



► **Design and Construction Team:**

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



Foundation Wall Construction



First Floor Concrete Slab

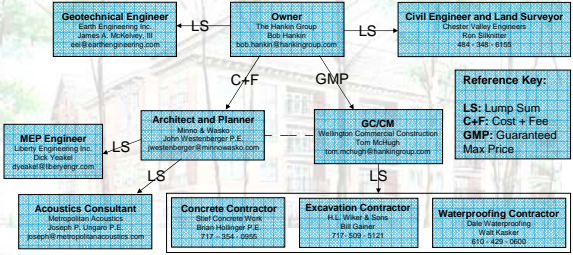


Project Overview




Wellington  
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► **CM @ RISK Contractual Relationship:**



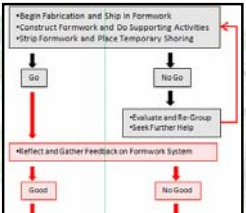
Reference Key:  
 LS: Lump Sum  
 C+F: Cost + Fee  
 GMP: Guaranteed Max Price



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► **Decision Process Model**

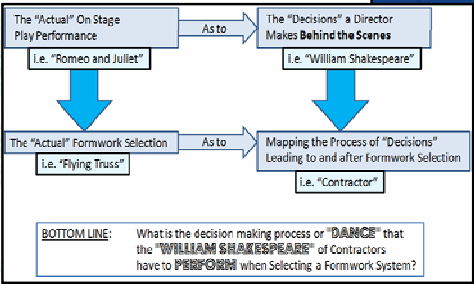
- **Situation:** What is the process of decisions that construction industry members make when selecting a new formwork product?
- **Previous research** focused on the selection but what is the process behind that decision?
- **Goal:** Can the decision process for formwork systems be modeled?




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**BOTTOM LINE:** What is the decision making process or "DANCE" that the "WILLIAM SHAKESPEARE" of Contractors have to PERFORM when Selecting a Formwork System?



Project Overview

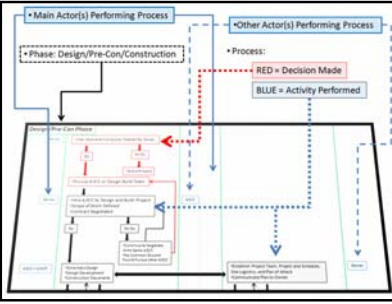



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► **KEY To Mapping the Formwork Decision Process**

► **Three Phases**

- Design
- Pre-Con
- Construction

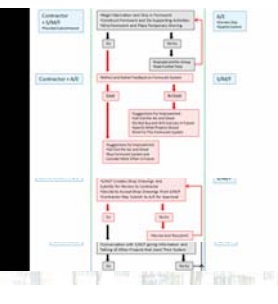



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► **Generic Formwork Decision Process Model**



- **A/E**  
 ► Architect  
 ► Engineer
- **C**  
 ► Contractor
- **S/M/F**  
 ► Supplier  
 ► Manufacturer  
 ► Fabricator
- **O**  
 ► Owner
- **D-B**  
 ► Design-Build



Project Overview



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► **What happened on the Wellington Condominiums Project?**

- **Owner decision to use Hambro in design**
- **Contractor brought on later**
  - Work dependent on developer in area
  - Never used Hambro System
- **Hambro has integrated formwork system**
- **Pre-Con Constructability Meeting Contractor had 2 choices**
  - Use Hambro system formwork OR change entire design
  - **NO Decision Process – NO Checks and Balances = Problem**
  - **Uncertainty**
  - **Risk and Responsibility of Formwork Systems is the Contractor**

**Fix By**

- S/M/F IN = C IN
- **Employ CM Agent**
- **Have**
- **Input**
- **Allows proper channels of decision processes**

Decision Process Model

► **What is the Most Ideal Formwork Decision Process Model?**

► **Answer: Design-Build**

- From research and modeling the decision process model:
- 5 participants and 9 processes **eliminated**
- **Design and Pre-Con Phase get compressed and decisions are made early on with all parties involved**
  - Proven statically why a Design-Build contract succeeds over a traditional format.
  - **Advantages:** Wasteful processes gone, better communication lines, faster and more productive working environment with the project team, reduces friction and creates a decrease in budget and schedule.
  - **Disadvantages:** Upfront cost due to the Contractor's early input.

Decision Process Model

► **What can we take out of this?**

- **Proven Design-Build to be a worthwhile investment and will continue to grow**
- **Ideal Process:** Contractors are encouraged to **explore new formwork products** and become educated as to the latest most productive systems on the market today.
- **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.** (Wellington Condominiums Scenario)
  - 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.
  - **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!**

Decision Process Model

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

► 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.

