chart based on the owner requirements of which system overall is better for the project.

| Compare and Contrast Facade Systems | Orginal Facade System | | | | | Precast Facade System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Categories of Interest | Ratings | Total Weight | Weight | Grade | Comment | Ratings | Total Weight | Weight | Grade | Comment |
| Material and Equipment | 7 | 7.83 | 4.31 | 55.00% | Poor | 7 | 7.83 | 5.87 | 75.00% | Good |
| Change Orders | 9 | 5.83 | 3.79 | 65.00% | Okay | 9 | 5.83 | 4.37 | 75.00% | Good |
| Cost | 1 | 13.83 | 11.76 | 85.00% | Great | 1 | 13.83 | 7.61 | 55.00% | Poor |
| Architectural Style | 2 | 12.83 | 10.91 | 85.00% | Great | 2 | 12.83 | 9.62 | 75.00% | Good |
| Schedule | 3 | 11.83 | 7.69 | 65.00% | Okay | 3 | 11.83 | 11.24 | 95.00% | Excellent |
| Mechanical | 11 | 3.83 | 2.87 | 75.00% | Good | 11 | 3.83 | 2.87 | 75.00% | Good |
| Fire Rating | 12 | 2.83 | 2.12 | 75.00% | Good | 12 | 2.83 | 2.12 | 75.00% | Good |
| Structural System Impact | 4 | 10.83 | 8.12 | 75.00% | Good | 4 | 10.83 | 5.96 | 55.00% | Poor |
| Labor Intensive | 5 | 9.83 | 5.41 | 55.00% | Poor | 5 | 9.83 | 8.36 | 85.00% | Great |
| Installation | 8 | 6.83 | 4.44 | 65.00% | Okay | 8 | 6.83 | 5.81 | 85.00% | Great |
| Versatility | 10 | 4.83 | 3.62 | 75.00% | Good | 10 | 4.83 | 3.14 | 65.00% | Okay |
| Quality Control | 6 | 8.83 | 4.86 | 55.00% | Poor | 6 | 8.83 | 8.39 | 95.00% | Excellent |
| TOTAL | | 100.00 | 69.9 | | Okay | | 100.00 | 75.4 | | Good |
| Average | | | | 70.00% | | | | | 72.50% | |

The comparison of the two façade systems have shown that a grade rating of 69.9 and 75.4 for the original and precast façade respectively. This indicates that the project team should select the precast façade system over the original façade system. The advantages of choosing the precast system are as followed:

- Large Schedule reduction
- No shelter and heating required
- Less Crews needed
- Higher safety and increased productivity
- Higher quality control
- Condominium Owners can move in earlier
- Increase profits of other facilities to counteract the additional cost of precast

With all these advantages it is worth if caught early enough by the project team to value engineer the façade and structural supporting system. This also adds to the mat slab redesign because it would add value to the project due to the excellent distribution of loading to subsurface conditions and would not require additional structural footings. Therefore with all these advantages it is of the project team's best interest to utilize thin brick precast panels.



## D.1 Summary and Conclusions

The following is a review of the summary and conclusions made about each analysis conducted in the report:

- **Critical Issues Research – Formwork Decision Process Model**
  - *Formwork Decision Process Modeling has proven to be a worthwhile investment* in exploring and viewing the connections between:
    - What occurs generically in the construction industry.
    - What actually occurred on the Wellington Condominiums Project.
    - And from that develop the most ideal formwork decision process model for the greatest probability of success.
    - It was found that to prevent the budget and schedule from inflation on the Wellington Condominiums Project; that the Contractor and not the Owner should work with the S/M/F early on in the design process.
    - If this does not occur, serious vulnerability to the project budget and schedule will result later on in the construction process.
  - Proven statically why a Design-Build contract succeeds over a traditional format.
    - **Advantages:** Wasteful processes have been taken out of the equation, better communication lines between project participants, and earlier involvement of all project participants leads to success. The Owner will also benefit due to a faster and more productive working environment with the project team. This reduces friction and creates a decrease in budget and schedule.
    - **Disadvantages:** More upfront cost due to the Contractor's early input. But it has been proven time and time again that it is well worth the investment of having good feedback, better communication lines, and working relationships.
  - By having the formwork decision process, Contractors are encouraged to explore new formwork products and become educated as to the latest most productive systems on the market today.
  - From the ideal decision process model for formwork systems, an interesting ideology transpires: Wherever a S/M/F enters into the scene; a Contractor is always there in the selected process.
    - This is due to the fact that **if an Owner and A/E are not experienced, it will lead to a possible loss in the Contractor's ability to learn and make rational constructability decisions and create an increased vulnerability in the project budget and schedule.**



- Therefore the following rule from this research hypothesizes the following statement: **For increased project success, a Contractor should be implemented if an S/M/F is to enter a formwork decision process.**
- **The correct products for a construction project enter under the influence of a Contractor. While the probability of incorrect products for a construction project enters without the influence of a Contractor.**
    - This hypothesis has been proven by the Wellington Condominiums Project and can be served very useful to all construction industry personnel.
- *Generic and ideal decision processes promote different ways for S/M/F to conduct business. Savvy S/M/F knows this and benefit greatly from it!*
    - **Under the Generic Decision Process:**
        - The generic decision process is what is commonly found in traditional way of construction projects. A step by step method in which the contractor is brought onto the project at a later date.
        - The Savvy S/M/F knows this and therefore attacks early on in the design phase with the Owner and A/E. It is a great place for S/M/F to get into a project and have the designs utilize their products.
        - By the time the Contractors step into the picture, the design is already completed and is too late for S/M/F to participate in the project.
        - The more the S/M/F can offer to the Owner and A/E, the more business and profits the S/M/F will create!
            - Design becomes more of a factor to the decision process.
    - **Under the Ideal Decision Process:**
        - The ideal decision process is generally referenced to the new style of construction of design-build.
        - In design-build the Contractor has more say in the design and constructability of the project.
        - Owners tend to play less of a role and A/E relies more heavily on the Contractor's decision as to what systems or products would be best.
        - Therefore it is the Contractor that savvy S/M/F now attacks for business and working relationships. The more S/M/F can do for the contractor the better!
            - Subcontracting work become more of a factor to the decision process.



- **Hambros Joist Composite Deck System:**
  - *From the analysis we can determine that for the Wellington Condominiums Project the selection of the Epicore MSR Composite Floor System would have been best.*
  - Even though the Hambros Joist Composite Deck System scored an “Okay-Good” rating, the Epicore MSR Composite Floor System scored a “Good-Great” rating.
    - One of the reasons for this is due to labor. Labor is a controlling factor and dictates what the schedule and budget will be for a given project.
  - For the Wellington Condominiums Project the utilization of the Hambros Joist Composite Deck System could have been better suited for other projects.
    - Some of the issues that have arisen during construction that have made the Hambros Joist Composite Deck System unpractical for the Wellington Condominiums Project are due to:
      - The project team’s inexperience with the system, highly labor intensive system, acoustical demands for the living spaces, constraints of the formwork system selection process, and non-repetitive joist spacing layout.
    - From industry interviews it was determined that the following points of reference be utilized when considering the implantation of the Hambros Joist Composite Deck System:
      - Repetitive Joist Spacing and Uniformity Throughout
      - Sound Vibration not a critical factor in the building design
      - Have highly skilled labor
      - **Recommended Use:** Factories, Stores, Warehouses, Malls, Airports
      - **Not Recommended Use:** Retirement Homes, Hospitals, Hotels, and Luxury Apartments and Condominiums

- **Foundation Redesign:**
  - The comparison and contrast of the two foundation systems have indicated that a score of 67.6% and 69.4% for the original and mat foundation system respectively. *Both are indicated as an okay system but it is the mat foundation which should be selected by the owner.*
  - This provides an interesting perspective in that the mat foundation even though cost was a number one concern and was over three times the original foundation system; the mat foundation should be perused if given the correct amount of funding availability.



  - The advantages of the mat foundation in subsurface interaction and load distribution create just enough of an advantage to spend the extra money on the system.
  - If however other variables were to change; it could give the possibility of the original foundation system being preferred over the mat foundation system. But with the current information provided, if the amount of funding is available, the mat foundation system should be selected for the Wellington Condominiums Project.

- **Façade Integration:**
  - The comparison of the two façade systems have shown that a grade rating of 69.9 and 75.4 for the original and precast façade respectively.
    - *This indicates that the project team should select the precast façade system over the original façade system.* The advantages of choosing the precast system are as followed:
      - Large Schedule reduction
      - No shelter and heating required
      - Less Crews needed
      - Higher safety and increased productivity
      - Higher quality control
      - Condominium Owners can move in earlier
      - Increase profits of other facilities to counteract the additional cost of precast.
      - With all these advantages it is worth if caught early enough by the project team to value engineer the façade and structural supporting system. This also adds to the mat slab redesign because it would add value to the project due to the excellent distribution of loading to subsurface conditions and would not require additional structural footings. Therefore with all these advantages it is of the project team's best interest to utilize thin brick precast panels.



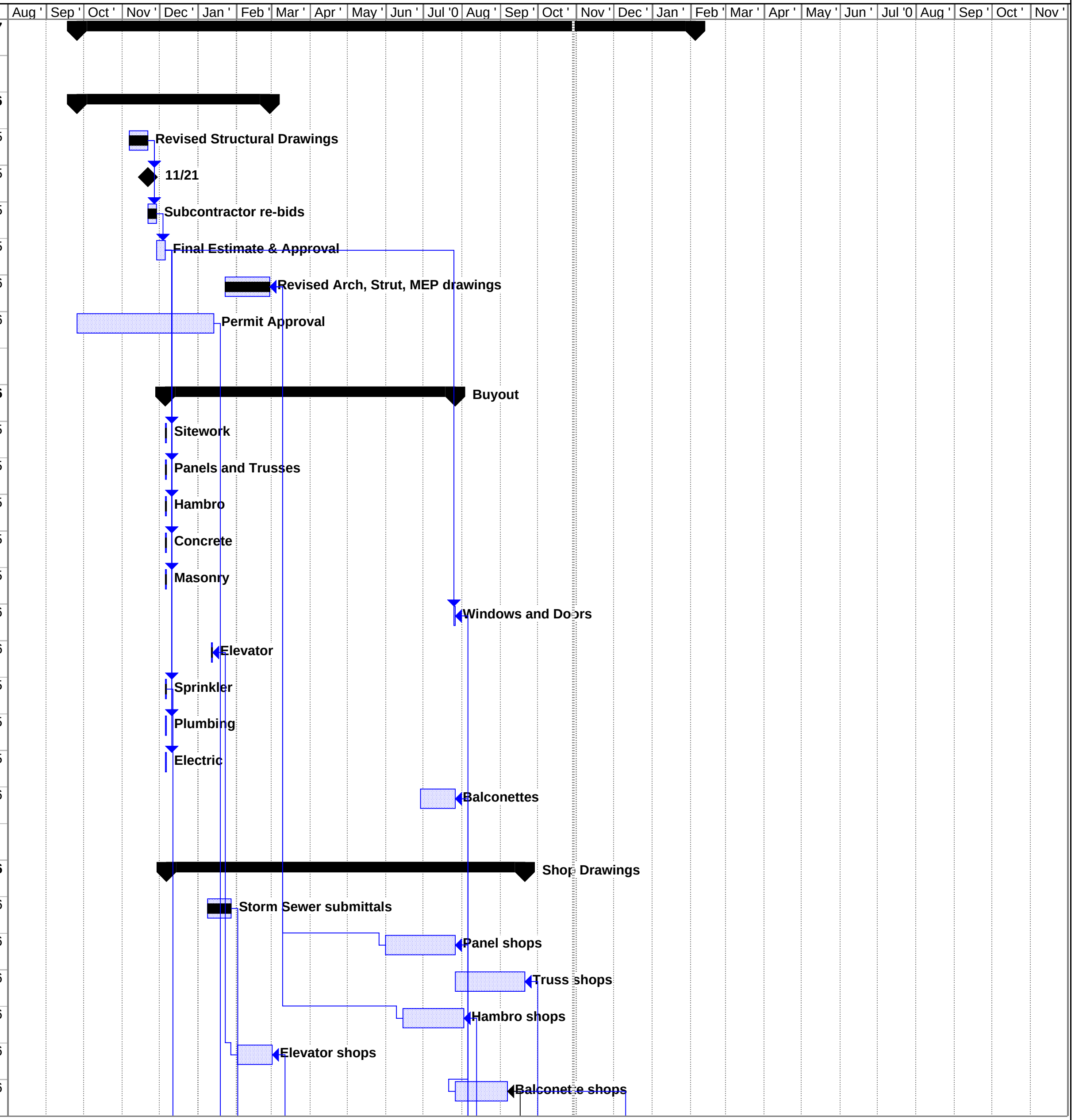
## D.2 Appendix

The following appendix references that are attached for further research support are listed as followed:

- Detailed Project Schedule
- D4 Cost Estimate
- Assemblies Estimate
- Structural Systems Estimate
- General Conditions
- Site Plan with Utilities
- Superstructure Phased Site Plan
- Hambros Joist Composite Deck System Comparison Chart
- Geotechnical Test Boring Results
- PCA MAT® Contours and Analysis
- Crane Selection Information

Wellington Condominiums Detailed Project Schedule

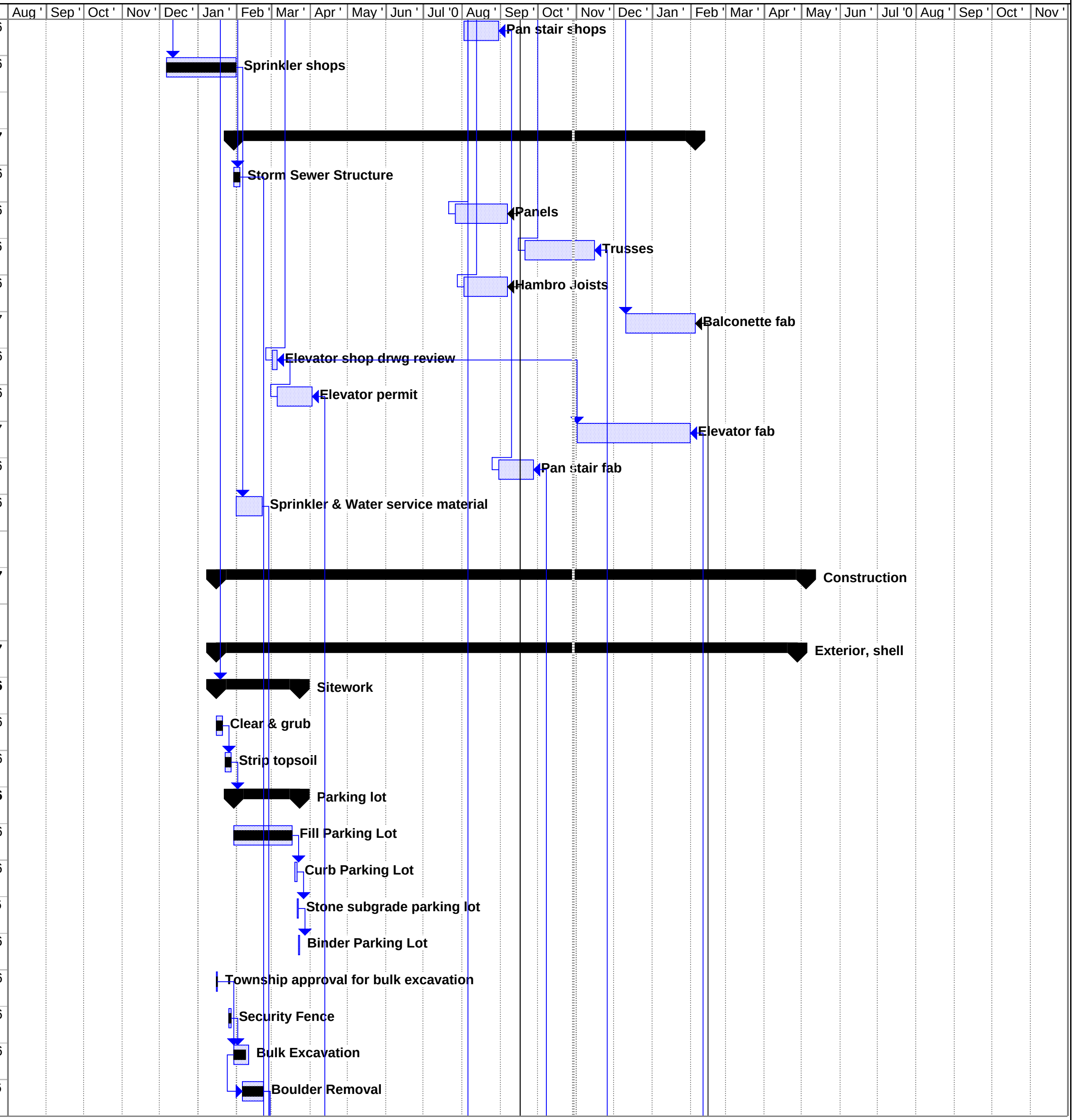
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | **Preconstruction** | **355 days** | **Mon 9/26/05** | **Mon 2/5/07** |
| 2 | | | | |
| 3 | **Project Management** | **111 days** | **Mon 9/26/05** | **Mon 2/27/06** |
| 4 | Revised Structural Drawings | 11 days | Mon 11/7/05 | Mon 11/21/05 |
| 5 | Re-submit for Permits | 0 days | Mon 11/21/05 | Mon 11/21/05 |
| 6 | Subcontractor re-bids | 5 days | Tue 11/22/05 | Mon 11/28/05 |
| 7 | Final Estimate & Approval | 5 days | Tue 11/29/05 | Mon 12/5/05 |
| 8 | Revised Arch, Strut, MEP drawings | 26 days | Mon 1/23/06 | Mon 2/27/06 |
| 9 | Permit Approval | 80 days | Mon 9/26/05 | Fri 1/13/06 |
| 10 | | | | |
| 11 | **Buyout** | **167 days** | **Tue 12/6/05** | **Thu 7/27/06** |
| 12 | Sitework | 1 day | Tue 12/6/05 | Tue 12/6/05 |
| 13 | Panels and Trusses | 1 day | Tue 12/6/05 | Tue 12/6/05 |
| 14 | Hambro | 1 day | Tue 12/6/05 | Tue 12/6/05 |
| 15 | Concrete | 1 day | Tue 12/6/05 | Tue 12/6/05 |
| 16 | Masonry | 1 day | Tue 12/6/05 | Tue 12/6/05 |
| 17 | Windows and Doors | 1 day | Wed 7/26/06 | Thu 7/27/06 |
| 18 | Elevator | 1 day | Thu 1/12/06 | Fri 1/13/06 |
| 19 | Sprinkler | 1 day | Tue 12/6/05 | Tue 12/6/05 |
| 20 | Plumbing | 1 day | Tue 12/6/05 | Tue 12/6/05 |
| 21 | Electric | 1 day | Tue 12/6/05 | Tue 12/6/05 |
| 22 | Balconettes | 20 days | Thu 6/29/06 | Thu 7/27/06 |
| 23 | | | | |
| 24 | **Shop Drawings** | **206 days** | **Wed 12/7/05** | **Thu 9/21/06** |
| 25 | Storm Sewer submittals | 15 days | Mon 1/9/06 | Fri 1/27/06 |
| 26 | Panel shops | 40 days | Thu 6/1/06 | Thu 7/27/06 |
| 27 | Truss shops | 40 days | Thu 7/27/06 | Thu 9/21/06 |
| 28 | Hambro shops | 35 days | Thu 6/15/06 | Thu 8/3/06 |
| 29 | Elevator shops | 20 days | Thu 2/2/06 | Thu 3/2/06 |
| 30 | Balconette shops | 30 days | Thu 7/27/06 | Thu 9/7/06 |




Project: Wellington Condominiums
Date: 10/30/06

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

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 31 | Pan stair shops | 20 days | Thu 8/3/06 | Thu 8/31/06 |
| 32 | Sprinkler shops | 40 days | Wed 12/7/05 | Tue 1/31/06 |
| 33 | | | | |
| 34 | **Fabrication** | **265 days** | **Mon 1/30/06** | **Mon 2/5/07** |
| 35 | Storm Sewer Structure | 5 days | Mon 1/30/06 | Fri 2/3/06 |
| 36 | Panels | 30 days | Thu 7/27/06 | Thu 9/7/06 |
| 37 | Trusses | 40 days | Thu 9/21/06 | Thu 11/16/06 |
| 38 | Hambro Joists | 25 days | Thu 8/3/06 | Thu 9/7/06 |
| 39 | Balconette fab | 40 days | Mon 12/11/06 | Mon 2/5/07 |
| 40 | Elevator shop drwg review | 2 days | Thu 3/2/06 | Mon 3/6/06 |
| 41 | Elevator permit | 20 days | Mon 3/6/06 | Mon 4/3/06 |
| 42 | Elevator fab | 65 days | Thu 11/2/06 | Thu 2/1/07 |
| 43 | Pan stair fab | 20 days | Thu 8/31/06 | Thu 9/28/06 |
| 44 | Sprinkler & Water service material | 15 days | Wed 2/1/06 | Tue 2/21/06 |
| 45 | | | | |
| 46 | **Construction** | **340 days** | **Mon 1/16/06** | **Fri 5/4/07** |
| 47 | | | | |
| 48 | **Exterior, shell** | **335 days** | **Mon 1/16/06** | **Fri 4/27/07** |
| 49 | **Sitework** | **49 days** | **Mon 1/16/06** | **Thu 3/23/06** |
| 50 | Clear & grub | 5 days | Mon 1/16/06 | Fri 1/20/06 |
| 51 | Strip topsoil | 5 days | Mon 1/23/06 | Fri 1/27/06 |
| 52 | **Parking lot** | **39 days** | **Mon 1/30/06** | **Thu 3/23/06** |
| 53 | Fill Parking Lot | 35 days | Mon 1/30/06 | Fri 3/17/06 |
| 54 | Curb Parking Lot | 2 days | Mon 3/20/06 | Tue 3/21/06 |
| 55 | Stone subgrade parking lot | 1 day | Wed 3/22/06 | Wed 3/22/06 |
| 56 | Binder Parking Lot | 1 day | Thu 3/23/06 | Thu 3/23/06 |
| 57 | Township approval for bulk excava | 1 day | Mon 1/16/06 | Mon 1/16/06 |
| 58 | Security Fence | 2 days | Thu 1/26/06 | Fri 1/27/06 |
| 59 | Bulk Excavation | 10 days | Mon 1/30/06 | Fri 2/10/06 |
| 60 | Boulder Removal | 13 days | Mon 2/6/06 | Wed 2/22/06 |




