A.E. THESIS

April 9

2008

St. Elizabeth's New Psychiatric Hospital
2700 Martin Luther King Jr. Ave., SE
Washington, DC 20032

Nicholas Nigro
Construction Management
Dr. Riley

SAINT ELIZABETH'S NEW PSYCHIATRIC HOSPITAL

Project Team

- owner: government of the district of columbia
- department of mental health
- gc: tompkins construction co.
- architect/ engineer: einhorn, yafee, prescott
- cm: gilbane building co.

Project Overview

- function: psychiatric hospital
- location: 2700 martin luther king, jr. avenue
- washington, dc 20032
- occupant: the department of mental health
- cost: $140m

Architectural Features

- 440,000 sq. ft.
- two stories with attic mechanical levels
- high security design
- separate forensic and civil wings
- weapon proof material usage
- brick Veneer facades
- 28,094 sf of green roof

Structural System

- load bearing geopiers
- structural concrete footings and s.o.g.
- grouted cmu load bearing exterior walls
- structural steel columns and beams
- composite deck and slab for intermediate floors and roof
- concrete 14,822 cy
- reinforcing steel 970 tons
- standard bricks 1,700,000 units
- cinder block 1,000,000 units

Mechanical System

- Central mechanical plant
- natural gas fired heating system
- constant volume forced air with v.a.v. reheat
- 2-700 ton chillers
- two dual fuel water tube hot water boilers

Electrical System

- distribution system:13.2 kV, 3-phase, 3 wire
- high security video monitoring devices
- 4 -4000 amp switchgear

Nicholas F. Nigro
Construction Management

CPEP WEBSITE:
HTTP://WWW.ENGR.PSU.EDU/AE/THESIS/PORTFOLIOS/2008/NFN101/

2007-2008

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Acknowledgements

Penn State AE Faculty

Dr. Riley – CM Consultant

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Capital Sun Group
The brightest ideas under the sun

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The Entire St. Elizabeth's Gilbane Staff

-Fellow AE Students-

1. Executive Summary

This document contains a comprehensive analysis of current industry issues and construction methods involved with the construction of St. Elizabeth's New Hospital. There are three major sections of interest beyond the project information provided at the forefront of text. A critical industry issue and two analyses of the buildings construction practices will be investigated. Construction management emphasis will be the main focus of each area.

The critical industry issue explored deals with the difficulty of recruiting and retaining labor with a particular focus on the roofing industry. This examination of the construction industry workforce development issues reveals the current hardship with industry perception and the resulting disinterest of domestic new hires. Ultimately, it is recommended that the roofing industry invest more heavily in the development of the foreign labor force rather than attempt to re-face the domestic construction outlook.

The first and second analyses both deal with green roof technology and its short and long term impacts with regards to construction cost and schedule as well as its environmental implications. The first analysis compares the structural impacts of a green roof to that of a white roof. The assessment reveals that by installing a white roof in place of the currently prescribed green roof, the construction schedule is reduced by three (3) weeks, costs are cut by 63% resulting in a $375,971 savings, and 340 tons of $C0_2$ are prevented from entering the atmosphere. The second deals with the effects on the hospitals' energy consumption caused by the installation of a white roof assembly. This analysis ultimately illustrates the benefits of a white roof assembly, when paired with a rainwater harvesting system, over those of a green roof.

2. Introduction

The project consists of a 2-story 448,000 square foot new psychiatric hospital that includes both criminal and civil wings, a central mechanical plant, auditorium, gymnasium, and commercial kitchen. The project broke ground in December 2006 and has been progressing at scheduled speed. Presently, the new hospital is midway through the erection of the building superstructure and the on-site personnel count is at approximately 125.

Area Statistics

- Gross Area: 448,190 sq ft
- Assignable Area: 349,730 sq ft
- Amenities and Building Support: 99,460 sq ft

Occupancy Classification:

Mixed Occupancy building with dining, treatment malls, wards, and small area of Assembly occupancy on the first floor.

2.1 Area location Map

Fig. 2.1 Google Maps

3. Project Overview

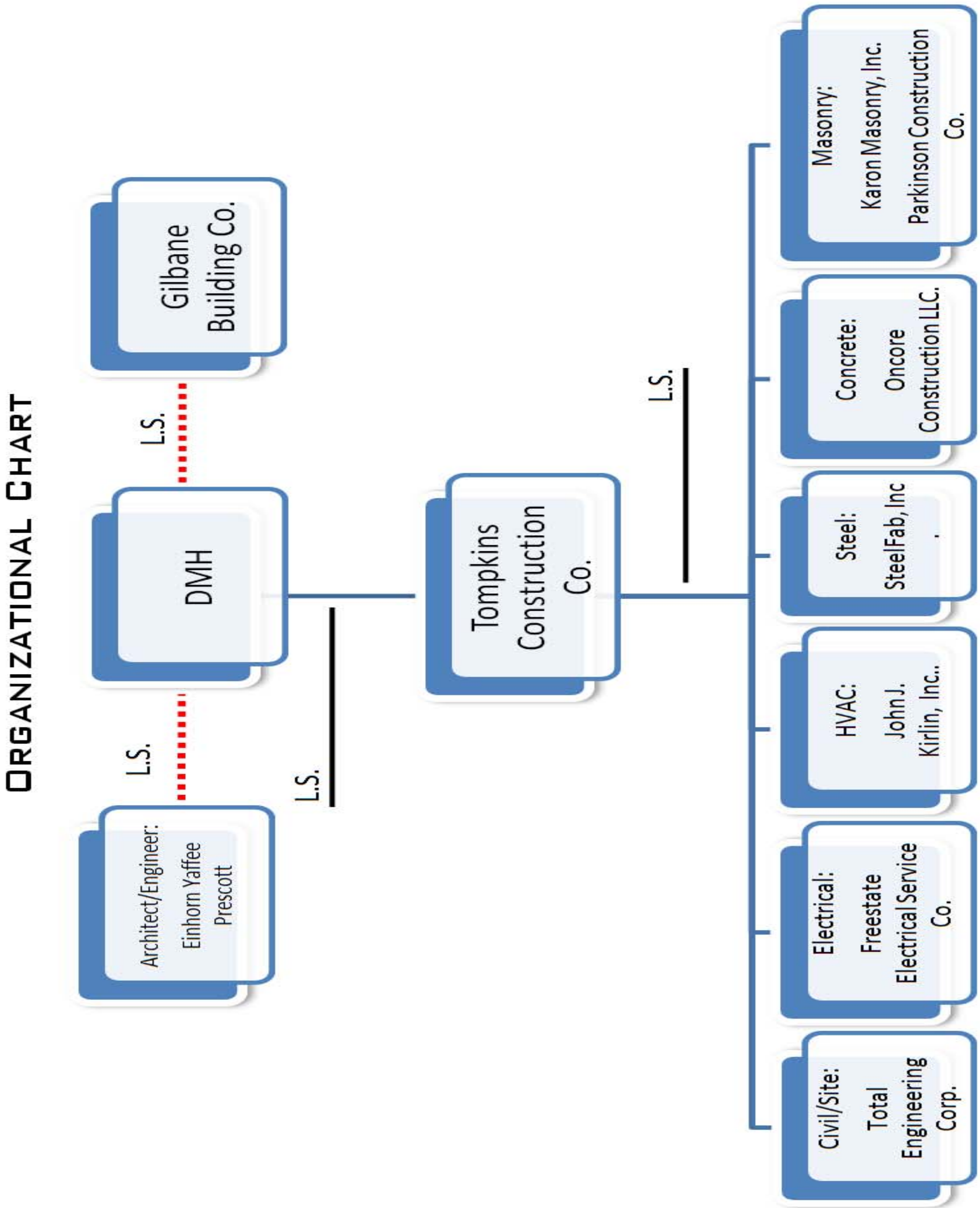
3.1 Client Information

The St. Elizabeth's campus has centuries of history reaching back to the days of the civil war when injured troops were quartered there. The campus has taken care of American soldier's through WWII, but the medical focus of the campus changed direction at the turn of the century when mental health exploration became paramount. The Department of Mental Health took over the property and began to use the campus structures as a research facilities dealing with the human brain.

Unfortunately, decades of neglect left many of the existing facilities on the St. Elizabeth's Campus to slowly become vacant and dilapidated. The buildings that are currently operational are extremely outdated and in dire need of rehabilitation. It was determined that renovating these existing structures would not sufficiently meet the needs of DMH and the idea of building a new hospital was explored. Presently, both civilly and criminally insane patients reside in the John Howard Pavilion, a facility that is both outdated structurally and technologically. This hospital is would need extensive renovations to be brought up to date, and even then would most likely fall short of the patients needs. Ultimately, the construction of a brand new hospital was decidedly the best route and DMH secured the monetary needs to begin the process.

