UMBC Performing Arts & Humanities Facility

Baltimore, MD

Penn State AE Senior Capstone Project

Courtney Glaub – Construction Management

Dr. Chimay Anumba – CM Advisor

PRESENTATION OUTLINE:

I. Project Background
II. Analysis 1 – Precast Façade
    I. Structural Breadth #1
III. Analysis 2 – Crane Comparison
    I. Constructability Review
IV. Analysis 3 – PV Array Feasibility Study
    I. Structural Breadth #2
    II. Energy/Electrical Breadth
V. Concluding Thoughts
VI. Acknowledgements

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PROJECT BACKGROUND

UMBC Performing Arts & Humanities Facility
Baltimore, MD
Courtney Glaub – Construction Management

PRESENTATION OUTLINE:

IMAGE COURTESY OF WHITING-TURNER

LOCATION:

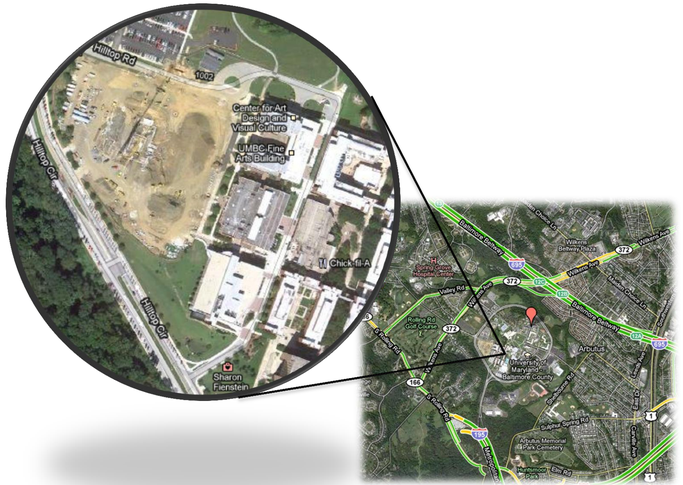
- 1000 Hilltop circle, baltimore, md 21250
- umbc performing arts & Humanities facility

Building parameters:

- 90,000 SF gross building area
- 4 stories + basement
- Upgrade to existing central utility plant & tunnel

Project parameters:

- projected cost: $67,000,000
- Dates of Construction: 7/1/2010 – 6/30/2012
- Delivery Method: CM at Risk
- LEED Certification: Silver



IMAGES COURTESY OF GOOGLE MAPS

PROJECT BACKGROUND

UMBC Performing Arts & Humanities Facility
Baltimore, MD
Courtney Glaub – Construction Management

PRESENTATION OUTLINE:

IMAGE COURTESY OF WHITING-TURNER

STRUCTURAL SYSTEM:

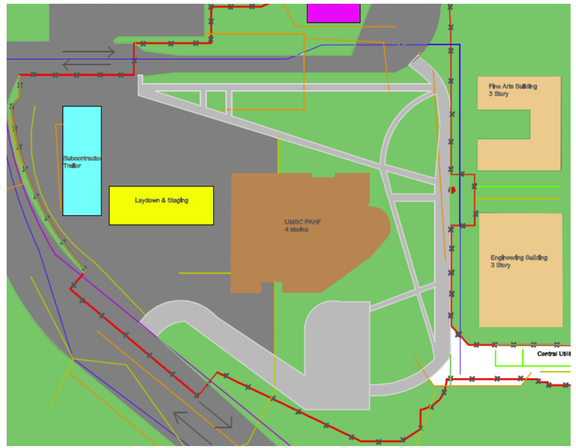
- Foundation Concrete Footings
- Steel Beams and Girders
- Cast-in-place Concrete
- Concrete Masonry Units

BUILDING ENCLOSURE:

- Brick Veneer with CMU back-up or Steel Stud back-up
- Glazed Aluminum Curtain Wall
- Stainless Steel Wall Panels with Concrete/Steel Stud back-up

CONSTRUCTION LOGISTICS:

- Phase One: 275 Seat Proscenium Theater
  100 Seat Black Box Theater
  Scene Shop, Rehearsal/Acting Studio,
  Offices, Classrooms, Conference Rooms



Precast Façade Design

UMBC Performing Arts & Humanities Facility
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PRESENTATION OUTLINE:

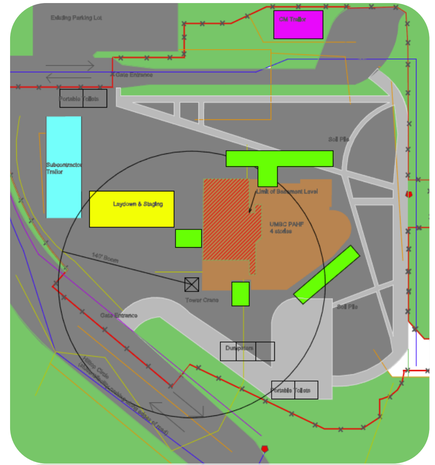
IMAGE COURTESY OF WHITING-TURNER

PROBLEM IDENTIFICATION:

