Baldwin High School

Pittsburgh Pennsylvania

Jeremy Jewart

Construction Management Option

2007 Senior Thesis Presentation

Presentation Outline

Project Overview

Research – Costs and Benefits of Providing Green Schools

Analysis 1 – Green Roof Design

Analysis 2 – Alternative Window Selection

Summary

Q & A

Project Overview

- **Project Overview**
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Front Elevation

- **Building Name**
  Baldwin High School
- **Location**
  Pittsburgh Pennsylvania
- **Function Type**
  Secondary Education
- **Size**
  395,667 ft^2
- **Type of Financing**
  Public
- **Total Cost**

Building Cost	$54.4 million
Soft Cost	$10 million
Overall Cost	$64 million

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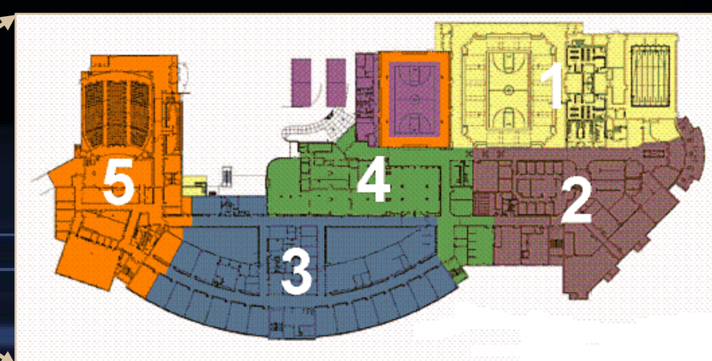
▸ **Owner**
Baldwin-Whitehall School District

▸ **Delivery Method**
CM Agent

▸ **Project Team**

CM Agent	PJ Dick
Architect	HHSDR (Architects & Engineers
GC	Yarborough Development Inc

▸ **Sequencing**
5 Phases



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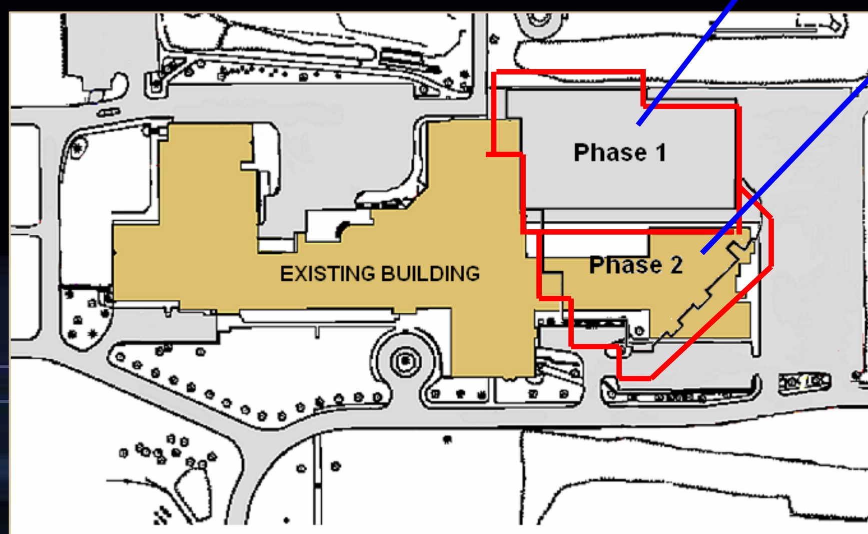
▸ **Renovation**
Existing Structure – Since 1939
80 % New Construction

▸ **Duration**
Sept. 2005 – Aug. 2008

▸ **Completed Construction**
Phases 1 & 2



▸ **Phases 1 & 2**
1 New gymnasium, natatorium, and locker rooms

2 New athletic entrance and classrooms

Project Overview

Cost and Benefits of Green Schools

Green Roof Design

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Research

Cost and Benefits of Green Schools

Cost and Benefits of Green Schools

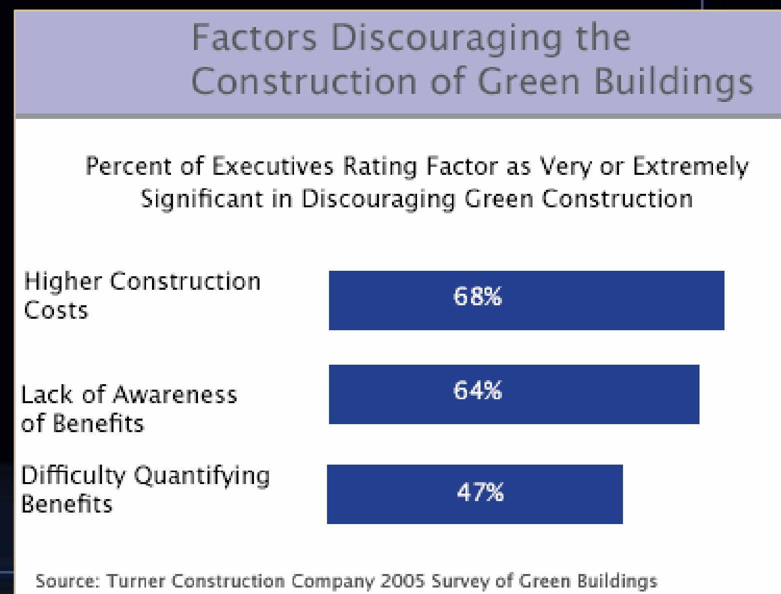
Motivation for Research

- Research directly associated with building type
- Design/Construction did not emphasize regard to green building practices
- Project had no vision to achieve LEED rating points
- 55 million students spend their days in schools that are often unhealthy and that restrict their ability to learn
- Benefits that a Green School suggests opposed to a Conventional School are overwhelming

Cost and Benefits of Green Schools

Discouragements of Building Green

Question:
Why are executives discouraged from undertaking green building practices?