Interactive Web Tool

Decision Process Model

► **Hambro System**

- **Situation:** Correct decision to be utilized on the Wellington Condominiums Project?
- Are other systems a **better alternative** to the Wellington Condominiums Project?
- **Goal:** What type of construction project would best benefit from using the Hambro System?

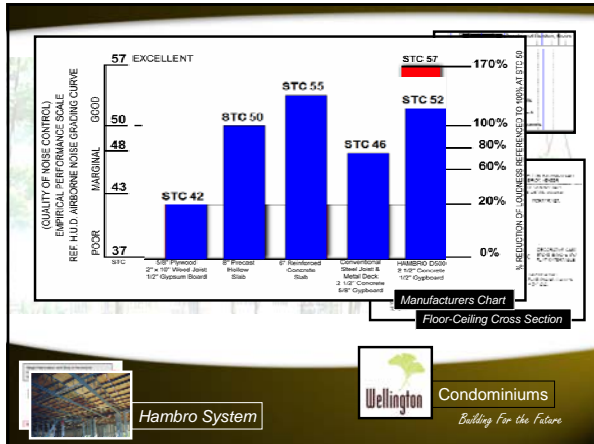
Decision Process Model

► **What is the Hambro System?**

- **Advantages**
  - **Standardization** of load bearing metal stud walls is independent on a flat concrete slab construction.
  - **Long concrete curing time** is not a problem.
  - **Formwork can be used 2-3 times** in a project.
  - **Formwork can be used on the next level** without the need of shoring or re-shoring.
  - **Concrete Seepage** is not a problem.
  - **Concrete Seepage** is not a problem.
  - **Concrete Seepage** is not a problem.
- **Very difficult to use** when the deck is not repetitive and linear.

Hambro System

Decision Process Model



Hambro System



### Was the Hambro System a Correct Choice?

Answer: Show Me 'The Report Card'

Compare and Contrast Floor-Ceiling Assemblies	Rate	Total Weight	Weight	Grade	Comment
Fire Ratings	4	4.00	4.00	100.00%	Good
Composite Design	3	3.00	3.00	100.00%	Good
Cost Savings	-1	-1.00	-1.00	0.00%	Costly
Slab Penetrations	10	4.00	3.00	75.00%	Good
Schedule Savings	2	2.00	10.00	50.00%	Good
Mechanical Interfacing	-1	-1.00	-1.00	0.00%	Costly
Acoustical Properties	3	3.00	3.00	100.00%	Good
Bearing Systems	11	3.00	2.00	66.67%	Good
Labor Intensive	4	4.00	3.00	75.00%	Good
Installation	-1	-1.00	-1.00	0.00%	Costly
Variability	12	2.00	2.00	100.00%	Good
Quality Control	-4	-4.00	-1.00	25.00%	Costly
<b>TOTAL</b>		<b>100.00</b>	<b>77.85</b>		<b>Good Great</b>
Average					77.85%

Utilizes steel joists/metal decking. Steel joist system built with metal decking. Uses Metal Stud Walls similar to assembly Hambro System.

Epicore MSR Floor System



Hambro System



### Main Comparison Between Composite Deck Systems?

- Highly labor intensive system
- Acoustical concerns for the living spaces
- Constraints of the formwork system selection process
- Non-repetitive joist spacing layout
- Conventional Steel Joist and Composite Deck System:
- When is it best to use HAMBRO?
  - Repetitive Joist Spacing and Uniformity Throughout
  - Sound/Vibration not a critical factor in the building design
  - Have high GRADE at the GOOD
- Recommended Use: Residential, Stores, Warehouses, Malls, Airports
- Not Recommended Use: Retirement Homes, Hospitals, Hotels, and Luxury Apartments and Condominiums (Not Required)
  - Shoring and Re-shoring: Required
  - GRADE: 77.85 GOOD-GREAT

#### Select for Project

- No Joists or formwork req.
- Faster and more conventional construction methodology
- Success some initial odd walls and do not have to worry about changing system



Hambro System



### Foundation Redesign

Situation: With poor subsurface conditions prevalent, cost and time spent to rock excavate to get to suitable bearing conditions, putting in an extensive permanent dewatering system, 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.

What do you do??

