THE VIRGINIA COMMONWEALTH UNIVERSITY

SCHOOL OF BUSINESS & ENGINEERING

RICHMOND, VIRGINIA

PRESENTED BY:

LORI E. FARLEY

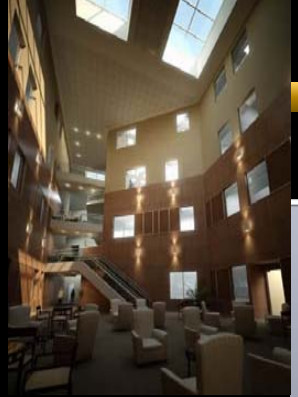
CONSTRUTION MANAGEMENT OPTION

TUESDAY, APRIL 15, 2008

THE VIRGINIA COMMONWEALTH UNIVERSITY

SCHOOL OF BUSINESS & ENGINEERING

RICHMOND, VIRGINIA



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presentation OUTLINE

- PROJECT OVERVIEW
- TECHNICAL ANALYSES
  - *ANALYSIS ONE* – STRUCTURAL REDESIGN OF SECTOR C
  - *ANALYSIS TWO* – SOLAR ARRAY ADDITION TO THE MECHANICAL ROOF SCREEN
- INCENTIVES AND DISINCENTIVES OF PREFABRICATION
- ACKNOWLEDGEMENTS
- QUESTIONS & COMMENTS

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project OVERVIEW

PROJECT LOCATION AND SIZE
Richmond Virginia, Monroe Park Campus

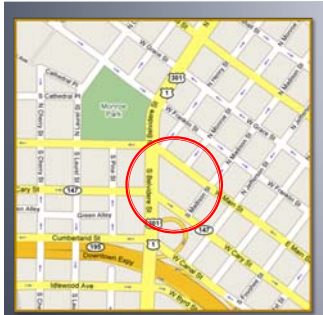
OCCUPANCY AND FUNCTION
New expansion for the schools of Business and Engineering

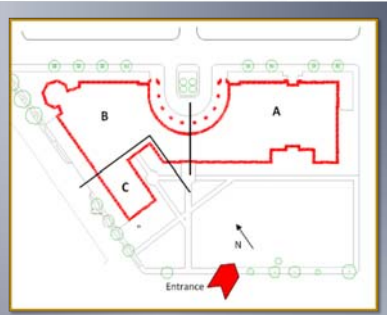
SIZE
243,717 GSF; 99,761 SOE, 112,680 SOB, 31,276 Common

SCHEDULE
January 16, 2006 – November 28, 2007

CONTRACT SIZE
$65 MM

project SITE





project OVERVIEW

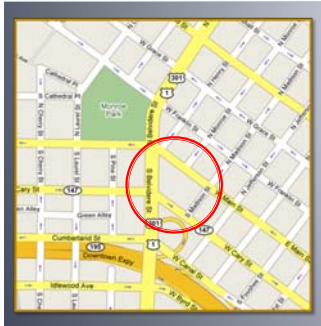
THE VIRGINIA COMMONWEALTH UNIVERSITY

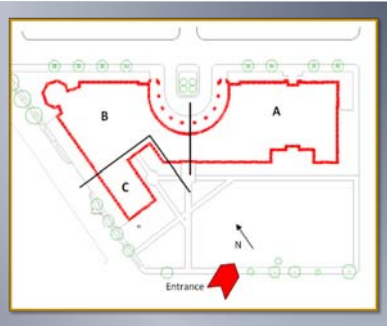
OWNER
The Virginia Commonwealth University