3.2 Project Delivery System

The Department of Mental Health, as with a lot of government agencies, opted to hire a Construction Manager to deliver the new hospital. Bringing on a CM agent alleviated the pressure on DMH to single-handedly get the project off the ground. As a result, Gilbane Construction Co. took the reins at a very early stage and provided insight on important construction decisions. Lining up all the necessary steps to put the construction of the new hospital in motion is an intricate chain of events that the Government of the District of Columbia felt would be best handled by a professional firm.


ORGANIZATIONAL CHART
Architect/Engineer:
Einhorn Yaffee Prescott
L.S.
DMH
L.S.
Gilbane Building Co.
L.S.
Tompkins Construction Co.
L.S.
Civil/Site:
Total Engineering Corp.
Electrical:
Freestate Electrical Service Co.
HVAC:
John J. Kirlin, Inc..
Steel:
SteelFab, Inc
.
Concrete:
Oncore Construction LLC.
Masonry:
Karon Masonry, Inc.
Parkinson Construction Co.

3.4 Project Management

Gilbanes' staff was brought on to the project in the very early stages. They provided estimating, scheduling, and budgeting services to the DMH in order to get the project off the ground. The staff also offered constructability reviews and took the project to bid. As Tompkins was brought on, the management effort combined and the two companies readied to mobilize. When construction began Gilbanes' team continued its' advisory role with schedule and budget updates, document management and field reports. Tompkins staff began to focus on subcontractor management and more specific construction issues such as material acquisition. However, both PMs shifted their efforts towards budget control, cost reporting and monthly progress reports. The Asst. PMs focused on schedule updates and progress tracking and the superintendants are mainly in charge of quality control and safety reporting. For Gilbanes staff, each area engineer is responsible for a given number of CSI sections. They each deal with RFI's, PCO's, submittals and product samples for their respective sections and report to their superintendant accordingly.

In addition to this basic staff, a MEP supervisor was also hired. Because of the hospitals complex MEP systems, Gilbane felt it would be beneficial to have and expert onboard for submittal reviews, RFIs, etc. Tompkins lower ranks are organized around a looser version of a CSI breakdown. Two main engineers, structural and MEP respectively, cover these areas with the assistance of field engineers under them who focus mainly on document control. Tompkins also opted to employ a full-time safety supervisor who patrols the site daily and produces reports that end up on the desk of the Gilbane superintendant for review.

4. Design and Construction Overview

4.1 Building Systems

Architectural Description

St. Elizabeth's Hospital is a new 300 bed psychiatric facility that will house both civil and forensic patients. The hospital was designed with the intent of separating the patients into they're respective wards so that the criminally insane are kept separate and secure from the general public. The forensic wing of the hospital was designed with high security in mind. EYP designed the building specifically using materials that could not easily be disassembled and potentially used as weapons.

The building envelope consists of CMU walls encased with a red brick veneer, which is common for almost the entirety of the building. The roofing system involves slab on deck with light steel support and either rubber or green roof applications are found at various locations. Each bedroom is designed with a single window and security glazing and small curtain walls are found at entrances. Overall, the exterior of the facility was aesthetically designed to complement the historical buildings found elsewhere on the St. Elizabeth's campus.

Structural System

The main structural system consists of load bearing masonry and an internal steel frame. Standard 8"x8"x16" CMU sits atop 4000psi footings and is carried up 3 stories, phased at a single story at a time. Each load bearing wall is reinforced and filled with a 3000psi masonry grout. At the height of the first and second floors beam pockets are cut to accept structural steel members ranging in size from W10x12 to W21x44. Each pocket is outfitted with, at minimum, a 1/2" steel bearing plate and is grouted solid to encase the steel member into the wall system. The steel system itself is comprised of standard W shapes for both beams and columns. These members carry a composite deck and slab that is found at the second and third floors. Each elevated slab is a 5" lightweight 4000psi mix. The roof decks are supported by steel joists and are comprised of the same lightweight mix. See table 4.1 for a detailed estimate.

Table 4.1

Structural Systems Estimate
Saint Elizabeth's Hospital

Division	Material	Unit	Amount	Material ($)/unit	Labor ($)/unit	Eqipment ($)/unit	M+L+E ($)	System Total ($)
03 30	**Concrete**	C.Y. Total	14,822					
03 30	Footings	C.Y.	1,103	106.00	12.70	0.41	119.11	131,378.33
03 30	S.O.G.	C.Y.	6,200	106.00	11.25	4.20	121.45	752,990.00
03 30	S.O.M.D.	C.Y.	7,519	138.00	14.90	5.55	158.45	1,191,385.55
03 30	Form	L.F.	8,000	0.70	2.66		3.36	26,880.00
03 30	Finish	S.F.	440,000		0.49	0.02	0.51	224,400.00
03 21	**Reinforcing steel**	Tons	970	925.00	515.00		1,440.00	1,396,800.00
04 21	**Standard bricks**	Units	1,700,000	0.81	0.95		1.76	2,992,000.00
04 22	**Load Bearing CMU**	S.F.	277,778	2.07	3.62		5.69	1,580,556.82
05 12	**Structural steel**	Tons	1,600	2,200.00	330.00	165.00	2,695.00	4,312,000.00
05 21	**Bar Joists**	Tons	80	1,500.00	283.00	153.00	1,936.00	154,880.00
05 31	**Metal deck**	S.F.	440,000	2.29	0.49	0.05	2.83	1,245,200.00
							Total	**14,008,470.70**

Electrical

The hospital distribution system is rated 13.2 kV, 3-phase, 3 Wire and is solidly grounded and the demanded load estimate is 6,624 kVA. The normal power for Substations 2-4 is fed by single ended substations and do not have redundant power sources. Redundancy is provided with emergency power generation. Emergency power will be supplied by two 2000 kW standby, three-phase, four-wire generators. The generator power will be distributed by emergency paralleling switchgear rated 6000A, 480/277V 3, 4W, 85 kAIC BUS Bracing.

Mechanical

There is one main mechanical plant located between the two wings at the west end of the building. The HVAC system consists of constant volume AHUs that distribute though rigid metal duct and terminate with VAV units. The chilled water system consists of two water cooled centrifugal chillers, two cooling towers, three primary chilled water pumps, two secondary chilled water pumps, and three condenser water pumps.

4.2 Local Conditions

- Preferred regional construction methods: Cast-in-Place Concrete, Masonry, Light Steel
- Construction Parking: Downtown area is very tight, outlying boroughs better but not ideal.
- Construction recycling services are available locally for most materials.
- Midwest average tipping fee: $34.96/ton (2004) (NSWMA)
- Regional Soil Types: Clay, Sands, Gravel, Silts
- Subsurface Conditions: Low lying areas encounter a high water table stemming from the nearby Potomic River. However, St. Elizabeth's @ 270ft. above sea level did not encounter any such issues.