Answer:
Turner Construction Company's survey of 665 Senior Executives

Cost and Benefits of Green Schools

Green Schools vs. Conventional Schools

Conventional Schools - have lower design and construction costs and higher operational costs

Green Schools - usually have higher design and construction costs and lower operational costs

Cost and Benefits of Green Schools

Green Schools vs. Conventional Schools

Financial Benefits

Life cycle cost savings of adopting green technologies can be up to 8 times as large as the initial direct cost

- Reduced cost of HVAC systems and code compliances
- Green roof can avoid the cost of a water retention system
- Reduced direct costs of energy consumption ($3/ft^2)
- Reduced indirect costs of energy consumption ($6/ft^2)

Cost and Benefits of Green Schools

Green Schools vs. Conventional Schools

Environmental Benefits

Residential, commercial and industrial buildings use about 45% of the nation's energy, including about 75% of the nation's electricity

- Improved ventilation and air quality
- Reduction in emissions and greenhouse gases ($0.53/ft2)
- Lower pollution and reduced costs of delivering, transporting, and treating wastewater
- Water usage reductions (32%)
- Reduced operation and maintenance costs ($8/ft^2)

Cost and Benefits of Green Schools

Project Overview

Cost and Benefits of Green Schools

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Green Schools vs. Conventional Schools

Health and Learning

Children's health is affected by indoor pollutants, while light and air quality affects their capacity to learn and succeed

- 25% reduction in asthma incidence
- 51% reduction in cold and flue incidences
- 30%-50% less likely to have respiratory problems
- 3%-5% improvement in learning and test scores

Cost and Benefits of Green Schools

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Green Schools vs. Conventional Schools

Overall Costs

Advantages for implementing green design into the construction sector of school buildings

Financial Benefits of Green Schools ($/ft²)	
Energy	$9
Emissions	$1
Water and Wastewater	$1
Increased Earnings	$49
Asthma Reduction	$3
Cold and Flu Reduction	$5
Teacher Retention	$4
Employment Impact	$2
TOTAL	$74
COST OF GREENING	($3)
NET FINANCIAL BENEFITS	$71

Cost and Benefits of Green Schools

Project Overview

Cost and Benefits of Green Schools

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Conclusions

1) Green schools initially cost an average of 2% more ($3/ft2)

2) Green Schools use 1/3 less energy than Conventional Schools

3) Increased benefits in energy reduction, improved healthcare, and increased learning capacity seem to outweigh initial cost

4) Life-cycle cost benefits can be as high as ($71/ft2)

5) Greening schools is extremely cost-effective, and represents a fiscally far better design choice

Analysis 1

Green Roof Design

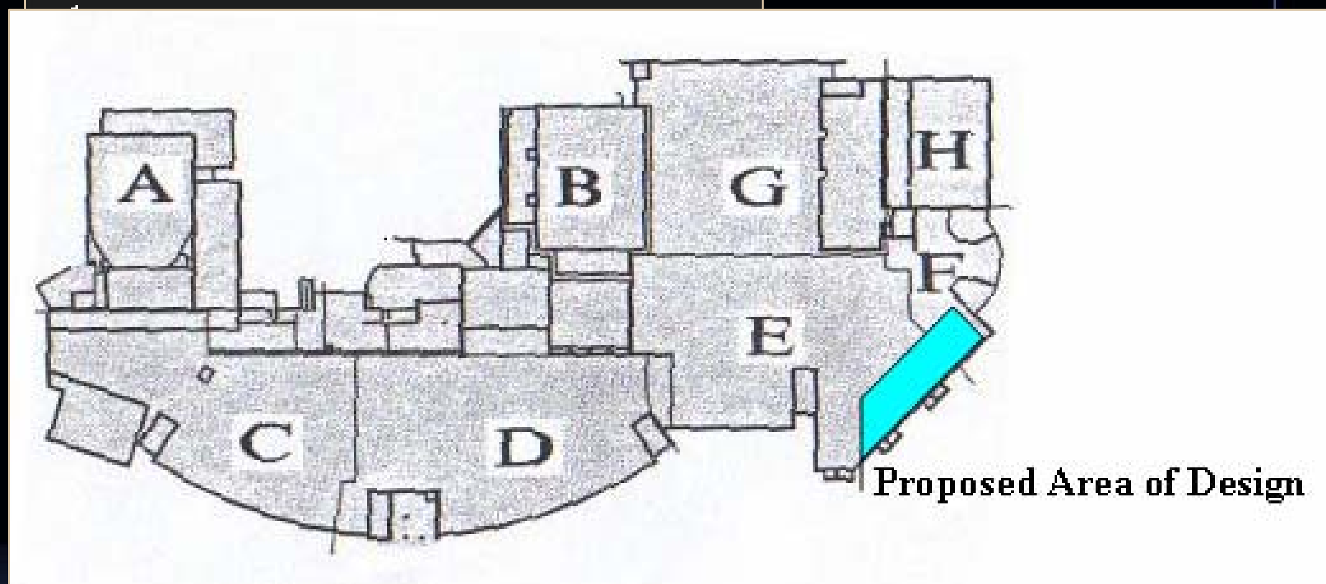
Green Roof Design

Motivation for Analysis

- Acquired knowledge of what green schools have to offer
- Parallelism of research topic and design topic
- Already incorporated design of “nature” within the school building’s construction documents i.e. (interior courtyards)
- Completion of phases 1 & 2 added to placement decision
- Opportunity to mirror the internal aesthetics that the gym’s sky lighting and third floor classroom windows already provide