- Complete project on time and efficiently
- Building is made up of three different structural elements
- delays encountered due to adjacent work being completed

RESEARCH GOAL:

- Perform preliminary design of precast façade
- Reduce masonry schedule and eliminate any delays



Precast Façade Design

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PRESENTATION OUTLINE:

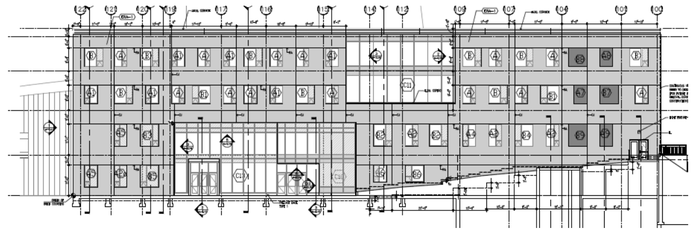
IMAGE COURTESY OF WHITING-TURNER

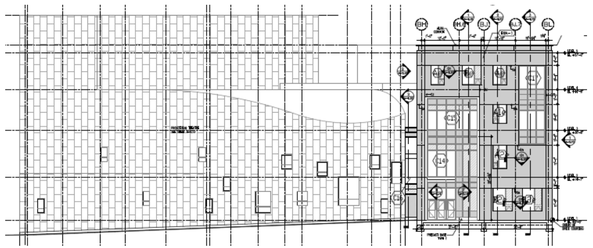
ORIGINAL FACADE:

- 70% Driftwood Grey and 30% Light Autumn by Cloud Ceramics, Roman Modular type
- $900,000 masonry package
- 4 month construction duration

PRECAST FACADE:

- Span from column to column
- Different Sizes of Panels up to 12ft and 35-40ft span
- 341 total pieces
- 20,835 sf of panels





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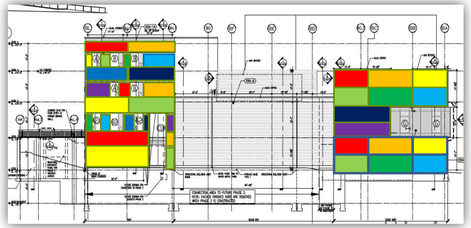

STRUCTURAL WEIGHTS:

- Precast heavier than masonry wall
- Assume 6" thick panel with normal weight concrete

EXTERIOR BEAM LOADS:

- W16x26 = 129FT-K < 241FT-K
- W14X22 = 129FT-K < 183FT-K
- W21X44 = 252FT-K < 510FT-K

EXTERIOR BEAM DEFLECTION:

- Governing factor of design
- Allowable deflection = L/240
- Beams can withstand heavier precast load

STRUCTURAL WEIGHTS			
MASONRY WALL		PRECAST	
MATERIAL	WEIGHT (PSF)	MATERIAL	WEIGHT (PSF)
Brick	40	6" Thick Panel	75

BEAM DEFLECTION		
BEAM SIZE	LOAD CASE	MAX DEFLECTION
W16X26	Masonry Wall Loads	0.374
	Precast Panel Loads	0.537
W14X22	Masonry Wall Loads	0.546
	Precast Panel Loads	0.783
W21X44	Masonry Wall Loads	0.538
	Precast Panel Loads	0.772

Precast Façade Design

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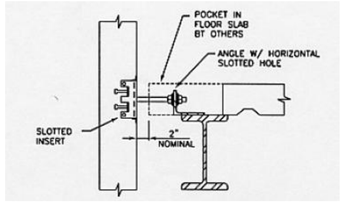


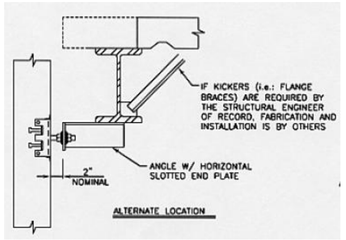
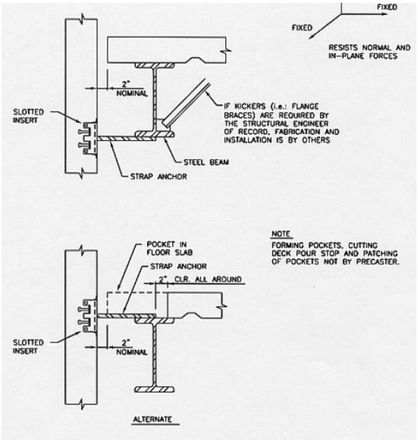