4.3 Site Layout Overview

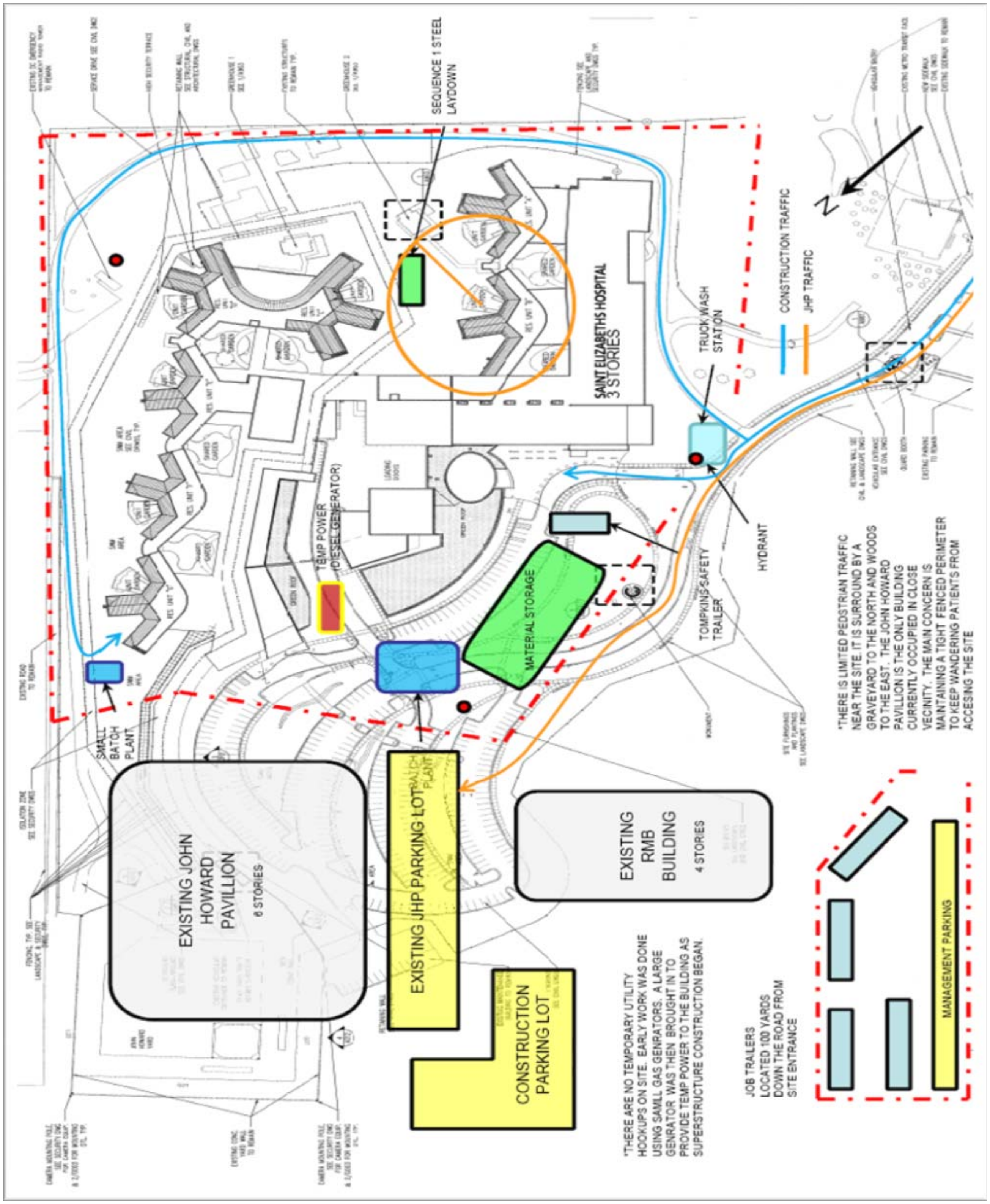
The new hospital site is extremely large covering almost 17 acres of land. This vast amount of area allowed Tompkins, the general contractor, to work with a relatively wide open space to layout the site. The footprint of the hospital is extremely large itself covering 251,000ft^2, but because of intensive horizontal phasing, abundant amounts of space are available, even as construction progresses, for material storage and steel lay down areas to be comfortably dispersed around the site. Because of the sheer size of the site, Tompkins layout plan was relatively simple and straight forward, and was mostly left to the trades to decide on where to place stock.

There are temporary construction roads that encompass the site to allow for worker traffic to travel with relative ease. In addition to small vehicle travel, it was imperative to construct well engineered surfaces so that the 75ton mobile track crane could move cross site safely.

There is one main material lay down area near the entrance and there are other small areas found around site depending on trade location. Refer to progress photo 4.1 and St. Elizabeth's site layout paln on the following pages for better visualization:

Progress Photo 4.1

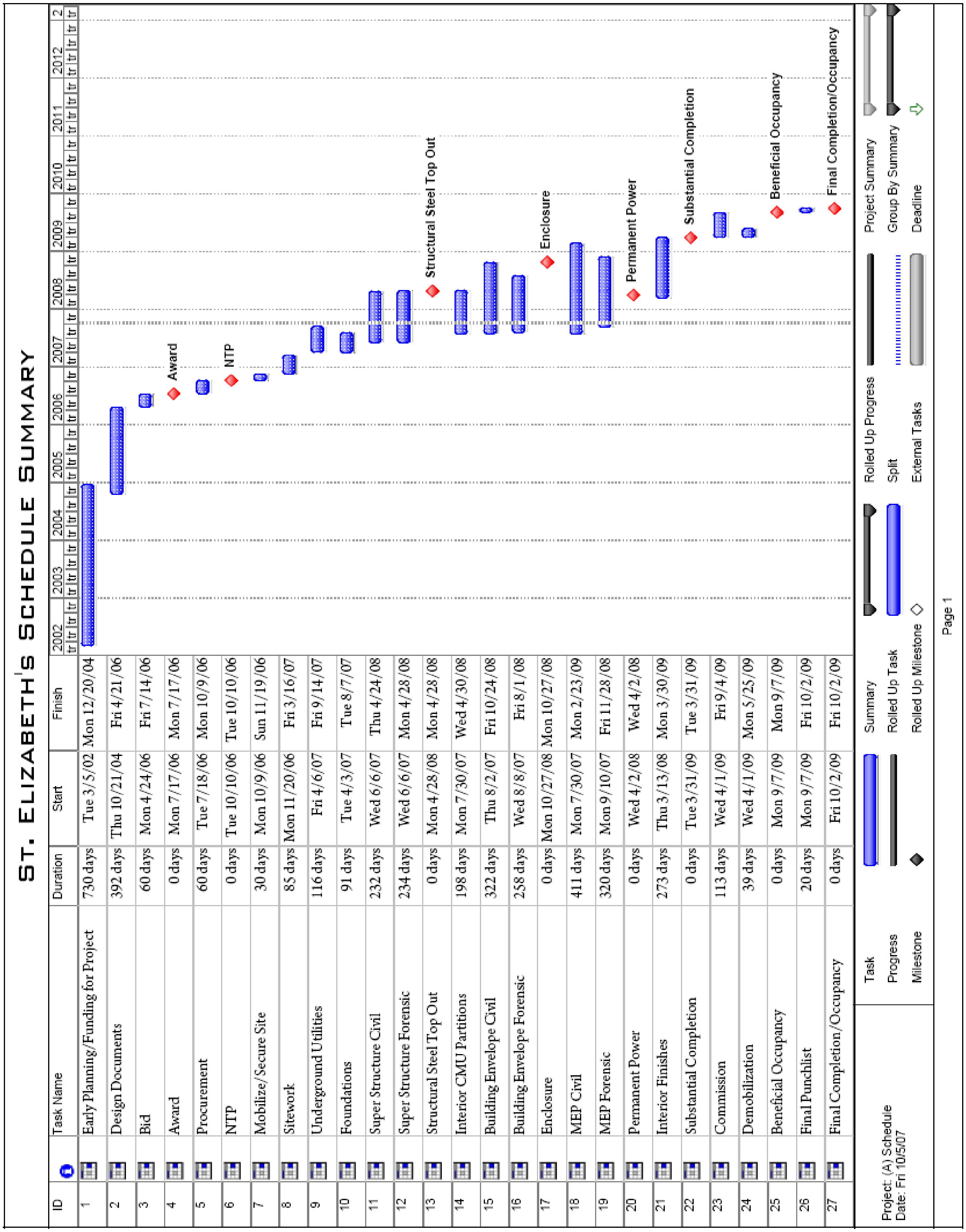
4.4 Site Layout



5. Project Logistics

5.1 Milestone Schedule

St. Elizabeth's Schedule Summary



ID	Task Name	Duration	Start	Finish
1	Early Planning/Funding for Project	730 days	Tue 3/5/02	Mon 12/20/04
2	Design Documents	392 days	Thu 10/21/04	Fri 4/21/06
3	Bid	60 days	Mon 4/24/06	Fri 7/14/06
4	Award	0 days	Mon 7/17/06	Mon 7/17/06
5	Procurement	60 days	Tue 7/18/06	Mon 10/9/06
6	NTP	0 days	Tue 10/10/06	Tue 10/10/06
7	Mobilize/Secure Site	30 days	Mon 10/9/06	Sun 11/19/06
8	Sitework	85 days	Mon 11/20/06	Fri 3/16/07
9	Underground Utilities	116 days	Fri 4/6/07	Fri 9/14/07
10	Foundations	91 days	Tue 4/3/07	Tue 8/7/07
11	Super Structure Civil	232 days	Wed 6/6/07	Thu 4/24/08
12	Super Structure Forensic	234 days	Wed 6/6/07	Mon 4/28/08
13	Structural Steel Top Out	0 days	Mon 4/28/08	Mon 4/28/08
14	Interior CMU Partitions	198 days	Mon 7/30/07	Wed 4/30/08
15	Building Envelope Civil	322 days	Thu 8/2/07	Fri 10/24/08
16	Building Envelope Forensic	258 days	Wed 8/8/07	Fri 8/1/08
17	Enclosure	0 days	Mon 10/27/08	Mon 10/27/08
18	MEP Civil	411 days	Mon 7/30/07	Mon 2/23/09
19	MEP Forensic	320 days	Mon 9/10/07	Fri 11/28/08
20	Permanent Power	0 days	Wed 4/2/08	Wed 4/2/08
21	Interior Finishes	273 days	Thu 3/13/08	Mon 3/30/09
22	Substantial Completion	0 days	Tue 3/31/09	Tue 3/31/09
23	Commission	113 days	Wed 4/1/09	Fri 9/4/09
24	Demobilization	39 days	Wed 4/1/09	Mon 5/25/09
25	Beneficial Occupancy	0 days	Mon 9/7/09	Mon 9/7/09
26	Final Punchlist	20 days	Mon 9/7/09	Fri 10/2/09
27	Final Completion/Occupancy	0 days	Fri 10/2/09	Fri 10/2/09

