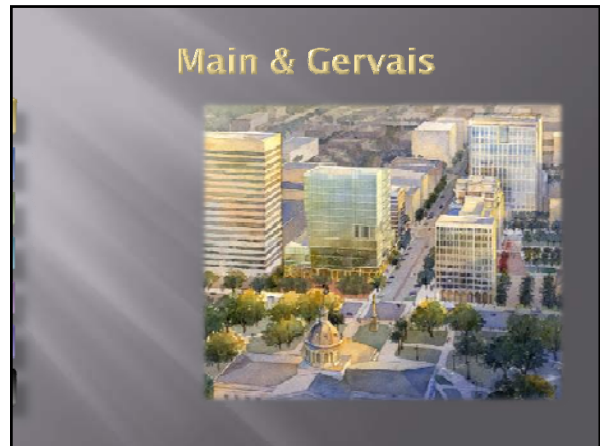


MAIN & GERVAIS

COLUMBIA, SOUTH CAROLINA

Adam De Luca
 Pennsylvania State University
 Architectural Engineering
 Construction Management Senior Thesis



Main & Gervais

- Building Summary
- Project Information
- Prefabrication Analysis
- Curtain Wall Analysis
- Structural Study
- Mechanical Study
- Thesis Conclusion
- Acknowledgements

Prominent Location

- Corner of Main & Gervais
- Columbia, South Carolina
- View of State Capitol

16 Story High Rise Building

- 400,000 Total Square Feet
- Exterior Plaza
- Ground Floor Lobby
- 6 Level Parking Garage
- 9 Floors of Office Space

Project Details

- Design-Bid-Build
- Duration: 7/1/2008 – 12/31/2009
- Contract Value: \$41,151,000

Main & Gervais

- Building Summary
- Project Information
- Project Team

<p>Owner</p> <p>General Contractor</p> <p>Architect</p> <p>Landscape Architect</p>	<p>Mechanical Engineer</p> <p>Structural Engineer</p> <p>Civil Engineer</p>
--	--

Main & Gervais

- Building Summary
- Project Information
- Prefabrication Analysis

Introduction

- Method Evaluation
- Current Method
- Proposed Method
- Schedule Evaluation
- Current Method
- Proposed Method
- Cost Evaluation
- Current Method
- Proposed Method
- Conclusion

Inefficient Construction

- Stick-Built Curtain Wall

Evaluation Criteria

Method
Schedule
Cost

Efficient Construction

- Prefabricated Curtain Wall

Main & Gervais

Construction Method Evaluation

- Prefabrication Analysis

Introduction

- Method Evaluation
- Current Method
- Proposed Method
- Schedule Evaluation
- Current Method
- Proposed Method
- Cost Evaluation
- Current Method
- Proposed Method
- Conclusion

Main & Gervais

Stick-Built Construction

Advantages

Disadvantages

Flexibility

Time

Delivery

Site

Money

QC

Hoisting

Cost

Prefabrication Analysis

Introduction
Method Evaluation
Current Method
Proposed Method
Schedule Evaluation
Current Method
Proposed Method
Cost Evaluation
Current Method
Proposed Method
Conclusion

Main & Gervais

Prefabricated Panels

Advantages

Disadvantages

Time

Delivery

QC

Crane

Secure

Cost

Site

Cost

Prefabrication Analysis

Introduction
Method Evaluation
Current Method
Proposed Method
Schedule Evaluation
Current Method
Proposed Method
Cost Evaluation
Current Method
Proposed Method
Conclusion

Main & Gervais

Schedule Evaluation

Prefabrication Analysis

Prefabrication Analysis

Introduction
Method Evaluation
Current Method
Proposed Method
Schedule Evaluation
Current Method
Proposed Method
Cost Evaluation
Current Method
Proposed Method
Conclusion

Main & Gervais

Stick-Built Construction

Prefabrication Analysis

Prefabrication Analysis

Introduction
Method Evaluation
Current Method
Proposed Method
Schedule Evaluation
Current Method
Proposed Method
Cost Evaluation
Current Method
Proposed Method
Conclusion

Main & Gervais

Prefabricated Panels

Prefabrication Analysis

Assumptions

- ▣ 42 panels delivered to site daily
- ▣ Capacity to install 50 panels daily
- ▣ Manipulator crane use
- ▣ 64 panels per garage level
- ▣ 94 panels per office floor

Prefabrication Analysis

Introduction
Method Evaluation
Current Method
Proposed Method
Schedule Evaluation
Current Method
Proposed Method
Cost Evaluation
Current Method
Proposed Method
Conclusion