IMAGE COURTESY OF MID-ATLANTIC PRECAST ASSOCIATION

STRUCTURAL PRECAST CONNECTION:

- Panel spans from column to column
- Precast Tie-Back Connection to the exterior beams
- Bearing/Adjustable Tie-Back Connection
- Fixed Tie-Back Connection



IMAGES COURTESY OF MID-ATLANTIC PRECAST ASSOCIATION

Precast Façade Design

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Courtney Glaub – Construction Management

PRESENTATION OUTLINE:

IMAGE COURTESY OF WHITING-TURNER

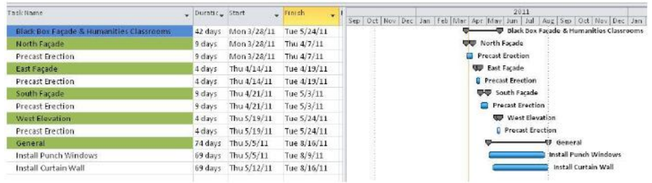
SCHEDULE REDUCTION:

- Original masonry façade duration = 115 days
- Precast erection = 12 pieces/day
- Precast façade duration = 29 days

IMPACT ON PROJECT:

- No overlap of steel and façade trades
- Façade is not on critical path
- Save 87 days of façade work

SCHEDULE REDUCTION DUE TO PRECAST FAÇADE						
ELEVATION	FAÇADE SF	MASONRY DURATION (DAYS)	TOTAL # OF PRECAST PANELS	PANELS/DAY	PRECAST DURATION (DAYS)	SCHEDULE SAVINGS (DAYS)
South	7126.12	40.00	103	12	8.58	(31.42)
North	6307.5	30.00	109	12	9.08	(20.92)
East	1923.87	15.00	42	12	3.50	(11.50)
West	4378.75	30.00	43	12	3.58	(26.42)
Corners	1098.8	0.00	44	12	3.67	3.67
TOTAL	**20835.04**	**115.00**	**341**	**12**	**28.42**	**(86.59)**



Precast Façade Design

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PRESENTATION OUTLINE:

IMAGE COURTESY OF WHITING-TURNER

MATERIAL PRICING:

- $41.50/SF DEDUCT FOR MASONRY WALL ASSEMBLY WITH BACK-UP
- $37.00/SF COST FOR PRECAST PANEL
- $50.50/SF COST FOR PRECAST PANEL WITH BACK-UP

COST IMPACT:

- PRECAST FAÇADE COSTS APPROXIMATELY 17% MORE THAN MASONRY
- $50,703.64 OVERALL INCREASE FROM FAÇADE RE-DESIGN

OVERALL SAVINGS	
Precast Panel Cost	$915,357.93
Masonry Wall Cost	$864,654.29
TOTAL SAVINGS	($50,703.64)

COST DIFFERENCE DUE TO PRECAST FAÇADE				
ELEVATION	FAÇADE SF	MASONRY TOTAL COST	PRECAST TOTAL COST	COST SAVINGS
South	7126.121	$ 295,734.02	$ 299,682.71	-$3,948.69
North	6307.499	$ 261,761.21	$ 318,528.67	-$56,767.47
East	1923.87	$ 79,840.61	$ 86,942.69	-$7,102.08
West	4378.75	$ 181,718.13	$ 162,013.75	$19,704.38
Corners	1098.803	$ 45,600.32	$ 48,190.11	-$2,589.79
TOTAL	**20835.043**	**$ 864,654.29**	**$ 915,357.93**	**-$50,703.64**

Precast Façade Design

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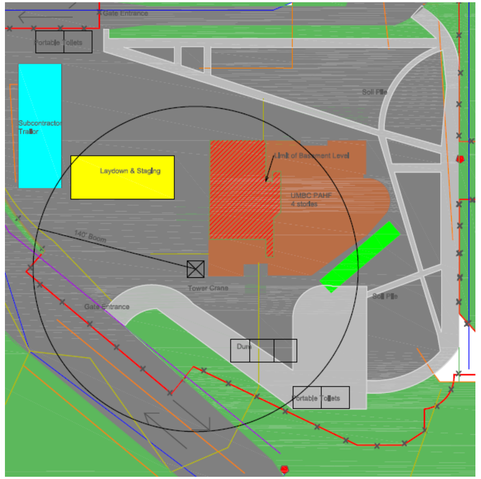
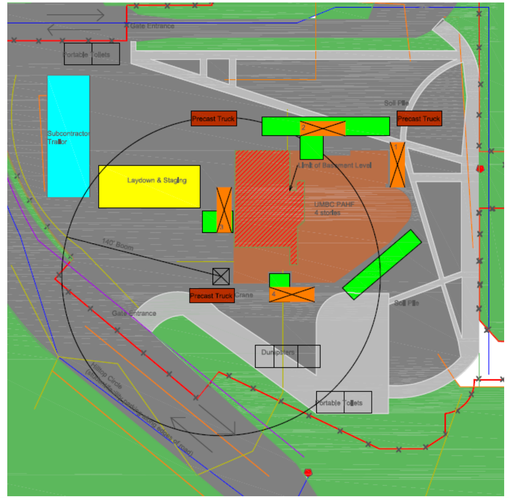