5.2 Detailed Schedule

See Appendix for detailed Schedule

5.3 Hospital Cost Summary

Table 5.1

Divisional Cost Breakdown		TC ($)	CC ($)	Cost/SF ($)
Division 1	General Requirements	800,000	~	
Division 2	Site Construction	14,105,918	~	
Division 3	Concrete	8,670,973	8,670,973	19.00
Division 4	Masonry	23,425,473	23,425,473	52.00
Division 5	Metals	10,296,446	10,296,446	23.00
Division 6	Woods and Plastics	2,700,000	2,700,000	
Division 7	Thermal and Moisture Protection	6,850,000	6,850,000	
Division 8	Doors and Windows	6,436,000	6,436,000	
Division 9	Finishes	6,960,000	6,960,000	16.00
Division 10	Specialties	661,700	661,700	
Division 11	Equipment	2,737,500	2,737,500	
Division 12	Furnishings	122,000	122,000	
Division 13	Special Construction	6,820,000	6,820,000	
Division 14	Conveying Systems	1,089,000	1,089,000	
Division 15	Mechanical	26,000,000	26,000,000	58.00
Division 16	Electrical	22,240,500	22,240,500	50.00
	Totals	**139,915,510**	**125,009,592**	
	Building Size: 448,190 ft^2			
	Cost/SF	**312.00**	**279.00**	

*Major Building Systems Considered

5.4 General Conditions Estimate Summary

The data used to compile this estimate was pulled partly from a current pay application from the General Contractor. The remaining items were put together logically by examining on site necessities through unit cost and monthly rates and estimated through RS Means. Assumptions Made:

- Temporary utility costs, which includes job power, lighting and water, was based off an approximate figure of $2,500 a week which came the asst. project manager.
- This estimate encompasses the general conditions costs of the GC **only** because of the availability of information. As a result, the construction management agency's staffing, job trailers, supplies etc. were excluded for accuracy sake.
- On site staffing percentages were logically applied.
- Individual Staff Salaries were derived from logical current day wages and RS Means references.
- Staff fringes and benefits assumed to be 25% of total staff salaries.
- Because of the lump sum contractual arrangement, the fee would not be shown, however for additional information, it is included here.

See Appendix for general conditions breakdown

6. Research Topic- *Work Force Development in the roofing Industry*

6.1 Problem Statement

The PACE roundtable attempted to address the current state of the construction industry with regards to its labor force. The discussion on Workforce Development brought up interesting points about the declining involvement of domestic workers. As a result, the workplace has been flooded by foreign help and language barriers are becoming problematic. Aside from this issues however, the industry deserves a thorough look into where the allure of being a tradesman was lost, and what can be done to restore it.

6.2 Research Goal

The past few generations have cultivated a negative perception of the construction industry. The desire to become a tradesman has decreased drastically and our industry is seeing the effects in many ways. My research goal is to analyze the methods of recruitment for the roofing industry and draw conclusions about what programs have been successful at stimulating interest in this trade. Through this research I hope to document features of successful workforce development approaches, and also identify barriers and challenges that remain to be solved if we are to overcome the workforce challenges facing the construction industry.

6.3 Background

History

The beginnings of domestic labor issues can be traced all the way back to WWII. As American soldiers returned, the G.I. Bill of 1944 was instated and each veteran was provided for college in addition to a single year unemployment pay[1]. This was the first massive seed planted into American culture that offered opportunity for widespread higher education. As a result, this generation sparked America's divergence from industry and labor based careers to those requiring levels of elevated education. Over time, this cultivated the notion of "white" and "blue" collar jobs, the latter of which slowly began losing integrity as the work force ladder became restricted within this sector. As a result, the by the time Generation Y (1982-2002) rolled around, tradesman had been steadily

1 "Servicemen's Readjustment Act." http://en.wikipedia.org/wiki/GI_bill

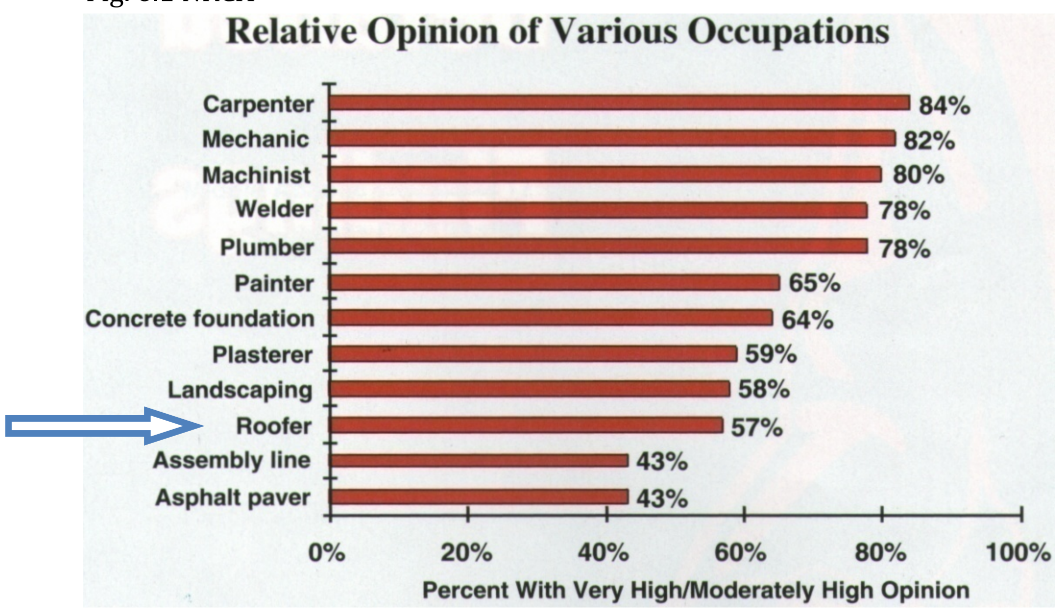
losing status for almost forty years.

The likelihood of this generation's parents to encourage their children to become a tradesman is almost zero. The formal stigma of higher education has been deeply imparted into the American culture by this point in time and resulting is a generation who is seemingly above the "dirty" jobs of yore. To better understand this current state of the industry, the statistics of one of the lowest respected trades, roofing, were investigated.

A Look into the Current State of the Roofing Industry[2]

A major issue with the trade industry is the negative perception that has been acquired over the years by the "white" collar community. Focusing on a more local level though, within the trades themselves there is a hierarchy of desirable jobs. Figure 6.1 depicts the internal perception of various tradesmen.

Fig. 6.1 NRCA



Clearly, the blue collar community doesn't hold a very high opinion of roofers, which in an already stressed labor pool, compounds recruiting difficulty. It's no secret that roofing is an outdoor job that can be dirty and require a certain degree of physical capability, but when 41% (Fig. 6.2) of workers seriously consider quitting within the first month of working, there are serious issues to be addressed.

[2] The National Roofing Foundation conducted research involving 1000 roofers that either currently or previously worked in the industry.