ARCHITECT
Moseley Architects

CONSTRUCTION MANAGER
Gilbane Building Company

project SITE





THE VIRGINIA COMMONWEALTH UNIVERSITY

project OVERVIEW

project FEATURES

2-Full Height Atriums

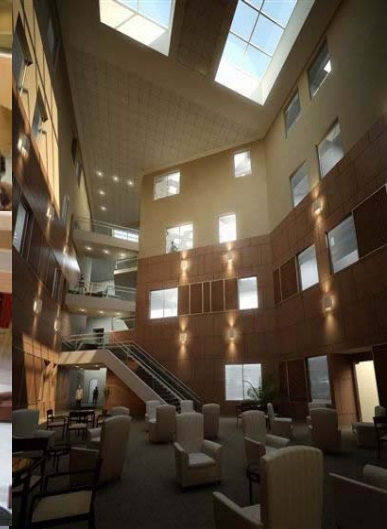
Research Laboratories

Cafés and Lounge Areas

Faculty Offices and Classrooms

Auditoriums and Lecture Halls

Specialized Team-Building Classrooms



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analysis ONE

structural redesign of SECTOR C

FUNCTION
Laboratories and Faculty Offices

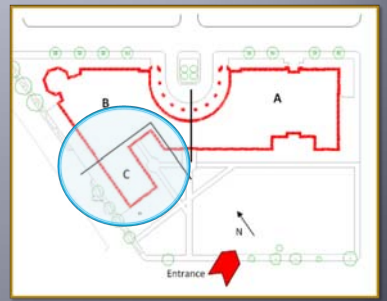
AS-BUILT STRUCTURE
Concrete

PROPOSAL
Change the Structural System to Steel

GOALS
Improve Constructability
Schedule Compression
Cost Savings

structural ANALYSIS

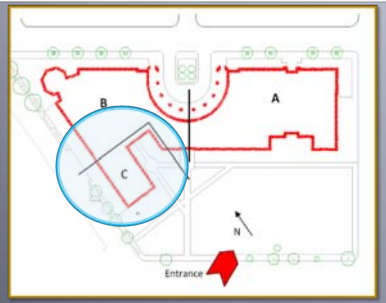
REDESIGN OF SECTOR C



analysis ONE

structural ANALYSIS

REDESIGN OF SECTOR C



re-design METHODOLOGY

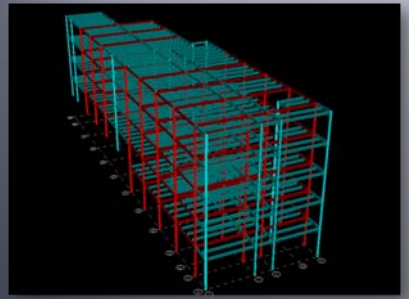
- Review as-built structure
  - Bay Sizes
  - Column Locations
  - Square Footages and Floor to Floor Heights
- Input Grid Into RAM STRUCTURAL SYSTEM
  - Lateral Frames – No Bracing
  - Vulcraft Decking – 4-inch, 4,000 psi NW Concrete
- Input Design Loads

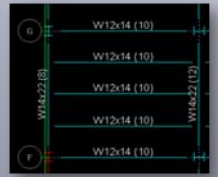
REDESIGN OF SECTOR C

OCCUPANCY	DESIGN LOAD
Roof	20 PSF
Offices	50 PSF + 20 PSF Partitions
Corridors	100 PSF
Research Laboratories – First Floor	125 PSF
Research Laboratories – Above First Floor	100 PSF

structural ANALYSIS

PERSPECITIVE OF THE STEEL REDESIGN AND A TYPICAL BAY





TYPICAL BAY 21' x 24'

re-design RESULTS

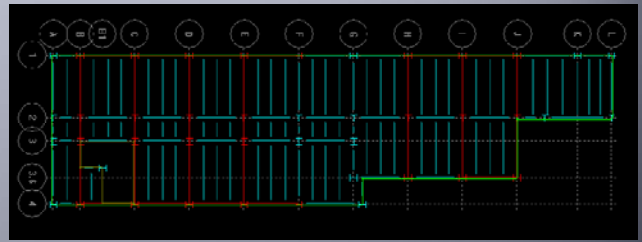
cost COMPARISON

COST COMPARISON SUMMARY OF SECTOR C			
STEEL		CONCRETE	
Beams & Girders	$341,151.67	Beams & Girders	$778,461.91
Columns	$252,897.98	Columns	$404,606.99
Fire Protection	$90,000.00	Joists	$406,531.90
Fabrication	$456,000.00		
TOTAL	**$1,140,048.65**	**TOTAL**	**$1,589,600.80**