Green Roof Design

Location of Design



Jeremy Jewart
Construction Management

Green Roof Design

Design Criteria

Extensive Green Roofs

- Light in weight with soil depths ranging from 3" to 7“
- Plants are typically low growing ground cover
- Primarily built for their environmental benefits, not for access

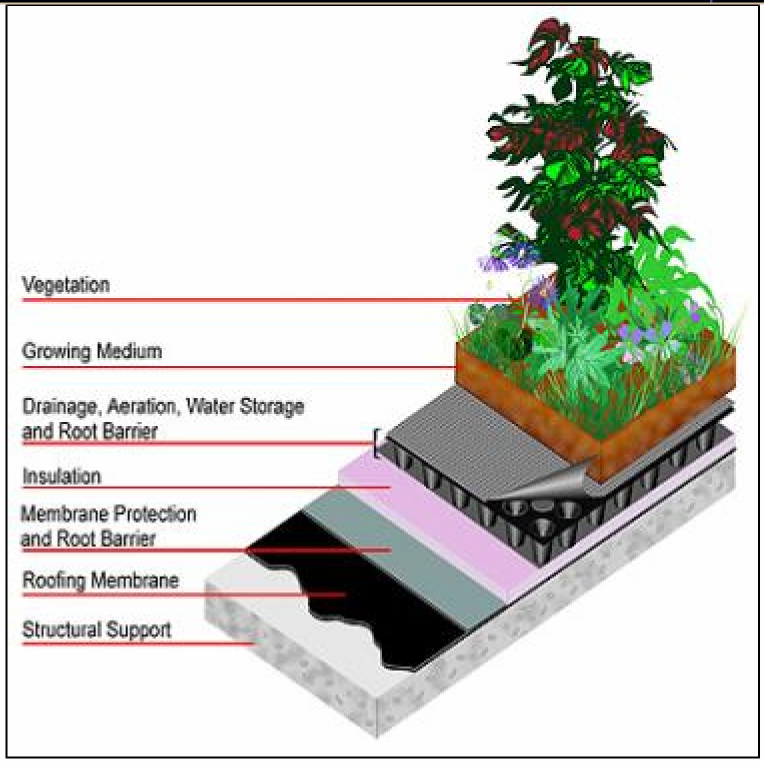
Intensive Green Roofs

- Heavy weight characterized by thick soil depths from 8”-4’
- Add considerable load to the structure
- Designed to be accessible and can be used as outdoor laboratories for schools

Green Roof Design

Actual Design (7 Layer System)

A semi- intensive roof draws qualities from both intensive and extensive design criteria



Semi-intensive System Layout

Green Roof Design

Actual Design (Layer 1)

Existing Structural Support

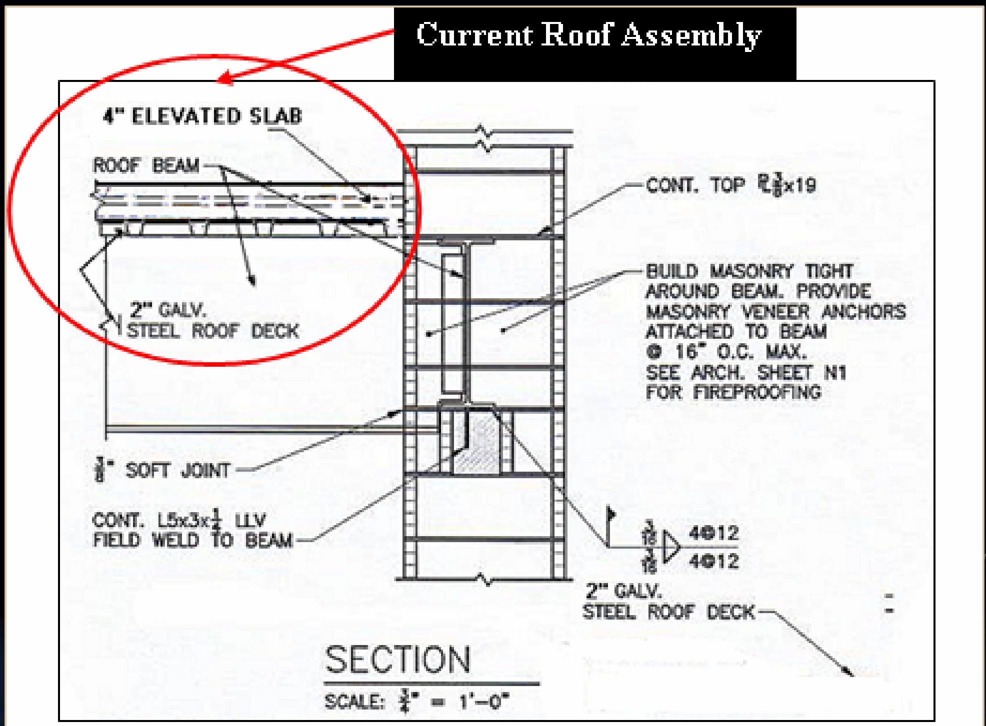
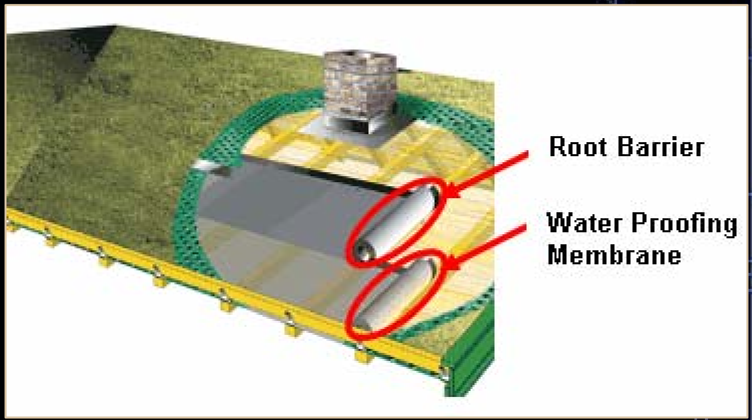