Project: Wellington Condominiums
Date: 10/30/06

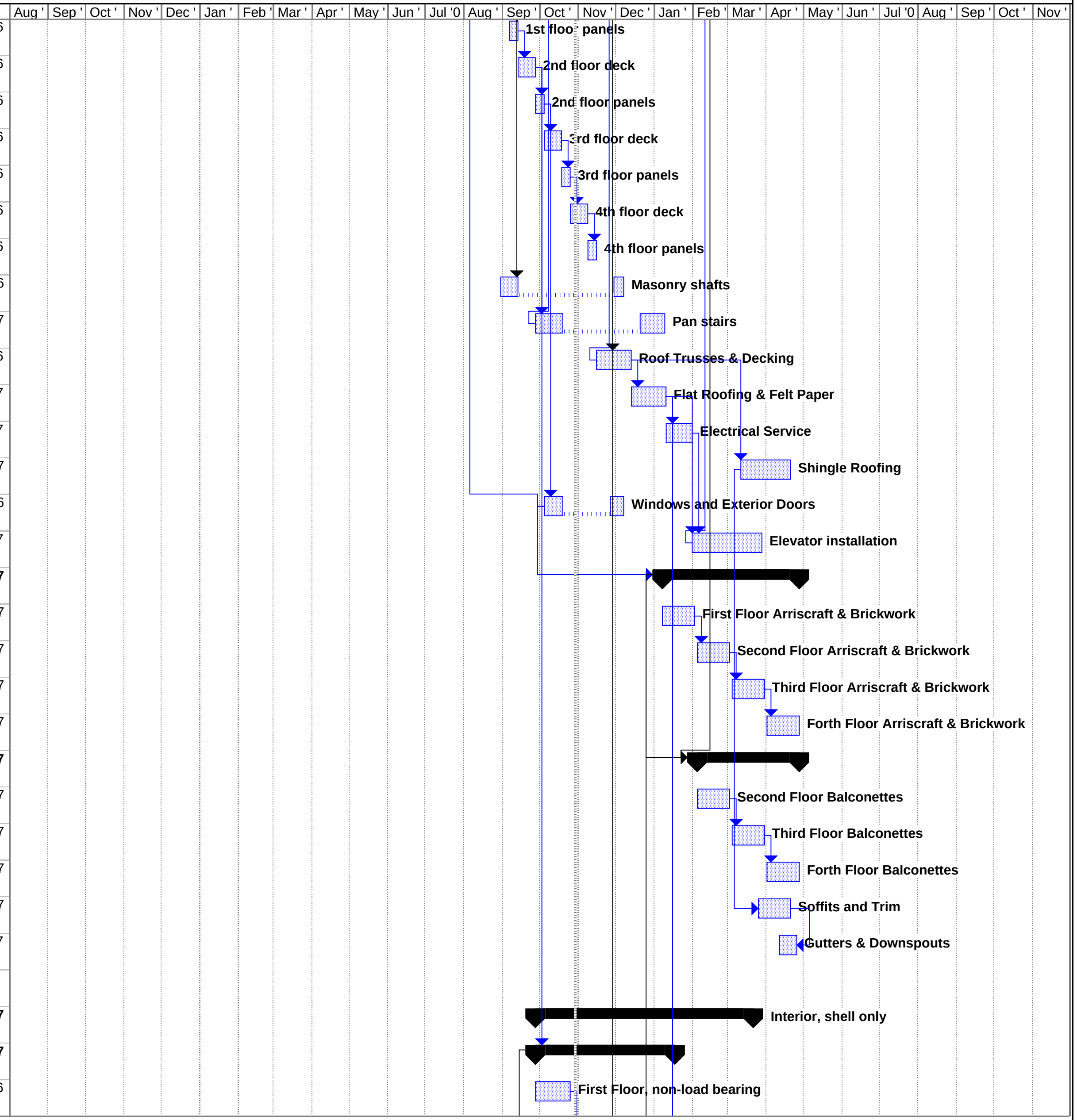
Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 61 | Dewatering pipe | 5 days | Thu 2/23/06 | Wed 3/1/06 |
| 62 | Storm Sewer | 6 days | Thu 2/23/06 | Thu 3/2/06 |
| 63 | **Substructure** | **146 days** | **Wed 2/22/06** | **Wed 9/13/06** |
| 64 | **Foundation & Columns** | **30 days** | **Mon 3/13/06** | **Fri 4/21/06** |
| 65 | Spread and Column Footing I | 2 days | Mon 3/13/06 | Tue 3/14/06 |
| 66 | Spread Footing Rebar and Co | 5 days | Mon 3/13/06 | Fri 3/17/06 |
| 67 | Column Footing Rebar and C | 10 days | Fri 3/17/06 | Thu 3/30/06 |
| 68 | Foundation Wall Formwork Pl | 5 days | Mon 3/27/06 | Fri 3/31/06 |
| 69 | Foundation Wall Rebar and C | 10 days | Wed 3/29/06 | Tue 4/11/06 |
| 70 | Foundation Columns Formwo | 10 days | Fri 4/7/06 | Thu 4/20/06 |
| 71 | Foundation Columns Rebar a | 10 days | Mon 4/10/06 | Fri 4/21/06 |
| 72 | Elevator Jack Holes | 5 days | Mon 4/3/06 | Fri 4/7/06 |
| 73 | Under-slab drainage system & sto | 5 days | Mon 4/17/06 | Mon 4/24/06 |
| 74 | Sprinkler and Domestic water serv | 10 days | Wed 2/22/06 | Tue 3/7/06 |
| 75 | **Garage Slab** | **5 days** | **Mon 4/24/06** | **Fri 4/28/06** |
| 76 | W.W.F. Layout | 2 days | Mon 4/24/06 | Tue 4/25/06 |
| 77 | Concrete Pour Bay 1 | 1 day | Wed 4/26/06 | Wed 4/26/06 |
| 78 | Concrete Pour Bay 2 | 1 day | Thu 4/27/06 | Thu 4/27/06 |
| 79 | Concrete Pour Bay 3 | 1 day | Fri 4/28/06 | Fri 4/28/06 |
| 80 | **Transfer Slab** | **65 days** | **Thu 6/1/06** | **Wed 8/30/06** |
| 81 | Formwork Placement and Sh | 17 days | Thu 6/1/06 | Fri 6/23/06 |
| 82 | Rebar Placement | 18 days | Mon 6/26/06 | Wed 7/19/06 |
| 83 | Concrete Pour Bay 1 | 10 days | Thu 7/20/06 | Wed 8/2/06 |
| 84 | Concrete Pour Bay 2 | 10 days | Thu 8/3/06 | Wed 8/16/06 |
| 85 | Concrete Pour Bay 3 | 10 days | Thu 8/17/06 | Wed 8/30/06 |
| 86 | Foundation waterproofing | 5 days | Mon 4/24/06 | Fri 4/28/06 |
| 87 | Footing, downspout & condensate | 10 days | Mon 5/1/06 | Fri 5/12/06 |
| 88 | Backfill | 10 days | Thu 8/31/06 | Wed 9/13/06 |
| 89 | **Superstructure** | **172 days** | **Thu 8/31/06** | **Fri 4/27/07** |
| 90 | **Panels and Hambro, floors 1-4** | **50 days** | **Thu 9/7/06** | **Wed 11/15/06** |


Project: Wellington Condominiums
Date: 10/30/06

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

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 91 | 1st floor panels | 5 days | Thu 9/7/06 | Wed 9/13/06 |
| 92 | 2nd floor deck | 10 days | Thu 9/14/06 | Wed 9/27/06 |
| 93 | 2nd floor panels | 5 days | Thu 9/28/06 | Wed 10/4/06 |
| 94 | 3rd floor deck | 10 days | Thu 10/5/06 | Wed 10/18/06 |
| 95 | 3rd floor panels | 5 days | Thu 10/19/06 | Wed 10/25/06 |
| 96 | 4th floor deck | 10 days | Thu 10/26/06 | Wed 11/8/06 |
| 97 | 4th floor panels | 5 days | Thu 11/9/06 | Wed 11/15/06 |
| 98 | Masonry shafts | 16 days | Thu 8/31/06 | Thu 12/7/06 |
| 99 | Pan stairs | 30 days | Thu 9/28/06 | Tue 1/9/07 |
| 100 | Roof Trusses & Decking | 20 days | Thu 11/16/06 | Wed 12/13/06 |
| 101 | Flat Roofing & Felt Paper | 20 days | Thu 12/14/06 | Wed 1/10/07 |
| 102 | Electrical Service | 15 days | Thu 1/11/07 | Wed 1/31/07 |
| 103 | Shingle Roofing | 30 days | Mon 3/12/07 | Fri 4/20/07 |
| 104 | Windows and Exterior Doors | 20 days | Thu 10/5/06 | Thu 12/7/06 |
| 105 | Elevator installation | 40 days | Thu 2/1/07 | Wed 3/28/07 |
| 106 | **Arriscraft & Brickwork** | **80 days** | **Mon 1/8/07** | **Fri 4/27/07** |
| 107 | First Floor Arriscraft & Brickw | 20 days | Mon 1/8/07 | Fri 2/2/07 |
| 108 | Second Floor Arriscraft & Bric | 20 days | Mon 2/5/07 | Fri 3/2/07 |
| 109 | Third Floor Arriscraft & Brickv | 20 days | Mon 3/5/07 | Fri 3/30/07 |
| 110 | Forth Floor Arriscraft & Brickv | 20 days | Mon 4/2/07 | Fri 4/27/07 |
| 111 | **Install balconettes** | **60 days** | **Mon 2/5/07** | **Fri 4/27/07** |
| 112 | Second Floor Balconettes | 20 days | Mon 2/5/07 | Fri 3/2/07 |
| 113 | Third Floor Balconettes | 20 days | Mon 3/5/07 | Fri 3/30/07 |
| 114 | Forth Floor Balconettes | 20 days | Mon 4/2/07 | Fri 4/27/07 |
| 115 | Soffits and Trim | 20 days | Mon 3/26/07 | Fri 4/20/07 |
| 116 | Gutters & Downspouts | 10 days | Thu 4/12/07 | Wed 4/25/07 |
| 117 | | | | |
| 118 | **Interior, shell only** | **125 days** | **Thu 9/28/06** | **Wed 3/21/07** |
| 119 | **Partitions, non-load bearing** | **80 days** | **Thu 9/28/06** | **Wed 1/17/07** |
| 120 | First Floor, non-load bearing | 20 days | Thu 9/28/06 | Wed 10/25/06 |




Project: Wellington Condominiums
Date: 10/30/06

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

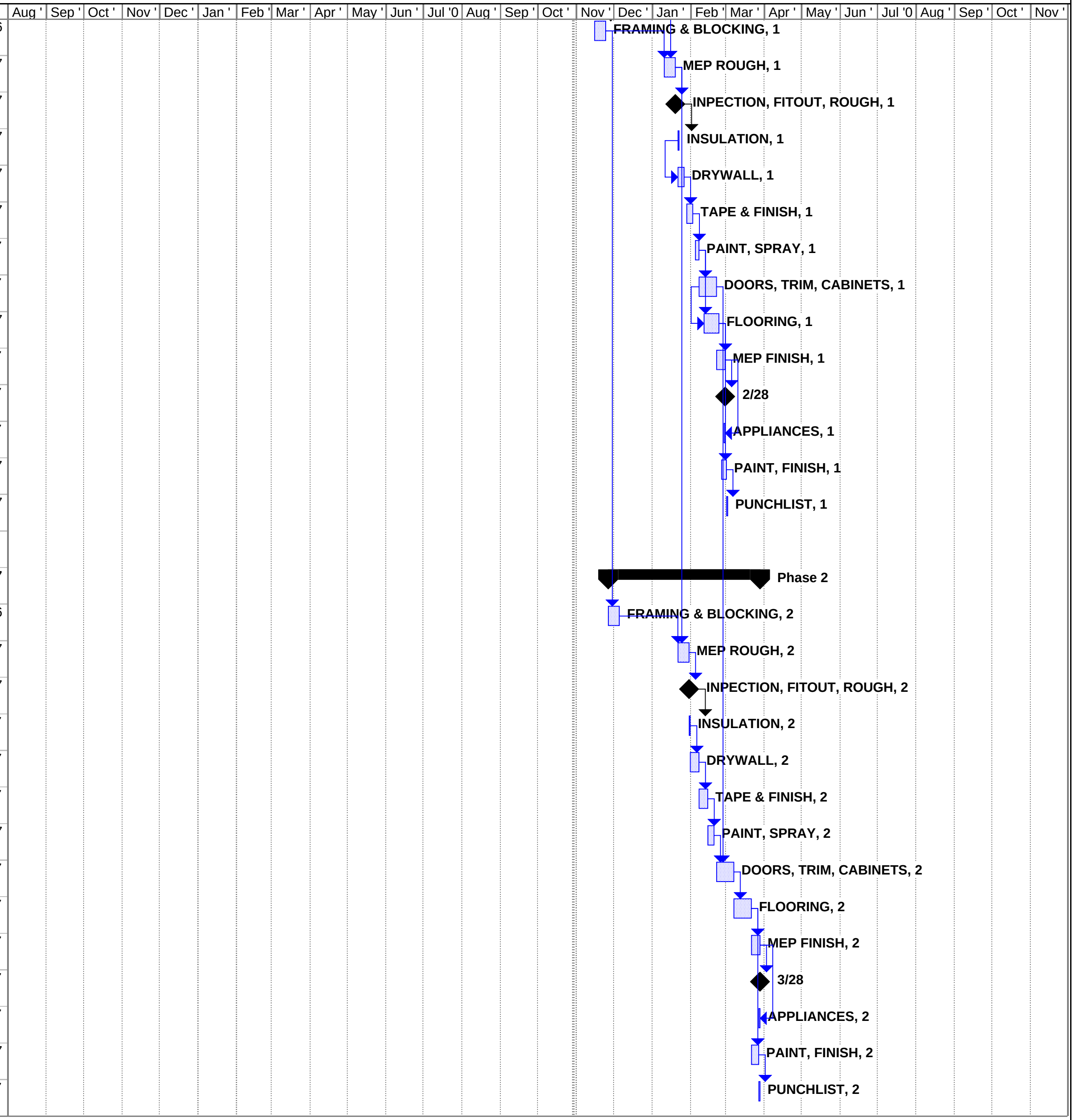
Wellington Condominiums Detailed Project Schedule

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 121 | Second Floor, non-load bearing | 20 days | Thu 10/26/06 | Wed 11/22/06 |
| 122 | Third Floor, non-load bearing | 20 days | Thu 11/23/06 | Wed 12/20/06 |
| 123 | Forth Floor, non-load bearing | 20 days | Thu 12/21/06 | Wed 1/17/07 |
| 124 | **MEP rough-in & Distribution** | **80 days** | **Thu 11/9/06** | **Wed 2/28/07** |
| 125 | First Floor MEP rough-in | 10 days | Thu 11/9/06 | Wed 11/22/06 |
| 126 | First Floor Distribution | 10 days | Thu 11/23/06 | Wed 12/6/06 |
| 127 | Second Floor MEP rough-in | 10 days | Thu 12/7/06 | Wed 12/20/06 |
| 128 | Second Floor Distribution | 10 days | Thu 12/21/06 | Wed 1/3/07 |
| 129 | Third Floor MEP rough-in | 10 days | Thu 1/4/07 | Wed 1/17/07 |
| 130 | Third Floor Distribution | 10 days | Thu 1/18/07 | Wed 1/31/07 |
| 131 | Forth Floor MEP rough-in | 10 days | Thu 2/1/07 | Wed 2/14/07 |
| 132 | Forth Floor Distribution | 10 days | Thu 2/15/07 | Wed 2/28/07 |
| 133 | **Drywall & Finishing** | **40 days** | **Thu 1/11/07** | **Wed 3/7/07** |
| 134 | First Floor Drywall & Finishing | 10 days | Thu 1/11/07 | Wed 1/24/07 |
| 135 | Second Floor Drywall & Finishing | 10 days | Thu 1/25/07 | Wed 2/7/07 |
| 136 | Third Floor Drywall & Finishing | 10 days | Thu 2/8/07 | Wed 2/21/07 |
| 137 | Forth Floor Drywall & Finishing | 10 days | Thu 2/22/07 | Wed 3/7/07 |
| 138 | Paint | 30 days | Thu 2/1/07 | Wed 3/14/07 |
| 139 | Doors, Frames, Hardware | 30 days | Thu 2/8/07 | Wed 3/21/07 |
| 140 | | | | |
| 141 | **Exterior** | **55 days** | **Mon 2/19/07** | **Fri 5/4/07** |
| 142 | Site lighting, rough-in | 10 days | Mon 2/19/07 | Mon 3/5/07 |
| 143 | Sidewalks | 10 days | Mon 3/5/07 | Fri 3/16/07 |
| 144 | Pavers | 10 days | Mon 3/19/07 | Fri 3/30/07 |
| 145 | Paving | 10 days | Mon 4/2/07 | Fri 4/13/07 |
| 146 | Landscaping | 15 days | Mon 4/16/07 | Fri 5/4/07 |
| 147 | | | | |
| 148 | **FITOUT** | **95 days** | **Thu 11/16/06** | **Wed 3/28/07** |
| 149 | | | | |
| 150 | **Phase 1** | **77 days** | **Thu 11/16/06** | **Fri 3/2/07** |


Project: Wellington Condominiums
Date: 10/30/06

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

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 151 | FRAMING & BLOCKING, 1 | 7 days | Thu 11/16/06 | Fri 11/24/06 |
| 152 | MEP ROUGH, 1 | 7 days | Thu 1/11/07 | Fri 1/19/07 |
| 153 | INPECTION, FITOUT, ROUGH, 1 | 0 days | Fri 1/19/07 | Fri 1/19/07 |
| 154 | INSULATION, 1 | 1 day | Mon 1/22/07 | Mon 1/22/07 |
| 155 | DRYWALL, 1 | 5 days | Mon 1/22/07 | Fri 1/26/07 |
| 156 | TAPE & FINISH, 1 | 5 days | Mon 1/29/07 | Fri 2/2/07 |
| 157 | PAINT, SPRAY, 1 | 3 days | Mon 2/5/07 | Wed 2/7/07 |
| 158 | DOORS, TRIM, CABINETS, 1 | 10 days | Thu 2/8/07 | Wed 2/21/07 |
| 159 | FLOORING, 1 | 10 days | Mon 2/12/07 | Fri 2/23/07 |
| 160 | MEP FINISH, 1 | 5 days | Thu 2/22/07 | Wed 2/28/07 |
| 161 | INSPECTION, FITOUT, FINAL, 2 | 0 days | Wed 2/28/07 | Wed 2/28/07 |
| 162 | APPLIANCES, 1 | 1 day | Wed 2/28/07 | Wed 2/28/07 |
| 163 | PAINT, FINISH, 1 | 4 days | Mon 2/26/07 | Thu 3/1/07 |
| 164 | PUNCHLIST, 1 | 1 day | Fri 3/2/07 | Fri 3/2/07 |
| 165 | | | | |
| 166 | **Phase 2** | **88 days** | **Mon 11/27/06** | **Wed 3/28/07** |
| 167 | FRAMING & BLOCKING, 2 | 7 days | Mon 11/27/06 | Tue 12/5/06 |
| 168 | MEP ROUGH, 2 | 7 days | Mon 1/22/07 | Tue 1/30/07 |
| 169 | INPECTION, FITOUT, ROUGH, 2 | 0 days | Tue 1/30/07 | Tue 1/30/07 |
| 170 | INSULATION, 2 | 1 day | Wed 1/31/07 | Wed 1/31/07 |
| 171 | DRYWALL, 2 | 5 days | Thu 2/1/07 | Wed 2/7/07 |
| 172 | TAPE & FINISH, 2 | 5 days | Thu 2/8/07 | Wed 2/14/07 |
| 173 | PAINT, SPRAY, 2 | 3 days | Thu 2/15/07 | Mon 2/19/07 |
| 174 | DOORS, TRIM, CABINETS, 2 | 10 days | Thu 2/22/07 | Wed 3/7/07 |
| 175 | FLOORING, 2 | 10 days | Thu 3/8/07 | Wed 3/21/07 |
| 176 | MEP FINISH, 2 | 5 days | Thu 3/22/07 | Wed 3/28/07 |
| 177 | INSPECTION, FITOUT, FINAL, 2 | 0 days | Wed 3/28/07 | Wed 3/28/07 |
| 178 | APPLIANCES, 2 | 1 day | Wed 3/28/07 | Wed 3/28/07 |
| 179 | PAINT, FINISH, 2 | 4 days | Thu 3/22/07 | Tue 3/27/07 |
| 180 | PUNCHLIST, 2 | 1 day | Wed 3/28/07 | Wed 3/28/07 |