Main & Gervais

Cost Evaluation

Prefabrication Analysis

Prefabrication Analysis

Introduction
Method Evaluation
Current Method
Proposed Method
Schedule Evaluation
Current Method
Proposed Method
Cost Evaluation
Current Method
Proposed Method
Conclusion

Main & Gervais

Stick-Built Construction

Prefabrication Analysis

- Introduction
- Method Evaluation
- Current Method
- Proposed Method
- Schedule Evaluation
- Current Method
- Proposed Method
- Cost Evaluation
- Current Method
- Proposed Method
- Conclusion

Labor Costs				
	Hr. Rate	Workers	Days	Total
Non-Union	\$ 28.47	30	115	\$ 785,905.00
Union	\$ 70.00	30	115	\$ 1,932,000.00

Total Costs					
	Material	Labor	Total	SF	Total \$/SF
Non-Union	\$ 3,634,691	\$ 785,905	\$ 4,420,596	94000	\$ 47.03
Union	\$ 3,634,691	\$ 1,932,000	\$ 5,566,691	94000	\$ 59.22

Material Costs	
Item	Cost
Materials	\$ 1,261,095.00
Glass/Panel	\$ 1,138,652.00
Glass/Panel Glazing	\$ 330,000.00
Interior Insulation & Trim	\$ 179,900.00
Imbeds & Inserts	\$ 78,000.00
Caulking	\$ 127,344.00
Total	\$ 3,634,691.00
Material \$/SF	\$ 38.67

Main & Gervais

Prefabricated Panels

Prefabrication Analysis

- Introduction
- Method Evaluation
- Current Method
- Proposed Method
- Schedule Evaluation
- Current Method
- Proposed Method
- Cost Evaluation
- Current Method
- Proposed Method
- Conclusion

Labor Costs				
	Hr. Rate	Workers	Days	Total
Non-Union	\$ 28.47	10	34	\$ 77,438.40
Union	\$ 70.00	10	34	\$ 190,400.00

	Material	Labor	Total	SF	Total \$/SF
Non-Union	\$ 5,640,000	\$ 77,438	\$ 5,717,438	94000	\$ 60.82
Union	\$ 5,640,000	\$ 190,400	\$ 5,830,400	94000	\$ 62.03

Material Costs			
	Cost/SF	SF	Cost
Material	\$ 60.00	94,000	\$ 5,640,000.00

Main & Gervais

Cost Savings from Schedule Savings

Prefabrication Analysis

- Introduction
- Method Evaluation
- Current Method
- Proposed Method
- Schedule Evaluation
- Current Method
- Proposed Method
- Cost Evaluation
- Current Method
- Proposed Method
- Conclusion

Schedule Savings		
Office Area	\$/ft ² /year	81 Days
200,000 ft ²	\$ 21.00	\$ 945,000.00

New Prefabrication Total Cost	
Non-Union	Union
\$ 5,217,438	\$ 5,830,709
\$ 945,000	\$ 945,000
\$ 4,772,438	\$ 4,885,709

Differences in Total Cost		
Method	Non-Union	Union Cost
Prefabrication	\$ 4,772,438	\$ 4,885,709
Stick-Built	\$ 4,420,596	\$ 5,566,691
Difference	\$ (351,842)	\$ 681,291

Assumptions

- Earlier Turnover (81 days)
- Total Area= 200,000 ft²
- Rent = \$21.00/ft²/year

Main & Gervais

Conclusion

Prefabrication Analysis

- Introduction
- Method Evaluation
- Current Method
- Proposed Method
- Schedule Evaluation
- Current Method
- Proposed Method
- Cost Evaluation
- Current Method
- Proposed Method
- Conclusion

Method Evaluation

- Prefabrication Preferred
- Quality Control
- Schedule Savings

Schedule Evaluation

- Prefabrication Preferred
- Quick Installation
- Earlier Turnover

Cost Evaluation

- Stick-Built Preferred
- Non-Union: 8% Less
- Union: 12% More

Main & Gervais

Prefabrication Analysis

- Introduction
- Method Evaluation
- Current Method
- Proposed Method
- Structural Load Analysis
- Column Addition
- Beam Replacement
- Joist Addition
- Construction Costs
- Solar Heat Gain Analysis
- Sloped Façade
- Vertical Façade
- Window Heat Gain
- Energy Load Comparison
- Conclusion

Current Curtain Wall Design

- Inefficient
- 5.63° Slope
- Complicated Section
- Limited Floor Plan
- Less Income

New Curtain Wall Design

- Efficient
- Eliminate Slope
- Easier for Prefab.
- Expanded Floor Plan
- More Income