SITE CONGESTION:

- Reduced façade schedule allows for no trade overlap
- Concrete/steel occupy site solely
- No masonry staging areas or scaffolding
- Increased efficiency
- Only metal decking will occur during precast erection

PRECAST ERECTION

- additional phase to construction
- erection begins on East façade, works counter clockwise
- Three delivery truck locations
- Four precast crane locations



Precast Façade Design

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PRESENTATION OUTLINE:

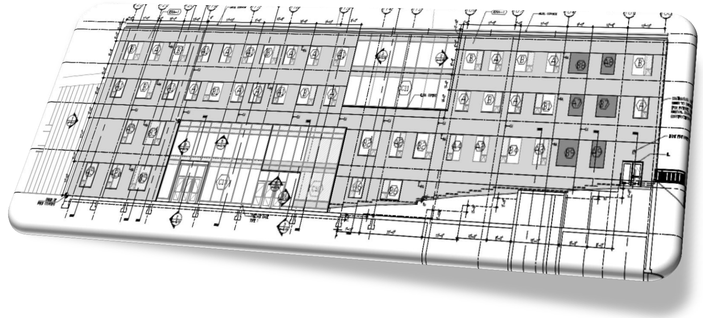
IMAGE COURTESY OF WHITING-TURNER

FINAL CONCLUSIONS:

- Precast façade reduces schedule
- Minor increased cost
- Eliminates confusion between trades
- Minor architectural implications

RECOMMENDATION:

- Pursue precast façade
- Met goal of analysis to reduce inefficiencies
- Ultimately owner/arch. must make decision



Crane Comparison

UMBC Performing Arts & Humanities Facility
Baltimore, MD
Courtney Glaub – Construction Management

PRESENTATION OUTLINE:

IMAGE COURTESY OF WHITING-TURNER, Multivista

PROBLEM IDENTIFICATION:

- Time efficiency/completion on time
- Time to mobilize tower crane
- Cost to use tower crane

RESEARCH GOAL:

- Reduce cost & schedule by utilizing mobile cranes
- Accelerate schedule & complete project on time

Crane Comparison

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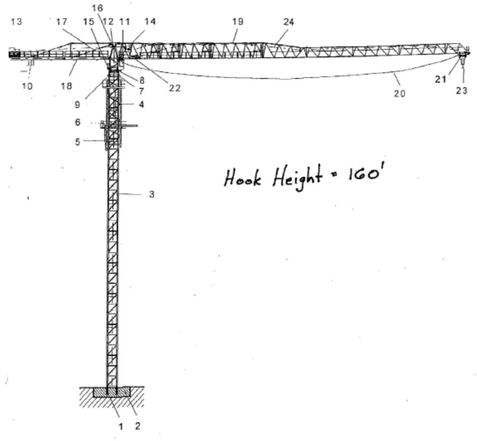
PRESENTATION OUTLINE:

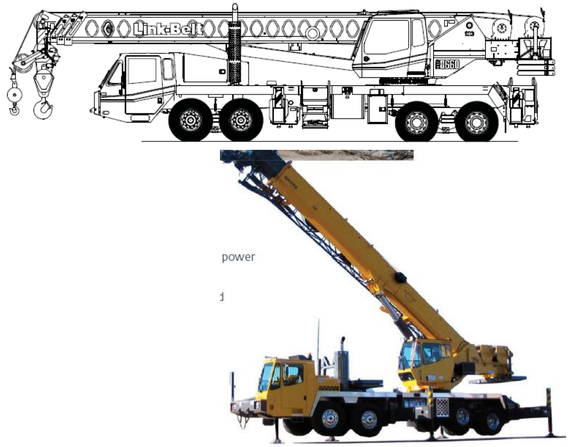


Mobile Crane:

- TMS700E – 60 ton lift
- HT8660 – 60 ton lift
- TMS800E – 80 ton lift

Tower Crane:

- BK 412-10
- Maximum Capacity – 22,000 lbs
- Requires foundation to be installed



Crane Comparison

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PRESENTATION OUTLINE:

IMAGE COURTESY OF WHITING-TURNER, MULTIVISTA

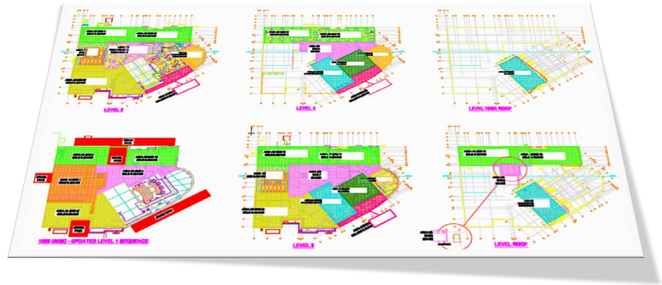
SCHEDULE IMPACT:

- Original lift duration = 318 days
- Gain 11 days of work w/o tower crane installation

IMPACT ON PROJECT:

- Require another mobile crane in place of tower crane
- Require a pump truck
- less time to erect mobile cranes
- Mobile cranes cost more on this project
  - Concrete contract contains tower crane

Crane Lift Areas		Days
HTC - TMS700E	Erect areas 1-4	187
HTC - HT8660	Erect areas 5 & 9	55
HTC - TMS800E	Erect areas 7 & 8	35
Tower Crane BK 412	Erect area 6	41



Crane Comparison

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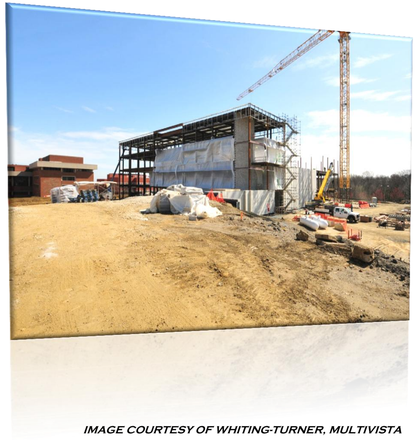

IMAGE COURTESY OF WHITING-TURNER, MULTIVISTA

CRANE PRICING:

- Initial crane costs = $1,317,069
- Crane costs w/o tower crane = $6,649,107
- Tower crane = $350,000

COST IMPACT:

- Increased cost w/ additional cranes & trucks
- $5,332,038 overall increase from eliminating tower crane
- Tower crane was cheaper with concrete contractor

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Total	Total O&P	Ext. Total O&P
242	015419500400	Crane crew, daily use for small jobs, 55-ton truck-mounted hydraulic crane, portal to portal	A3K	1	16	Day	$ -	$ 610.00	$ 1,525.00	$ 2,135.00	$ 516,670.00	$ 2,595.00	$ 627,990.00
35	015419500500	Crane crew, daily use for small jobs, 80-ton truck-mounted hydraulic crane, portal to portal	A3L	1	16	Day	$ -	$ 610.00	$ 1,700.00	$ 2,310.00	$ 80,850.00	$ 2,795.00	$ 97,825.00
9.7	015433602600	Rent crane truck mounted, hydraulic, 55 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$19,677.00	$ 19,677.00	$ 190,866.90	$ 21,644.70	$ 209,953.59
1.25	015433602700	Rent crane truck mounted, hydraulic, 80 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$22,764.00	$ 22,764.00	$ 28,455.00	$ 25,040.40	$ 31,300.50
Total											$ 816,841.90		$ 967,069.09
												Tower Crane	$ 350,000.00
													$ 1,317,069.09

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Total	Total O&P	Ext. Total O&P
9.7	015433602600	Rent crane truck mounted, hydraulic, 55 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$19,677.00	$ 19,677.00	$ 190,866.90	$ 21,644.70	$ 209,953.59
1.25	015433602700	Rent crane truck mounted, hydraulic, 80 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$22,764.00	$ 22,764.00	$ 28,455.00	$ 25,040.40	$ 31,300.50
242	015419500400	Crane crew, daily use for small jobs, 55-ton truck-mounted hydraulic crane, portal to portal	A3K	1	16	Day	$ -	$ 610.00	$ 1,525.00	$ 2,135.00	$ 516,670.00	$ 2,595.00	$ 627,990.00
35	015419500500	Crane crew, daily use for small jobs, 80-ton truck-mounted hydraulic crane, portal to portal	A3L	1	16	Day	$ -	$ 610.00	$ 1,700.00	$ 2,310.00	$ 80,850.00	$ 2,795.00	$ 97,825.00
3	015419500600	Crane crew, daily use for small jobs, 100-ton truck-mounted hydraulic crane, portal to portal	A3M	1	16	Day	$ -	$ 610.00	$ 3,375.00	$ 3,985.00	$ 11,955.00	$ 4,620.00	$ 13,860.00
0.1	015433602720	Rent crane truck mounted, hydraulic, 100 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$30,704.00	$ 30,704.00	$ 3,070.40	$ 33,774.40	$ 3,377.44
10.6	015433102140	Rent pump concrete truck mounted 5" line 110' boom, Incl. Hourly Oper. Cost.	C-14D			Month	$ -	$ -	$15,672.00	$ 15,672.00	$ 166,123.20	$ 17,239.20	$ 182,735.52
318	015433102140	Crew C-14D for pump concrete truck.				Days	$ -	$9,337.40		$9,337.40	$2,969,293.20	$ 17,239.20	$5,482,965.60
Total											$3,967,283.70		$6,649,107.65