Project: Wellington Condominiums
Date: 10/30/06

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

# Estimate of Probable Cost



Wellington Condominiums Estimate - Oct 2006 - PA - Allentown

| Prepared By: | | Prepared For: | |
|---|---|---|---|
| | , | | , |
| | **Fax:** | | **Fax:** |
| Building Sq. Size: | **116349** | Site Sq. Size: | **1807740** |
| Bid Date: | | Building use: | **Residential** |
| No. of floors: | **4** | Foundation: | **CON** |
| No. of buildings: | **1** | Exterior Walls: | **MET** |
| Project Height: | **59** | Interior Walls: | **MET** |
| 1st Floor Height: | | Roof Type: | **SLA** |
| 1st Floor Size: | **29134** | Floor Type: | **CON** |
| | | Project Type: | **NEW** |

| Division | | Percent | Sq. Cost | Amount |
|---|---|---|---|---|
| **00** | **Bidding Requirements** | **0.49** | **0.74** | **86,421** |
| | Bidding Requirements | 0.49 | 0.74 | 86,421 |
| **01** | **General Requirements** | **11.48** | **17.23** | **2,005,168** |
| | General Requirements | 11.48 | 17.23 | 2,005,168 |
| **02** | **Site Work** | **12.34** | **18.51** | **2,154,162** |
| | Site Work | 12.34 | 18.51 | 2,154,162 |
| **03** | **Concrete** | **9.25** | **13.88** | **1,615,254** |
| | Concrete | 9.25 | 13.88 | 1,615,254 |
| **04** | **Masonry** | **1.87** | **2.81** | **327,256** |
| | Masonry | 1.87 | 2.81 | 327,256 |
| **05** | **Metals** | **2.25** | **3.38** | **392,830** |
| | Metals | 2.25 | 3.38 | 392,830 |
| **06** | **Wood & Plastics** | **7.08** | **10.63** | **1,236,949** |
| | Wood & Plastics | 7.08 | 10.63 | 1,236,949 |
| **07** | **Thermal & Moisture Protection** | **1.80** | **2.70** | **314,027** |
| | Thermal & Moisture Protection | 1.80 | 2.70 | 314,027 |
| **08** | **Doors & Windows** | **6.64** | **9.97** | **1,159,506** |
| | Doors & Windows | 6.64 | 9.97 | 1,159,506 |
| **09** | **Finishes** | **15.61** | **23.42** | **2,724,936** |
| | Finishes | 15.61 | 23.42 | 2,724,936 |
| **10** | **Specialties** | **0.79** | **1.18** | **137,381** |
| | Specialties | 0.79 | 1.18 | 137,381 |
| **11** | **Equipment** | **1.40** | **2.10** | **243,768** |
| | Equipment | 1.40 | 2.10 | 243,768 |
| **12** | **Furnishings** | **0.20** | **0.30** | **35,411** |
| | Furnishings | 0.20 | 0.30 | 35,411 |
| **13** | **Special Construction** | **0.57** | **0.86** | **99,921** |
| | Special Construction | 0.57 | 0.86 | 99,921 |
| **14** | **Conveying Systems** | **1.08** | **1.63** | **189,366** |
| | Conveying Systems | 1.08 | 1.63 | 189,366 |
| **15** | **Mechanical** | **18.08** | **27.14** | **3,157,420** |
| | Mechanical | 18.08 | 27.14 | 3,157,420 |
| **16** | **Electrical** | **9.05** | **13.59** | **1,581,068** |
| | Electrical | 9.05 | 13.59 | 1,581,068 |
| **Total Building Costs** | | **100.00** | **150.07** | **17,460,844** |

# Estimate of Probable Cost



Eola South Residential Condominium - Nov 2003 - FL - Orlando

Prepared By:
**Baker Barrios Architects, Inc.**
**300 South Orange Avenue Ste 900**
**Orlando, FL 32801**
**Fax:**

Prepared For:
**,**
**Fax:**

| | | | |
|---|---|---|---|
| Building Sq. Size: | **60000** | Site Sq. Size: | **435600** |
| Bid Date: | **11/1/2003** | Building use: | **Residential** |
| No. of floors: | **4** | Foundation: | **PIL** |
| No. of buildings: | **1** | Exterior Walls: | **PRE** |
| Project Height: | **50.8** | Interior Walls: | **MAS** |
| 1st Floor Height: | **11.8** | Roof Type: | **BUP** |
| 1st Floor Size: | **15000** | Floor Type: | **CON** |
| | | Project Type: | **NEW** |

| Division | | Percent | Sq. Cost | Amount |
|---|---|---|---|---|
| **00** | **Bidding Requirements** | **0.31** | **0.30** | **18,000** |
| | Permits | 0.31 | 0.30 | 18,000 |
| **01** | **General Requirements** | **14.29** | **13.72** | **823,342** |
| | Builder's Risk Insurance | 0.12 | 0.12 | 7,000 |
| | Building Permit Fees | 0.43 | 0.42 | 25,000 |
| | Change Orders | 3.18 | 3.05 | 183,222 |
| | Contractor's Fee | 3.41 | 3.27 | 196,250 |
| | Equipment Tools | 0.14 | 0.13 | 8,050 |
| | Field Labor, Safety, Clean-up | 1.29 | 1.24 | 74,500 |
| | Field Supervision | 1.15 | 1.10 | 66,000 |
| | General Conditions | 1.14 | 1.10 | 65,700 |
| | General Requirements | 1.56 | 1.50 | 90,000 |
| | Insurance (General Condition Items) | 0.42 | 0.40 | 24,200 |
| | MEP Consulting Fees | 0.63 | 0.61 | 36,330 |
| | MOT, Traffic Control | 0.20 | 0.19 | 11,500 |
| | Temporary Utilities | 0.39 | 0.37 | 22,250 |
| | Trash Removal/Hoisting | 0.23 | 0.22 | 13,340 |
| **03** | **Concrete** | **36.01** | **34.58** | **2,074,734** |
| | 2nd Fl Post Tension-1st Fl Columns | 4.25 | 4.08 | 245,000 |
| | 3rd Fl Post Tension-2nd Fl Columns | 4.25 | 4.08 | 245,000 |
| | 4th Fl Post Tension-3rd Fl Columns | 4.25 | 4.08 | 245,000 |
| | Architectural Precast North Elevati on | 2.60 | 2.50 | 150,000 |
| | Architectural Precast South Elevati on | 2.60 | 2.50 | 150,000 |
| | Architectural Precast West Elevatio n | 6.77 | 6.50 | 390,100 |
| | Elevator Shaft | 0.69 | 0.67 | 40,000 |
| | Pile Caps/Foundations | 3.47 | 3.33 | 200,000 |
| | Retaining Wall | 0.31 | 0.30 | 18,000 |
| | Roof Post Tension-4th Fl Columns | 4.25 | 4.08 | 245,000 |
| | Slab-On-Grade | 1.24 | 1.19 | 71,634 |
| | Stair Enclosures/Shear Wall | 1.30 | 1.25 | 75,000 |
| **04** | **Masonry** | **1.04** | **1.00** | **60,000** |
| | Masonry | 1.04 | 1.00 | 60,000 |
| **05** | **Metals** | **3.38** | **3.25** | **194,750** |
| | Exterior Handrails | 1.52 | 1.46 | 87,750 |
| | Metal Stairs (2) | 1.13 | 1.08 | 65,000 |
| | Misc. Metals | 0.03 | 0.03 | 2,000 |
| | Roof HVAC Screen Wall | 0.69 | 0.67 | 40,000 |
| **06** | **Wood & Plastics** | **3.54** | **3.40** | **204,100** |
| | Closets | 0.22 | 0.21 | 12,650 |
| | Millwork/Countertops | 2.60 | 2.50 | 150,000 |
| | Rough Carpentry-Blocking | 0.46 | 0.44 | 26,600 |
| | Wood Trim/Base | 0.26 | 0.25 | 14,850 |
| **07** | **Thermal & Moisture Protection** | **2.32** | **2.23** | **133,535** |
| | Balcony Coatings | 0.29 | 0.28 | 16,650 |

| | | | | |
|---|---|---|---|---|
| | Dampproofing/Caulking | 0.49 | 0.47 | 28,390 |
| | Modified Bituminous Roof System | 1.54 | 1.47 | 88,495 |
| **08** | **Doors & Windows** | **4.72** | **4.54** | **272,230** |
| | Aluminum Windows & Doors | 2.67 | 2.57 | 153,930 |
| | Doors, Frames & Hardware | 1.63 | 1.56 | 93,800 |
| | Mirrors | 0.12 | 0.12 | 7,000 |
| | Shower Doors | 0.30 | 0.29 | 17,500 |
| **09** | **Finishes** | **15.89** | **15.26** | **915,379** |
| | Carpet/VCT | 1.08 | 1.03 | 62,000 |
| | Drywall | 4.06 | 3.90 | 234,000 |
| | Floor Topping | 0.38 | 0.37 | 22,000 |
| | Metal Studs/Drywall/Plaster | 4.76 | 4.58 | 274,500 |
| | Painting | 2.60 | 2.50 | 150,000 |
| | Special Coating - Stain | 0.12 | 0.12 | 7,175 |
| | Stone Flooring | 0.14 | 0.14 | 8,204 |
| | Tile | 0.78 | 0.75 | 45,000 |
| | Wood Floor | 1.95 | 1.88 | 112,500 |
| **10** | **Specialties** | **0.57** | **0.54** | **32,600** |
| | Entrance Canopy | 0.09 | 0.08 | 5,000 |
| | Fire Extinguishers | 0.02 | 0.02 | 1,050 |
| | Lockers | 0.03 | 0.03 | 1,800 |
| | Mailboxes | 0.07 | 0.07 | 4,000 |
| | Signage | 0.09 | 0.08 | 5,000 |
| | Toilet Accessories | 0.27 | 0.26 | 15,750 |
| **11** | **Equipment** | **1.28** | **1.23** | **73,600** |
| | Appliances | 1.28 | 1.23 | 73,600 |
| **12** | **Furnishings** | **0.33** | **0.32** | **18,995** |
| | Garage Entrance Door | 0.23 | 0.23 | 13,500 |
| | Trash Chute | 0.10 | 0.09 | 5,495 |
| **14** | **Conveying Systems** | **0.95** | **0.92** | **55,025** |
| | Elevator System | 0.95 | 0.92 | 55,025 |
| **15** | **Mechanical** | **8.93** | **8.58** | **514,600** |
| | Fire Protection | 1.29 | 1.24 | 74,100 |
| | Fixtures | 0.43 | 0.42 | 25,000 |
| | HVAC/Ductwork/Piping | 3.73 | 3.58 | 215,000 |
| | Plumbing | 3.48 | 3.34 | 200,500 |
| **16** | **Electrical** | **6.44** | **6.18** | **370,993** |
| | CATV/Audio/Music | 0.17 | 0.17 | 10,000 |
| | Distribution Panels | 0.26 | 0.25 | 15,000 |
| | Electrical | 3.75 | 3.60 | 216,050 |
| | Fire Alarm | 0.17 | 0.17 | 10,000 |
| | Panel Boards | 0.26 | 0.25 | 15,000 |
| | Rough-In/Wire/Conduit | 1.82 | 1.75 | 104,943 |
| **Total Building Costs** | | **100.00** | **96.03** | **5,761,883** |
| **02** | **Site Work** | **100.00** | **0.88** | **381,339** |
| | Asphalt Pavement/Striping | 7.87 | 0.07 | 30,000 |
| | Auger Cast Piling | 38.20 | 0.33 | 145,665 |
| | Building Demolition | 4.89 | 0.04 | 18,650 |
| | Chain Link Fence | 0.79 | 0.01 | 3,024 |
| | Concrete Sidewalks/Curbs | 3.67 | 0.03 | 14,000 |
| | Dewatering System | 5.77 | 0.05 | 22,000 |
| | Earthwork | 6.82 | 0.06 | 26,000 |
| | Gravity Wall | 1.84 | 0.02 | 7,000 |
| | Landscape Irrigation | 6.56 | 0.06 | 25,000 |
| | Utilities | 23.60 | 0.21 | 90,000 |
| **Total Site Costs** | | **100.00** | **0.88** | **381,339** |
| **Total Project Costs** | | **--** | **--** | **6,143,222** |

# Project Notes

Eola South Residential Condominium - Nov 2003 - FL - Orlando

* Orlando, Florida
** Construction Period: Dec 2003 to Jan 2005

Special Project Notes

Sited in downtown Orlando, at the edge of the Thornton Park residential fabric and immediately across the street from a high-rise/multi-family condominium, Eola South Condominium becomes an important element of scale and proportion. The four-story height of the building tempers the 10-story vertical element located across the street as it acts as a proper introduction and transition to the surrounding residential neighborhood.

Its character and design supports the nearby commercial and mixed use buildings. The increased density will support the new, burgeoning retail businesses while the streamlined contemporary design will create a sense of unity with the existing and growing new urban fabric. One of the primary considerations in the design was identifying a way to responsibly take advantage of the natural beauty of Lake Eola Park, located northwest of the building site.

The building program is issue driven and responds to the need for height, both as a transition and a way to take advantage of the view of Lake Eola and the surrounding green-space. Other identified issues that influenced the design were parking density, circulation, security of unit occupants, and the market ability of the units themselves based on current trends and developer philosophies.

The building design responds to the identified program issues by utilizing large glass expanses on the afternoon shaded western and northern elevations of the building. The fenestrations and massing interplay create a unique rhythm connecting the units to the streets below. The building units also feature large balconies, some of which are partially covered.

The building is constructed of cast-in-place concrete as it provided the best quality finish opportunities expected by the developer and prospective occupants. The majority of the units are sized to allow more moderate-income levels the opportunity to experience the downtown urban lifestyle becoming more prevalent in Orlando.

The overall design provides a sense of connectedness and unity to the surrounding urban fabric. The design results in positive interaction and interplay between the building residents and the surrounding neighbors and businesses, providing an expanded sense of community.

MANUFACTURERS/SUPPLIERS
DIV 07: Roofing: Johns Manville.
DIV 08: Window System, Entrances & Storefronts: Vistawall.

CONSTRUCTION TEAM
STRUCTURAL ENGINEER: Walter P. Moore and Associates, Inc. - 300 South Orange Avenue, #875, Orlando, FL 32801
GENERAL CONTRACTOR: Jennings Construction Services, LLC - 1030 Wilfred Drive, Orlando, FL 32803
ELECTRICAL & MECHANICAL ENGINEER: CHP & Associates Consulting Engineers, Inc. - 1051 Winderly Place, #101, Maitland, FL 32751
LANDSCAPE ARCHITECT: Lucido & Sole Design - 827 N. Thornton Avenue, Orlando, FL 32803

Photos Courtesy of Ray Acosta/Taina Benitez

# Estimate of Probable Cost



Convent & High School - Jan 2002 - PA - Other

| | | | |
|---|---|---|---|
| Prepared By: | **Perkins Eastman**<br>**1100 Liberty Avenue**<br>**Pittsburgh, PA 15222**<br>**Fax:** | Prepared For: | **,**<br>**Fax:** |
| Building Sq. Size: | **161428** | Site Sq. Size: | **3179880** |
| Bid Date: | **1/1/2002** | Building use: | **Residential** |
| No. of floors: | **4** | Foundation: | **EXT** |
| No. of buildings: | **1** | Exterior Walls: | **EXT** |
| Project Height: | **49** | Interior Walls: | **GYP** |
| 1st Floor Height: | **9.8** | Roof Type: | **MEM** |
| 1st Floor Size: | **46482** | Floor Type: | **WOD** |
| | | Project Type: | **REN** |

| Division | | Percent | Sq. Cost | Amount |
|---|---|---|---|---|
| **00** | **Bidding Requirements** | **0.66** | **0.65** | **104,754** |
| | Bond | 0.66 | 0.65 | 104,754 |
| **01** | **General Requirements** | **12.74** | **12.58** | **2,031,254** |
| | Scaffold at Chapel | 0.31 | 0.31 | 49,815 |
| | General Conditions | 8.19 | 8.09 | 1,306,529 |
| | Fees | 4.23 | 4.18 | 674,910 |
| **03** | **Concrete** | **1.55** | **1.53** | **247,095** |
| | Building Concrete | 1.07 | 1.06 | 170,704 |
| | Light Weight Concrete | 0.05 | 0.05 | 7,973 |
| | Cementitious Underlayment | 0.03 | 0.03 | 5,298 |
| | Patching | 0.40 | 0.39 | 63,120 |
| **04** | **Masonry** | **2.54** | **2.51** | **404,712** |
| | Masonry Repairs - New Openings | 0.71 | 0.71 | 113,826 |
| | Masonry | 1.66 | 1.64 | 264,038 |
| | Restoration | 0.17 | 0.17 | 26,848 |
| **05** | **Metals** | **2.29** | **2.26** | **365,020** |
| | Structural Steel/Joists & Decking | 1.72 | 1.70 | 274,800 |
| | Miscellaneous | 0.54 | 0.54 | 86,810 |
| | Architectural Joint Systems | 0.02 | 0.02 | 3,410 |
| **06** | **Wood & Plastics** | **9.73** | **9.61** | **1,552,040** |
| | Rough Carpentry | 0.57 | 0.57 | 91,435 |
| | Plywood Underlayment | 0.73 | 0.72 | 116,719 |
| | Finish Carpentry | 2.71 | 2.68 | 432,412 |
| | Install Salvaged Items | 2.06 | 2.04 | 328,766 |
| | Architectural Woodwork (Casework) | 2.97 | 2.94 | 474,296 |
| | Wood Laboratory Casework | 0.68 | 0.67 | 108,412 |
| **07** | **Thermal & Moisture Protection** | **1.97** | **1.94** | **313,593** |
| | Waterproofing | 0.05 | 0.05 | 7,350 |
| | Membrane Roofing | 1.77 | 1.75 | 282,100 |
| | Metal Roofing | 0.12 | 0.12 | 19,072 |
| | Roof Accessories | 0.01 | 0.01 | 1,556 |
| | Caulking | 0.02 | 0.02 | 3,515 |
| **08** | **Doors & Windows** | **8.62** | **8.52** | **1,375,241** |
| | Doors & Hardware | 2.21 | 2.19 | 352,913 |
| | Storefront/Glass & Glazing | 0.22 | 0.22 | 34,995 |
| | Metal Windows | 5.29 | 5.23 | 844,048 |
| | Decorative Glass & Mirrors | 0.45 | 0.45 | 72,285 |
| | Fireproofing | 0.45 | 0.44 | 71,000 |
| **09** | **Finishes** | **18.56** | **18.34** | **2,960,675** |
| | Plaster - (Patching) | 0.40 | 0.40 | 64,513 |
| | Drywall/Metal Studs | 10.73 | 10.60 | 1,711,424 |
| | Acoustical Wall Panels | 0.29 | 0.29 | 46,667 |
| | Ceramic Tile Work Allowance | 1.06 | 1.05 | 169,165 |
| | Terrazzo (Patch & Repair) | 0.13 | 0.12 | 20,000 |
| | Wood Floor & Refinishing | 1.44 | 1.42 | 229,566 |

| | | | | |
|---|---|---|---|---|
| | Stone Window Sills | 0.45 | 0.44 | 71,340 |
| | Painting/High Performace Coatings | 1.88 | 1.86 | 300,000 |
| | Flooring Carpet/Resilient | 2.18 | 2.16 | 348,000 |
| **10** | **Specialties** | **1.02** | **1.01** | **162,602** |
| | Visual Display Boards | 0.03 | 0.03 | 5,500 |
| | Toilet Compartments | 0.13 | 0.13 | 20,457 |
| | Impact-Resistant Wall Protection | 0.01 | 0.01 | 1,386 |
| | Signs Allowance | 0.13 | 0.12 | 20,000 |
| | Metal Lockers | 0.20 | 0.20 | 32,000 |
| | Fire Protection | 0.03 | 0.03 | 4,605 |
| | Toilet Accessories | 0.29 | 0.28 | 45,660 |
| | Folding & Portable Stages | 0.16 | 0.15 | 24,994 |
| | Stage Curtains | 0.05 | 0.05 | 8,000 |
| **11** | **Equipment** | **1.71** | **1.69** | **273,014** |
| | Projection Screens | 0.01 | 0.01 | 2,236 |
| | Food Service | 1.52 | 1.50 | 242,270 |
| | Residential Appliances | 0.16 | 0.16 | 25,824 |
| | Barber & Beauty | 0.02 | 0.02 | 2,684 |
| **12** | **Furnishings** | **0.20** | **0.20** | **31,487** |
| | Floor Mats & Frames | 0.03 | 0.03 | 4,167 |
| | Window Treatment | 0.17 | 0.17 | 27,320 |
| **13** | **Special Construction** | **0.44** | **0.44** | **70,800** |
| | Fixed Auditorium Seating | 0.44 | 0.44 | 70,800 |
| **14** | **Conveying Systems** | **1.34** | **1.33** | **214,200** |
| | Elevator | 1.34 | 1.33 | 214,200 |
| **15** | **Mechanical** | **24.88** | **24.58** | **3,968,000** |
| | Plumbing | 5.44 | 5.37 | 867,000 |
| | Fire Protection | 2.34 | 2.31 | 373,000 |
| | HVAC | 17.10 | 16.90 | 2,728,000 |
| **16** | **Electrical** | **11.76** | **11.62** | **1,875,446** |
| | Electrical | 11.57 | 11.44 | 1,845,946 |
| | Light Allowance | 0.18 | 0.18 | 29,500 |
| **Total Building Costs** | | **100.00** | **98.81** | **15,949,933** |
| **02** | **Site Work** | **100.00** | **0.84** | **2,677,411** |
| | Demo/Salvage/ASB Abate Phase 1 | 53.78 | 0.45 | 1,439,965 |
| | Structural Demolition Phase 1a | 17.35 | 0.15 | 464,439 |
| | Excavation & Grading | 9.66 | 0.08 | 258,548 |
| | Asphalt Paving | 2.17 | 0.02 | 58,111 |
| | Landscaping | 4.93 | 0.04 | 132,000 |
| | Site Concrete | 2.25 | 0.02 | 60,258 |
| | Trash Enclosure Fence | 0.13 | 0.00 | 3,410 |
| | Relocation of Statues | 0.67 | 0.01 | 18,000 |
| | Storm Drainage | 0.86 | 0.01 | 22,950 |
| | Relocation of Underground Pipelines | 0.37 | 0.00 | 10,000 |
| | Site Retaining Walls | 0.46 | 0.00 | 12,420 |
| | Underpinning | 1.21 | 0.01 | 32,310 |
| | Courtyard Improvements | 5.60 | 0.05 | 150,000 |
| | Remote Garage | 0.56 | 0.00 | 15,000 |
| **Total Site Costs** | | **100.00** | **0.84** | **2,677,411** |
| **Total Project Costs** | | **--** | **--** | **18,627,344** |

# Project Notes

Convent & High School - Jan 2002 - PA - Other

* Coraopolis, Pennsylvania
** Construction Period: Mar 2002 to Aug 2003
*** LEED(R) GOLD PENDING

Special Project Notes

The Franciscan nuns of the Felician Sisters Convent wanted to renovate their 70-year-old provincial house to feel less like an institution and more like a home. The community was living in two buildings: St. Joseph Hall, a 1960's infirmary building, and the 1930's motherhouse, which also housed Our Lady of the Sacred Heart High School.

Perkins Eastman completed a master planning study and the Sisters decided to renovate the motherhouse and consolidate the community under one roof. As such, the existing building plan was not workable as an assisted living facility. The elderly Sisters' bedrooms were too far from existing gang bathrooms, which were too small to negotiate with walkers or wheelchairs. The building systems had not been upgraded since the 1930's, there were no individual temperature controls, and the existing partitions contained asbestos. The building needed to be gutted, yet doing so would jeopardize the very reason for renovating the motherhouse.

With full community participation, Perkins Eastman re-configured the 150,000-square-foot convent into clusters of individual rooms with private baths in 10 households arrayed around a living room, kitchen and dining room. Spatially, four different Halls organize the new school plan and express the Franciscan Order's ethics: the Hall of Life, the Hall of Social Justice, the Hall of Peace, and the Hall of Community. These Halls are focal points on each floor and are used for the presentation of student work and as informal gathering spaces. Large openings in the classrooms provide natural light, along with high reflectance paint and mecco shades. On the grounds, the students enjoy trails cut into seven acres of newly planted meadow from an area previously maintained as lawn. All plants are selected from native species.