Savings: $449,552

structural ANALYSIS

PLAN VIEW OF STEEL REDESIGN TYPICAL FOR FLOORS 2-ROOF



structural ANALYSIS

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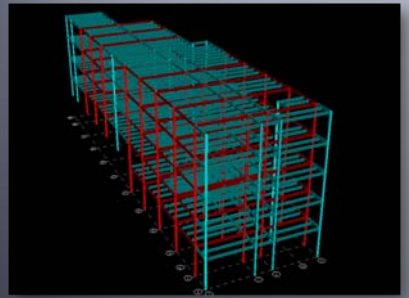
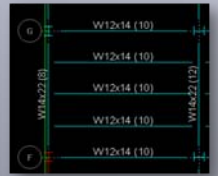


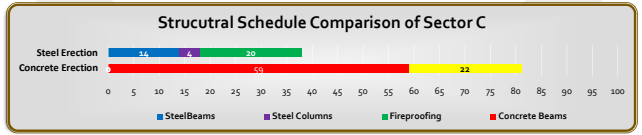


TYPICAL BAY 21' x 24'

re-design RESULTS

schedule COMPARISON

TYPE OF STRUCTURE	QUANTITY	DAILY OUTPUT/CREW	CREW NO.	TOTAL DURATION	
STEEL					
Beams	12424 L.F.	900 L.F.	E-2	14	18
Columns	3886 L.F.	1032 L.F.	E-2	4	
CONCRETE					
Beams	1090.37 C.Y.	18.55 C.Y.	C-14A	59	81
Columns	374.63 C.Y.	17.71 C.Y.	C-14A	22	



structural ANALYSIS

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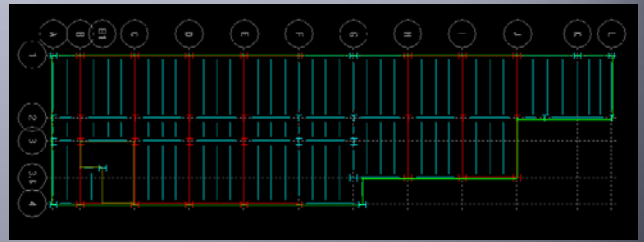

structural ANALYSIS

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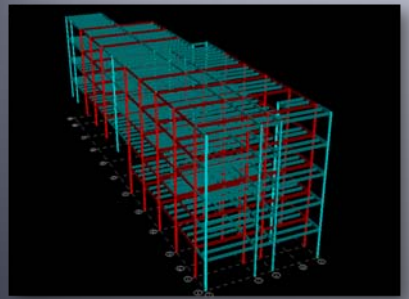
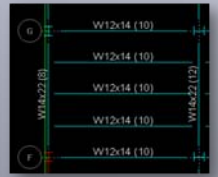




TYPICAL BAY 21' x 24'

re-design RESULTS

constructability REVIEW

CRANE SIZE

No larger members when compared to sectors A and B

Re-use cranes from erection of sectors A and B

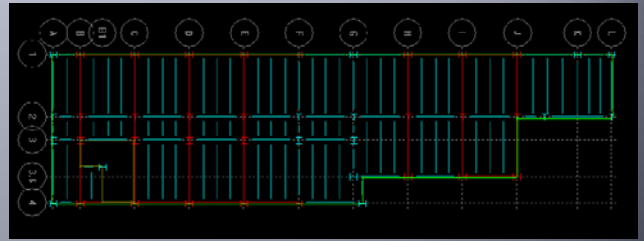
PLENUM SPACE

Concrete beams are larger than the steel beams - 24" vs. 18"

Smoother coordination between MEP trades

structural ANALYSIS

PLAN VIEW OF STEEL REDESIGN TYPICAL FOR FLOORS 2-ROOF



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analysis TWO

solar array addition to SECTOR C

BACKGROIUND

Green Construction within Universities
Not LEED® certified
No Green Policy

PROPOSAL

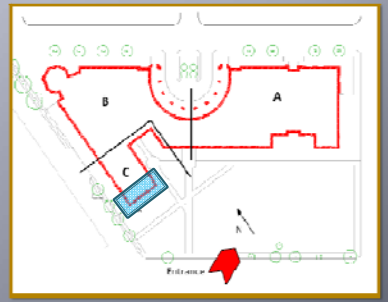
Add a solar array to south facing roof screen