Figure Original Structural Design (2" Galvanized Roof Deck)

Green Roof Design

Actual Design (Layers 2-3)

Waterproofing Membrane



Product Chosen

Famogreen

Reasoning

- Provides root barrier, secondary drainage layer, and waterproofing system all in one
- One of the most lightweight and easily installed green roof systems in the industry
- Special root resistant polyester with copper film

Green Roof Design

Project Overview

Cost and Benefits of Green Schools

Green Roof Design

Alternate Window Selection

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Actual Design (Layer 4)

Insulation

Indicates how insulation product performs when subjected to moisture.

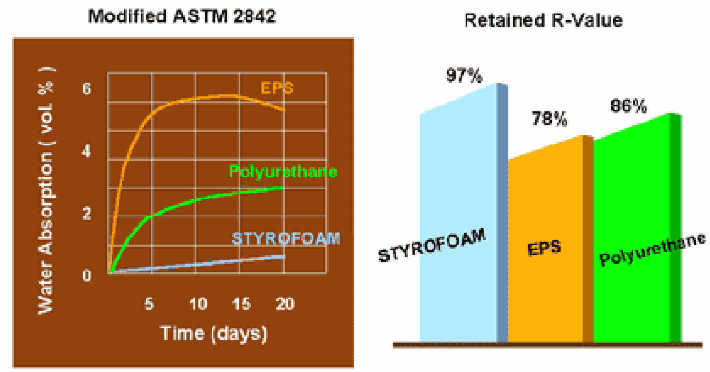


Figure Water Submersion Test Results

Product Chosen

STYROFOAM® Brand R-5

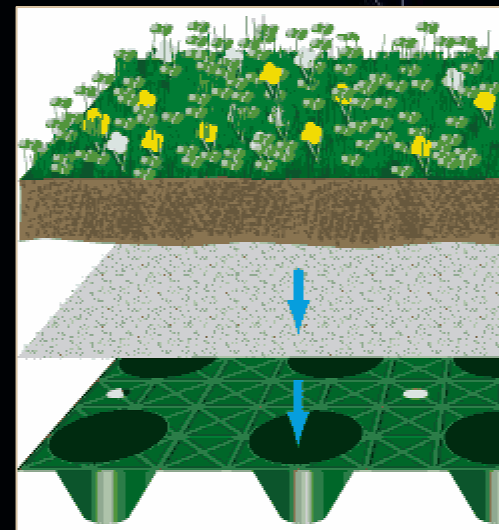
Reasoning

- Cell structure has no voids, which allows for higher compressive strength
- When subjected to moisture the product retains its R-value

Green Roof Design

Actual Design (Layer 5)

Drainage Layer



Product Chosen

Oldroyd Green Range

Reasoning

- Multi-layer technology allows recycled material to be used
- Allows a low slip surface for contractors working on roof
- Studs collectively form a rainwater reservoir, providing water for roof plantings
- 8 mm diameter perforations allow any excess water to drain away

Green Roof Design

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Actual Design (Layer 6)

Growing Medium

Figure Materials in G-SKY Soil Mixture

Product Chosen

G-Sky Intensive Green Roof System

Reasoning

- Soil type and depth is the deciding factor for which types of vegetation to plant
- Supports 95% of all plants on the roof environment for decades
- Comprised of 100% organic materials
- Half the weight of traditional landscape soil or naturally-occurring soil

Green Roof Design

Actual Design (Layer 7)