Goal: Redesign to Mat Slab



Hambro System



### Is it possible that a Mat Slab would be better than strip and column footings??

Answer: Yes, it is possible

- Rule of Thumb: Mat foundation is often constructed when the sum of individual footing areas exceeds about 1/2 of the foundation area.
- Wellington: 45.95% < 50% SUM (Very Close)
- Foundation Problems
  - Bearing Capacity of soil is very low. (3.5 KSF)
  - Very large footings are required, at a cost disadvantage.
  - Soil under footing is very compressible, with the probability of causing excessive or differential settlement.
  - Good bearing soil is deep.
  - Varying subsoil conditions within building perimeter.

Foundation System



Foundation Redesign



### Original Estimate and Schedule

\$357,119 + \$253,159 Change Orders = \$610,278

83 Work Days = 17 Weeks

Mon 1/16/06 - Mon 5/1/06 (Delays added 3 Weeks+)

Change Orders	Amount
1. Foundation	\$400,000
1. Site prep/topography setting, and/or soil test to be excavated	\$30,000
1. Foundation walls	\$48,000
1. Foundation walls	\$12,000
1. Change order: add drainage pipe from SOARC to 20' steel to be cut. Invert ground	\$1,500
1. Foundation walls	\$12,000
1. Rock Coffer	\$40,000
1. Change order: add foot drains to permit	\$10,000
1. Foundation columns and cap (1)	\$10,000
1. Add 3' Ungravel	\$1,000
1. Foundation columns and cap (1)	\$10,000
1. Shoring/bracing	\$80,000
<b>TOTAL CHANGES</b>	<b>\$553,159</b>

Foundation Column



Foundation Redesign

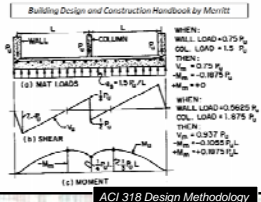


**Mat Foundation Redesign**


Utilized PCA MAT® Software by Structure Point

Main Load Data Input:


- Earth Engineering
  - Column loads will not exceed 473 kips
  - Wall loads will not exceed 10 kips per lineal foot.
  - No unbalanced moments or lateral loads are imposed on the columns and walls.
  - Total settlement must be less than one inch and the differential settlement to be within tolerable limits.




ACI 318 Design Methodology



PCA MAT® Interface



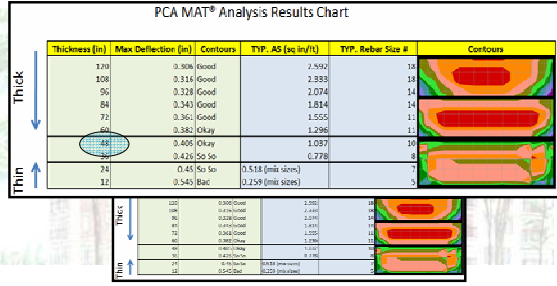

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Foundation Redesign

PCA MAT® Analysis Results Chart

Thickness [in]	Max Deflection [in]	Contours	TYP. AS [sq.in./ft.]	TYP. Rebar Size #	Contours
170	0.306	Good	2,592	18	
108	0.316	Good	2,388	18	
96	0.328	Good	2,074	14	
84	0.343	Good	1,814	14	
72	0.363	Good	1,555	11	
60	0.382	Okay	1,296	11	
48	0.405	Okay	1,037	10	
36	0.421	55 56	0.778	8	
24	0.45	50 56	0.518 [min. 50#s]	7	
12	0.543	Bad	0.258 [min. 50#s]	5	

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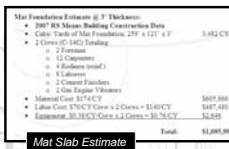


Foundation Redesign


Estimate and Schedule Impacts

\$1,095,994 (2.5X More)


- Construction: No increase or decrease in project schedule.
  - Start and finish on same days.
- Substructure: Increase by 17 days.
  - Start on the same day but finish at a later time.
- Foundation and Columns: Increase by 22 days.
  - Start on the same day but finish at a later time.
- Superstructure: Decrease by 17 days.
  - Start time will be pushed back but will finish on the same day as the original schedule. (DUE TO FLOAT IN SUPERSTRUCTURE PHASE- Project Team w/ Hambro System - Uncertainty)




Mat Slab Estimate



Mat Slab Schedule



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Foundation Redesign

Wide Mat Slab is best for cost.

Risk with Single Fiber Rebar Card system

For Owner is willing to pay for a mat slab foundation system

It would be beneficial to the project in other means and methods.

Higher quality and better system overall for this project.

Verifiable Mat foundation system may deem more viable in the following analysis.