Main & Gervais

Floor Plan Addition

Curtain Wall Analysis

- Introduction
- Floor Plan Addition
- Structural Load Analysis
- Column Addition
- Beam Replacement
- Joist Addition
- Construction Costs
- Solar Heat Gain Analysis
- Sloped Façade
- Vertical Façade
- Window Heat Gain
- Energy Load Comparison
- Conclusion


Office Floor	Length	Width	Additional Area
9	12'-0 5/8"	41'-6"	335 ft ²
10	11'-5 1/2"	41'-6"	475 ft ²
11	10'-7"	41'-6"	435 ft ²
12	8'-8 1/2"	41'-6"	362 ft ²
14	7'-3 7/8"	41'-6"	304 ft ²
15	5'-11 3/8"	41'-6"	247 ft ²
16	5'-6"	41'-6"	200 ft ²
17	3'-2 1/2"	41'-6"	133 ft ²
18	1'-9 3/4"	41'-6"	75 ft ²
Total			2756 ft²

Area (ft ²)	Rent (\$/ft ² /year)	Rent (\$/year)	Ten Year Period
2756	\$ 21.00	\$ 57,876.00	\$ 578,760.00

Main & Gervais Structural Load Analysis

Curtain Wall Analysis


- Introduction
- Floor Plan Addition
- Structural Load Analysis**
- Column Addition
- Beam Replacement
- Joist Addition
- Construction Costs
- Solar Heat Gain Analysis
- Sloped Façade
- Vertical Façade
- Window Heat Gain
- Energy Load Comparison
- Conclusion



Main & Gervais Column Addition

Curtain Wall Analysis

- Introduction
- Floor Plan Addition
- Structural Load Analysis
- Column Addition**
- Beam Replacement
- Joist Addition
- Construction Costs
- Solar Heat Gain Analysis
- Sloped Façade
- Vertical Façade
- Window Heat Gain
- Energy Load Comparison
- Conclusion



Assumptions

- Symmetry
- pcaColumn
- Column A (Floor 9)
 - Circular
 - 30" Diameter
 - 13' Height
 - $f'_c = 7000$ psi
- Column B (Floor 15)
 - $f'_c = 5000$ psi

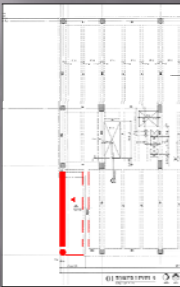
	Load	Factor	Factored Load
Live	120	1.6	192 psf
Dead	65	1.2	76 psf
Column	9572	1.2	11486 lbs

Main & Gervais Beam Replacement

Curtain Wall Analysis

Structural Study

- Column Addition
- Beam Replacement**
- Joist Addition
- Construction Costs
- Solar Heat Gain Analysis
- Sloped Façade
- Vertical Façade
- Window Heat Gain
- Energy Load Comparison
- Conclusion



Assumptions


- Symmetry
- RAM Concept
- Existing Beam
 - Post-tensioned
 - 23 3/4" Width
 - 21" Depth
 - 45' Length
- Replacement Beam
 - 36" Width

Main & Gervais Joist Addition

Curtain Wall Analysis

Structural Study

- Column Addition
- Beam Replacement
- Joist Addition**
- Construction Costs
- Solar Heat Gain Analysis
- Sloped Façade
- Vertical Façade
- Window Heat Gain
- Energy Load Comparison
- Conclusion



Assumptions

- Symmetry
- Beam Assumption
- New Joist
 - Post-tensioned
 - 14" Width
 - 21" Depth
 - 45' Length

Main & Gervais Construction Costs

Item	Description	Quant	Unit	Material	Labour	Equip.	Construction	Total
Concrete	6000 psi (elevated slabs)	40	CY	\$ 909.00			\$ 36360.00	\$ 4,960.00
	6000 psi (joists)	40	CY	\$ 124.00			\$ 4960.00	\$ 4,960.00
	8000 psi (columns)	36	CY	\$ 203.00			\$ 7308.00	\$ 7,308.00
Rebar	Joists, #4 to #18	1.69	tons	\$ 960.00	\$ 520.00		\$ 1,500.00	\$ 2,040.00
	Columns, #4 to #18	0.25	tons	\$ 960.00	\$ 600.00		\$ 1,560.00	\$ 1,560.00
	Elevated Slabs, #4 to #7	0.86	tons	\$ 1,020.00	\$ 480.00		\$ 1,500.00	\$ 1,260.00
Placement	Joists, crane & bucket	40	CY	\$ 52.50	\$ 26.50	\$ 29.00	\$ 3,040.00	\$ 3,040.00
	Columns	36	CY	\$ 215.00	\$ 11.90	\$ 32.40	\$ 1,274.40	\$ 1,274.40
	Elevated Slabs	40	CY	\$ 21.50	\$ 10.80	\$ 33.30	\$ 1,286.00	\$ 1,286.00
Prestressing	PT, 50' spans, 300 kip	0.84	tons	1420	\$ 1,860.00	\$ 80.00	\$ 1,740.00	\$ 3,147.97
Total								\$ 30,828.07