Vegetation

Product Chosen

Sedum, Grand, Perennial Plants

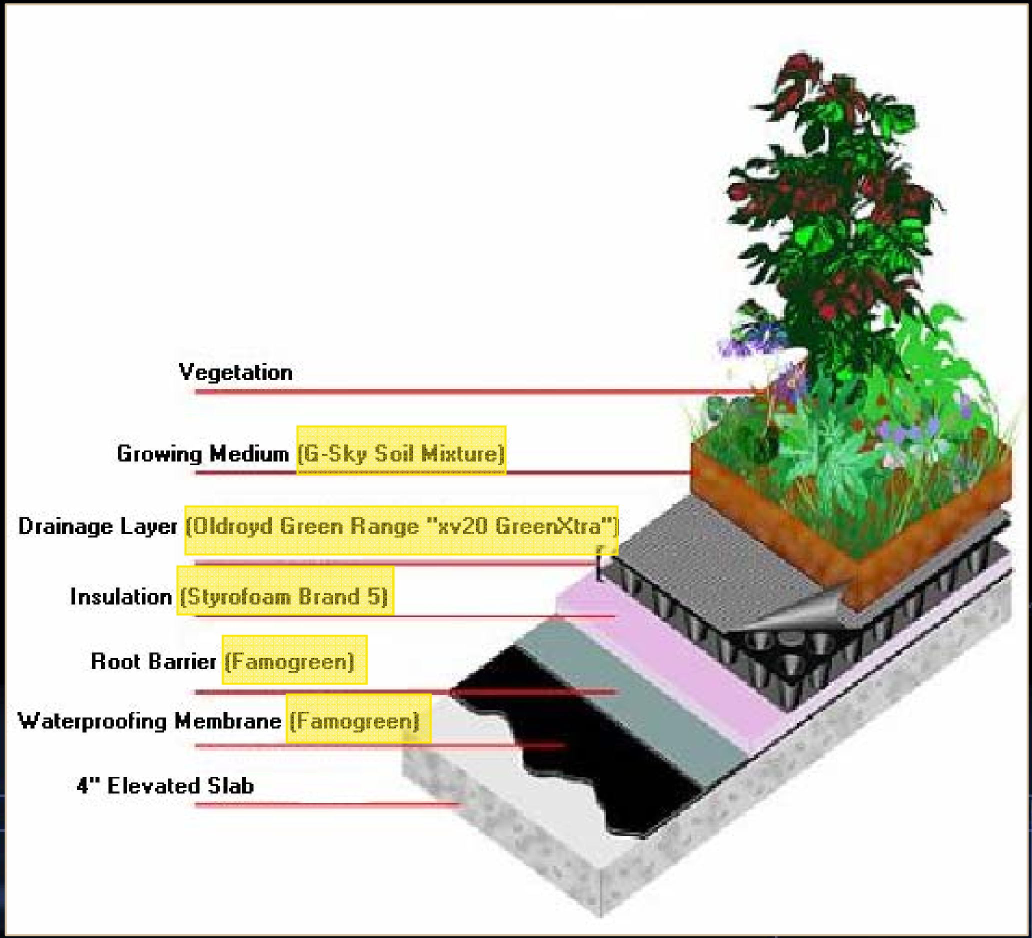
Grasses & Low-medium height trees

Reasoning

- 16” soil depth allows for a variety of plants to be chosen
- Deep soil profiles can support lawns, shrubs and trees
- Plant variety encourages a better aesthetic appeal
- Plants such as “Sedum” absorb large amounts of water

Green Roof Design

Complete Design (7 Layer System)



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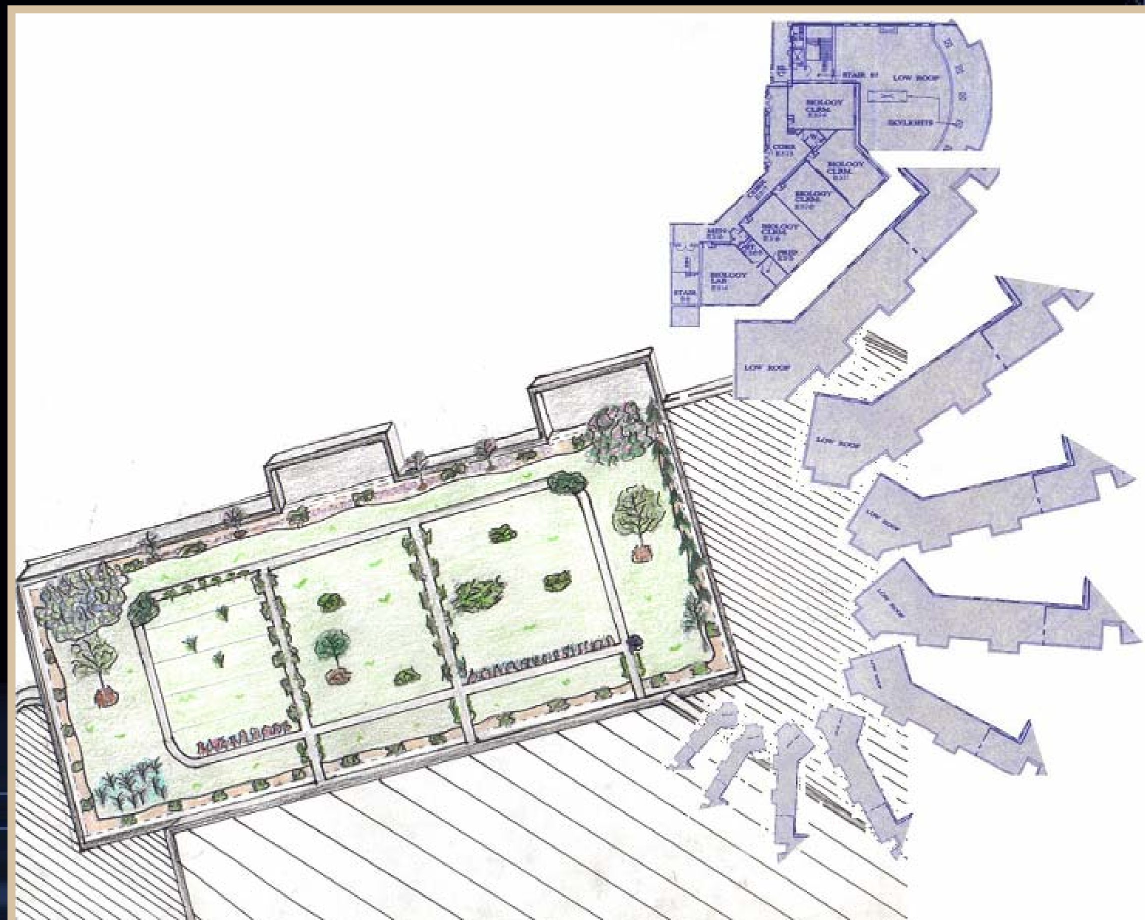
Design Sketch (7 Layer System)