The project team held a strong commitment to making the renovation environmentally responsible and to preserving the house's historic architectural character. While the Felician Sisters were not educated about many environmental issues, they are followers of Saint Francis of Assisi who is the Patron Saint of the Environment. This commitment allows them to view environmental stewardship as a responsibility. As the project evolved and the Sisters became more aware of the building's potential environmental impacts, they consistently made decisions based on stewardship.

Working through the project and environmental goals, the team soon realized the value in the resources that the building contained. Many materials installed in 1930 were still in excellent condition. If the Sisters wanted low maintenance and durable materials, they could not buy new materials that would perform as well as the old. A subcontractor was hired to catalog, remove, touch-up, repair and reinstall the doors, flooring, trim and cabinetry.

More than 300 original hardwood doors and transoms were refinished and re-hung; over an acre of hardwood flooring was lifted, cleaned and re-laid; over a mile of trim was removed, preserved and installed; and over 275,000 pounds of ballast for the roof was stockpiled and reused as underlayment for paving. New windows were made using energy efficient technologies but were manufactured to look like the original windows. The perimeter of the building was studded out and insulated. Construction waste was recycled and all new finishes were made from low emitting materials to preserve indoor air quality. New energy efficient systems for both lighting and heating were installed as well as solar hot water panels to aid in energy reduction.

As the project progressed it became clear that decisions most benefiting the community were also beneficial to the environment. The building has preserved the character of the original structure, is energy efficient, better serves an aging and student population, and promotes environmental stewardship. The architect achieved over a 30% reduction in energy consumption compared to a baseline model. Systems used to achieve the reduction included heat recovery from air and kitchen exhausts; individual controls in each classroom; landscaped plantings that shade the south and west facades; and recycled roof water used in the evaporative cooler. The client has used the project, which is seeking a gold LEED(R) rating, to educate their Sisters, students and staff in issues of the environment including green cleaning, recycling, vermicomposting, renewable energy, and the building itself.

MANUFACTURERS/SUPPLIERS
DIV 02: Pavers: Hanover Architectural Products.
DIV 07: Wall Insulation: Johns Manville; Roof Insulation: Carlisle Sure-Seal(R); Membrane Roofing: Carlisle Sure-Weld(R).
DIV 08: Windows: Keystone Industries.
DIV 09: Paint: Sherwin Williams; Linoleum: Forbo Marmoleum; Carpet: Interface, Collins & Aikman; Ceramic Tile: Terra Green.

CONSTRUCTION TEAM
GENERAL CONTRACTOR: Sota Construction Services, Inc. - 80 Union Avenue, Pittsburgh, PA 15202
STRUCTURAL ENGINEER: The Kachele Group - 1014 Perry Highway, #100, Pittsburgh, PA 15237
ELECTRICAL/MECHANICAL/PLUMBING ENGINEER: Elwood S. Tower Corp. - 115 Evergreen Heights Drive, #400, Pittsburgh, PA 15229
MATERIALS REUSE CONTRACTOR: Clearview Project Services Company - 3977 William Flynn Highway, Allison Park, PA 15101
LANDSCAPE ARCHITECT: Rolf Sauer and Partners, Ltd. - 3868 Terrace Street, Philadelphia, PA 19128

Photos Courtesy of Denmarsh Photography

| Estimating Form | | Project Summary | |
|---|---|---|---|
| PROJECT | Wellington Condominiums | TOTAL SITE AREA | 5.88 Acres |
| BUILDING TYPE | Residential | OWNER | Hankin Group |
| LOCATION | Exton PA | ARCHITECT | Minno & Wasko |
| DATE OF CONSTRUCTION | Spring '06 - Spring '07 | ESTIMATED CONSTRUCTION PERIOD | 18 Months |
| BRIEF DESCRIPTION | Wellington Condominiums is a 4 story luxery complex that houses a parking garage on the ground level. The 147,069 SF condominium project features a concrete substructure followed by a series of Hambros Joist 3" Slab on Deck Composite System. The roof system utilizes a single ply EPDM roofing membrane and slate roof system supporting by metal rafters. | | |

*Assemblies Estimate - Wellington Condominiums Building Envelope*

| Estimating Form | | | | Systems Costs | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Qty** | **Assembly Number** | **Description** | **Unit** | **Mat.** | **Inst.** | **Total** | **Zip Code Prefix** | **Type** | **Release** | **Note** |
| **B20 Exterior Closure** | | | | | | | | | | |
| 9,312.000 | B20101017600 | Conc wall reinforced, 8' high, 12" thick, plain finish, 5000 PSI | S.F. | 63,787.20 | 142,939.20 | 206,726.40 | 181 | Open | 2006 | Walls are 12' high, 6000 PSI Strength |
| 670.910 | B20101023000 | Flt precast conc,4" thick,5x18',smooth gray,low rise | S.F. | 4,193.19 | 2,475.66 | 6,668.85 | 181 | Open | 2006 | |
| 8,998.600 | B20101023150 | Flt precast conc,4" thick,12x20',smooth gray,low rise | S.F. | 79,187.68 | 9,898.46 | 89,086.14 | 181 | Open | 2006 | |
| 14,588.330 | B20101305200 | Brk vnr/met std bkup,std face,20gax3-5/8"nlb std,16" OC sp,rnng bnd | S.F. | 86,071.15 | 199,860.12 | 285,931.27 | 181 | Open | 2006 | 22 Gage studs utilized |
| 350.000 | B20201046350 | Windows,steel,csmt,insul gl,5'-11" x 5'-2",3 lite | Ea. | 586,250.00 | 154,000.00 | 740,250.00 | 181 | Open | 2006 | Average window size |
| 221.000 | B20302102500 | Doors,birch,solid core,single door,hinged,3'-0" x 7'-0" opening | Opng. | 226,525.00 | 54,587.00 | 281,112.00 | 181 | Open | 2006 | |
| **B30 Roofing** | | | | | | | | | | |
| 7,289.000 | B30101202000 | Sgl ply memb, EPDM, 45mils, fully adhered | S.F. | 6,195.65 | 5,758.31 | 11,953.96 | 181 | Open | 2006 | |
| 25,018.000 | B30101402800 | Slate roofing, 4" min slope, shingles, 3/16" thick, 8.0 PSF | S.F. | 162,617.00 | 61,043.92 | 223,660.92 | 181 | Open | 2006 | |
| 7,289.000 | B30104300700 | Flashing,copper,no backing,16 oz,< 500 lbs | S.F. | 22,158.56 | 26,313.29 | 48,471.85 | 181 | Open | 2006 | 6" Half round copper gutter |
| 776.000 | B30106103300 | Gutters,half round,copper,16 oz thick,5",mill finish | L.F. | 4,462.00 | 3,360.08 | 7,822.08 | 181 | Open | 2006 | |
| 1,395.875 | B30106200700 | Downspouts,copper,rectangular corr,3"x4",mill,16 oz thick | V.L.F. | 7,049.17 | 4,997.23 | 12,046.40 | 181 | Open | 2006 | |
| 1.000 | B30202100200 | Roof hatches, with curb, and 1" fiberglass insulation, 2'-6"x3'-0",al | Opng. | 605.00 | 172.00 | 777.00 | 181 | Open | 2006 | |
| | | **Totals** | | **$1,249,101.59** | **$665,405.27** | **$1,914,506.86** | | | | |
| | | | | x | x | x | | | | |
| | | **Allentown PA location factor multiplier** | | 0.98 | 1.074 | 1.027 | | | | |
| | | | | **$1,224,119.56** | **$714,645.26** | **$1,966,198.55** | | | | |

*Detailed Structural Estimate for Wellington Condominiums*

| Total Unit Costs | | Foundations, Substructure, Superstructure | |
|---|---|---|---|
| Qty | CSI Number | Description | Total |
| **Division 3 Concrete - Forms and Accessories** | | | |
| 1.000 | 31104107750 | C.I.P. concrete forms, column, square, steel framed plywood, 24" x 24", rent, 4 uses per month, includes erecting, bracing, stripping and cleaning | $14,951.04 |
| 1.000 | 31104201000 | C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 1 use, includes shoring, erecting, bracing, stripping and cleaning | $250,836.35 |
| 1.000 | 31104206500 | C.I.P. concrete forms, elevated slab, curb forms, wood, 6" to 12" high, 1 use, includes shoring, erecting, bracing, stripping and cleaning | $4,578.40 |
| 1.000 | 31104207000 | C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, erecting, bracing, stripping and cleaning | $1,750.00 |
| 1.000 | 31104559260 | C.I.P. concrete forms, walls, steel framed plywood, over 8' to 16' high, based on 100 uses of purchased forms, 4 uses of bracing lumber, includes erecting, bracing, stripping and cleaning | $66,704.20 |
| 1.000 | 31500800020 | Anchor bolts, J-type, 1/2" diameter x 6" long, includes nut and washer | $1,338.60 |
| 1.000 | 31501701000 | Column clamp, adjustable, buy, to 24" x 24" | $85.00 |
| 1.000 | 31506001500 | Shores, reshoring | $20,912.40 |
| **Division 3 Concrete - Reinforcement** | | | |
| 1.000 | 32101001200 | High chairs, for reinforcing steel, individual, no plates, plain, to 3" high, includes material only | $19,821.00 |
| 1.000 | 32101001500 | Bar chair, for reinforcing steel, plain, includes material only | $14,852.26 |
| 1.000 | 32106000200 | Reinforcing steel, in place, columns, #3 to #7, A615, grade 60, incl access. Labor | $8,465.76 |
| 1.000 | 32106000400 | Reinforcing steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl access. Labor | $67,314.35 |
| 1.000 | 32106000500 | Reinforcing steel, in place, footings, #4 to #7, A615, grade 60, incl access. Labor | $40,692.09 |
| 1.000 | 32106000700 | Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl access. Labor | $16,049.42 |
| 1.000 | 32202000200 | Welded wire fabric, sheets, 6 x 6 - W2.1 x W2.1 (8 x 8) 30 lb. per C.S.F., A185 | $12,748.80 |
| 1.000 | 32202000300 | Welded wire fabric, sheets, 6 x 6 - W2.9 x W2.9 (6 x 6) 42 lb. per C.S.F., A185 | $58,268.00 |
| **Division 3 Concrete - Cast-In-Place** | | | |
| 1.000 | 33102200150 | Structural concrete, ready mix, normal weight, 3000 psi, includes material only | $132,168.96 |
| 1.000 | 33102200411 | Structural concrete, ready mix, normal weight, 6000 PSI, includes material only | $207,304.69 |
| 0.000 | 33102201000 | Structural concrete, ready mix, high early strength cement, add, includes material only | |
| 1.000 | 33107000800 | Structural concrete, placing, column, square or round, pumped, 24" thick, includes vibrating, excludes material | $1,820.03 |
| 1.000 | 33107001400 | Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes vibrating, excludes material | $18,764.50 |
| 1.000 | 33107001600 | Structural concrete, placing, elevated slab, pumped, over 10" thick, includes vibrating, excludes material | $14,104.62 |
| 1.000 | 33107002650 | Structural concrete, placing, spread footing, pumped, over 5 C.Y., includes vibrating, excludes material | $8,204.02 |
| 1.000 | 33107003250 | Structural concrete, placing, grade beam, pumped, includes vibrating, excludes material | $1,043.47 |
| 1.000 | 33107004350 | Structural concrete, placing, slab on grade, pumped, 4" thick, includes vibrating, excludes material | $8,267.89 |
| 1.000 | 33107005100 | Structural concrete, placing, walls, pumped, 12" thick, includes vibrating, excludes material | $8,208.07 |
| 1.000 | 33503000250 | Concrete finishing, floors, monolithic, machine trowel finish | $61,705.35 |
| 1.000 | 33503250120 | Control joint, concrete floor slab, saw cut in green concrete, 1" depth | $794.04 |
| **Division 5 Metals - Cold Formed Framing** | | | |
| 1.000 | 54104006400 | Partition, galv LB studs, 16 ga x 6" W studs 16" O.C. x 12' H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging | $403,447.20 |
| 1.000 | 54204100550 | Floor joist, galv CF steel, 12 ga x 12" D, incl joists (2" flange) & fasteners, excl band joists (track), web stiffeners, headers, beams, bridging & bracing, materials only | $153,159.24 |
| 1.000 | 54204101550 | Floor joist, galv CF steel, 12 ga x 12" D, incl fastening to band joists, beams & headers, excl materials, labor only | $46,305.00 |
| | | **Total:** | **$1,664,664.75** |
| | | **ENR Building Cost Index Inflation from 2005 to 2006** | (Addition of 3.9% Total Cost Escalation) |
| | | **Allentown, PA Location Factor already in calculations** | |
| | | | **$1,729,586.68** |

*Detailed Structural Estimate for Wellington Condominiums*

## Wall Strip Footings — Foundations

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 3 Concrete** | | | | | | | | | | | | | | |
| 7.610 | 32101001200 | High chairs, for reinforcing steel | | | | C | 506.07 | 0.00 | 0.00 | 506.07 | 555.53 | 181 | Open | 2005 |
| 7.610 | 32101001500 | Bar chair, for reinforcing steel | | | | C | 285.38 | 0.00 | 0.00 | 285.38 | 312.01 | 181 | Open | 2005 |
| 2.445 | 32106000500 | Reinforcing steel, in place, footings, #4 to #7 | 4 Rodm | 2.1 | 15.238 | Ton | 1,919.33 | 1,088.03 | 0.00 | 3,007.35 | 4,034.25 | 181 | Open | 2005 |
| 84.56 | 33102200411 | Structural concrete, ready mix, normal weight | | | | C.Y. | 7,737.24 | 0.00 | 0.00 | 7,737.24 | 8,510.96 | 181 | Open | 2005 |
| 84.56 | 33107003250 | Structural concrete, placing, grade beam | C20 | 180 | 0.356 | C.Y. | 0.00 | 634.20 | 409.27 | 1,043.47 | 1,509.40 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$10,448.01** | **$1,722.23** | **$409.27** | **$12,579.50** | **$14,922.15** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

**Allentown, PA Location Factor already in calculations**

**$13,070.10**

## Single Slab Column Footings — Foundations

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 3 Concrete** | | | | | | | | | | | | | | |
| 98.000 | 32101001500 | Bar chair, for reinforcing steel | | | | C | 3,675.00 | 0.00 | 0.00 | 3,675.00 | 4,018.00 | 181 | Open | 2005 |
| 30.638 | 32106000500 | Reinforcing steel, in place, footings, #4 to #7 | 4 Rodm | 2.1 | 15.238 | Ton | 24,050.83 | 13,633.91 | 0.00 | 37,684.74 | 50,552.70 | 181 | Open | 2005 |
| 556.205 | 33102200411 | Structural concrete, ready mix, normal weight | | | | C.Y. | 50,892.76 | 0.00 | 0.00 | 50,892.76 | 55,982.03 | 181 | Open | 2005 |
| 556.205 | 33107002650 | Structural concrete, placing, spread footing | C20 | 150 | 0.427 | C.Y. | 0.00 | 4,978.03 | 3,225.99 | 8,204.02 | 11,958.41 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$78,618.59** | **$18,611.94** | **$3,225.99** | **$100,456.52** | **$122,511.14** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

**Allentown, PA Location Factor already in calculations**

**$104,374.32**

## Foundation Walls — Substructure

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 3 Concrete** | | | | | | | | | | | | | | |
| 21,942.170 | 31104559260 | C.I.P. concrete forms, walls | C2 | 450 | 0.107 | SFCA | 8,338.02 | 58,366.17 | 0.00 | 66,704.20 | 108,174.90 | 181 | Open | 2005 |
| 14.657 | 32106000700 | Reinforcing steel, in place, walls, #3 to #7 | 4 Rodm | 3 | 10.667 | Ton | 11,505.75 | 4,543.67 | 0.00 | 16,049.42 | 20,886.23 | 181 | Open | 2005 |
| 406.340 | 33102200411 | Structural concrete, ready mix, normal weight | | | | C.Y. | 37,180.11 | 0.00 | 0.00 | 37,180.11 | 40,898.12 | 181 | Open | 2005 |
| 406.340 | 33107005100 | Structural concrete, placing, walls, pumped | C20 | 110 | 0.582 | C.Y. | 0.00 | 4,977.67 | 3,230.40 | 8,208.07 | 11,783.86 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$57,023.88** | **$67,887.51** | **$3,230.40** | **$128,141.79** | **$181,743.10** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

**Allentown, PA Location Factor already in calculations**

**$133,139.32**

***Detailed Structural Estimate for Wellington Condominiums***

## Foundation Columns — Substructure

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 3 Concrete** | | | | | | | | | | | | | | |
| 4,516.930 | 31104107750 | C.I.P. concrete forms, column, square | C1 | 440 | 0.073 | SFCA | 6,865.73 | 8,085.30 | 0.00 | 14,951.04 | 21,274.74 | 181 | Open | 2005 |
| 1.000 | 31501701000 | Column clamp, adjustable, buy, to 24" x 24" | | | | Set | 85.00 | 0.00 | 0.00 | 85.00 | 93.50 | 181 | Open | 2005 |
| 5.879 | 32106000200 | Reinforcing steel, in place, columns, #3 to #7 | 4 Rodm | 1.5 | 21.333 | Ton | 4,850.18 | 3,615.59 | 0.00 | 8,465.76 | 11,758.00 | 181 | Open | 2005 |
| 75.520 | 33102200411 | Structural concrete, ready mix, normal weight | | | | C.Y. | 6,910.08 | 0.00 | 0.00 | 6,910.08 | 7,601.09 | 181 | Open | 2005 |
| 75.520 | 33107000800 | Structural concrete, placing, column, square | C20 | 92 | 0.696 | C.Y. | 0.00 | 1,106.37 | 713.66 | 1,820.03 | 2,643.20 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$18,710.99** | **$12,807.26** | **$713.66** | **$32,231.91** | **$43,370.53** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

**Allentown, PA Location Factor already in calculations**

**$33,488.95**

## Slab on Grade — Substructure

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 3 Concrete** | | | | | | | | | | | | | | |
| 307.200 | 32202000200 | Welded wire fabric, sheets, 6 x 6 - W2.1 x W2.1 | 2 Rodm | 31 | 0.516 | C.S.F. | 8,140.80 | 4,608.00 | 0.00 | 12,748.80 | 17,203.20 | 181 | Open | 2005 |
| 484.920 | 33102200150 | Structural concrete, ready mix, normal weight | | | | C.Y. | 38,405.66 | 0.00 | 0.00 | 38,405.66 | 42,246.23 | 181 | Open | 2005 |
| 484.920 | 33107004350 | Structural concrete, placing, slab on grade | C20 | 130 | 0.492 | C.Y. | 0.00 | 5,018.92 | 3,248.96 | 8,267.89 | 11,880.54 | 181 | Open | 2005 |
| 30,720.000 | 33503000250 | Concrete finishing, floors, monolithic | 1 Cefi | 550 | 0.015 | S.F. | 0.00 | 10,752.00 | 0.00 | 10,752.00 | 17,510.40 | 181 | Open | 2005 |
| 509.000 | 33503250120 | Control joint, concrete floor slab | C27 | 2,000 | 0.008 | L.F. | 0.00 | 96.71 | 35.63 | 132.34 | 193.42 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$46,546.46** | **$20,475.63** | **$3,284.59** | **$70,306.69** | **$89,033.79** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

**Allentown, PA Location Factor already in calculations**

**$73,048.65**

## Transfer Slab — Superstructure

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 3 Concrete** | | | | | | | | | | | | | | |
| 29,045.000 | 31104201000 | C.I.P. concrete forms, elevated slab, flat plate | C2 | 470 | 0.102 | S.F. | 118,503.60 | 74,064.75 | 0.00 | 192,568.35 | 255,596.00 | 181 | Open | 2005 |
| 776.000 | 31104206500 | C.I.P. concrete forms, elevated slab, curb forms | C1 | 180 | 0.178 | SFCA | 1,171.76 | 3,406.64 | 0.00 | 4,578.40 | 7,022.80 | 181 | Open | 2005 |
| 388.000 | 31500800020 | Anchor bolts, J-type, 1/2" diameter x 6" long | 1 Carp | 90 | 0.089 | Ea. | 372.48 | 966.12 | 0.00 | 1,338.60 | 2,056.40 | 181 | Open | 2005 |
| 29,045.000 | 31506001500 | Shores, reshoring | 2 Carp | 1,400 | 0.011 | S.F. | 11,327.55 | 9,584.85 | 0.00 | 20,912.40 | 28,173.65 | 181 | Open | 2005 |
| 290.450 | 32101001200 | High chairs, for reinforcing steel | | | | C | 19,314.93 | 0.00 | 0.00 | 19,314.93 | 21,202.85 | 181 | Open | 2005 |
| 290.450 | 32101001500 | Bar chair, for reinforcing steel, plain | | | | C | 10,891.88 | 0.00 | 0.00 | 10,891.88 | 11,908.45 | 181 | Open | 2005 |
| 56.330 | 32106000400 | Reinforcing steel, in place, elevated slabs | 4 Rodm | 2.9 | 11.034 | Ton | 49,288.75 | 18,025.60 | 0.00 | 67,314.35 | 85,903.25 | 181 | Open | 2005 |
| 1,143.000 | 33102200411 | Structural concrete, ready mix, normal weigh | | | | C.Y. | 104,584.50 | 0.00 | 0.00 | 104,584.50 | 115,042.95 | 181 | Open | 2005 |
| 1,143.000 | 33107001600 | Structural concrete, placing, elevated slab | C20 | 180 | 0.356 | C.Y. | 0.00 | 8,572.50 | 5,532.12 | 14,104.62 | 20,402.55 | 181 | Open | 2005 |
| 29,045.000 | 33503000250 | Concrete finishing, floors, monolithic | 1 Cefi | 550 | 0.015 | S.F. | 0.00 | 10,165.75 | 0.00 | 10,165.75 | 16,555.65 | 181 | Open | 2005 |
| 509.000 | 33503250120 | Control joint, concrete floor slab | C27 | 2,000 | 0.008 | L.F. | 0.00 | 96.71 | 35.63 | 132.34 | 193.42 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$315,455.44** | **$124,882.92** | **$5,567.75** | **$445,906.11** | **$564,057.97** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