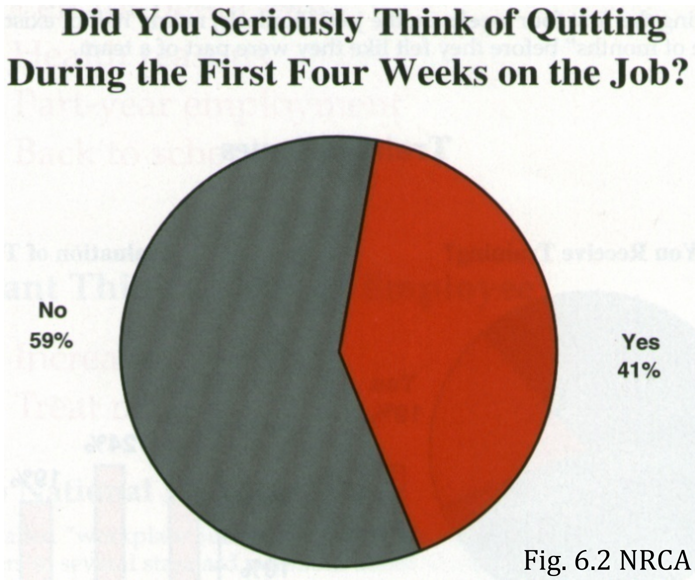


Fig. 6.2 NRCA

The main areas of dissatisfaction stem from limited vacation time and the lack of desire to advance based on poor pay incentives. This most probably relates to the demographic of workers involved with roofing (Fig. 6.3). They are mostly undereducated, lower class workers who can not afford to sacrifice a day's pay and therefore are unable take time off. Contractors take advantage of this fact and limit or offer zero paid time off as a result. Unfortunately, this sets up a difficult cycle to break when people are dependent on their job to survive, literally.

Fig. 6.3 NRCA

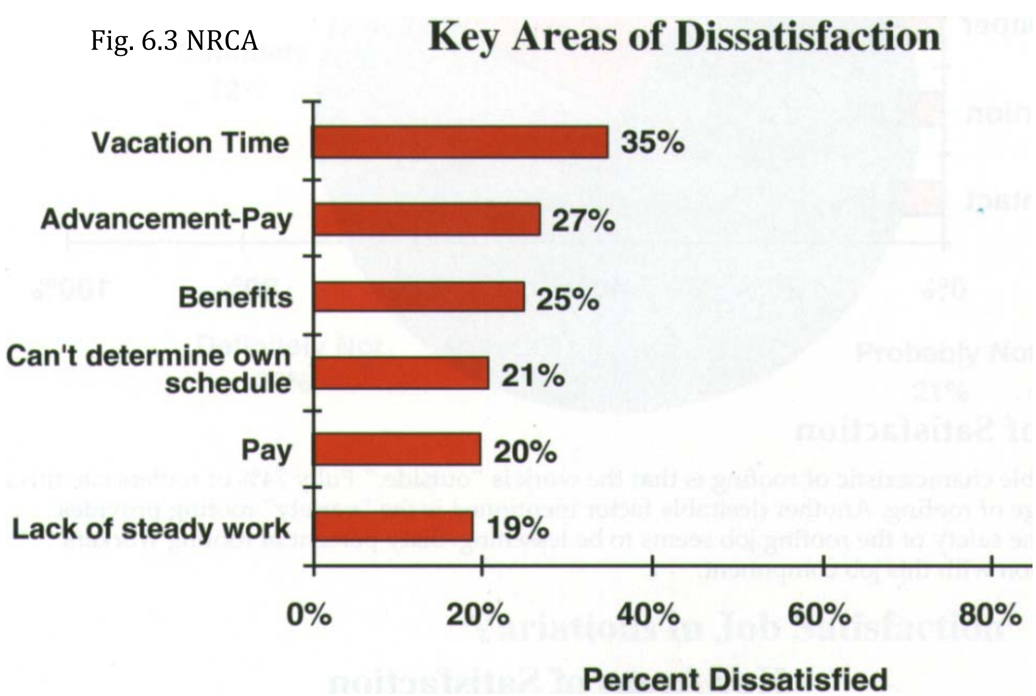
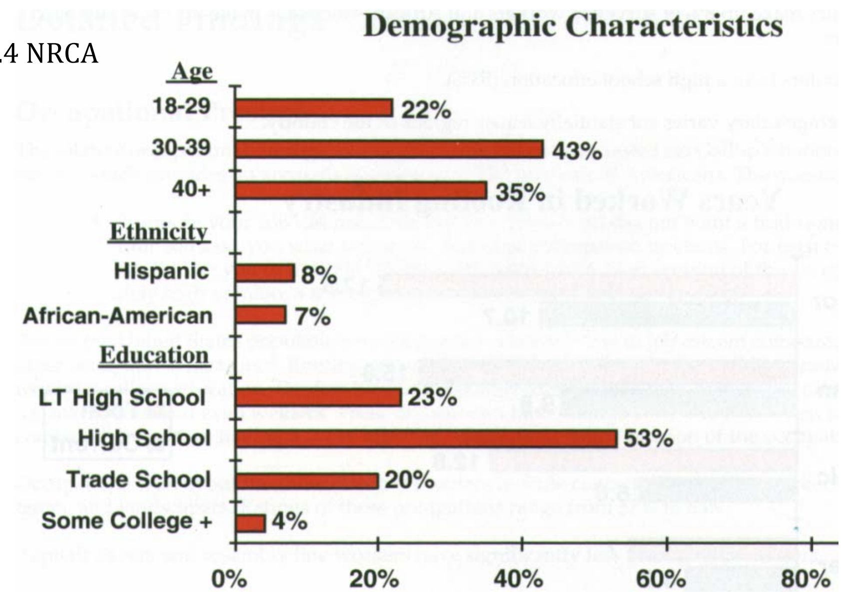


Fig. 6.4 NRCA



As seen above (Fig. 6.4), only about half of the respondents received a high school degree. This fact alone drastically limits their job pool. That being the case, finding a steady job with decent pay is the only concern they have. At this basic level of employment, novelties native to most careers such as health benefits, paid vacation time, etc. become practically irrelevant when the main purpose of working is to feed a family week to week. The idea of living from paycheck to paycheck comes to mind when describing this demographic and if this continues to be the case, domestic labor improvements have a bleak outlook in this industry.

Immigrant Labor

This situation directly relates to the influx of foreign workers into this industry. "Foreign-born workers in 2007 were more likely than their native-born counterparts to be employed in natural resources, **construction**, and maintenance occupations (16.4 versus 9.7 percent)."[3] As America strives to elevate each generation's relative level of education, the labor pool continues to shrink and the negative perception continues to propagate. "Native-born workers were more likely than foreign-born workers to be employed in management, professional, and related occupations—37.0 versus 27.2 percent."[4]

As a result, countries with lower costs of living, relative to the U.S. dollar, still hold

[3] U.S. Department of Labor
[4] U.S. Department of Labor

our construction industry jobs highly. While the United States is continually losing prospective tradesmen to education and higher paying more "professional" jobs, foreign workers, especially Hispanics, are arriving daily with industry skill and a strong work ethic. In a nation where the labor demand outweighs the U.S. demographic, it looks as though the current foreign labor situation is here to stay indefinitely.

If this continues, the roofing industry, as well as others, will see an ever growing population of Spanish speaking workers infiltrating the labor market. Until this fact becomes generally accepted by the construction industry, language difficulties will continue to grow. Whether, it is the industry that adjusts by offering language education, or it's the immigrant labor force that bends to the U.S. demand, something has to give if this relationship is to be productive.

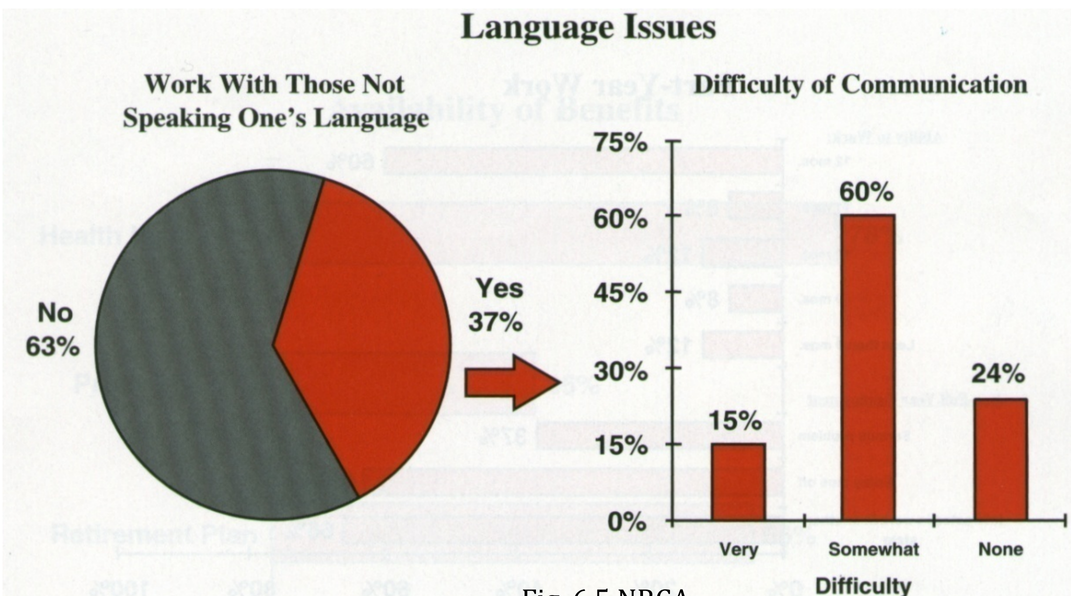


Fig. 6.5 NRCA

6.4 Looking to the Future

So what are the answers to this labor deficiency? The reality is that there is no immediate solution. Let's explore two major areas of interest that repeatedly entered conversation when roofing industry members were interviewed:

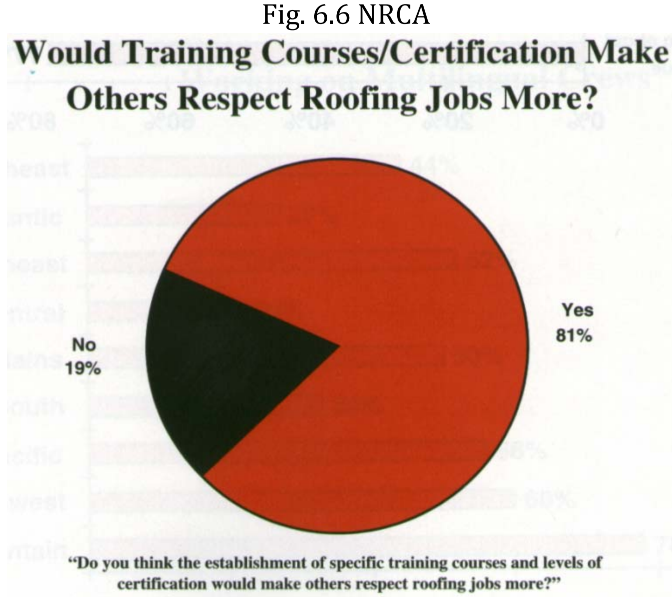
- Industry Perception & Education
- The Roll of Technology

Industry Perception & Education

There were two major trends in responses to where the success of the future labor pool lies: marketing and education. It was unanimously agreed upon that the marketing angle of the industry has to undergo a drastic re-facing if the domestic labor pool is to seriously consider a career as a roofer. As a member of the NRF put it, the industry needs to "inspire professionalism," that is, create an environment that visibly promotes structured promotion and incentive. In other words, the old school has to adopt a much more forward thinking mentality to accommodate a generation that wants everything yesterday. In order to attract new hires in this day and age, a clear promotional outline needs to be explicitly laid out and pay increases clearly explained and attractive.

In addition to this, an accreditation system of some sort was repeatedly discussed. Supporting this response was the NRF study (Fig. 6.6). In order to further promote a professional image, a roofer's certification process seemed to be an attractive idea. The feeling of accomplishment can be an influential tool if imparted properly. When a large portion of the roofing labor pool is under-educated, creating educational training goals, perhaps supported by monetary incentive, may generate a state of satisfaction that many new hires desire. This milestone reinforcement may also help create respect due to the time and dedication required to obtain a prescribed certification. Ultimately, just as in any other profession, roofers need to feel like they are doing something worthwhile be treated with respect for doing so. Currently, no such perception exists, however, by setting these training standards and goals, it might help to garner a more positive industry outlook.

Fig. 6.6 NRCA



More than anything else though, the "dirty job" image must transform into a more positive counterpart. At this point in time it's rather apparent that the general public associates "outdoor" jobs with a decreased level importance. That being the case, individuals would rather work inside at a lower wage than work outside with higher pay, not because of the physical implications, but because of how they are perceived by society and peers. This is an obvious result of years of parental influence that can, again, only be altered through intensive professional imaging. Realistically speaking, until the parents of America can be *proud* of the fact that their son or daughter can have a successful career in the construction industry, and *support* it, the domestic labor pool will continue to suffer.

The only way to accomplish this is to increase support of technical education and promote it as an accepted alternative to higher education. Currently, technical schools have to heavily advertise to draw interest into their programs, and just as the trades do, they are forced to target the lower classes and minorities. Even though many of the careers that become available after completing a technical education pay much more than most entry level office jobs, the same "dirty job" stigma applies. When roofing industry members were asked what they would do, if they could change one thing tomorrow to better their industry, the overwhelming response was to invest more in technical educations. For this to happen there would have to be support by both the public and private sectors. A NRF member stated that, 2 billion dollars, a seemingly insignificant amount of money to the U.S. Government, would be all that was needed to change the face of technical education and open the public to multitude of fruitful career opportunities. Yet, as a society, we continue to look past these opportunities because we have seemingly risen above this "outdoor" lifestyle.

The Roll of Technology

As the sustainability wave continues to gain momentum, new construction materials, systems and methods are continually being developed. As a result, traditional roofing practices are transitioning into new sectors like green roof and solar installations. This is good news. When asked if technology relating to sustainability would be a future selling point for new hires, roofing contractors agreed that it most definitely would be and is already.

Returning to the desire to be involved in a worthwhile respected career, a new term "green collar" was brought to attention. This generation of roofer will be working with new and exciting roof applications that will be contributing to the initiative to save our planet. These technologies will require additional training and expertise that the roofing industry has not seen in the past. Resulting is a new demand for individuals who are motivated to be trained in specialty applications and technologies that are fairly new. This will hopefully create an increased interest among perspective hires due to the environmental contribution/awareness associated with their roofing career. Beyond this however, the technological knowhow required to deal with cutting edge green products will hopefully raise the level of respect associated with roofers. Unlike before, they will now be familiar with technologies seen in the media every day that are still relatively unknown to the general public.

6.5 Conclusions and Recommendation

The roofing industry is going to continue experiencing labor issues until drastic changes are made. As I see it, there are two options; appropriate mass amounts of money back into the marketing and reimaging of vocational education, or invest heavily into foreign labor programs. I recommend the latter of these two alternatives.

The industry has been flooded for years with immigrants looking to make an honest living by whatever means possible. The employment requirements that the U.S. construction market requires already outweighs this countries domestic supply of workers. Furthermore, the declining pool of domestic labor has been influenced for years that manual outdoor labor is "beneath them", and therefore would rather make minimum wage at a super market than roof. The U.S. Department of Labor quoted the national avg. roofing wage at **$16.99**. This is a **66% increase** over the national minimum wage of $5.85. Yet this industry struggles to maintain a steady influx of domestic hires.

Therefore, I feel the roofing industry should pour their resources into the population that is currently clawing for employment in this industry. Investment in language programs, relocation packages and industry education for foreign born workers will be entirely more effective than attempting to change the mentality of the domestic labor pool. Ultimately, catering to a population that is ready and willing to roof tomorrow if given the chance, will most likely be the most productive solution.

7. Analysis 1 – *Green Roof Structural Comparison & CO_2 Impact*

7.1 Problem Statement

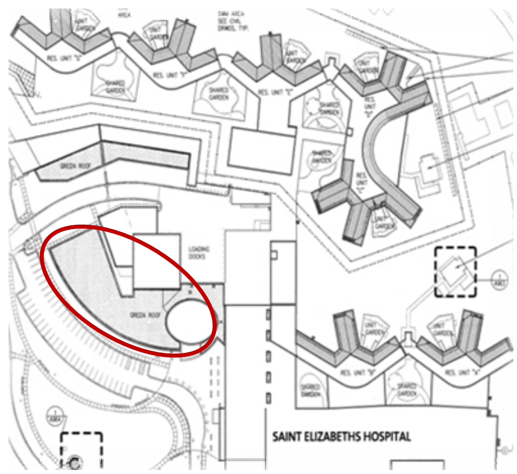
A non-inhabitable Green Roof was designed for a large portion of the hospital's roof. As a structure that pursued no LEED® rating or any other sustainability practices, was the green roof structurally economical and do its long run benefits actually outweigh its environmental construction impacts?