GOALS

Aesthetic Movement
Investment vs. Cost Offset
Value Engineering Review

electrical ANALYSIS

SOLAR ARRAY ADDTION TO SECTOR C



electrical ANALYSIS

PRODUCT SELCTION

MODULE CHARACTERISTICS	
Maximum Power	190W
Voltage at Maximum Power	24.3V
Open-Circuit Voltage	30.6V
Current at Maximum Power	7.82A
Solar Cells	50
Maximum System Voltage	600V
Dimensions	
Length	66.0"
Width	33.0"
Depth	2.00"
Weight	33.95 lbs.

SMA

Sunny Boy 3800U

analysis TWO

design METHODOLOGY

MECHANICAL ROOF SCREEN (southern pitch)

39.5° Tilt

57' by 27.5'

100 Panel Array

5 Rows of 20 Panels

19 kW array

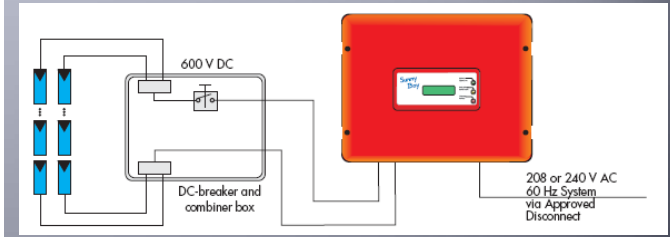
GRID CONNECTION

20 Panels connected in series (maximum 600V by NEC)

5 – 3800 Watt Inverters (one inverter per row of panels)

electrical ANALYSIS

SIMPLIFIED WIRING DIAGRAM



electrical ANALYSIS

PANEL BOARD LOADING

PANEL P2N4A3 — RATING: 208/120V, 3ϕ, 4W — 225 AMPS

LOAD DISCRIPTION	WIRE & CONDUIT	KW LOAD ϕA	KW LOAD ϕB	KW LOAD ϕC	CB/ Phase	CIRC. NO.	ϕ
INVERTER 1	2#12AWG + 1#12AWG	1.9			20/2	1	A
			1.9			3	B
INVERTER 2	2#12AWG + 1#12AWG			1.9	20/2	5	C
		1.9				7	A
INVERTER 3	2#12AWG + 1#12AWG		1.9		20/2	9	B
				1.9		11	C
INVERTER 4	2#12AWG + 1#12AWG	1.9			20/2	13	A
			1.9			15	B
INVERTER 5	2#12AWG + 1#12AWG			1.9	20/2	17	C
		1.9				19	A

design RESULSTS

electrical IMPACT

INVERTER DATA AND DEMANDS

Single Phase

- Each inverter requires 2 "spare" locations
- Need a panel board with 10 "spares"

PANEL BOARD LOCATION

Electrical Room on 4th Floor

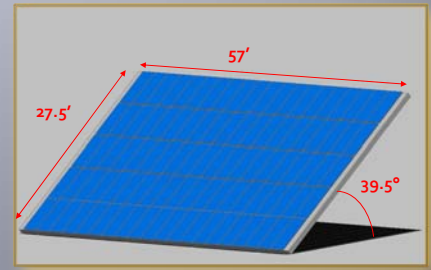
- Panel Board P2N3A4 – Close to the Array

PANEL BOARD LOADINGS

3.8 kW = (2) 1.9 kW Loading on Panel Board per Inverter

electrical ANALYSIS

CONCEPTUAL VIEW OF ARRAY



electrical ANALYSIS

INTERPOLATED SOLAR DATA FOR RICHMOND, VIRGINIA

ANGLED SURFACE DATA (kWh/m²day) FOR RICHMOND, VA													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	AVG
S	3.29	3.9	4.57	5.05	5.21	5.40	4.85	5.10	4.74	4.30	3.54	3.02	4.47