Curtain Wall Analysis

Structural Study

- Column Addition
- Beam Replacement
- Joist Addition
- Construction Costs**
- Solar Heat Gain Analysis
- Sloped Façade
- Vertical Façade
- Window Heat Gain
- Energy Load Comparison
- Conclusion

Assumptions

- R.S. Means
- Beams Accounted For
- Reuse of Formwork

Grand Total


□ \$30,828.07

Main & Gervais Solar Heat Gain Analysis

Curtain Wall Analysis

Structural Study

- Column Addition
- Beam Replacement
- Joist Addition
- Construction Costs
- Solar Heat Gain Analysis**
- Sloped Façade
- Vertical Façade
- Window Heat Gain
- Energy Load Comparison
- Conclusion



Main & Gervais

Sloped Façade (Current)

Curtain Wall Analysis

Structural Study

- Column Addition
- Beam Replacement
- Joist Addition
- Construction Costs

Assumptions

- West Façade
- ~1:30-7:30
- 21st of the Month
- May
- June
- July
- August

Radiation Calculated

- Direct: 65.51
- Diffuse: 15.87
- Reflected: 42.84

Total Radiation

- May 21st: 3:00 pm
- 124.22 btu/hr-ft²

Vertical Façade
Window Heat Gain
Energy Load Comparison
Conclusion

Main & Gervais

Vertical Façade (New)

Curtain Wall Analysis

Structural Study

Mechanical Study

Assumptions

- West Façade
- ~1:30-7:30
- 21st of the Month
- May
- June
- July
- August

Radiation Calculated

- Direct: 89.88 (+)
- Diffuse: 25.69 (+)
- Reflected: 39.01 (-)

Total Radiation

- May 21st: 3:00 pm
- 154.58 btu/hr-ft²

Vertical Façade
Window Heat Gain
Energy Load Comparison
Conclusion

Main & Gervais

Window Heat Gain

Curtain Wall Analysis

Structural Study

Mechanical Study

Assumptions

- SHGC: 0.278
- $q_t = (G_t)/SHGC$

Sloped Façade

- 34.53 btu/hr-ft²

Vertical Façade

- 43.06 btu/hr-ft²

25% Increase

Vertical Façade
Window Heat Gain
Energy Load Comparison
Conclusion

Main & Gervais

Energy Load Comparison

	btu/hr		btu/hr		kwh	
	Sloped	Vertical	Sloped	Vertical	Sloped	Vertical
May	39.83	47.56	5262	6263	15.41	18.45
June	40.18	48.17	5315	6325	15.57	18.67
July	39.00	46.29	5150	6189	15.12	18.14
August	34.67	41.85	4430	5321	13.52	16.23

	(\$/day)		(\$/month)		(\$ Inc)	% Inc
	Sloped	Vertical	Sloped	Vertical		
May	\$324.58	\$387.29	\$9,737.39	\$11,633.73	\$1,896.34	19%
June	\$327.44	\$392.54	\$9,823.44	\$11,776.29	\$1,953.15	20%
July	\$327.81	\$381.30	\$9,534.31	\$11,438.95	\$1,904.64	20%
August	\$284.16	\$341.09	\$8,524.81	\$10,232.61	\$1,707.80	20%

Assumptions

- Area: 4,536 ft²
- \$/kwh: 0.876

Annual Cost

- \$7,461.94

Curtain Wall Analysis
Structural Study
Mechanical Study
Vertical Façade
Window Heat Gain
Energy Load Comparison
Conclusion

Main & Gervais

Conclusion

Structural Load Analysis

- Design Verified
- Initial Cost: \$30,828.07
- Schedule Impact: Minimal

	Construction Cost	Energy Cost	Rent Income	Difference
Year 1	\$ 30,828.07	\$ 7,461.94	\$ 57,876.00	\$ 19,585.99
Year 2	\$ -	\$ 7,461.94	\$ 57,876.00	\$ 50,414.06
Year 3	\$ -	\$ 7,461.94	\$ 57,876.00	\$ 50,414.06

Solar Heat Gain Analysis

- Disadvantage: Vertical
- Cost Increase
- Annual Cost: \$7,461.94

Curtain Wall Analysis
Structural Study
Mechanical Study
Vertical Façade
Window Heat Gain
Energy Load Comparison
Conclusion