Green Roof Design

Feasibility Study

Structural Redesign vs. Initial Design

- Extra loading required further examination of existing structural plan
- Separated beam framing plan into 5 bays

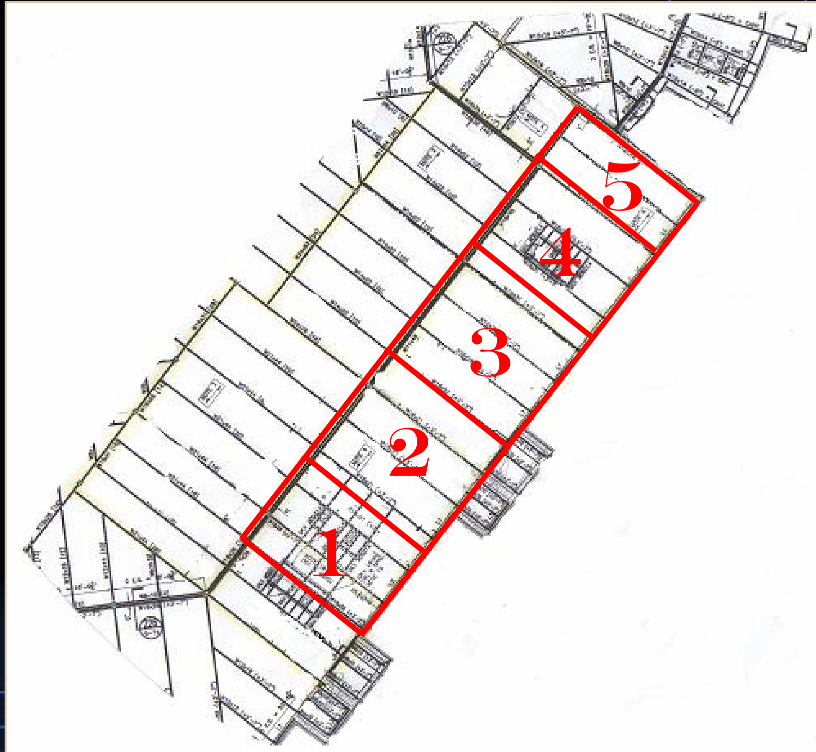


Figure Structural Beam Framing and Bay Separation

Green Roof Design

Feasibility Study

Structural Redesign vs. Initial Design

- Used original design to determine the maximum allowable Moment **(ØMN)** from the ASTM manual for Wide-Flange beams

- Worked backwards using the equation **[W(l)^2]/8=ØMN**, in regard to uniformly distributed loads on simple beams

(ϕMN) Maximum Moment

Z_X

Table 3–2 (continued)
W Shapes
Selection by Z_x

F_y = 50 ksi

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF		L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.^{3}	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.^{4}	ASD	LRFD
W18×35	66.5	166	249	101	151	8.07	12.1	4.31	12.4	510	106	159
W12×45	64.2	160	241	101	151	3.83	5.75	6.89	22.4	348	80.8	121
W16×36	64.0	160	240	98.7	148	6.19	9.31	5.37	15.2	448	93.6	140
W14×38	61.5	153	231	95.4	143	5.39	8.10	5.47	16.2	385	87.4	131
W10×49	60.4	151	227	95.4	143	2.44	3.67	8.97	31.6	272	68.0	102
W8×58	59.8	149	224	90.8	137	1.70	2.56	7.42	41.7	228	89.3	134
W12×40	57.0	142	214	89.9	135	3.66	5.50	6.85	21.1	307	70.4	106
W10×45	54.9	137	206	85.8	129	2.59	3.89	7.10	26.9	248	70.7	106
W14×34	54.6	136	205	84.9	128	5.05	7.59	5.40	15.6	340	79.7	120
W16×31	54.0	135	203	82.4	124	6.76	10.2	4.13	11.9	375	87.3	131
W12×35	51.2	128	192	79.6	120	4.28	6.43	5.44	16.7	285	75.0	113
W8×48	49.0	122	184	75.4	113	1.68	2.53	7.35	35.2	184	68.0	102

Figure ASTM (ϕMN) maximum allowable load

Green Roof Design

Feasibility Study

Structural Redesign vs. Initial Design

EXAMPLE CALCULATION (Max. Dist. Weight)

Beam = W 16 x 26
Length = 29 ft.
Span = 7 ft.
ASTM Table (ϕMN) = 166 ft-kip
W = ?
Max. Distributed Load. = ?

1.) 166 ft- kip = $\frac{W(29 \text{ ft.})^2}{8}$

W = 1,579 klf

2.) 1,579 klf / 7 ft. o.c. = 225.6 psf.

3.) **225.6 psf**. = maximum allowable load before failure and redesign must occur.

Green Roof Design

Feasibility Study

Structural Redesign vs. Initial Design

CALCULATION (New Roof Max. Load (psf))

Area = 29' x 144' = 3871 ft.^2

Green Roof Load

	Roof Dead Load	= 60 psf
new	Green Roof Dead Load Increase	= 20 psf
	Mechanical	= 4 psf
	Roof Live Load	= 30 psf
new	Green Roof Live Load Increase	= 30 psf

*Assume snow load is accounted for in live load quantity.