**Allentown, PA Location Factor already in calculations**

**$463,296.45**

### *Detailed Structural Estimate for Wellington Condominiums*

## Metal Stud Framing — Superstructure

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 5 Metals** | | | | | | | | | | | | | | |
| 13,936.000 | 54104006400 | Partition, galv LB studs, 16 ga x 6" W studs | 2 Carp | 51 | 0.314 | L.F. | 262,693.60 | 140,753.60 | 0.00 | 403,447.20 | 529,568.00 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$262,693.60** | **$140,753.60** | **$0.00** | **$403,447.20** | **$529,568.00** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

**Allentown, PA Location Factor already in calculations**

**$419,181.64**

## Hambro Joist System and Components — Superstructure

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 5 Metals** | | | | | | | | | | | | | | |
| 25526.54 | 54204100550 | Floor joist, galv CF steel, 12 ga x 12" D | | | | L.F. | 153,159.24 | 0.00 | 0.00 | 153,159.24 | 167,198.84 | 181 | Open | 2005 |
| 2,700.000 | 54204101550 | Floor joist, galv CF steel, 12 ga x 12" D | 2 Carp | 30 | 0.533 | Ea. | 0.00 | 46,305.00 | 0.00 | 46,305.00 | 78,300.00 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$153,159.24** | **$46,305.00** | **$0.00** | **$199,464.24** | **$245,498.84** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

**Allentown, PA Location Factor already in calculations**

**$207,243.35**

## Deck Slabs — Superstructure

| Qty | CSI Number | Description | Crew | Daily Output | Labor Hours | Unit | Bare Mat. | Bare Labor | Bare Equip. | Total | Total Incl. O&P | Zip Code Prefix | Type | Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Division 3 Concrete** | | | | | | | | | | | | | | |
| 29,134.000 | 31104201000 | C.I.P. concrete forms, elevated slab, flat plate | C2 | 470 | 0.102 | S.F. | 14,567.00 | 14,567.00 | 0.00 | 58,268.00 | 98,181.58 | 181 | Open | 2005 |
| 1,000.000 | 31104207000 | C.I.P. concrete forms, elevated slab, edge forms | C1 | 500 | 0.064 | L.F. | 170.00 | 1,580.00 | 0.00 | 1,750.00 | 2,860.00 | 181 | Open | 2005 |
| 1,165.360 | 32202000300 | Welded wire fabric, sheets, 6 x 6 - W2.9 x W2.9 | 2 Rodm | 29 | 0.552 | C.S.F. | 39,622.24 | 18,645.76 | 0.00 | 58,268.00 | 76,331.08 | 181 | Open | 2005 |
| 1,183.880 | 33102200150 | Structural concrete, ready mix, normal weight | | | | C.Y. | 93,763.30 | 0.00 | 0.00 | 93,763.30 | 103,139.63 | 181 | Open | 2005 |
| 1,183.880 | 33102201000 | Structural concrete, ready mix | | | | C.Y. | 10.00% | | | | | 181 | Open | 2005 |
| 1,183.880 | 33107001400 | Structural concrete, placing, elevated slab | C20 | 140 | 0.457 | C.Y. | 0.00 | 11,424.44 | 7,340.06 | 18,764.50 | 27,229.24 | 181 | Open | 2005 |
| 116,536.000 | 33503000250 | Concrete finishing, floors, monolithic | 1 Cefi | 550 | 0.015 | S.F. | 0.00 | 40,787.60 | 0.00 | 40,787.60 | 66,425.52 | 181 | Open | 2005 |
| 2,036.000 | 33503250120 | Control joint, concrete floor slab | C27 | 2,000 | 0.008 | L.F. | 0.00 | 386.84 | 142.52 | 529.36 | 773.68 | 181 | Open | 2005 |
| | | **Totals** | | | | | **$148,122.64** | **$87,391.64** | **$7,482.58** | **$272,130.75** | **$374,940.73** | | | |

**ENR Building Cost Index Inflation from 2005 to 2006** (Addition of 3.9% Total Cost Escalation)

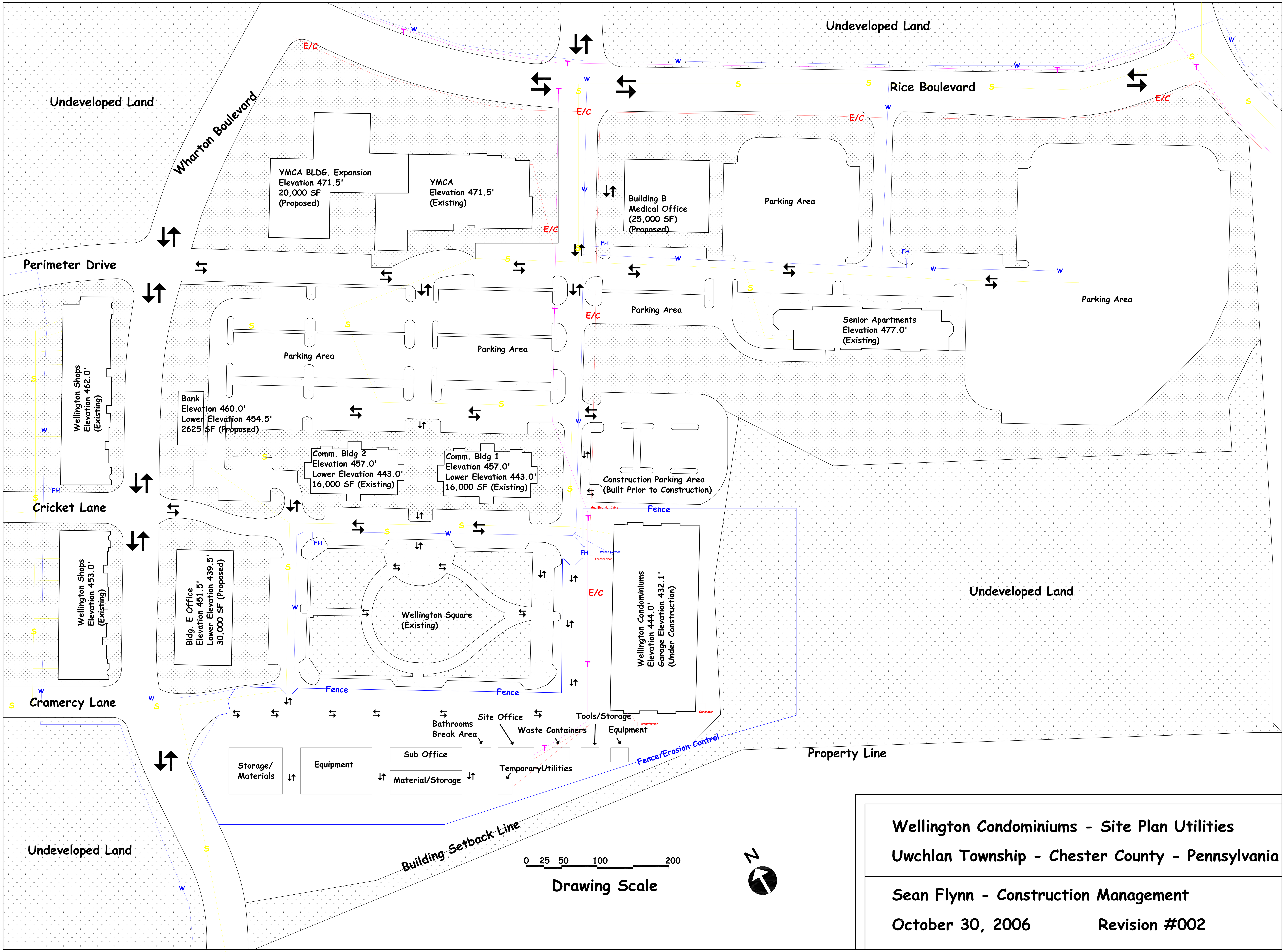
**Allentown, PA Location Factor already in calculations**

**$282,743.85**

***General Conditions Estimate for Wellington Condominiums***

## General Conditions

| Description | Quantity | Unit | Unit Cost | Total |
|---|---|---|---|---|
| SR. PROJECT MANAGER | 35 | WKS | $3,500.00 | $122,500 |
| SUPERINTENDENT | 60 | WKS | $3,000.00 | $180,000 |
| LABORER | 52 | WKS | $800.00 | $41,600 |
| ASSISTANT SUPERINTENDENT | 30 | WKS | $2,500.00 | $75,000 |
| SURVEYING | 1 | L.S | $22,000.00 | $22,000 |
| INSPECTIONS | 1 | L.S | $30,000.00 | $30,000 |
| TWP BLDG PERMIT | 1 | L.S | $44,405.00 | $44,405 |
| FITOUT PERMIT | 48 | EACH | $400.00 | $19,200 |
| TEMPORARY UTILITIES | 1 | L.S | $30,000.00 | $30,000 |
| TEMPORARY SIGNS | 1 | EACH | $2,500.00 | $2,500 |
| CONSTRUCTION TRAILERS | 14 | MTH | $300.00 | $4,200 |
| OFFICE EXPENSES (BLUE PRINTS) | 116,000 | S.F. | $0.22 | $25,520 |
| TRASH REMOVAL (DUMPSTERS) | 60 | EACH | $500.00 | $30,000 |
| EQUIP & TOOL RENTALS | 1 | L.S | $20,000.00 | $20,000 |
| MATERIALS & SUPPLIES | 12 | MTH | $200.00 | $2,400 |
| FINAL SITE CLEAN-UP | 1 | EACH | $5,000.00 | $5,000 |
| FINAL BUILDING CLEAN-UP | 48 | EACH | $400.00 | $19,200 |
| PUNCH LIST | 48 | EACH | $400.00 | $19,200 |
| | | | **Total:** | **$692,725.00** |

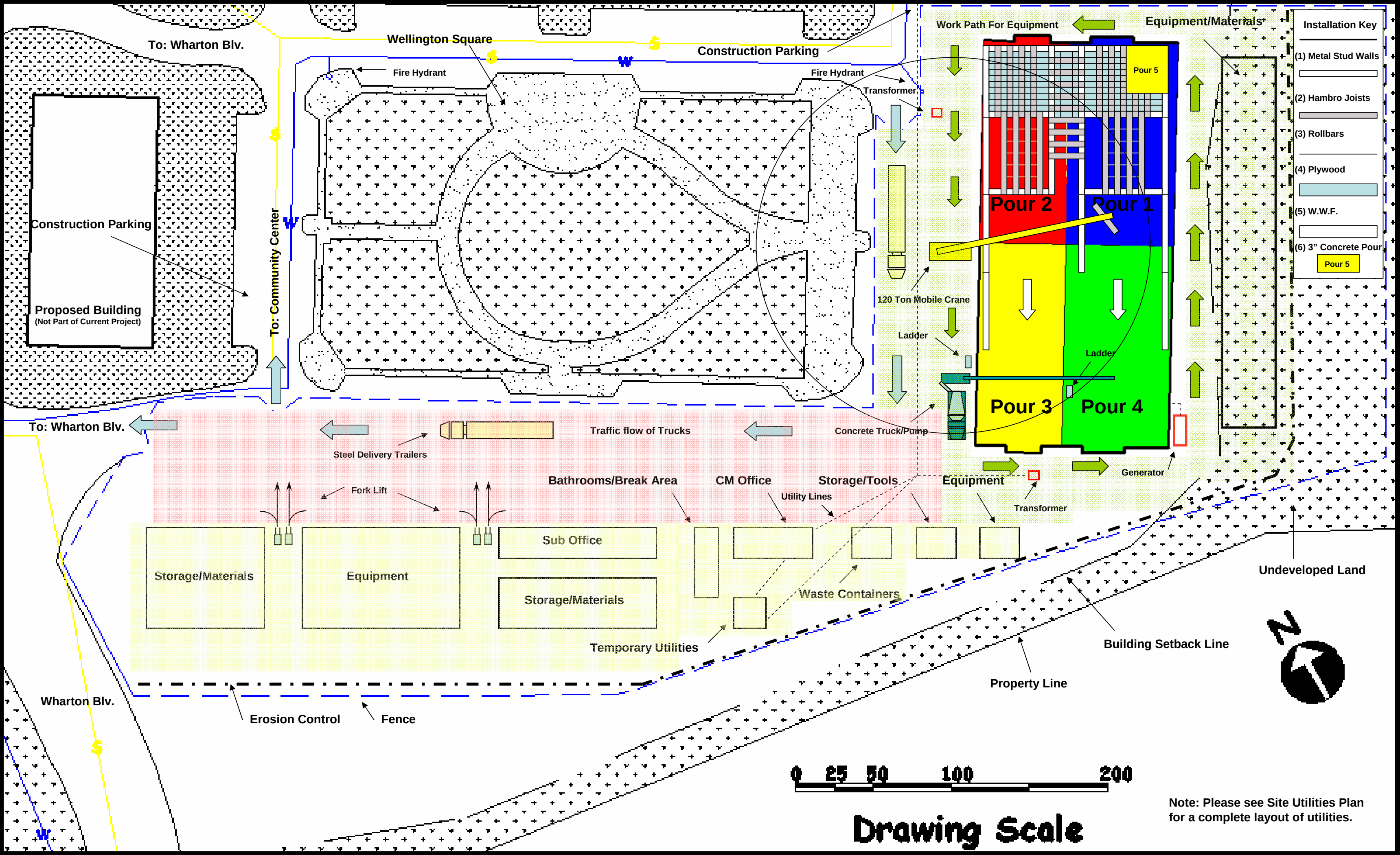



Wellington Condominiums - Site Plan Utilities

Uwchlan Township - Chester County - Pennsylvania

Sean Flynn - Construction Management

October 30, 2006 Revision #002



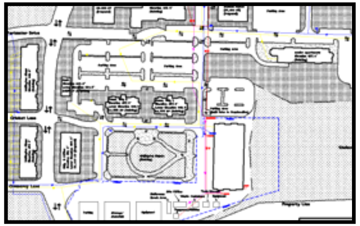

## Wellington Condominiums Site Layout

## Superstructure Construction Analysis

Uwchlan Township – Chester County - Pennsylvania

Sean Flynn – Construction Management

October 30, 2006 Revision #001



**Wellington Condominium Zones**

Unloading and Vehicle Traffic Zone

Storage/Equipment/Offices Zone

Construction Zone

# Report Card for Assemblies

| Compare and Contrast Floor-Ceiling Assemblies | Hambros Joist Composite Deck System | | | | | Conventional Steel Joist & Metal Deck System | | | | | Epicore MSR Composite Floor System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Categories of Interest | Ratings | Total Weight | Weight | Grade | Comment | Ratings | Total Weight | Weight | Grade | Comment | Ratings | Total Weight | Weight | Grade | Comment |
| **Fire Ratings** | 8 | 6.83 | 5.12 | 75.00% | Good | 8 | 6.83 | 5.12 | 75.00% | Good | 8 | 6.83 | 5.81 | 85.00% | Great |
| **Composite Design** | 9 | 5.83 | 4.37 | 75.00% | Good | 9 | 5.83 | 4.37 | 75.00% | Good | 9 | 5.83 | 4.96 | 85.00% | Great |
| **Cost Savings** | 1 | 13.83 | 10.37 | 75.00% | Good | 1 | 13.83 | 8.99 | 65.00% | Okay | 1 | 13.83 | 10.37 | 75.00% | Good |
| **Slab Penetrations** | 10 | 4.83 | 4.11 | 85.00% | Great | 10 | 4.83 | 3.14 | 65.00% | Okay | 10 | 4.83 | 3.14 | 65.00% | Okay |
| **Schedule Savings** | 2 | 12.83 | 9.62 | 75.00% | Good | 2 | 12.83 | 9.62 | 75.00% | Good | 2 | 12.83 | 10.91 | 85.00% | Great |
| **Mechanical Interfacing** | 7 | 7.83 | 6.66 | 85.00% | Great | 7 | 7.83 | 5.87 | 75.00% | Good | 7 | 7.83 | 5.87 | 75.00% | Good |
| **Acoustical Properties** | 3 | 11.83 | 7.69 | 65.00% | Okay | 3 | 11.83 | 8.87 | 75.00% | Good | 3 | 11.83 | 8.87 | 75.00% | Good |
| **Bearing Systems** | 11 | 3.83 | 2.49 | 65.00% | Okay | 11 | 3.83 | 2.49 | 65.00% | Okay | 11 | 3.83 | 2.49 | 65.00% | Okay |
| **Labor Intensive** | 6 | 8.83 | 4.86 | 55.00% | Poor | 6 | 8.83 | 6.62 | 75.00% | Good | 6 | 8.83 | 7.51 | 85.00% | Great |
| **Installation** | 5 | 9.83 | 6.39 | 65.00% | Okay | 5 | 9.83 | 7.37 | 75.00% | Good | 5 | 9.83 | 7.37 | 75.00% | Good |
| **Versatility** | 12 | 2.83 | 1.56 | 55.00% | Poor | 12 | 2.83 | 2.12 | 75.00% | Good | 12 | 2.83 | 2.41 | 85.00% | Great |
| **Quality Control** | 4 | 10.83 | 7.04 | 65.00% | Okay | 4 | 10.83 | 8.12 | 75.00% | Good | 4 | 10.83 | 8.12 | 75.00% | Good |
| **TOTAL** | | 100.00 | **70.3** | | **Okay-Good** | | 100.00 | **72.75** | | **Good** | | 100.00 | **77.85** | | **Good-Great** |
| **Average** | | | | 70.00% | | | | | 72.50% | | | | | 77.50% | |

| Scaling Factor | | Rating Factor | | |
|---|---|---|---|---|
| 12 | 2.83333333 | A | 100-90 | Excellent |
| 11 | 3.83333333 | B | 90-80 | Great |
| 10 | 4.83333333 | C | 80-70 | Good |
| 9 | 5.83333333 | D | 70-60 | Okay |
| 8 | 6.83333333 | F | 60-50 | Poor |
| 7 | 7.83333333 | | | |
| 6 | 8.83333333 | | | |
| 5 | 9.83333333 | | | |
| 4 | 10.83333333 | | | |
| 3 | 11.83333333 | | | |
| 2 | 12.83333333 | | | |
| 1 | 13.83333333 | | | |

# Main Line Drilling Company

101 Calvarese Lane - Wayne, PA 19087

Phone/Fax: (610) 341-9296 - Email: MLDrill@aol.com


Boring#: 5

Client: Earth Engineering Inc

Project: Eagleview Condominiums

Location: Eagleville, Pa

Drill Rig: Mobile B-57

Job#: 1871

Date Started: 5/23/2005

Completed: 5/23/2005

Driller: William Corcoran

Assistant: Stephen Luner

Ground Surface Elevation: 434.1

| Equipment Used for Boring Advancement | | | | |
|---|---|---|---|---|
| 1 | 3 1/4" Hollow auger | 0" | To | 18'6" |
| 2 | Split spoon | 18'6" | To | 18'10" |

| Groundwater Information | | |
|---|---|---|
| Depth | Time | Date |
| Dry | 1/4 hr | 5/23/2005 |
| 13'10" | 2.5 hrs | 5/23/2005 |

| Depth | S# | Sample Depth | Blow/Counts | Soil Description |
|---|---|---|---|---|
| | | | | Topsoil 4" |
| | S1 | 0" - 2' | 3-5-10-27-SR | |
| | S2 | 3'6"-5'6" | 5-5-6-7 | Sandy silt to silty sand with rock fragments, some clay, trace organics orange-brown, brown, and gray |
| 5' | S3 | 5'6"-7'6" | 11-14-18-15 | |
| | S4 | 7'6"-9'6" | 12-16-15-13 | (Fill) |
| 10' | S5 | 9'6"-11'6" | 12-16-20-19 | 11'6" |
| | | | | Sandy silt, gray and orange brown 13' |
| 15' | S6 | 13'6"-15' | 19-18-20 | Fine to medium sand, with rock fragments gray, tan, and orange-brown (Weathered gneiss) |
| 20' | S7 | 18'6"-18'10" | 100/4" | 18'10" |
| 25' | | | | |
| 30' | | | | |
| 35' | | | | |
| 40' | | | | |
| 45' | | | | |
| 50' | | | | |

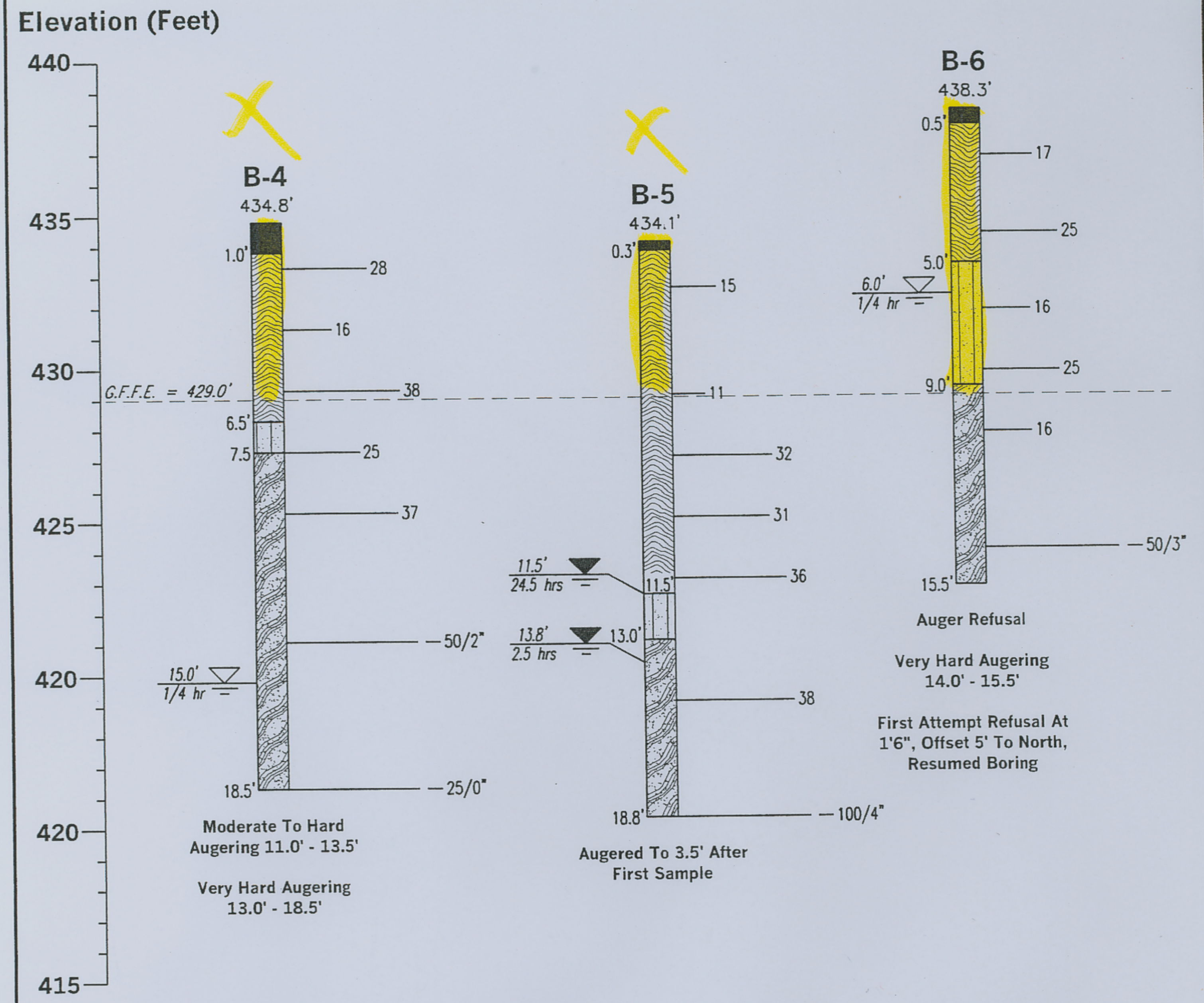
**Comments**

SR= Spoon refusal, large rock fragments to 3', augered to 3'6" after first sample