7.2 Background

The sustainability craze has impacted the construction industry in a major way. Any material that helps keep our planet from deteriorating further has been a source of attention. As a result, the "Green Roof" has been gaining significant notoriety in recent history due to its environmentally friendly characteristics, which include:

- Storm water management
- Reduction of the "heat island" effect
- Very good thermal properties
- $C0_2$ sequestering
- Organic material usage

Fig 7.1



A 21,350 ft^2 Extensive Green Roof (highlighted in the figure to the left) by Hydro-Tech Inc. is to sit atop single story office space within the administrative portion of the hospital. The roof system is supported by an array of steel joists and W-shapes that transfer their weight through load-bearing CMU. The roof system itself consists of a 4" lightweight composite slab, moisture membranes, insulation and the soil/planting assembly. Refer to the diagram at the right depicting the actual product assembly to be installed.

7.3 Research Goal

I intend to investigate the long term benefits of a green roof in comparison to its environmental construction impacts. For example, does the additional steel required to support the roof have a greater environmental impact than the roof is able to return in the future? A white membrane "cool roof" will be explored and contrasted both environmentally and economically to the green roof system. In addition to this alternative roofing system, a storm water collection system will be examined in the second analysis.

7.4 Analysis Steps

1. Hydro-Tech Garden Roof® Assembly Loads

Dead Loads	lb/ft^2
20G. Composite B-lock Deck	1.9
4" Lightweight Concrete Slab	29
Hydro-Tech Green roof Assembly	35
Ceiling	2
Utilities	10
Drainage	5
	82.9

Live Load	lb/ft^2
Snow load	25

Garden Roof®

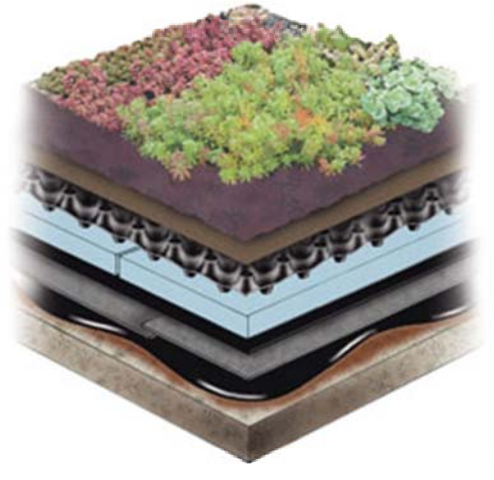


Fig. 7.2

Factored Load:

1.2(82.9) + 1.6(25) = **139.5 lb/ft^2**

Line Load:

139.5lb/ft^2 (5') ≈ **700 lb/ft**

2. Calculate Duro-Last Cool Zone® Assembly Loads

Dead Loads	lb/ft^2
22G. B-W.R. Roof Deck	1.7
5" Polyiso Insulation	2.5
50 Mil. Polyvinyl White Membrane	0.25
Ceiling	2
Utilities	10
Drainage	3
	19.45

Live Load	lb/ft^2
Snow load	25

Duro-Last® Membrane

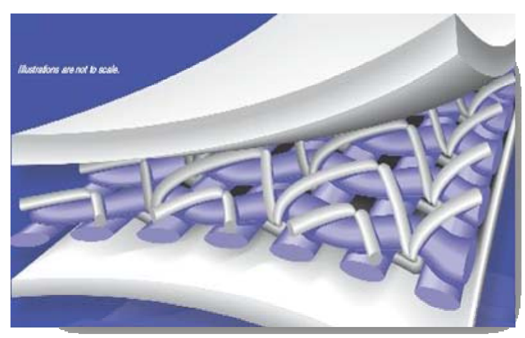


Fig. 7.3

Factored Load:

1.2(19.45) + 1.6(25) = **63.82 lb/ft^2**

Line Load:

63.82 lb/ft^2 (5') ≈ **320 lb/ft**

3. Steel Redesign

The joist layout and sizing was determined by the new factored line load associated with the cool roof assembly. The 5' max. spacing remained intact so that mechanical support conditions remained the same. However, the joists were resized to the smallest allowable member based on the 320 lb/ft loading condition using the Vulcraft Economical Joist Guide (see appendix C). Table 7.1 outlines the original tonnage of steel required while table 7.2 shows the redesigned requirement.

TABLE 7.1

Joist	L.F.	lb./lf	Tons
18K5	18	7.7	0.0693
24K7	22	10.1	0.1111
26K9	28	12.2	0.1708
28K9	30	13	0.195
16K7	16	8.6	0.0688
14K1	795	5.2	2.067
18K3	54	6.6	0.1782
22K5	90	8.8	0.396
26K7	136	10.9	0.7412
24LH06	995	16	7.96
24LH07	800	17	6.8
		Total Tonnage	**18.8**

TABLE 7.2

Joist	New Joist	L.F.	lb./lf	Tons
18K5	14K3	18	5	0.045
24K7	16K3	22	6.2	0.0682
26K9	18K6	28	8.5	0.119
28K9	20K6	30	8.7	0.1305
16K7	12K1	16	5	0.04
14K1	10K1	795	5	1.9875
18K3	16K2	54	5.5	0.1485
22K5	16K4	90	6.9	0.3105
26K7	18K6	136	8.5	0.578
24LH06	26K6	995	8.5	4.22875
24LH07	28K8	800	9.9	3.96
			Total Tonnage	**11.6**

There are also a fair amount of W-shapes designed to support the East end of the roof system. Additionally, there are a number of deep I-beams serving as joist girders. Table 7.3 shows each shape called for and the lineal feet associated with each shape.

TABLE 7.3

Member	L.F.	lb./lf	Tons
W16X31	294	31	4.557
W16X26	159	26	2.067
W10X12	232	12	1.392
W12X19	44	19	0.418
W12X16	202	16	1.616
W12X14	28	14	0.196
W12X22	24	22	0.264
W24X62	60	62	1.86
W24X55	56	55	1.54
W24X68	56	68	1.904
W16X26	26	26	0.338
W16X31	20	31	0.31
W21X44	24	44	0.528
W18X35	20	35	0.35
W30X90	32	90	1.44
W30X99	94	99	4.653
W27X84	34	84	1.428
		Total Tonnage	**24.9**

In order to determine the percentage of load reduction a ratio of the old loading condition compared to the new lb/ft^2 was calculated. This calculation is seen below.

$$\frac{63.82\text{lb/sf}}{139.5\text{lb/sf}} - 45.7\%$$

This depicts a 54.3% reduction in overall roof load. In order to safely calculate the reduced tonnage of W-shapes required, without redesigning each individual beam, a conservative reduction factor of 30% was assumed. The remaining 24.3% was left as a design cushion as well as an allowance for any additional miscellaneous steel required by redesign. The reduced tonnage was then calculated:

Load Redux $30\% \quad \therefore \quad .70(24.86tons) = 17.4tons$

	Old	New
Joist Tonnage	18.8	11.6
W-Shape Tonnage	24.9	17.4
Total Tonnage	43.7	29

Therefore the resulting overall reduction is:

$$\frac{29tons}{43.7tons} = 1 - 66.4\% \approx 34\%$$

4. Green Roof Carbon Emissions Investigation

I. Steel Production

Quite obviously, the resulting tonnage required is significantly less than the green roof design. By reducing this number, the amount of green house gases (GHG) released into the atmosphere during production is reduced. The process of producing 1 Ton of steel emits about 2 Tons of $C0_2$ into the atmosphere[5]. Without even taking into account the reduced amount of trucking, these steel savings alone reduced $C0_2$ emissions by **29.4** tons.

II. Concrete Production

By removing the need for the composite slab underneath the green roof assembly, 310 tons of concrete were saved. It is generally accepted that producing 1 ton of concrete produces just over one ton of CO_2 and 5.5GJ of energy[6]. This equates to an additional CO_2 savings of **310** tons without even taking into account additional energy emissions.

III. Soil Heat Treatment

Lightweight green roof soil is a highly processed material that consumes a large amount of energy in production.

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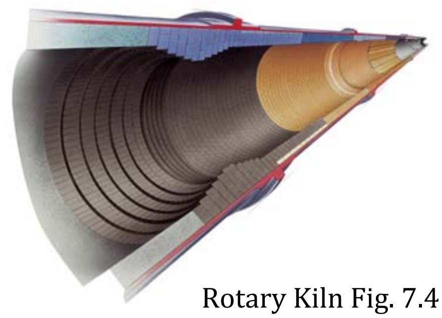
[5] "Steel Industry Resolves to Achieve Long-term CO2 Reductions," 22-Feb-2005 http://www.foodproductiondaily.com/news/ng.asp?id=58235-steel-industry-resolves

[6] *Great Pacific Pumice Inc.* http://www.pumice.ca/

"Manufactured lightweight aggregate and manufactured ultralightweight aggregate products are produced by heating certain types of clay, shale, slate, or other materials in a rotary kiln, which causes the materials to expand or "bloat," resulting in a porous product. The product will retain its physical strength despite its lighter unit weight (lower density) when cooled."[7]



Rotary Kiln Fig. 7.4

This process adds to the overall energy consumption of the green roof manufacturing process which in turn accounts for additional GHG emissions.