Main & Gervais

Thesis Conclusion

Prefabrication Analysis

- Better Constructability
- Faster Schedule
- More Expensive

↓

Prefab
Costs:
\$551,942.30

↗

Rent Profit:
\$372,884.41
(8 years)

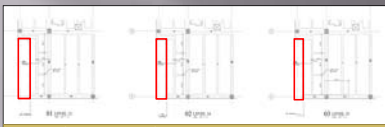
↑

Curtain Wall Analysis

- Initial Construction Cost
- Higher Energy Bill
- Profit from Rent

Curtain Wall Analysis
Structural Study
Mechanical Study
Vertical Façade
Window Heat Gain
Energy Load Comparison
Conclusion


Additional Area



Area (ft²)	Rent (\$/ft²/year)	Rent (\$/year)	Ten Year Period
2756	\$ 21.00	\$ 57,876.00	\$ 578,760.00

Choice Door	Length	Width	Additional Area
9	12'-10 5/8"	41'-6"	535 ft²
10	11'-5 1/2"	41'-6"	475 ft²
11	10'-6"	41'-6"	435 ft²
12	8'-8 1/2"	41'-6"	362 ft²
14	7'-3 7/8"	41'-6"	304 ft²
15	5'-11 3/8"	41'-6"	247 ft²
16	4'-6 3/4"	41'-6"	190 ft²
17	5'-2 1/4"	41'-6"	133 ft²
18	1'-9 3/4"	41'-6"	75 ft²
Total	-	-	2756 ft²

Structural Addition



Structural Addition Costs

Item	Description	Count	Unit	Material	Labor	Equip.	Cost/Unit	Total
Concrete	5000 psi (elevated slab)	40	CY	\$ 109.00			\$ 4360.00	\$ 4,360.00
	6000 psi (joist)	40	CY	\$ 124.00			\$ 4960.00	\$ 4,960.00
	3000 psi (precast)	36	CY	\$ 203.00			\$ 7308.00	\$ 7,308.00
Rebar	Joist, #8 to #18	1.89	kans	\$ 980.00	\$ 520.00		\$ 1,500.00	\$ 2,835.00
	Columns, #8 to #18	0.26	kans	\$ 980.00	\$ 680.00		\$ 1,580.00	\$ 1,200.00
	Elevated Slab, #4 to #7	0.86	kans	\$ 1,020.00	\$ 480.00		\$ 1,500.00	\$ 1,290.00
Formwork	Joist, cross & header	40	CY	\$ 32.80	\$ 28.50	\$ 79.00	\$ 136.80	\$ 1,368.00
	Columns	36	CY	\$ 21.50	\$ 11.90	\$ 35.40	\$ 127.40	\$ 1,274.40
	Elevated Slab, 1"	40	CY	\$ 21.50	\$ 10.80	\$ 32.30	\$ 120.60	\$ 1,206.00
Prestressing	PT, 5/8" span, 300 kip	0.84	kans	1820	\$ 80.00	\$ 3,760.00	\$ 3,147.82	\$ 3,147.82
Total								\$ 30,828.07

	(ft²/ft²/hr)		(ft²/ft²)		(cubic)	
	Sloped	Vertical	Sloped	Vertical	Sloped	Vertical
May	29.83	47.58	52092	62953	15.44	19.45
June	40.18	48.17	53156	63725	15.57	18.67
July	39.00	46.79	51593	61899	15.12	18.14
August	34.87	41.85	46130	55371	13.52	16.22

	(ft²/ft²)		(ft²/ft²)		(\$/ft²/ft²)	
	Sloped	Vertical	Sloped	Vertical	Sloped	Vertical
May	\$ 324.58	\$ 387.79	\$ 9,737.79	\$ 11,633.73	\$ 1,896.31	19%
June	\$ 327.44	\$ 392.54	\$ 9,823.34	\$ 11,726.29	\$ 1,953.15	20%
July	\$ 317.81	\$ 381.50	\$ 9,534.31	\$ 11,438.95	\$ 1,894.61	20%
August	\$ 284.16	\$ 341.09	\$ 8,524.81	\$ 10,232.61	\$ 1,707.80	20%

	Construction Cost	Energy Cost	Rent Income	Difference
Year 1	\$ 30,828.07	\$ 7,461.94	\$ 57,876.00	\$ 19,585.99
Year 2	\$ -	\$ 7,461.94	\$ 57,876.00	\$ 50,414.06
Year 3	\$ -	\$ 7,461.94	\$ 57,876.00	\$ 50,414.06