*Assume Mechanical Units will remain on roof, however distribution may need to be reconfigured.

Total Force = 1.2 (Dead Load) + 1.6 (Live Load)
= 1.2 (84 psf) + 1.6 (60 psf) = **162.4 psf**

1.) Is load more than the maximum allowable load for any of the beams?
2.) If not, no redesign is necessary.
3.) Substitute into *Beam Calculation Worksheet* to find out.

Green Roof Design

Feasibility Study

Structural Redesign vs. Initial Design

Structral Beam Analysis
Detailed Worksheet

Project Name: Balwin High School
Dates of Construction: September 2005 - February 2006

BEAM	SIZE	ΦMN (kip-ft)	MAX. LOAD (psf)	>	DESIGN LOAD (psf)	REDESIGN REQD.
AREA 1 (7FT O.C.)			SPAN = 29'			
A1-B1	W 16 X 31	203	275.8	>	162.4	NO
A2-B2	W 16 X 26	166	225.6	>	162.4	NO
A3-B3	W 16 X 26	166	225.6	>	162.4	NO
A4-B4	W 16 X 26	166	225.6	>	162.4	NO
AREA 2 (8FT O.C.)			SPAN = 29'			
A4-B4	W 16 X 26	166	197.4	>	162.4	NO
A5-B5	W 16 X 31	203	241.4	>	162.4	NO
A6-B6	W 16 X 31	203	241.4	>	162.4	NO
A7-B7	W 16 X 31	203	241.4	>	162.4	NO
A8-B8	W 16 X 31	203	241.4	>	162.4	NO
AREA 3 (8FT O.C.)			SPAN = 29'			
A8-B8	W 16 X 31	203	241.4	>	162.4	NO
A9-B9	W 16 X 26	166	197.4	>	162.4	NO
A10-B10	W 16 X 26	166	197.4	>	162.4	NO
A11-B11	W 16 X 26	166	197.4	>	162.4	NO
A12-B12	W 16 X 31	203	241.4	>	162.4	NO
AREA 4 (8FT O.C.)			SPAN = 29'			
A12-B12	W 16 X 31	203	241.4	>	162.4	NO
A13-B13	W 16 X 31	203	241.4	>	162.4	NO
A14-B14	W 16 X 31	203	241.4	>	162.4	NO
A15-B15	W 16 X 26	166	197.4	>	162.4	NO
AREA 5 (7.5FT O.C.)			SPAN = 29'			
A15-B15	W 16 X 26	166	210.5	>	162.4	NO
A16-B16	W 16 X 26	166	210.5	>	162.4	NO
A17-B17	W 16 X 26	166	210.5	>	162.4	NO

Analysis: NO redesign will be required for the already installed W-flange beam frame system.

Green Roof Design

Project Overview

Cost and Benefits of Green Schools

Green Roof Design

Alternate Window Selection

Summary

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Feasibility Study

Upfront Cost

CALCULATION (Upfront-Cost Comparison)

Area of Green Roof Placement
(29' x 134') - (320' *roof openings*) = 3551 ft^2

Actual Roof Design (See Figure 47)
Steel Joists, Beams, and Slab on Concrete
1. (Cost per SF) x (Area SF) = Cost on Project
2. ($14.17) x (3551 ft^2) = $54,852.00

Roof Returns	= $3,520.00
Gravel stop	= $2,220.00
Copings	= $375.00
Remove & Replace Coping	= $400.00
Total Cost	= $61,367.00

Green Roof Design
1. (Cost per SF) x (Area SF) = Cost on Project
2. ($35.00) x (3551 ft^2) = $124,285.00

Green Roof Design

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Feasibility Study

Upfront Cost

Increased Upfront-Cost

= (Designed Green Roof Cost) – (Actual Roof Cost)
= ($124,285.00) – ($61,387.00)
= $62,918.00

$62,918.00 = (Increased Upfront-Cost)

202% = (Increased Upfront-Cost %)

Cost Relative to Total Project Cost

= (Designed Green Roof Cost) / (Actual Project Cost)
= ($124,285.00) / ($64,000,000.00)
= 0.2%

0.2% = (Total % of Renovation Cost)

0.1% = (Increased Renovation Cost)

Green Roof Design

Conclusions

1) Design demonstrates a multitude of learning experiences

2) Material selection takes consideration for both cost and sustainability

3) Components within a green roof can actually benefit the environment just as much as the entire system itself can

4) Benefits of a green roof include a lower cooling load, reduced roof temperature, and a potentially longer roof membrane life

5) The exact benefits my system will provide from an energy-cost basis are hard to define (Life-cycle dependency)

Green Roof Design

Conclusions

6) A semi-intensive system with low vegetation height adds minimal weight to a building, while also satisfying environmental, educational, and visual needs

7) Roof live load design increase was not substantial enough to produce a structural redesign

8) The up-front cost increase was (202%) more than the original design cost

9) A 202% cost increase is fairly minimal; when regarding the green design's contribution (0.2%) to the overall renovation's $64 million budget

10) Further study has proven that 202% is around the industry average for a green roof cost increase

Project Overview

Cost and Benefits of Green Schools

Green Roof Design

Alternate Window Selection

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Analysis 2

Alternate Window Selection

Alternate Window Selection

Motivation for Analysis

- After conducting research and establishing the principles needed for my green roof design
- Noticed the same trend which currently discourages implementation of green building practices (up-front cost)
- Led to evaluation of certain materials in my own building which were designed solely for the purposes of specification requirements and low cost purchasing
- Researched how student performance directly correlates to their indoor environment

Alternate Window Selection

Project Overview

Cost and Benefits of Green Schools

Green Roof Design

Alternate Window Selection

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Analysis Detailed

- California Energy Commission found that “various window characteristics in classrooms explain variation in student performance as much as metrics such as teacher characteristics, number of computers, and attendance rates”
- Students in classrooms with the most daylight showed a **21 %** improvement in learning rates

Brings to Question

How can we provide a window selection that encourages the best performance for students, is environmentally friendly, and sees no upfront cost increase?