- A power of 190 W (maximum power)
- A voltage of 30.6 V (open-circuit voltage)
- The corresponding days/month
- An average price of $0.09/kWh
- 1.4 lbs of CO_2/kWh

design RESULTS

estimated SAVINGS

SOUTHERN PITCH SAVINGS PER YEAR		
MO.	SAVINGS ($)	SAVINGS (LBS OF CO_2)
JAN	$190.31	2960.31
FEB	$186.73	2904.72
MAR	$242.26	3768.42
APR	$259.07	4029.90
MAY	$276.18	4296.17
JUN	$277.02	4309.20
JUL	$257.10	3999.31
AUG	$270.35	4205.46
SEPT	$243.16	3782.52
OCT	$227.94	3545.78
NOV	$181.60	2824.92
DEC	$160.09	2490.29
AVG	$230.98	3593.08
TOT	$2771.81	43,117lbs

ELECTRIC SAVINGS
$2770 PER YEAR

SAVINGS OF CO_2 EMISSIONS
43,117 LBS PER YEAR

electrical ANALYSIS

MATERIALS SAVINGS

ESTIMATED MATERIALS SAVINGS	Total SF	Material Cost per SF	Total Material Cost	Installation Cost per SF	Total Installation Cost	TOTAL SAVINGS
Pre-Formed Metal Roofing	1567.5	$2.86	$4,483.05	$1.88	$2,946.9	$7,429.95
Formed Metal Roofing	1567.5	$14.35	$22,493.62	$4.71	$7,382.93	$29,876.55
Treated Wood Blocking						$1000.00
					TOTAL MATERIAL SAVINGS	$38,306.5

electrical ANALYSIS

CONSTRUCTABILITY REVIEW

Panel Weights – Lightweight Design
Fixed-Mounted – Cheaper Alternative
Panels are Wired for Connection
Low Maintenance
Utility Interconnection Requirements
Roof Penetrations

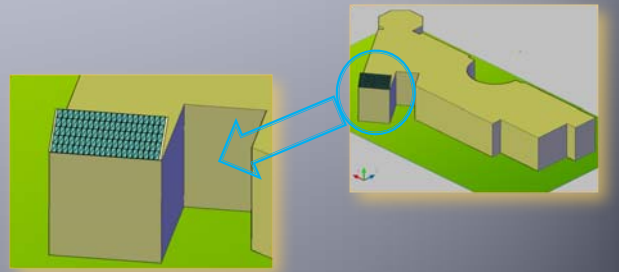
design RESULTS

estimated INVESTMENT

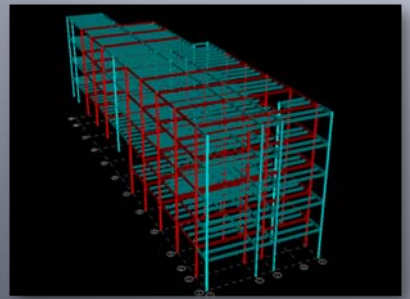
INVESTMENT			
ITEM	QTY.	COST/UNIT	TOTAL
Solar Panels	100 – 190W	$6.00/W	$114,000
Inverters	5 – 3800U	$2,500.00 ea.	$12,500
Savings			-38,306
TOTAL			$88,194

electrical ANALYSIS

CONCEPTUAL VIEW OF ARRAY ON THE BUILDING



CONCLUSIONS AND RECOMMENDATIONS



conclusions RECOMMENDATIONS

✓Structural Redesign

Allows Substantial Completion to be Met Over 2 Months Earlier

Estimated Savings of $450,000

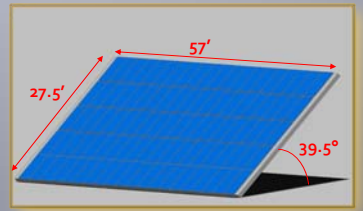
✓Solar Array Addition

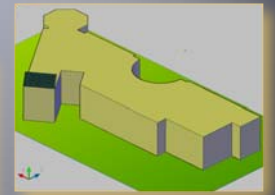
Trivial Initial Investment

Estimated Savings of $2,700 per Year on Electricity

Value Engineering Design – Price of Electricity Will Increase

CONCLUSIONS AND RECOMMENDATIONS





research ISSUE

PREFABRICATION

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research ISSUE

PROBLEM STATEMENT

No Single Applicable Technique – Project Specific

Prefabrication impacts:
Management
Project Execution

PREFABRICATION DEMANDS

Clearly Defined Scope of Work
Early Decision Making and Proper Planning
Increase in Design Detail