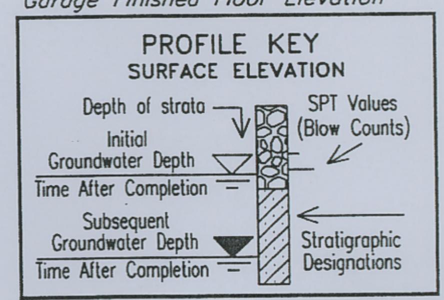
S1 13"
S2 12"
S3 14"
S4 15"
S5 13"
S6 12"
S7 4"

* TEST BORING RESULTS REPRESENT EACH BORING LOCATION ONLY *

* GROUNDWATER LEVELS SHOWN ARE RECORDED AT BORING COMPLETION UNLESS OTHERWISE NOTED *




G.F.F.E. = Garage Finished Floor Elevation




| | |
|---|---|
| TOPSOIL | |
| FILL | TAN TO ORANGE-BROWN, AND GRAY TO BROWN, SANDY SILT WITH ROCK FRAGMENTS, SOME CLAY, AND TRACE ORGANICS |
| STRATUM I | TAN TO ORANGE-BROWN, AND GRAY TO BROWN, SANDY SILT TO SILTY SAND, AND SOME SILTY CLAY, WITH ROCK FRAGMENTS |
| STRATUM II | MULTICOLORED SILTY SAND TO SAND WITH ROCK FRAGMENTS (WEATHERED GNEISS) |

## BORING PROFILES

EARTH ENGINEERING INCORPORATED
*Geotechnical Engineers & Geologists*
115 W. Germantown Pike
East Norriton, PA 19401
(610)277-0880
FAX (610)277-0878
www.earthengineering.com

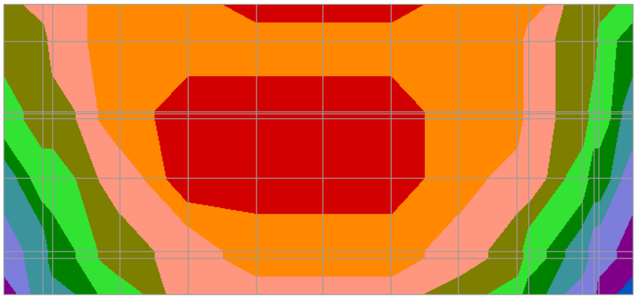
PREPARED FOR

## EAGLEVIEW CONDOMINIUMS

UWCHLAN TOWNSHIP CHESTER COUNTY PENNSYLVANIA

| Scale: | Date: | Drawn By: | Checked By: |
|---|---|---|---|
| 1"= 5'V | 6/29/2005 | VAR | GW |
| Drawing Number: 19615.00-A-103 | | Approved By: JAM | |

- **PCA MAT® Contours**



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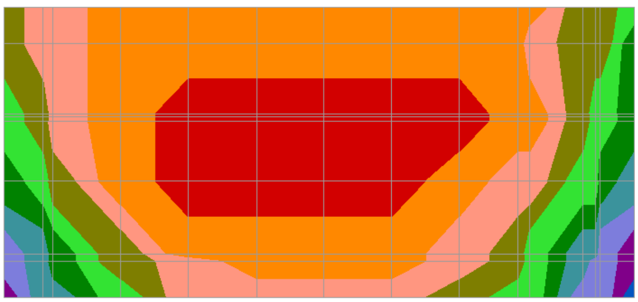

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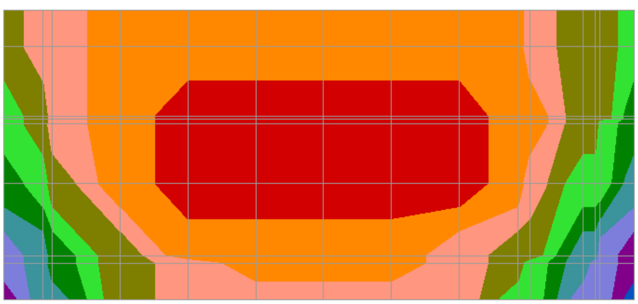

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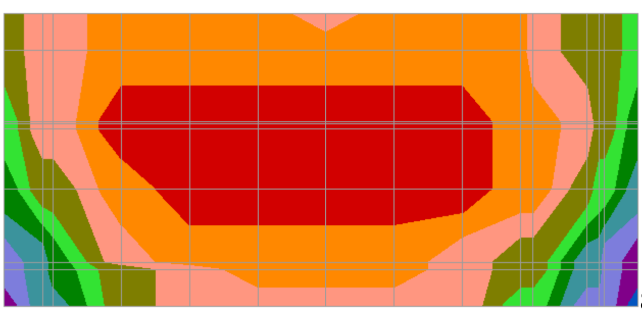

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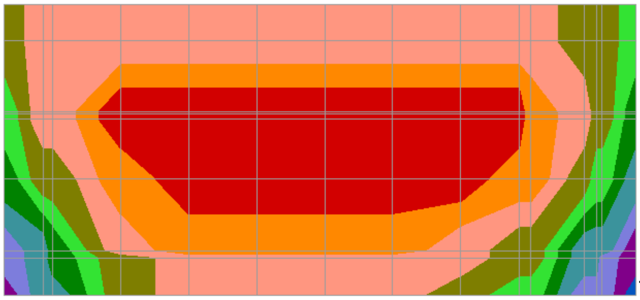
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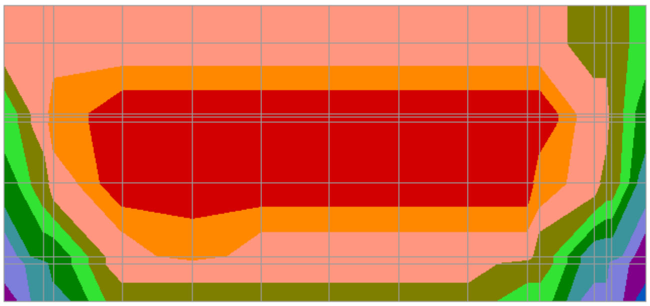
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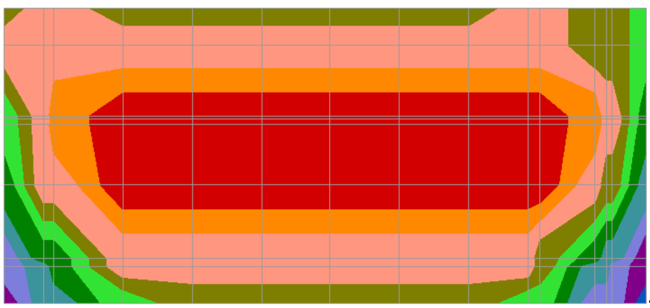
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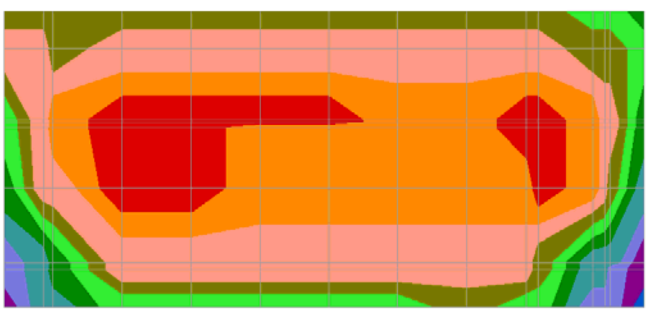
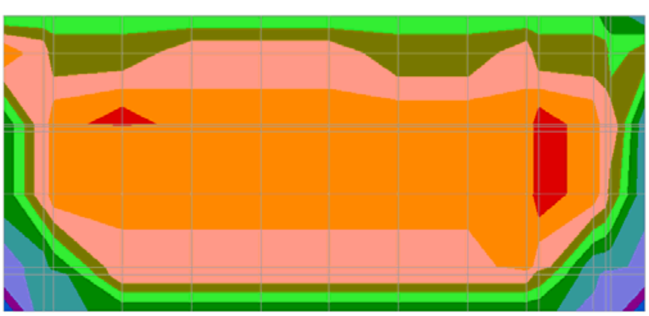
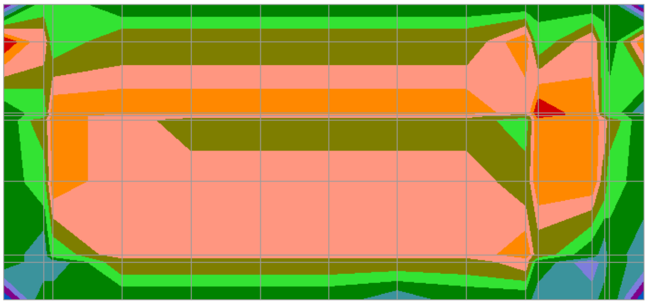

36”


24”



12”

- **PCA MAT® Analysis**

Envelope - Design Moment & Steel - Top

C5a - ELEMENT TOP DESIGN MOMENT AND REINFORCEMENT:

==================================================

Units --> Moment (kip-ft/ft), As (in^2/ft)

Flags --> [m] Minimum controls. [x] Exceeds maximum. [*] Cannot compute.

| Elem | Node | Ld Comb. | Max. M(ux) | As(xx) | Node | Ld Comb. | Max. M(uy) | As(yy) |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | U1 | 9.26 | 0.518m | 16 | U1 | 46.97 | 0.522 |
| 2 | 3 | U1 | 20.69 | 0.518m | 3 | U1 | 17.00 | 0.518m |
| 3 | 3 | U1 | 10.10 | 0.518m | 3 | U1 | 14.72 | 0.518m |
| 4 | 19 | U1 | 4.39 | 0.518m | 19 | - | 0.00 | 0.518m |
| 5 | 5 | - | 0.00 | 0.518m | 5 | - | 0.00 | 0.518m |
| 6 | 6 | - | 0.00 | 0.518m | 6 | - | 0.00 | 0.518m |
| 7 | 8 | - | 0.00 | 0.518m | 7 | - | 0.00 | 0.518m |
| 8 | 23 | U1 | 0.45 | 0.518m | 9 | - | 0.00 | 0.518m |
| 9 | 25 | U1 | 37.31 | 0.518m | 25 | U1 | 14.63 | 0.518m |
| 10 | 25 | U1 | 57.52 | 0.635 | 25 | U1 | 19.87 | 0.518m |
| 11 | 27 | - | 0.00 | 0.518m | 12 | U1 | 7.66 | 0.518m |
| 12 | 28 | U1 | 12.82 | 0.518m | 12 | U1 | 11.85 | 0.518m |
| 13 | 14 | U1 | 13.40 | 0.518m | 28 | - | 0.00 | 0.518m |
| 14 | 29 | U1 | 16.25 | 0.518m | 30 | U1 | 50.11 | 0.558 |
| 15 | 17 | U1 | 13.76 | 0.518m | 17 | U1 | 31.47 | 0.518m |
| 16 | 33 | U1 | 16.85 | 0.518m | 17 | U1 | 25.39 | 0.518m |
| 17 | 33 | U1 | 15.40 | 0.518m | 34 | U1 | 23.84 | 0.518m |
| 18 | 34 | U1 | 10.68 | 0.518m | 34 | U1 | 24.57 | 0.518m |
| 19 | 36 | U1 | 3.56 | 0.518m | 35 | U1 | 23.51 | 0.518m |
| 20 | 36 | U1 | 3.50 | 0.518m | 37 | U1 | 23.24 | 0.518m |
| 21 | 38 | U1 | 4.40 | 0.518m | 37 | U1 | 23.24 | 0.518m |
| 22 | 38 | U1 | 4.96 | 0.518m | 39 | U1 | 26.39 | 0.518m |
| 23 | 25 | U1 | 39.08 | 0.518m | 40 | U1 | 27.45 | 0.518m |

## Envelope - Design Moment & Steel - Bot

C5b - ELEMENT BOTTOM DESIGN MOMENT AND REINFORCEMENT:

=====================================================

Units --> Moment (kip-ft/ft), As (in^2/ft)

Flags --> [m] Minimum controls. [x] Exceeds maximum. [*] Cannot compute.

| Elem | Node | Ld Comb. | Max. M(ux) | As(xx) | Node | Ld Comb. | Max. M(uy) | As(yy) |
|---|---|---|---|---|---|---|---|---|
| 1 | 17 | U1 | -13.22 | 0.518m | 1 | U1 | -49.32 | 0.549 |
| 2 | 18 | U1 | -37.79 | 0.518m | 18 | U1 | -45.64 | 0.518m |
| 3 | 18 | U1 | -8.51 | 0.518m | 18 | U1 | -30.80 | 0.518m |
| 4 | 4 | U1 | -5.65 | 0.518m | 4 | U1 | -29.41 | 0.518m |
| 5 | 5 | U1 | -4.54 | 0.518m | 5 | U1 | -26.56 | 0.518m |
| 6 | 7 | U1 | -4.07 | 0.518m | 6 | U1 | -26.41 | 0.518m |
| 7 | 7 | U1 | -4.02 | 0.518m | 8 | U1 | -26.67 | 0.518m |
| 8 | 9 | U1 | -8.52 | 0.518m | 8 | U1 | -26.88 | 0.518m |
| 9 | 24 | U1 | -14.35 | 0.518m | 10 | U1 | -38.32 | 0.518m |
| 10 | 26 | U1 | -37.70 | 0.518m | 10 | U1 | -40.16 | 0.518m |
| 11 | 26 | U1 | -19.58 | 0.518m | 27 | U1 | -35.25 | 0.518m |
| 12 | 27 | U1 | -45.93 | 0.518m | 27 | U1 | -52.06 | 0.580 |
| 13 | 28 | U1 | -1.03 | 0.518m | 28 | U1 | -9.85 | 0.518m |
| 14 | 15 | U1 | -5.43 | 0.518m | 15 | U1 | -47.75 | 0.531 |
| 15 | 32 | U1 | -36.59 | 0.518m | 32 | U1 | -52.92 | 0.590 |
| 16 | 32 | U1 | -36.49 | 0.518m | 32 | U1 | -48.44 | 0.539 |
| 17 | 18 | U1 | -20.91 | 0.518m | 18 | U1 | -48.37 | 0.538 |
| 18 | 20 | U1 | -3.08 | 0.518m | 20 | U1 | -9.73 | 0.518m |
| 19 | 20 | U1 | -2.27 | 0.518m | 20 | U1 | -9.67 | 0.518m |
| 20 | 22 | U1 | -1.52 | 0.518m | 22 | U1 | -9.25 | 0.518m |
| 21 | 22 | U1 | -1.58 | 0.518m | 22 | U1 | -9.26 | 0.518m |
| 22 | 24 | U1 | -9.06 | 0.518m | 24 | U1 | -15.12 | 0.518m |
| 23 | 24 | U1 | -13.55 | 0.518m | 24 | U1 | -15.17 | 0.518m |

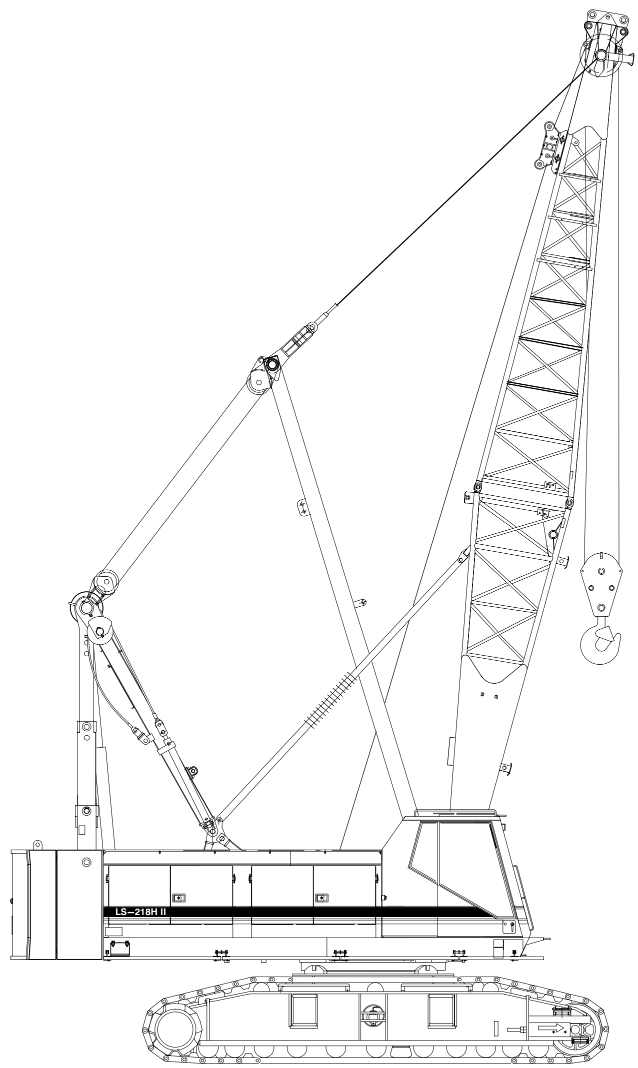
Link-Belt
CONSTRUCTION EQUIPMENT

# Lifting Capacities

Lattice Boom Crawler Crane

# LS–218H II 100–ton *(90.72 metric ton)*

## HYLAB Series




### Angle Boom Capacities
### 40' – 150' *(12.19 – 45.72 m)*

**26' *(7.92 m)* Live Mast Capacities**
- Extended / Retracted Side Frames
- On Carbody Jacks

**5' *(1.52 m)* Tip Extension Capacities**

**Duty Cycle Capacities**
- 40' – 100' *(12.19 – 30.48 m)* Angle Boom
- Extended Side Frames
- Dragline
- Clamshell / Magnet
- "AB" and "A" Counterweight Options

**Angle Boom Capacities**
- 40' – 150' *(12.19 – 45.72 m)* Angle Boom
- 48" *(1.22 m)* Wide x 48" *(1.22 m)* Deep Boom
- 20' *(6.10 m)* Open Throat Top Section
- With or without 26' *(7.92 m)* Live Mast
- Extended / Retracted Side Frames
- 360° Capacities
- Over End Blocked Capacities
- "AB", "A", and "0" Counterweight Options
- 20' 10.5" in. *(6.36 m)* Crawler Length

**CAUTION: This material is supplied for reference use only. Operator must refer to in–cab Crane Rating Manual to determine allowable machine lifting capacities and operating procedures.**


Litho in U.S.A. 7/00 #6273

# WARNING

**READ AND UNDERSTAND THE OPERATOR'S AND SAFETY MANUALS AND THE FOLLOWING INSTRUCTIONS AND CHART VALUES BEFORE OPERATING THE CRANE. OPERATION WHICH DOES NOT FOLLOW THESE INSTRUCTIONS MAY RESULT IN AN ACCIDENT.**

## OPERATING INSTRUCTIONS

### GENERAL:

1 Rated lifting capacities in pounds as shown on lift charts pertain to this crane as originally manufactured and normally equipped. Modifications to the crane or use of optional equipment other than that specified can result in a reduction of capacity.
2. Construction equipment can be dangerous if improperly operated or maintained. Operation and maintenance of this crane must be in compliance with the information in the Operator's, Parts, and Safety Manuals supplied with this crane. If these manuals are missing, order replacements through the distributor.
3. The operator and other personnel associated with this crane shall read and fully understand the latest applicable American National Standards Institute (ANSI) safety standards for cranes.
4. All capacities listed in this book are in compliance with ASME/ANSI B30.5c–1998, SAE J987–April 1994, and SAE J–765 October 1990.

### LIFT CR ANE OPERATION:

1. Capacities shown are in pounds and are not more than 75% of the tipping loads with the crane standing level on firm supporting surface. A deduction must be made from these capacities for weight of hook block, hook ball, sling, grapple, etc. When using main hook while jib is attached, reduce capacities by values shown on Capacity Deductions For Lifting Off Main Boom Hook With Jib Installed. When using main hook while 5 foot tip extension or pile driver lead adapter is attached, reduce capacities by values shown on Capacity Deductions For Lifting Off Main Boom Hook With 5 Foot Tip Extension or Pile Driver Lead Adapter Installed. See Operator's Manual for all limitations when raising or lowering attachment.
2. The crane capacities in the shaded areas are based on structural strength. The crane capacities in the non–shaded areas are based on stability.
3. For recommended reeving, parts of line, wire rope type, and wire rope inspection, see Wire Rope Capacity Chart, Operator's Manual, and Parts Manual. Rated lifting capacities are based on correct reeving. Deduction must be made for excessive reeving. Any reeving over minimum required (see Wire Rope Capacity Chart) is considered excessive and must be accounted for when making lifts. Use Working Range Diagram to estimate the extra feet of rope. See Wire Rope Capacity for the weight to deduct for each extra foot of wire rope before attempting to lift a load.
4. Rated lifting capacities in this Crane Rating Manual are based on freely suspended loads and make no allowances for such factors as the effect of ground conditions and operating speeds. The operator shall therefore reduce load ratings in order to take these conditions into account.
5. Rated lifting capacities do not account for the effects of wind on a suspended load or boom. Lifting capacities should be considered acceptable for wind speeds less than 20 mph and appropriately reduced for wind speeds greater than 20 mph. (See General Wind Restrictions Guide.)
6. The capacities listed are for the crane equipped with or without live mast and with the gantry in the raised position.
7. The least stable rated condition is over the side.
8. Booms should be erected and lowered over the end for maximum stability. See Liftoff Capabilities before erecting or lowering boom.
9. Do not operate at radii and boom lengths where the Crane Rating Manual lists no capacity. Do not use longer booms or jibs than those listed in this Crane Rating Manual. Any of the above can cause a tipping condition, or boom and jib failure.
10. These capacities apply only to the crane as originally manufactured and normally equipped by Link–Belt Construction Equipment Company.