Alternate Window Selection

Integrated Criteria to Selection

- Theory is to select an energy-efficient window and analyze how cost effective it may be when compared to a traditional window selection
- Used the International Energy Conservation Code’s requirements for my window selection

Alternate Window Selection

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Integrated Criteria to Selection

IECC CLIMATE ZONE 5			
Adams	Columbia	Lackawanna	Pike
Allegheny	Crawford	Lancaster	Schuylkill
Armstrong	Cumberland	Lawrence	Snyder
Beaver	Dauphin	Lebanon	Somerset
Bedford	Erie	Lehigh	Sullivan
Berks	Fayette	Luzerne	Union
Blair	Forest	Lycoming	Venango
Bradford	Franklin	Mercer	Warren
Butler	Fulton	Mifflin	Washington
Cambria	Greene	Monroe	Westmoreland
Carbon	Huntingdon	Montour	Wyoming
Centre	Indiana	Northampton	
Clarion	Jefferson	Northumberland	
Clinton	Juniata	Perry	

Figure IECC County Selection (Pennsylvania)

Package	Window & Door U-factor	Skylight U-Factor	Window, Door & Skylight SHGC
Climate Zone 4	0.40	0.60	NR
Climate Zone 5	0.35	0.60	NR
Climate Zone 6	0.35	0.60	NR

Figure Windows Req. for Climate Zone 5

Alternate Window Selection

Window Selection

- Selected double-glazed window based on U-factor and SHGC values which were less than or equal to the values of Climate Zone 5

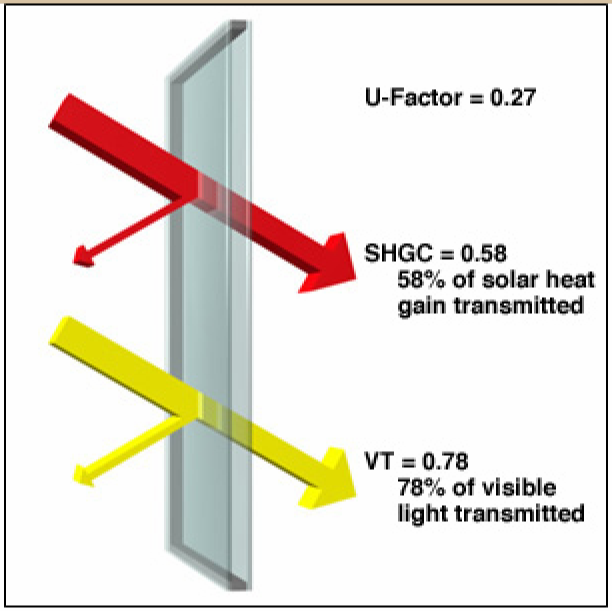

Figure Double-Glazed with Moderate-Solar-Gain Low-E Glass Window

Alternate Window Selection

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Window Selection

Cost Comparison

Alternative Window Comparison
Worksheet

Project Name: Baldwin High School
Dates of Construction: September 2005 - February 2006

Original (Double Glazed Window)	Qty (SF)	Unit	Price/SF	Total Cost
Traditional Double Glazed Window	3564	SF	$40.00	$142,560.00
			Total	$142,560.00
Alternative (Double Glazed Window)	**Qty**	**Unit**	**Price**	**Amount**
Double Glazed Window (Low E)	3,564.00	SF	$42.00	$149,680.00
			Total	$149,680.00

Alternate Window Selection

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Window Selection

Cost Comparison

CALCULATION (Alternative Window Selection)

Area of windows = 3564 ft^2

Original Window Cost (See Figure 57)

Total Cost = $142,560.00

Low-E Window Cost (See Figure 57)

Total Cost = $149,680.00

Increased Cost if Any
= (Low-E Window Cost) – (Original Window Cost)
= ($149,680.00) – ($142,560.00)
= $7,120

$7,120 = (Increased Cost)

5% = (Increased Cost %)

Alternate Window Selection

Conclusions

1) Selection of a Low-E, more sustainable window, only surmounted a 5% increase in cost

2) You can successfully purchase a traditional estimated bid item for roughly the same cost as a more environmentally respectable selection

Summary

Project Overview

Cost and Benefits of Green Schools

Green Roof Design

Alternate Window Selection

Summary

Q & A

- The design and research for this thesis have all been related to the ideas of a high performance school building
- With the continual education of how green building systems work and the initiative to make a difference –there seems to be little debate as to "Why not implement?" The only discrepancy, however, is the cost aspect of this implementation
- The construction industry is continually receiving education on the environmental, health, and life-cycle benefits that green building systems can provide.
- Currently owners, designers, and contractors are trying to compromise on the cost aspect of supplying, designing, and implementing these types of systems

Questions?