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Foundation Redesign


Façade Integration

Situation: 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?

Goal: Integrate façade components

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Foundation Redesign

Original Estimate and Schedule

Integrate the facade without ruining the architectural style and vision of the owner and architect design?

Answer: Yes, but caution must be placed when wanting to change the architectural style and vision of the owner.

Original Façade Estimate

ahead of schedule to make up for lost time?

Due to the formwork in place for the cantilevered cast-in-place concrete, the original facade schedule could be pushed back to allow for the balcony construction to be completed before the facade is removed.




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Foundation Redesign

### Who Can Pre-Cast out?

- Pre-cast fabricated earlier on in project schedule
- Architectural Firm, Contractor or API is a manufacturing company that can control the brick pre-cast panels within the local area
- No shelter by location of building, about 2 hours away from the Wellington need to minimize the subcontractor or general conditions




Map between API and Project Site

API Website

Producing Quality Products

CONSTRUCTION PRODUCTION PRODUCE THEN SET BRICK

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Façade Integration

### What would Wellington Condominiums look if utilized thin brick pre cast panels?

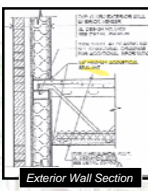
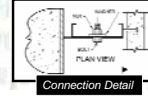


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Façade Integration

### Construction and Structural Implications

- Current load bearing metal stud walls will not have enough structural integrity to withstand the loading of the Pre-Cast Panels

Exterior Wall Section


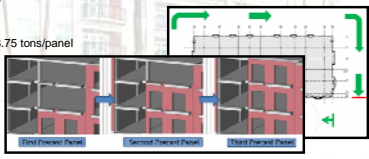
Connection Detail

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Façade Integration

### Construction and Structural Implications

- 100 Ton Amquip Lattice Boom Crawler Crane Works
- 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<sup>3</sup>
  - 875 lbs./ft
  - 17,500 lbs./panel ~ 8.75 tons/panel
- Productivity
  - 40 man hours/panel
  - 8-15 pieces/day
- Cost
  - \$30 - \$35 / panel

Crane - 75' @ 65 Degrees

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Façade Integration

### Pre-Cast Estimate and Schedule

- Total: \$767,909
- 1.96 Times the Original Cost
- 12 Work Days = 2.4 Weeks
- Mon 1/8/07 - Tue 1/23/07
- 4.8 Weeks Saved on Schedule
- Due to decrease in schedule will result in a net savings of: \$47,275
- Developer - Move 48 homeowners and family into development (\$\$\$ in revenue from condominiums, food and living costs, restaurants, shops, entertainment, and other areas.)
- General Conditions savings and value of spending 4.8 Weeks on other projects

GENERAL CONDITIONS	SAVINGS TOTAL	SAF VALUE	
CONTRACT ADMINISTRATION	1.00%	\$8,000.00	\$76,000.00
SUPPORT PERSONNEL	1.00%	\$8,000.00	\$76,000.00
LADDER	4.00%	\$32,000.00	\$2,984,000.00
CONCRETE FORMWORK	4.00%	\$32,000.00	\$2,984,000.00
CONCRETE PUMP TRUCK	1.00%	\$8,000.00	\$76,000.00
MATERIALS & SUPPLIES	1.00%	\$8,000.00	\$76,000.00

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Façade Integration

### Pre-Cast Wins Not To Pre-Cast... That is the question!

#### Let's Look at the 'Report Cards'

- 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 Pre-cast
- If utilizing the Hambro System and are to implement the structural-steel-column-tubing and steel-reinforcement: Mat Slab Foundation would be best to distribute loads

Component	Quantity	Unit	Cost	Notes	Form	Total Weight	Cost	Notes
Concrete	100	yd <sup>3</sup>	100.00			100.00	100.00	
Rebar	100	lb	100.00			100.00	100.00	
Formwork	100	sq ft	100.00			100.00	100.00	
Steel	100	lb	100.00			100.00	100.00	
Other	100	unit	100.00			100.00	100.00	
TOTAL			400.00			400.00	400.00	

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Façade Integration



**THE HANKIN GROUP**



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### Final Thoughts

- ▶ **Future:** Continual growth in **building and respecting** the communication of the decisions and processes between project participants early on
  - ▶ Design-Build Philosophy
- ▶ **Many ways of solving the equation of design and constructability**
  - ▶ How well you solve the equation is for **'the report card'** to decide
- ▶ **Special Thanks To:**
  - ▶ **Architectural Engineering Department Hankin Group** and supporting mentors
  - ▶ **Family and Friends**