### FOR OVER END BLOCKED CAPACITIES ONLY:

1. These capacities can be lifted over either end with the crane standing level on a firm supporting surface with adequate blocking placed under the tread member sprockets/idlers, to prevent rocking.
2. Do not travel with a load.

### TRAVELING WITH A LOAD:

1. All 360° Rotation Capacities listed in this Crane Rating Manual are pick and carry capacities.
2. The boom must be pointing straight over one end of the crawler lower. If the load was lifted over the side, swing the load over the end and/or if the load was lifted at a long radius and the load is at or near capacity for that radius, boom up to obtain a greater lifting capacity before beginning travel.
3. Engage the swing lock and apply swing brake.
4. Travel slowly and cautiously on a firm and level–supporting surface.

### DEFINITIONS:

1. Load Radius: Horizontal distance from a projection of the axis of rotation to the supporting surface, before loading, to the center of the vertical hoist line or tackle with load applied.
2. Boom Angle: The angle between the boom base section and horizontal with freely suspended load at the rated radius.
3. Working Area: Area measured in a circular arc about the centerline of rotation as shown on the Working Area Diagram.
4. Freely Suspended Load: Load hanging free with no direct external force applied except by the hoist line.
5. Side Load: Horizontal side force applied to the lifted load either on the ground or in the air.

## WIRE ROPE CAPACITY

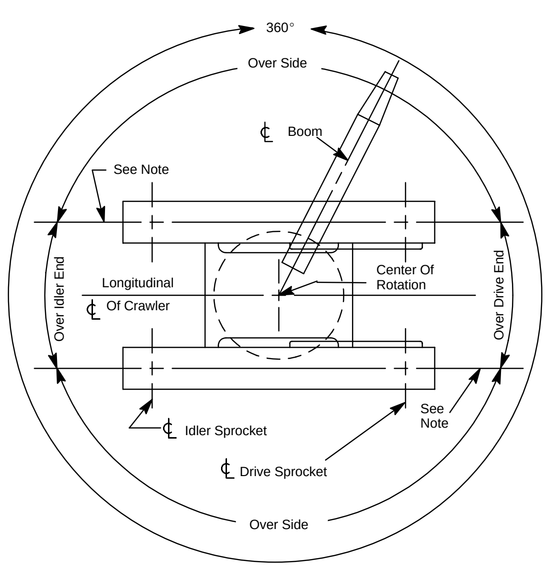
| Parts of Line | 1" | | | 3/4" | |
|---|---|---|---|---|---|
| | Type "CC" | Type "RB" | Type "DB" | Type "DB" | Notes |
| 1 | 30,760 | 22,700 | 29,500 | 16,800 | Capacities shown are in pounds and working loads must not exceed the ratings on the capacity charts in this Crane Rating Manual. Study Operator's Manual for wire rope inspection procedures. |
| 2 | 61,520 | 45,400 | 59,000 | 33,600 | |
| 3 | 92,280 | 68,100 | 88,500 | 50,400 | |
| 4 | 123,040 | 90,800 | 118,000 | 67,200 | |
| 5 | 153,800 | 113,500 | 147,500 | 84,000 | |
| 6 | 184,560 | 136,200 | 177,000 | 100,800 | |
| 7 | 215,320 | 158,900 | 206,500 | 117,600 | |
| 8 | 246,080 | 181,600 | 236,000 | 134,400 | |
| Rope weight per foot | 2.03 | 2.00 | 1.85 | 1.04 | |

| LBCE Type | Description |
|---|---|
| DB | 6 x 26 (6 x 19 Class) – Warrington Seale – Extra Improved Plow Steel – Preformed – Right Lay – Regular Lay – I.W.R.C. |
| RB* | 19 x 19 Rotation Resistant– Extra Extra Improved Plow Steel – Preformed – Right Lay – Regular Lay. Swaged – SF = 5:1 |
| CC | 36 x 7 Class – Non–Rotating – Extra Extra Improved Plow Steel – Right Lay – Regular Lay – S.F. = 5:1 |

* Use of swivel end with 1 part of line is not recommended.

**Weight to be deducted from main capacities when using extra reeving.

## WORKING AREAS




**Note:** These Lines Determine The Limiting Position Of Any Load For Operation Within Working Areas Indicated.

## LIFTOFF CAPABILITIES

| Counterweight (Side Frames) | Over End / Over Side (Gantry In Raised Position) | |
|---|---|---|
| | Maximum Boom (ft.) | Maximum Boom + Jib (ft.) |
| NO (RETRACTED) | 90 | N/A |
| NO (EXTENDED) | 120 | N/A |
| A (RETRACTED) | 120 | N/A |
| A (EXTENDED) | 150 | N/A |
| AB (EXTENDED) | 150 | 150 + 60 |

### NOTES:

1. For maximum boom stability, booms must be erected or lowered over the end with no load – hook block on ground.
2. Crane on firm and level surface.
3. Gantry pins must be installed with the gantry in the raised position.
4. For 140 ft. + 60 ft. or 150 ft. + 60 ft. (side frame extended) with "AB" counterweight only – Adequate blocking must be placed under both treadmembers sprockets (or idler rollers) at the end that the boom is to be lifted to prevent rocking. Liftoff over end with 140 ft. + 60 ft. and 150 ft. + 60 ft. boom. The ramps supplied with the crane are considered to be adequate blocking.

## GENERAL WIND RESTRICTIONS GUIDE

**⚠ WARNING**

Failure to follow these wind speed restrictions may result in structural failure of the boom, which would cause property damage and/or bodily injury.

1. The effects of the wind force on the hook load are the responsibility of the user and are not taken into account. When hoisting any load in windy conditions, the load wind area and load controllability must be considered for safe crane operation.
2. Wind speed is to be determined at the boom top section.

## WIND SPEED CHART

| Boom Lengths: 40' to 250' | |
|---|---|
| **DESCRIPTION** | **ALLOWABLE WINDSPEEDS** |
| 1. Normal Lifting Operation. (See Capacity Charts.) | 0–20 m.p.h. |
| 2. Reduced Operation. **Capacities must be reduced by 20%.** | 21–30 m.p.h. |
| 3. Reduced Operation. **Capacities must be reduced by 40%.** | 31–40 m.p.h. |
| 4. Reduced Operation. **Capacities must be reduced by 70%.** | 41–45 m.p.h. |
| 4. No Operation. **Store Attachment On Ground.** | Over 45 m.p.h. |

## CRANE ASSEMBLY COMPONENT WEIGHTS

| Component | Weight | |
|---|---|---|
| | lbs. | *kg* |
| 1. 20 Ft. Top Section With Sheave Machinery | 3,646 | *1 654* |
| 2. 20 Ft. Top Section With Sheave Machinery and 5 Ft. Tip Extension | 4,286 | *1 944* |
| 3. 20 Ft. Base Section | 2,695 | *1 222* |
| 4. Boom Extensions | | |
| • 10' Boom Extension With Pendants | 823 | *373* |
| • 20' Boom Extension With Pendants | 1,318 | *598* |
| • 30' Boom Extension With Pendants | 1,845 | *837* |
| 5. Upper Counterweights | | |
| • Counterweight "A" | 25,350 | *11 499* |
| • Counterweight "B" | 25,350 | *11 499* |
| 6. Side Frames (Each) | 23,561 | *10 687* |
| 7. Tube Jib Including Strut, Head Machinery, and Pendants | | |
| • 30' Tube Jib Assembly | 1,965 | *891* |
| • 15' Extension With Pendants | 290 | *132* |

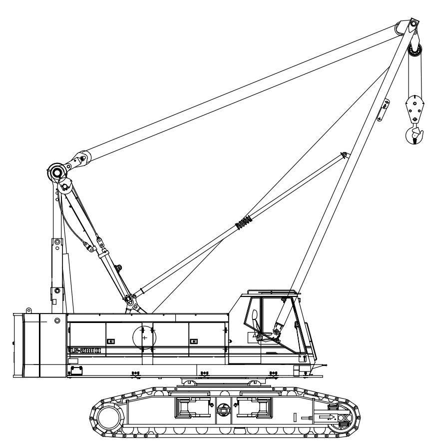
## LIVE MAST LIFTING CAPACITIES

| Live Mast | | Load (lbs.) |
|---|---|---|
| **Radius (ft.)** | **Angle (deg)** | **(See Note 10)** |
| 10 | 78.0 | 30,000 |
| 11 | 75.7 | 30,000 |
| 12 | 73.4 | 30,000 |
| 13 | 71.1 | 25,000 |
| 14 | 68.8 | 20,000 |
| 15 | 66.4 | 20,000 |
| 16 | 64.0 | 15,000 |
| 17 | 61.5 | 15,000 |
| 18 | 59.0 | 15,000 |
| 19 | 56.4 | 15,000 |
| 20 | 53.7 | 15,000 |
| 21 | 50.9 | 10,000 |
| 22 | 48.0 | 10,000 |
| 23 | 44.9 | 10,000 |
| 24 | 41.7 | 10,000 |
| 25 | 38.3 | 10,000 |

### NOTES:

1. Refer to the Operator's Manual.
2. Live mast backstops must be in position and operative.
3. Assemble track frames to carbody prior to assembly of counterweights to upper frame.
4. Reeve hoist rope with three (3) parts of 1" diameter wire rope on rear drum.
5. The crane shall be leveled on a firm supporting surface.
6. All capacities are listed in pounds and are not more than 75% of the tipping loads.
7. For self–assembly of counterweights, boom extensions, and side frames only. See Crane Assembly Component Weights chart for weight of components for crane assembly.
8. Rated capacities for 360° rotation.
9. Gantry must be in the high (working) position.
10. Mast capacities apply to the following conditions:

| | COUNTERWEIGHTS | | |
|---|---|---|---|
| | NONE | A | AB |
| ON CARBODY JACKS | ✓ | N/A | N/A |
| SIDE FRAMES RETRACTED | ✓ | ✓ | N/A |
| SIDE FRAMES EXTENDED | ✓ | ✓ | ✓ |



# DUTY CYCLE NOTES FOR ANGLE BOOM

1. The capacities included in the “Duty Cycle Capacities – Angle Boom” chart are the maximum allowable, and are based on an LS–218H II crawler crane with counterweight standing level on firm supporting surface under ideal job conditions.
2. Capacities are based on 75% of minimum tipping loads for dragline; 67.5% for clamshell.
3. Capacities are maximum recommended by PCSA Standard #4. Operator must make allowances for soft or uneven supporting surfaces, rapid cycle operations, bucket suction, or other unfavorable conditions which may require smaller buckets for most efficient operation.
4. Weight of bucket plus load, must not exceed these capacities.
5. Dragline operation is not recommended with boom angles less than 35°.
6. Boom length for dragline/clamshell attachment operation should not exceed 100 ft.
7. Retractable high gantry must be pinned in the raised position for all capacities on the “Duty Cycle Capacities – Angle Boom” chart.
8. These capacities apply to the crane as originally manufactured and normally equipped by Link–Belt Construction Equipment Company.

# DUTY CYCLE CAPACITIES — ANGLE BOOM

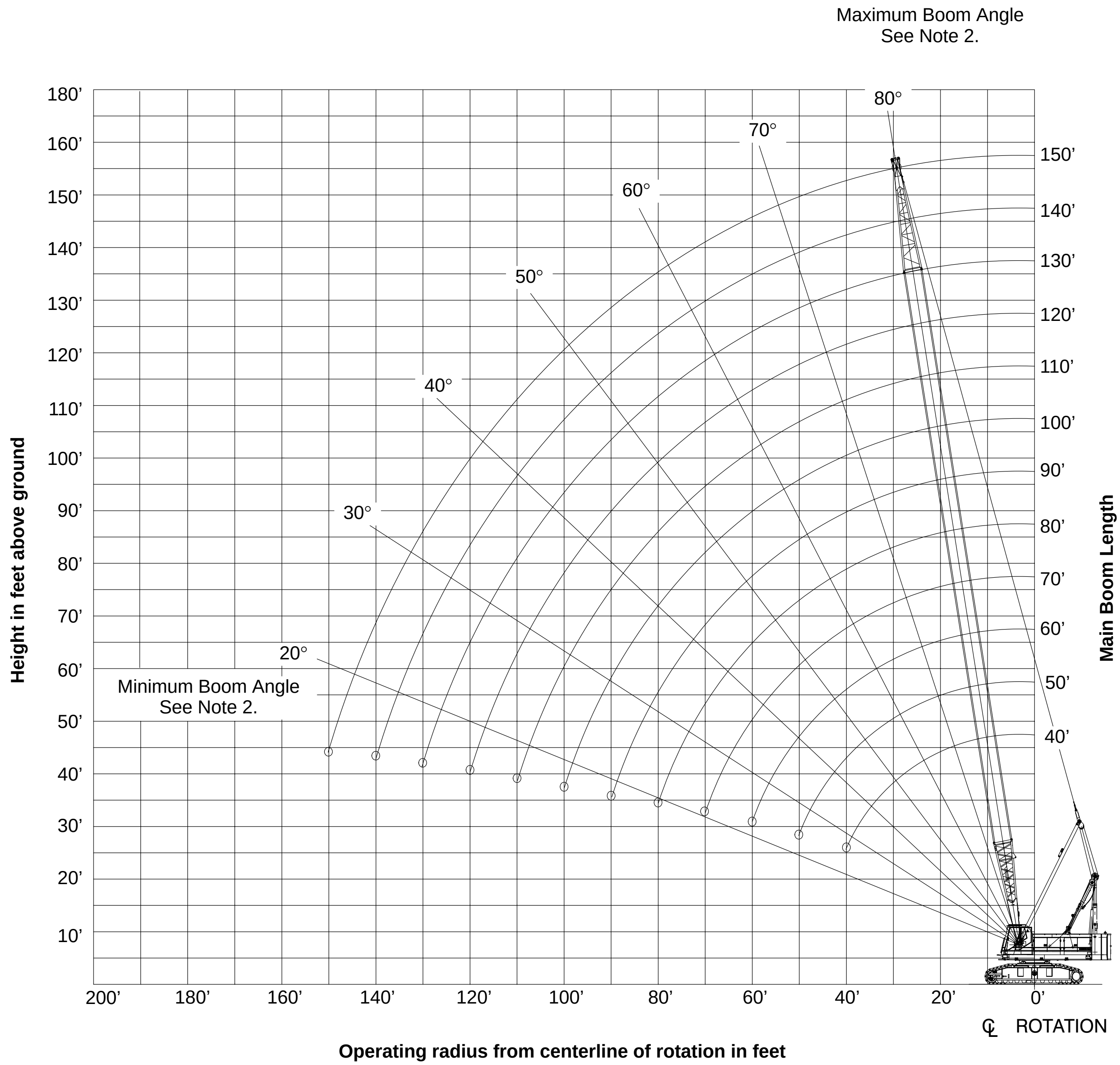
| Load Radius (ft.) | Boom Length (ft.) | Boom Angle (deg) | Side Frames Extended “A” Counterweight (All capacities listed are in pounds) | | | |
|---|---|---|---|---|---|---|
| | | | Dragline | | Clamshell / Magnet | |
| | | | “A” ctwt | “AB” ctwt | “A” ctwt | “AB” ctwt |
| **40** | 11 | 80.8 | – – – | – – – | 29,500 | 29,500 |
| **40** | 12 | 79.3 | – – – | – – – | 29,500 | 29,500 |
| **40** | 13 | 77.9 | – – – | – – – | 29,500 | 29,500 |
| **40** | 14 | 76.4 | – – – | – – – | 29,500 | 29,500 |
| **40** | 15 | 74.9 | – – – | – – – | 29,500 | 29,500 |
| **40** | 16 | 73.4 | – – – | – – – | 29,500 | 29,500 |
| **40** | 17 | 71.9 | – – – | – – – | 29,500 | 29,500 |
| **40** | 18 | 70.4 | – – – | – – – | 29,500 | 29,500 |
| **40** | 19 | 68.9 | – – – | – – – | 29,500 | 29,500 |
| **40** | 20 | 67.3 | – – – | – – – | 29,500 | 29,500 |
| **40** | 25 | 59.3 | 29,500 | 29,500 | 29,500 | 29,500 |
| **40** | 30 | 50.6 | 29,500 | 29,500 | 29,500 | 29,500 |
| **40** | 35 | 40.5 | 29,500 | 29,500 | 29,500 | 29,500 |
| **40** | 40 | 27.7 | – – – | – – – | 28,530 | 29,500 |
| **50** | 12 | 81.5 | – – – | – – – | 29,500 | 29,500 |
| **50** | 13 | 80.3 | – – – | – – – | 29,500 | 29,500 |
| **50** | 14 | 79.2 | – – – | – – – | 29,500 | 29,500 |
| **50** | 15 | 78.0 | – – – | – – – | 29,500 | 29,500 |
| **50** | 16 | 76.8 | – – – | – – – | 29,500 | 29,500 |
| **50** | 17 | 75.6 | – – – | – – – | 29,500 | 29,500 |
| **50** | 18 | 74.4 | – – – | – – – | 29,500 | 29,500 |
| **50** | 19 | 73.3 | – – – | – – – | 29,500 | 29,500 |
| **50** | 20 | 72.1 | – – – | – – – | 29,500 | 29,500 |
| **50** | 25 | 65.9 | – – – | – – – | 29,500 | 29,500 |
| **50** | 30 | 59.5 | 29,500 | 29,500 | 29,500 | 29,500 |
| **50** | 35 | 52.5 | 29,500 | 29,500 | 29,500 | 29,500 |
| **50** | 40 | 44.9 | 28,710 | 29,500 | 28,710 | 29,500 |
| **50** | 50 | 24.8 | – – – | – – – | 20,800 | 29,500 |
| **60** | 13 | 81.9 | – – – | – – – | 29,500 | 29,500 |
| **60** | 14 | 81.0 | – – – | – – – | 29,500 | 29,500 |
| **60** | 15 | 80.0 | – – – | – – – | 29,500 | 29,500 |
| **60** | 16 | 79.0 | – – – | – – – | 29,500 | 29,500 |
| **60** | 17 | 78.1 | – – – | – – – | 29,500 | 29,500 |
| **60** | 18 | 77.1 | – – – | – – – | 29,500 | 29,500 |
| **60** | 19 | 76.1 | – – – | – – – | 29,500 | 29,500 |
| **60** | 20 | 75.1 | – – – | – – – | 29,500 | 29,500 |
| **60** | 25 | 70.1 | – – – | – – – | 29,500 | 29,500 |
| **60** | 30 | 64.9 | – – – | – – – | 29,500 | 29,500 |
| **60** | 35 | 59.6 | 29,500 | 29,500 | 29,500 | 29,500 |
| **60** | 40 | 53.8 | 28,710 | 29,500 | 28,710 | 29,500 |
| **60** | 50 | 40.8 | 20,800 | 29,500 | 20,880 | 29,500 |
| **60** | 60 | 22.6 | – – – | – – – | 15,930 | 23,220 |
| **70** | 15 | 81.5 | – – – | – – – | 29,500 | 29,500 |
| **70** | 16 | 80.6 | – – – | – – – | 29,500 | 29,500 |
| **70** | 17 | 79.8 | – – – | – – – | 29,500 | 29,500 |
| **70** | 18 | 79.0 | – – – | – – – | 29,500 | 29,500 |

| Boom Length (ft.) | Load Radius (ft.) | Boom Angle (deg) | Side Frames Extended “A” Counterweight (All capacities listed are in pounds) | | | |
|---|---|---|---|---|---|---|
| | | | Dragline | | Clamshell / Magnet | |
| | | | “A” ctwt | “AB” ctwt | “A” ctwt | “AB” ctwt |
| **70** | 19 | 78.1 | – – – | – – – | 29,500 | 29,500 |
| **70** | 20 | 77.3 | – – – | – – – | 29,500 | 29,500 |
| **70** | 25 | 73.1 | – – – | – – – | 29,500 | 29,500 |
| **70** | 30 | 68.7 | – – – | – – – | 29,500 | 29,500 |
| **70** | 35 | 64.3 | – – – | – – – | 29,500 | 29,500 |
| **70** | 40 | 59.6 | 28,620 | 29,500 | 28,620 | 29,500 |
| **70** | 50 | 49.6 | 20,790 | 29,500 | 20,790 | 29,500 |
| **70** | 60 | 37.7 | 15,930 | 25,700 | 15,930 | 23,130 |
| **70** | 70 | 20.9 | – – – | – – – | 12,510 | 18,630 |
| **80** | 16 | 81.8 | – – – | – – – | 29,500 | 29,500 |
| **80** | 17 | 81.1 | – – – | – – – | 29,500 | 29,500 |
| **80** | 18 | 80.4 | – – – | – – – | 29,500 | 29,500 |
| **80** | 19 | 79.6 | – – – | – – – | 29,500 | 29,500 |
| **80** | 20 | 78.9 | – – – | – – – | 29,500 | 29,500 |
| **80** | 25 | 75.2 | – – – | – – – | 29,500 | 29,500 |
| **80** | 30 | 71.5 | – – – | – – – | 29,500 | 29,500 |
| **80** | 35 | 67.7 | – – – | – – – | 29,500 | 29,500 |
| **80** | 40 | 63.7 | – – – | – – – | 28,440 | 29,500 |
| **80** | 50 | 55.4 | 20,610 | 29,500 | 20,610 | 29,500 |
| **80** | 60 | 46.2 | 15,750 | 25,600 | 15,750 | 23,040 |
| **80** | 70 | 35.2 | 12,420 | 20,600 | 12,420 | 18,540 |
| **80** | 80 | 19.5 | – – – | – – – | 9,900 | 15,210 |
| **90** | 18 | 81.4 | | – – – | | 29,500 |
| **90** | 19 | 80.8 | | – – – | | 29,500 |
| **90** | 20 | 80.1 | | – – – | | 29,500 |
| **90** | 25 | 76.9 | | – – – | | 29,500 |
| **90** | 30 | 73.6 | | – – – | | 29,500 |
| **90** | 35 | 70.3 | | – – – | | 29,500 |
| **90** | 40 | 66.8 | PROHIBITED | – – – | PROHIBITED | 29,500 |
| **90** | 50 | 59.7 | | 29,500 | | 29,430 |
| **90** | 60 | 52.0 | | 25,400 | | 22,860 |
| **90** | 70 | 43.4 | | 20,400 | | 18,360 |
| **90** | 80 | 33.1 | | – – – | | 15,030 |
| **90** | 90 | 18.4 | | – – – | | 12,510 |
| **100** | 19 | 81.7 | | – – – | | 29,500 |
| **100** | 20 | 81.1 | | – – – | | 29,500 |
| **100** | 25 | 78.2 | | – – – | | 29,500 |
| **100** | 30 | 75.3 | | – – – | | 29,500 |
| **100** | 35 | 72.3 | | – – – | | 29,500 |
| **100** | 40 | 69.3 | | – – – | | 29,500 |
| **100** | 50 | 63.0 | PROHIBITED | – – – | PROHIBITED | 29,250 |
| **100** | 60 | 56.4 | | 25,100 | | 22,590 |
| **100** | 70 | 49.2 | | 20,200 | | 18,180 |
| **100** | 80 | 41.1 | | 16,500 | | 14,850 |
| **100** | 90 | 31.3 | | – – – | | 12,330 |
| **100** | 100 | 17.4 | | – – – | | 10,350 |

Link-Belt
CONSTRUCTION EQUIPMENT

# WORKING RANGE DIAGRAM

## 40’ TO 150’ MAIN BOOM




**Notes:**

1. **Boom geometry shown is for unloaded condition and crane standing level on firm supporting surface. Boom deflection, subsequent radius, and boom angle change must be accounted for when applying load to hook.**

2. **Maximum and minimum boom angles are equal to the values listed in the capacity chart for each boom length.**

## CAPACITY DEDUCTIONS FOR LIFTING OFF MAIN BOOM HOOK WITH JIB INSTALLED

When using main boom hook, while jib is attached, reduce boom capacities by the values in the following chart:

| Jib Length (ft.) | Capacity Deduction (lb) |
|---|---|
| 30 | 2,000 |
| 45 | 2,400 |
| 60 | 3,200 |

## CAPACITY DEDUCTIONS FOR LIFTING OFF MAIN BOOM HOOK WITH 5 FOOT TIP EXTENSION OR PILE DRIVER LEAD ADAPTERS INSTALLED

When using main boom hook, while 5 foot tip extension or pile driver lead adapter is attached, reduce boom capacities by the values in the following chart:

| Extension/Adapter | Capacity Deduction (lb) |
|---|---|
| 5 (ft.) | 700 |
| Pile Driver Lead Adapter | 200 |

## MAXIMUM ALLOWABLE CAPACITIES FOR 5 FOOT TIP EXTENSION

LIFTING CAPACITY TO BE THE SMALLEST OF THE FOLLOWING VALUES:

1. 18,000 lb (Maximum).
2. The standard crane lift capacity minus 700 lb for the crane configuration in use.