Crane Comparison

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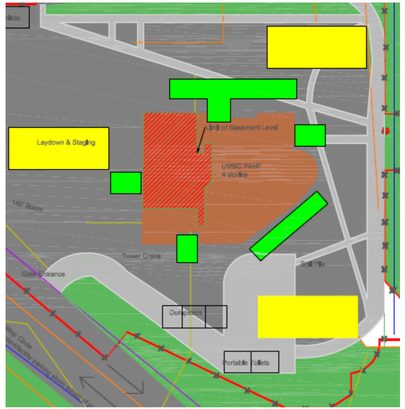
PRESENTATION OUTLINE:



SITE CONGESTION:

- Added more laydown areas
- Required more crane travel space
- More space by the southwest corner w/o tower crane
- Increased efficiency

CRANE ERECTION

- additional mobile crane replacing tower crane
- additional pump truck
- Two delivery truck entrances
- Five crane location paths

IMAGES COURTESY OF WHITING-TURNER, MULTIVISTA

Crane Comparison

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PRESENTATION OUTLINE:

IMAGE COURTESY OF WHITING-TURNER, MULTIVISTA

FINAL CONCLUSIONS:

- Tower crane is more efficient
- Crane total is more w/o tower crane
- Tower crane cheaper because it's w/ the concrete contractor
- Different cranes depend on different scenarios

RECOMMENDATION:

- Utilize the contractors tower crane
- Tower crane needs less path locations
- Longer foundation to install = better in this case
  - Cost efficient

IMAGES COURTESY OF WHITING-TURNER, MULTIVISTA

Photovoltaic Panel System

UMBC Performing Arts & Humanities Facility
Baltimore, MD
Courtney Glaub – Construction Management

PRESENTATION OUTLINE:

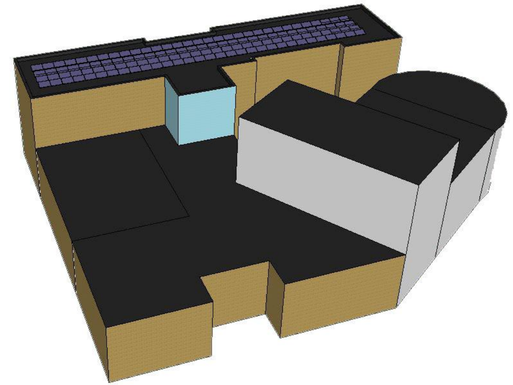
IMAGES COURTESY OF SHARP CATALOG

PROBLEM IDENTIFICATION

- Project is pursuing LEED Silver certification
- Few sustainable techniques pursued in project
- PV system eliminated from scope

RESEARCH GOAL:

- Perform preliminary design of a building integrated PV system
- Determine financial feasibility of system
- reduce energy costs for UMBC



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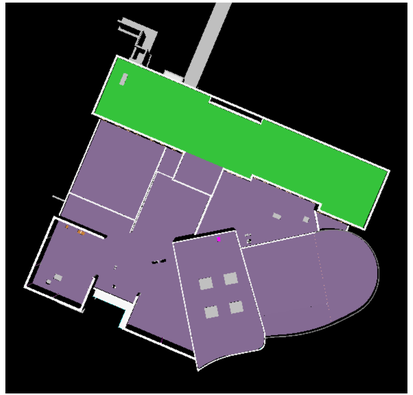


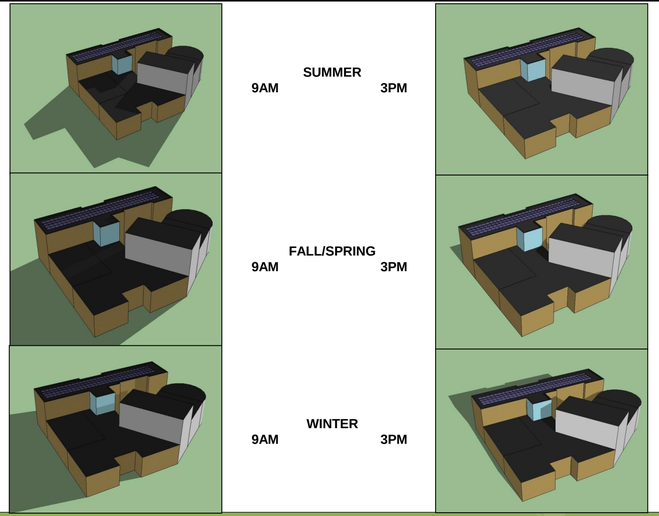
IMAGE COURTESY OF WHITING-TURNER

ORIENTATION:

- Humanities Roof faces Southwest
- 9000 sf of roof space
- flat roof

SOLAR SHADING:

- shading at 9Am and 3PM for each case
- Maintain 6' perimeter to avoid shading from parapet wall



Photovoltaic Panel System

UMBC Performing Arts & Humanities Facility
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Courtney Glaub – Construction Management

PRESENTATION OUTLINE:

PRODUCT SELECTION:

- Sharp Solar Electricity Catalog
- NU-U235F1 Panel (39”x 65”)
- Ballasted Roof Mounts (35 degree tilt)

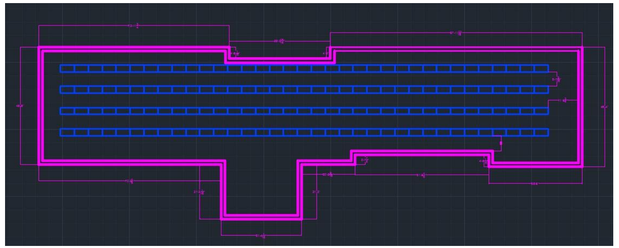
TOTAL HUMANITIES LIGHTING ENERGY:

- Estimate 27000 W for all four floors
- Requires 116 Panels for humanities
- Requires < 9000 sf of roof space

ACTUAL SYSTEM SIZE:

- 32.9 kW
- 140 PV panels
- Fixed at 30 degree tilt

ENERGY LOADS - HUMANITIES LIGHTS		
FLOOR LEVEL	QUANTITY	WATTS
Level 1	173	6751.7
Level 2	175	8292.85
Level 3	187	6744.1
Level 4	165	5412.9
TOTAL	700	27201.55



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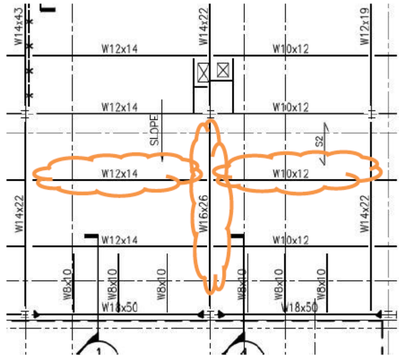

UNIT WEIGHTS:

- PV Panels = 44 lbs. each
- Mounts = 406 lbs. each (each cap is 14.5lbs * 28 per mount)

TRIBUTARY AREA:

- 15' beam spacing
- Trib. Area = 7.5' in each direction = 15' total

RESULTING LOAD:

- Total Load = 6 psf
- existing beams and girders are able to support additional load

Photovoltaic Panel System

UMBC Performing Arts & Humanities Facility
Baltimore, MD
Courtney Glaub – Construction Management

PRESENTATION OUTLINE:

PV WATTS ENERGY PRODUCTION RESULTS			
MONTH	SOLAR RADIATION (kWh/m²/day)	AC ENERGY (kWh)	ENERGY VALUE ($)
1	3.30	2649	206.62
2	4.20	3030	236.34
3	4.74	3630	283.14
4	5.14	3756	292.97
5	5.38	3901	304.28
6	5.83	3917	305.53
7	5.78	4004	312.31
8	5.38	3734	291.25
9	4.91	3362	262.24
10	4.75	3497	272.77
11	3.42	2528	197.18
12	2.70	2112	164.74
Year	4.63	40121	3129.4
PV WATTS FACTOR = Annual AC Energy/System DC Rating = 40121/32.9 = 1219.5			

SYSTEM PRODUCTION:

- 40,121 kWh per year
- 3300 kWh average per month
- 110 kWh average per day
- PV Watts factor = 1219.5

ENERGY PRODUCTION:

- Humanities section of the building
- 100 % of all four levels of lights

PHOTOVOLTAIC PANEL SYSTEM

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PRESENTATION OUTLINE:

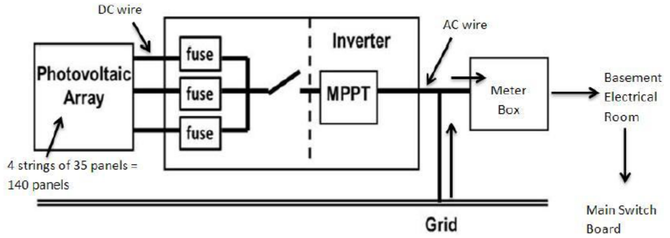
IMAGESCOURTESY OF SMA CATALOG

GRID CONNECTION:

- ADDITIONAL LOAD ON MAIN PANEL FOR LOAD-SIDE CONNECTION
- USE SUPPLY-SIDE INTERCONNECTION

ELECTRICAL COMPONENTS REQUIRED:

- DC WIRE RUN
- DC DISCONNECTS
- INVERTER
- AC DISCONNECTS
- AC WIRE RUN
- SERVICE-TAP METER BOX



Photovoltaic Panel System

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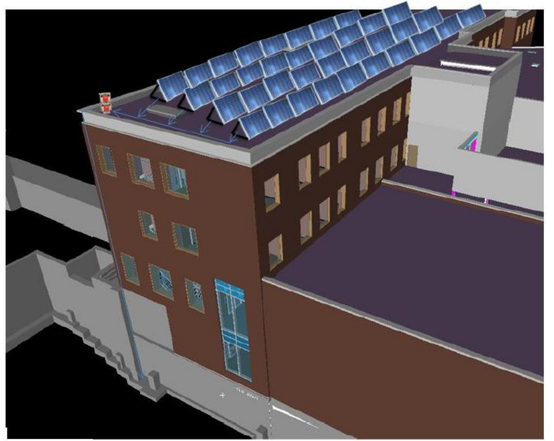
PRESENTATION OUTLINE:

IMAGES COURTESY OF SHARP CATALOG

SYSTEM SET-UP:

- Locate inverter on roof level at Northwest corner
- Minimize DC run
- Cover inverter to minimize sun/moisture exposure
- 200' DC wire run per row of panels
- 91' AC wire run
- 31% less wire due to locating inverters on roof



Photovoltaic Panel System

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PRESENTATION OUTLINE:

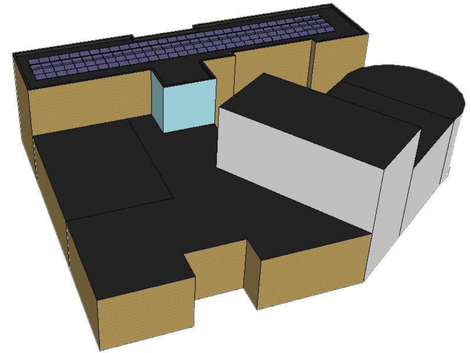
IMAGES COURTESY OF SHARP CATALOG

SYSTEM COST:

- Solar Gaines Proposed System Cost Summary
- System Cost = $121,654 after incentives

REBATES/INCENTIVES:

- Maryland State Energy Program - $500/kW system
- Federal Tax Credit – 30% of gross installation cost
- Maryland Alternative Energy Credit – 0.40$/kWh produced



PHOTOVOLTAIC PANEL SYSTEM

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PRESENTATION OUTLINE:

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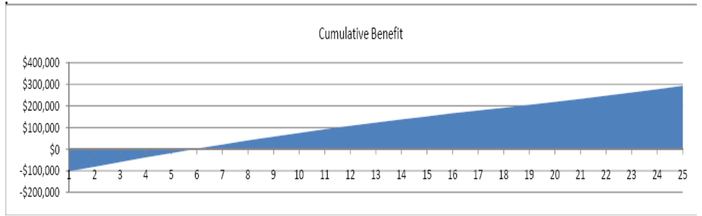
FINANCING OPTION:

- 0% Borrowed

FINANCING PARAMATERS

- $0.156 current cost of electricity (Maryland)
- 3% market rate increase each year
- Average Yearly ROI = 14%
- Payback Period = 6.09 years



Photovoltaic Panel System

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PRESENTATION OUTLINE:

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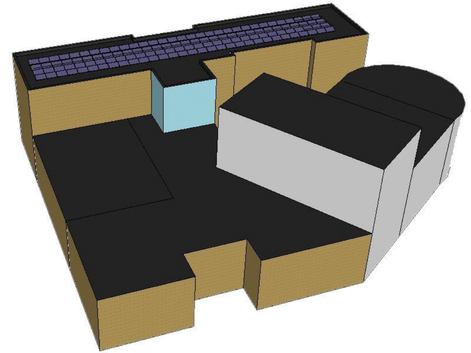
RECOMMENDATION:

- Humanities roof optimal for solar array
- 32.9kW, 140 panel system
- Fully fund up-front costs, i.e. no loan ($121,654)
- Payback Period of 6.09 years
- Operational building for at least 50 years



Conclusion

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PRESENTATION OUTLINE:

ANALYSIS #1:

- Precast panels can be cost and time effective
- Must analyze schedule benefits beyond critical path

ANALYSIS #2:

- Mobile cranes & Tower cranes are both beneficial
- Analyze cost and schedule early in project

ANALYSIS #3:

- Critical to perform feasibility study early in project development
- Rebates/incentives available that make PV systems affordable

Acknowledgements

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PRESENTATION OUTLINE:

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