research ISSUE

PREFABRICATION

LACK OF AWARENESS

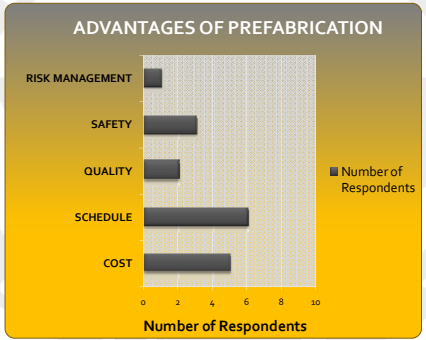
Understand Risks and Benefits
Early Decision Making is Crucial

PREFABRICATION

INCENTIVES OF PREFABRICATION

Lower Costs (overhead, labor, equipment)
Risk Management
Schedule
Quality
Safety

research ISSUE



research ISSUE

PREFABRICATION

The schedule becomes much more predictable and, from that, the planning makes the management easier.

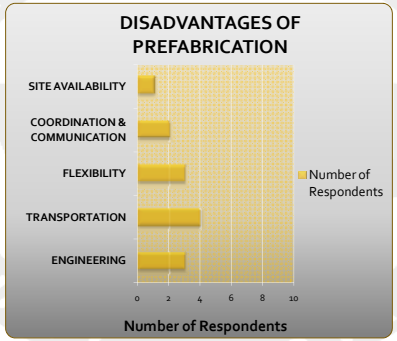
research ISSUE

PREFABRICATION

DISINCENTIVES OF PREFABRICATION

Engineering
Transportation
Reduced Design Flexibility
Coordination and Communication
Site Availability

research ISSUE



research ISSUE

PREFABRICATION

Transportation is a major logistical concern as to what you can actually put on the road.

research ISSUE

research ISSUE
PREFABRICATION

INTERPRETATION OF RESULTS

Establish Important Drivers
Early Decision Making
Explore Options of Prefabrication

research ISSUE

research ISSUE

PREFABRICATION AT VCU

IMPLEMENTATION OF PREFABRICATION

The Mechanical Roof Screen

Safety Concerns
Time Consuming
Maneuverability Around Mechanical Equipment
Damage to the Finished Roof

PREFABRICATION AT VCU

research ISSUE

research ISSUE

PREFABRICATION AT VCU

PREFABRICATION AT VCU

CONSTRUCTION INDUSTRY INSTITUTE

A FRAME-WORK FOR DECISION MAKING
Effectively Applying the Drivers

PARKING LOT
NEXT TO SITE

research ISSUE

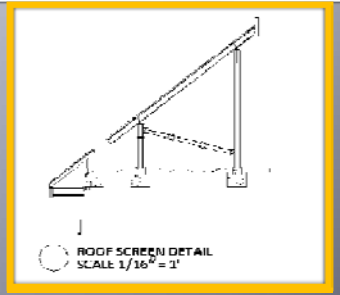
PREFABRICATION AT VCU

GATHERING OF PRELIMINARY INFORMATION

Typical Panel Size: 21' x 27.5"
Typical Panel Weight: 3500 lbs
Total Number of Panels: 65
On - Site Assembly

research ISSUE

PREFABRICATION AT VCU



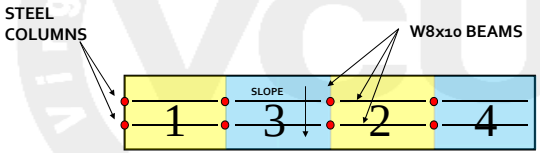
ERECTION SEQUENCING

Erect Panels 1 and 2 with steel posts
Lay and Connect Panels 3 and 4

research ISSUE

PREFABRICATION AT VCU

ERECTION SEQUENCING



research ISSUE

PREFABRICATION AT VCU

ERECTION TIME

6-9 Panels per Day (~65 Panels Total)
8-11 Days for Installation

CONSTRUCTABILITY REVIEW

Transportation from Lot to Site
Temporary Supports for Panels
"Incomplete Erection" for Connecting Purposes
Security Issues with Parking Lot Assembly Site
Decide Early

research ISSUE

CONCLUSIONS AND RECOMMENDATIONS

✓Logical Alternative in Terms of:
- Weather Delays
- Pace of Trades on Roof
- Safety of Workers
- Incurred Damages to Roof

research ISSUE

PREFABRICATION AT VCU

QUESTIONS

QUESTIONS

ACKNOWLEDGEMENTS

ISEC, INC.