### NOTES:

1. All notes are to be adhered to as listed on the standard lift crane capacity charts .
2. Reduce the main boom lift capacities by 700 lb when the tip extension is installed.
3. The maximum boom length on which the tip extension can be installed is 150 ft.
4. Do not lift or suspend a load from the boom tip extension and main boom at the same time.

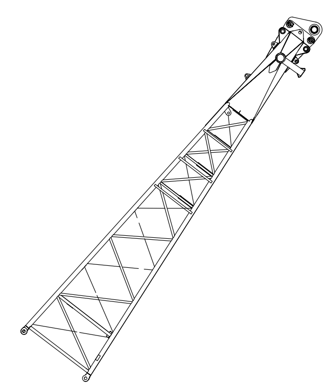
## MAXIMUM ALLOWABLE CAPACITIES FOR PILE DRIVER LEAD ADAPTER

LIFTING CAPACITY TO BE THE SMALLEST OF THE FOLLOWING VALUES:

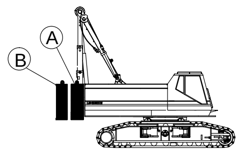
1. 70,000 lbs.
2. The standard crane lift capacity minus 200 lbs. for crane configuration in use.

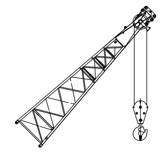
### NOTES:

1. All notes are to be adhered to as listed on the standard lift crane capacity charts.
2. Reduce the main boom lift capacities by 200 lb when the pile driver lead adapter is installed.
3. The maximum boom length on which the pile driver lead adapter can be installed is 150 ft.



**20’ Open Throat Boom With Pile Driver Lead Adapter**



**Note: Refer To Page 7 For “Capacity Deductions” Caused By Any Attachment At The Boom Tip.**

**MAIN BOOM CAPACITIES – 40 FT OPEN THROAT ANGLE BOOM**

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 11 | 80.8 | 200,000 | 200,000 | 199,600 | 179,600 | 139,600 | 85,500 |
| 12 | 79.3 | 200,000 | 200,000 | 184,200 | 165,700 | 119,900 | 73,200 |
| 13 | 77.9 | 190,600 | 190,600 | 171,000 | 137,100 | 105,000 | 63,900 |
| 14 | 76.4 | 177,900 | 177,900 | 159,500 | 115,700 | 93,200 | 56,500 |
| 15 | 74.9 | 166,600 | 166,600 | 149,400 | 100,000 | 83,800 | 50,600 |
| 16 | 73.4 | 156,700 | 156,700 | 133,500 | 87,900 | 76,000 | 45,800 |
| 17 | 71.9 | 147,800 | 147,800 | 119,200 | 78,300 | 69,500 | 41,700 |
| 18 | 70.4 | 139,900 | 139,900 | 107,500 | 70,500 | 63,900 | 38,200 |
| 19 | 68.9 | 132,700 | 132,700 | 97,900 | 64,000 | 59,100 | 35,200 |
| 20 | 67.3 | 126,300 | 123,500 | 89,800 | 58,600 | 55,000 | 32,600 |
| 25 | 59.3 | 101,200 | 87,200 | 63,000 | 40,700 | 40,300 | 23,500 |
| 30 | 50.6 | 80,400 | 66,900 | 48,000 | 30,600 | 31,400 | 17,900 |
| 35 | 40.5 | 64,100 | 53,800 | 38,400 | 24,200 | 25,400 | 14,100 |
| 40 | 27.7 | 52,900 | 44,800 | 31,700 | 19,600 | 21,000 | 11,300 |

**MAIN BOOM CAPACITIES – 50 FT OPEN THROAT ANGLE BOOM**

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 12 | 81.5 | 200,000 | 200,000 | 183,800 | 165,400 | 120,200 | 73,500 |
| 13 | 80.3 | 190,300 | 190,300 | 170,600 | 137,800 | 105,300 | 64,100 |
| 14 | 79.2 | 177,500 | 177,500 | 159,200 | 116,300 | 93,500 | 56,800 |
| 15 | 78.0 | 166,300 | 166,300 | 149,100 | 100,500 | 84,000 | 50,800 |
| 16 | 76.8 | 156,400 | 156,400 | 134,000 | 88,300 | 76,200 | 45,900 |
| 17 | 75.6 | 147,600 | 147,600 | 119,600 | 78,600 | 69,600 | 41,800 |
| 18 | 74.4 | 139,700 | 139,700 | 107,900 | 70,800 | 64,000 | 38,400 |
| 19 | 73.3 | 132,500 | 132,500 | 98,200 | 64,300 | 59,300 | 35,400 |
| 20 | 72.1 | 126,100 | 123,800 | 90,100 | 58,900 | 55,100 | 32,800 |
| 25 | 65.9 | 101,000 | 87,400 | 63,200 | 40,900 | 40,400 | 23,600 |
| 30 | 59.5 | 80,600 | 67,000 | 48,200 | 30,800 | 31,500 | 18,000 |
| 35 | 52.5 | 64,300 | 54,000 | 38,600 | 24,300 | 25,500 | 14,200 |
| 40 | 44.9 | 53,100 | 45,000 | 31,900 | 19,800 | 21,200 | 11,500 |
| 50 | 24.8 | 38,900 | 33,200 | 23,200 | 13,900 | 15,300 | 7,800 |

**MAIN BOOM CAPACITIES – 60 FT OPEN THROAT ANGLE BOOM**

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 13 | 81.9 | 189,700 | 189,700 | 170,100 | 138,300 | 105,300 | 64,200 |
| 14 | 81.0 | 177,000 | 177,000 | 158,700 | 116,700 | 93,500 | 56,800 |
| 15 | 80.0 | 165,900 | 165,900 | 148,700 | 100,700 | 84,000 | 50,900 |
| 16 | 79.0 | 156,000 | 156,000 | 134,200 | 88,500 | 76,200 | 46,000 |
| 17 | 78.1 | 147,200 | 147,200 | 119,700 | 78,800 | 69,600 | 41,800 |
| 18 | 77.1 | 139,300 | 139,300 | 108,000 | 71,000 | 64,000 | 38,300 |
| 19 | 76.1 | 132,200 | 132,200 | 98,300 | 64,400 | 59,200 | 35,300 |
| 20 | 75.1 | 125,700 | 123,900 | 90,200 | 59,000 | 55,000 | 32,700 |
| 25 | 70.1 | 100,700 | 87,400 | 63,200 | 40,900 | 40,300 | 23,500 |
| 30 | 64.9 | 80,600 | 67,000 | 48,200 | 30,800 | 31,400 | 17,900 |
| 35 | 59.6 | 64,300 | 54,000 | 38,600 | 24,300 | 25,400 | 14,100 |
| 40 | 53.8 | 53,100 | 44,900 | 31,900 | 19,800 | 21,100 | 11,400 |
| 50 | 40.8 | 39,000 | 33,200 | 23,200 | 14,000 | 15,300 | 7,800 |
| 60 | 22.6 | 30,300 | 25,800 | 17,700 | 10,200 | 11,500 | 5,300 |

**MAIN BOOM CAPACITIES – 70 FT OPEN THROAT ANGLE BOOM**

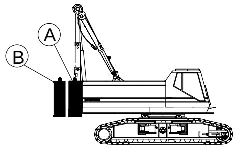
| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 15 | 81.5 | 165,300 | 165,300 | 148,200 | 100,900 | 83,900 | 50,800 |
| 16 | 80.6 | 155,500 | 155,500 | 134,300 | 88,600 | 76,100 | 45,900 |
| 17 | 79.8 | 146,800 | 146,800 | 119,800 | 78,900 | 69,500 | 41,700 |
| 18 | 79.0 | 138,900 | 138,900 | 108,100 | 71,000 | 63,900 | 38,200 |
| 19 | 78.1 | 131,800 | 131,800 | 98,300 | 64,500 | 59,100 | 35,200 |
| 20 | 77.3 | 125,300 | 123,900 | 90,200 | 59,000 | 54,900 | 32,600 |
| 25 | 73.1 | 100,300 | 87,300 | 63,200 | 40,800 | 40,200 | 23,300 |
| 30 | 68.7 | 80,600 | 66,900 | 48,100 | 30,700 | 31,200 | 17,700 |
| 35 | 64.3 | 64,200 | 53,900 | 38,400 | 24,200 | 25,200 | 14,000 |
| 40 | 59.6 | 53,100 | 44,800 | 31,800 | 19,700 | 20,900 | 11,300 |
| 50 | 49.6 | 38,900 | 33,100 | 23,100 | 13,800 | 15,200 | 7,600 |
| 60 | 37.7 | 30,200 | 25,700 | 17,700 | 10,200 | 11,400 | 5,200 |
| 70 | 20.9 | 24,300 | 20,700 | 13,900 | 7,600 | 8,800 | 3,500 |

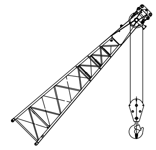
**MAIN BOOM CAPACITIES – 80 FT OPEN THROAT ANGLE BOOM**

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 16 | 81.8 | 154,900 | 154,900 | 134,300 | 88,700 | 76,000 | 45,700 |
| 17 | 81.1 | 146,200 | 146,200 | 119,800 | 78,900 | 69,400 | 41,600 |
| 18 | 80.4 | 138,400 | 138,400 | 108,100 | 71,000 | 63,800 | 38,100 |
| 19 | 79.6 | 131,300 | 131,300 | 98,300 | 64,400 | 59,000 | 35,100 |
| 20 | 78.9 | 124,800 | 123,900 | 90,100 | 58,900 | 54,800 | 32,400 |
| 25 | 75.2 | 99,900 | 87,200 | 63,000 | 40,700 | 40,000 | 23,200 |
| 30 | 71.5 | 80,500 | 66,800 | 47,900 | 30,500 | 31,000 | 17,500 |
| 35 | 67.7 | 64,100 | 53,700 | 38,300 | 24,000 | 25,000 | 13,800 |
| 40 | 63.7 | 52,900 | 44,700 | 31,600 | 19,500 | 20,700 | 11,100 |
| 50 | 55.4 | 38,700 | 32,900 | 22,900 | 13,700 | 15,000 | 7,400 |
| 60 | 46.2 | 30,100 | 25,600 | 17,500 | 10,000 | 11,200 | 5,100 |
| 70 | 35.2 | 24,200 | 20,600 | 13,800 | 7,500 | 8,600 | 3,400 |
| 80 | 19.5 | 19,900 | 16,900 | 11,000 | 5,600 | 6,700 | 2,100 |

**MAIN BOOM CAPACITIES – 90 FT OPEN THROAT ANGLE BOOM**

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 18 | 81.4 | 137,900 | 137,900 | 108,000 | 70,900 | 63,600 | 37,900 |
| 19 | 80.8 | 130,800 | 130,800 | 98,200 | 64,400 | 58,800 | 34,900 |
| 20 | 80.1 | 124,300 | 123,800 | 90,000 | 58,800 | 54,600 | 32,200 |
| 25 | 76.9 | 99,400 | 87,100 | 62,900 | 40,600 | 39,800 | 22,900 |
| 30 | 73.6 | 80,300 | 66,600 | 47,800 | 30,400 | 30,800 | 17,300 |
| 35 | 70.3 | 63,900 | 53,500 | 38,100 | 23,900 | 24,800 | 13,500 |
| 40 | 66.8 | 52,700 | 44,500 | 31,400 | 19,300 | 20,500 | 10,800 |
| 50 | 59.7 | 38,500 | 32,700 | 22,700 | 13,500 | 14,700 | 7,200 |
| 60 | 52.0 | 29,900 | 25,400 | 17,300 | 9,800 | 11,000 | 4,800 |
| 70 | 43.4 | 24,000 | 20,400 | 13,600 | 7,300 | 8,400 | 3,200 |
| 80 | 33.1 | 19,800 | 16,700 | 10,900 | 5,500 | 6,500 | 2,000 |
| 90 | 18.4 | 16,600 | 13,900 | 8,800 | 4,000 | 5,000 | —— |



### MAIN BOOM CAPACITIES – 100 FT OPEN THROAT ANGLE BOOM

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 19 | 81.7 | 130,200 | 130,200 | 98,100 | 64,300 | 58,600 | PROHIBITED |
| 20 | 81.1 | 123,800 | 123,700 | 89,900 | 58,700 | 54,400 | |
| 25 | 78.2 | 98,900 | 86,900 | 62,700 | 40,400 | 39,600 | |
| 30 | 75.3 | 80,200 | 66,400 | 47,600 | 30,200 | 30,600 | |
| 35 | 72.3 | 63,700 | 53,300 | 37,900 | 23,600 | 24,600 | |
| 40 | 69.3 | 52,500 | 44,200 | 31,200 | 19,100 | 20,200 | |
| 50 | 63.0 | 38,300 | 32,500 | 22,500 | 13,200 | 14,500 | |
| 60 | 56.4 | 29,600 | 25,100 | 17,000 | 9,600 | 10,800 | |
| 70 | 49.2 | 23,800 | 20,200 | 13,400 | 7,100 | 8,200 | |
| 80 | 41.1 | 19,600 | 16,500 | 10,700 | 5,200 | 6,300 | |
| 90 | 31.3 | 16,400 | 13,700 | 8,600 | 3,800 | 4,800 | |
| 100 | 17.4 | 13,800 | 11,500 | 6,900 | 2,700 | 3,600 | |

### MAIN BOOM CAPACITIES – 110 FT OPEN THROAT ANGLE BOOM

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 20 | 81.9 | 120,600 | 120,600 | 89,800 | 58,600 | 54,100 | PROHIBITED |
| 25 | 79.3 | 98,400 | 86,700 | 62,600 | 40,200 | 39,300 | |
| 30 | 76.6 | 80,000 | 66,200 | 47,400 | 30,000 | 30,300 | |
| 35 | 74.0 | 63,500 | 53,100 | 37,700 | 23,400 | 24,300 | |
| 40 | 71.2 | 52,300 | 44,000 | 30,900 | 18,900 | 20,000 | |
| 50 | 65.6 | 38,100 | 32,200 | 22,200 | 13,000 | 14,200 | |
| 60 | 59.8 | 29,400 | 24,900 | 16,800 | 9,300 | 10,500 | |
| 70 | 53.5 | 23,600 | 19,900 | 13,100 | 6,800 | 7,900 | |
| 80 | 46.7 | 19,300 | 16,300 | 10,400 | 5,000 | 6,000 | |
| 90 | 39.1 | 16,200 | 13,500 | 8,400 | 3,600 | 4,500 | |
| 100 | 29.8 | 13,600 | 11,300 | 6,700 | 2,500 | 3,300 | |
| 110 | 16.6 | 11,600 | 9,500 | 5,400 | —— | 2,400 | |

### MAIN BOOM CAPACITIES – 120 FT OPEN THROAT ANGLE BOOM

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 25 | 80.2 | 93,400 | 86,600 | 62,400 | 40,000 | 39,100 | PROHIBITED |
| 30 | 77.8 | 79,800 | 66,000 | 47,200 | 29,800 | 30,100 | |
| 35 | 75.3 | 63,300 | 52,900 | 37,400 | 23,200 | 24,000 | |
| 40 | 72.8 | 52,100 | 43,800 | 30,700 | 18,600 | 19,700 | |
| 50 | 67.8 | 37,800 | 32,000 | 22,000 | 12,700 | 13,900 | |
| 60 | 62.5 | 29,200 | 24,600 | 16,500 | 9,100 | 10,200 | |
| 70 | 57.0 | 23,300 | 19,600 | 12,800 | 6,500 | 7,600 | |
| 80 | 51.1 | 19,100 | 16,000 | 10,100 | 4,700 | 5,700 | |
| 90 | 44.6 | 15,900 | 13,200 | 8,100 | 3,300 | 4,300 | |
| 100 | 37.3 | 13,400 | 11,100 | 6,500 | 2,200 | 3,100 | |
| 110 | 28.6 | 11,400 | 9,300 | 5,200 | —— | 2,100 | |
| 120 | 15.9 | 9,700 | 7,800 | 4,000 | —— | —— | |

### MAIN BOOM CAPACITIES – 130 FT OPEN THROAT ANGLE BOOM

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 25 | 81.0 | 82,900 | 73,500 | 62,200 | PROHIBITED | | |
| 30 | 78.7 | 72,500 | 62,500 | 46,900 | | | |
| 35 | 76.5 | 62,500 | 52,600 | 37,200 | | | |
| 40 | 74.2 | 51,900 | 43,500 | 30,500 | | | |
| 50 | 69.6 | 37,600 | 31,700 | 21,700 | | | |
| 60 | 64.8 | 28,900 | 24,400 | 16,300 | | | |
| 70 | 59.8 | 23,000 | 19,400 | 12,600 | | | |
| 80 | 54.5 | 18,800 | 15,700 | 9,900 | | | |
| 90 | 48.9 | 15,600 | 13,000 | 7,800 | | | |
| 100 | 42.8 | 13,100 | 10,800 | 6,200 | | | |
| 110 | 35.8 | 11,100 | 9,000 | 4,900 | | | |
| 120 | 27.4 | 9,500 | 7,600 | 3,800 | | | |
| 130 | 15.3 | 8,000 | 6,300 | 2,900 | | | |

### MAIN BOOM CAPACITIES – 140 FT OPEN THROAT ANGLE BOOM

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 25 | 81.6 | 65,200 | 62,800 | 62,000 | PROHIBITED | | |
| 30 | 79.5 | 55,400 | 52,600 | 46,700 | | | |
| 35 | 77.5 | 52,100 | 44,700 | 37,000 | | | |
| 40 | 75.4 | 45,600 | 39,100 | 30,200 | | | |
| 50 | 71.1 | 34,800 | 28,300 | 21,400 | | | |
| 60 | 66.7 | 26,500 | 21,900 | 16,000 | | | |
| 70 | 62.1 | 21,200 | 17,000 | 12,300 | | | |
| 80 | 57.4 | 16,900 | 13,600 | 9,600 | | | |
| 90 | 52.4 | 14,000 | 11,200 | 7,500 | | | |
| 100 | 47.0 | 11,500 | 9,500 | 5,900 | | | |
| 110 | 41.2 | 9,800 | 7,800 | 4,600 | | | |
| 120 | 34.5 | 8,500 | 6,700 | 3,500 | | | |
| 130 | 26.4 | 7,300 | 5,800 | 2,600 | | | |
| 140 | 14.7 | 4,500 | 4,500 | —— | | | |

### MAIN BOOM CAPACITIES – 150 FT OPEN THROAT ANGLE BOOM

| Load Radius (Ft.) | Boom Angle (deg) | Over End Blocked | 360° Rotation | | | | |
|---|---|---|---|---|---|---|---|
| | | | Side Frames Extended | | | Side Frames Retracted | |
| | | AB CTWT (lb) | AB CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) | A CTWT (lb) | 0 CTWT (lb) |
| 30 | 80.2 | 46,600 | 46,600 | 46,500 | PROHIBITED | | |
| 35 | 78.3 | 40,200 | 40,200 | 36,700 | | | |
| 40 | 76.3 | 35,200 | 35,200 | 29,900 | | | |
| 50 | 72.4 | 25,800 | 25,800 | 21,200 | | | |
| 60 | 68.3 | 20,300 | 20,300 | 15,700 | | | |
| 70 | 64.1 | 16,000 | 16,000 | 12,000 | | | |
| 80 | 59.8 | 12,700 | 12,700 | 9,300 | | | |
| 90 | 55.3 | 10,300 | 10,300 | 7,200 | | | |
| 100 | 50.5 | 8,500 | 8,500 | 5,600 | | | |
| 110 | 45.4 | 7,200 | 7,200 | 4,300 | | | |
| 120 | 39.7 | 6,000 | 6,000 | 3,300 | | | |
| 130 | 33.3 | 5,100 | 5,100 | 2,300 | | | |
| 140 | 25.5 | 4,300 | 4,300 | —— | | | |
| 150 | 14.2 | 3,200 | 3,200 | —— | | | |