GILBANE BUILDING COMPANY

AE FACULTY

FELLOW STUDENTS

FRIENDS AND FAMILY

steel design NOTES

L.R.F.D. was used

Beams have a maximum 100% composite action and a minimum 25% composite action

steel VALUES

R.S. MEANS COST DATA – steel pricing per linear foot includes labor and erection costs

FABRICATION COST - $3,000 per ton for Fabrication Cost
228 tons of steel

fireproofing steel CODE

Section 304 under business group (B) of IBC 2006

2-hr fire rating

adjusted solar DATA

ADJUSTED AVERAGE SOLAR DATA FOR RICHMOND VIRGINIA - kW/hm^2day														
Direction	Angle	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	AVG
North Pitch	39.5°	1.84	2.48	3.33	4.19	4.78	5.19	4.53	4.43	3.65	2.85	2.04	1.61	**3.46**
South Pitch	39.5°	3.29	3.9	4.57	5.05	5.21	5.4	4.85	5.1	4.74	4.3	3.54	3.02	**4.47**
East Pitch	39.5°	2.27	3.04	4.04	5.02	5.55	5.95	5.29	5.22	4.41	3.49	2.52	2.03	**4.12**
West Pitch	39.5°	2.29	3.03	4.04	5	5.52	5.91	5.24	5.19	4.39	3.47	2.52	2.03	**4.11**
NW Pitch	39.5°	2.06	2.75	3.68	4.6	5.15	5.55	4.89	4.81	4.02	3.16	2.28	1.82	**3.78**
SW Pitch	39.5°	2.79	3.46	4.3	5.03	5.36	5.66	5.05	5.14	4.57	3.89	3.03	2.53	**4.29**
NE Pitch	39.5°	2.05	2.76	3.68	4.61	5.17	5.57	4.91	4.82	4.03	3.17	2.28	1.82	**3.79**
SE Pitch	39.5°	2.78	3.47	4.3	5.03	5.38	5.68	5.07	5.16	4.58	3.89	3.03	2.53	**4.3**

savings CALCULATIONS

Southern Pitch Savings Estimation

Month	kW/h*m^2*day	kW/h	Savings Per Month	Savings per Month (lbs CO2)
JAN	3.59	2114.51	$190.31	2960.31
FEB	3.9	2074.80	$186.73	2904.72
MAR	4.57	2691.73	$242.26	3768.42
APR	5.05	2878.50	$259.07	4029.90
MAY	5.21	3068.69	$276.18	4296.17
JUN	5.4	3078.00	$277.02	4309.20
JUL	4.85	2856.65	$257.10	3999.31
AUG	5.1	3003.90	$270.35	4205.46
SEPT	4.74	2701.80	$243.16	3782.52
OCT	4.3	2532.70	$227.94	3545.78
NOV	3.54	2017.80	$181.60	2824.92
DEC	3.02	1778.78	$160.09	2490.29
AVG	4.47	2566.49	$230.98	3593.08
TOTAL SAVINGS PER YEAR			$2,771.81	43117.00

Vaules				
Total Panels	Maximum Power	Total kW of System	Cost of Electricty per kW	CO2 lbs per kWh
100	190 W	19	$0.09	1.4

additional solar CALCULATIONS

No. of Panels in Series = 600V/30.6V/panel = 19.6 *Panels*

No. of Inverters = (100 *panels**190W)/3800W/*Inverter* = *5 Inverters*

Maximum Panel Loading = (225A)(208V)(3)$^{1/2}$ = 81.1 *kW*

Total Inverter Loading on Panel Board = (5 inverters)(3.8kW) = 19 *kW*

81.1 kW > 19 kW

Circuit Breaker Size = 3800W/208 = 18.27A *use 20A Circuit Breaker*