IV. CO_2 Sequestering

A common misconception about green roof vegetation and soil is that they are good $C0_2$ sequestering mediums. However, a square foot of sedum is only able to consume about 2lb. of $C0_2$ before reaching a state of equilibrium.[8] This effectively renders the green roof surfaces ability to absorb $C0_2$ negligible. Consequently, It was suggested by several professionals to "plant a tree" to achieve recordable levels of $C0_2$ depreciation.

7.5 Cost and Schedule Impact

Referring to the tables below, the construction costs of the white roof is significantly less. The total savings amount to **$375,971.10** which is a **63% reduction** in price. Refer to the appendix for a list of assumptions and a more specific cost breakdown.

Hydro-Tech Garden Roof® Assembly

Structural Component	Total ($)
Steel Joists	16,920.00
Structural Steel	60,482.10
Composite Deck & 4" Slab	90,737.50
Green Roof Assembly	427,000.00
	$595,139.60

Duro-Last Cool Zone® Assembly

Structural Component	Total ($)
Steel Joists	10,044.00
Structural Steel	43,479.00
20 G' Metal Roof Deck	45,048.00
Cool Roof Assembly	120,200.50
	$219,117.50

[7] "LIGHTWEIGHT AGGREGATE PRODUCTION AND AIR POLLUTION CONTROL WASTES" Office of Solid Waste U.S. Environmental Protection Agency, December 1995

[8] PSU Green Roof Research Center

The original roofing schedule (see appendix C) allowed ten (10) days for steel erection and steel deck installation, ten (10) days to prep and pour the composite slab, and ten (10) days to install the green roof assembly. This totals a four (6) week allowance for the construction of the green roof assembly. In contrast, pouring of the slab is eliminated and the installation of the white roof assembly is reduced the schedule by five (5) days. This amounts to just over three (3) weeks of construction time. By Installing the Duro-Last Cool Zone® Assembly, the roof construction schedule for this portion of the hospital is reduced by almost half.

7.6 Conclusion and Recommendation

Quite obviously, the white roof system not only saved a significant amount of schedule time and money, but more importantly, **prevented almost 340 tons of C02** from entering the atmosphere. That is the equivalent emissions of a Ford F-150 driving cross country a dozen times burning 36,083 gallons of gas[9]. Based on these facts, it is recommended that the Duro-Last Cool Zone® roof system be installed in place of the Hydro-Tech Garden Roof®.

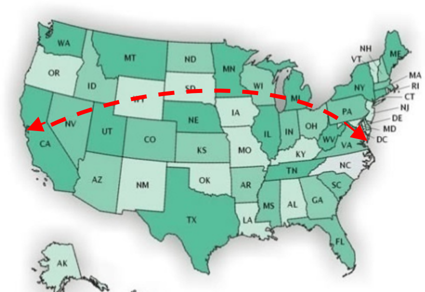


Fig. 7.5

[9] 19.4 lbs CO_2/gallon @ 20 mpg
http://www.epa.gov/OMS/climate/420f05001.htm#calculating

8. Analysis 2 – *Green vs. White Roof Energy Comparison*

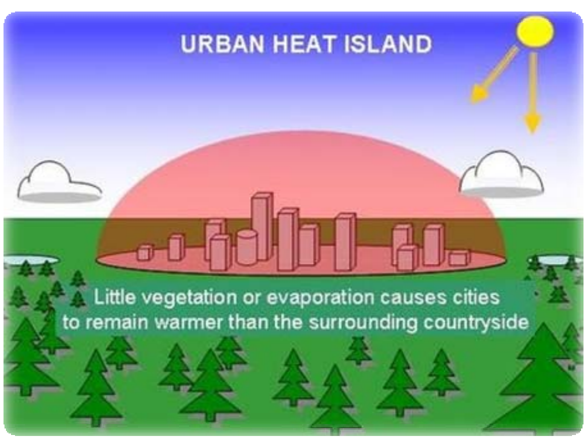
8.1 Problem Statement

Duro-Last Cool Zone®
- 50mil
- 2 Layer Polyvinyl Construction
- 86.5% Reflective
- 100% No Waste – Cut Offs Recycled by Sister Plastics Co.
- 5" Polyiso Foam Insulation by Firestone (R-30)

Replacing the Hydro-Tech Garden Roof® with the Duro-Last Cool Zone® roof clearly offers both monetary and schedule savings. These upfront advantages, however, can be quickly negated by the life cycle cost of the hospital. As a result, it is of interest to investigate the long term implications of changing to a white roof system by investigating the HVAC impacts as well as other life cycle costs.

8.2 Background

Traditionally, common materials for commercial flat roof surfaces were oil based dark surfaced membranes that were either fully adhered or ballasted with stone. Thermally speaking, these dark type surfaces weighed heavily on the cooling ability of a structures HVAC system due to their extreme capability to absorb solar radiation. In warm to hot climates this translates into higher energy consumption and in turn increased GHG emissions. This situation becomes especially crucial in urban settings where a large percentage of the land area is roof top space. The expanse of dark hot surfaces can increase the relative temperature of a metropolis by 2^0-10^0F[10]. This is referred to as the Heat Island Effect (see figure[11]).



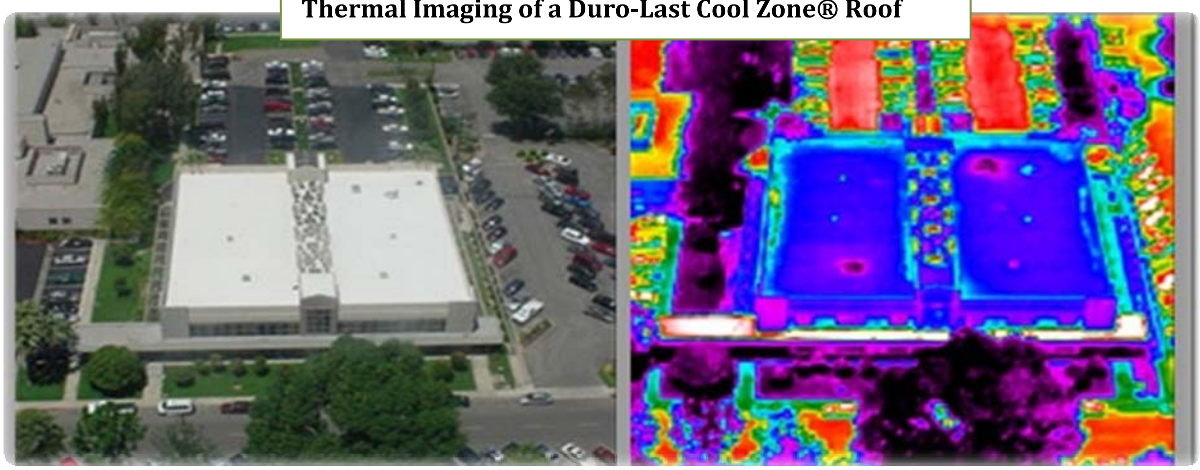
In an attempt to curb this phenomenon and decrease energy consumption, "green roof" systems have become a popular alternative to more traditional roof construction. Their environmentally friendly composition and superior cooling capability has rapidly helped green roofs move to the forefront of construction news. Consequently, this "Green"

[10] *Heat Island Effect* : http://www.epa.gov/hiri
[11] http://static.flickr.com/61/203802589_81a53b96c2_o.jpg

craze has caused widespread investment in new sustainable technologies to conserve our planet. This poses an interesting question however; has the green roof been hastily adopted as an ultimate green solution? Or, are there alternatives that offer similar cooling effects while maintaining or exceeding the green roof "level" of sustainability?

As seen earlier, the alternative roof system being investigated is the Duro-Last Cool Zone®. This particular product is a white poly-vinyl membrane that has a solar reflectance of 85.6%. This compares to the reflectance of a high gloss white paint, which, when compared to dark asphalt, is a 70% increase in reflectance.

Thermal Imaging of a Duro-Last Cool Zone® Roof



The obvious advantage of installing a highly reflective roof surface, in a warm climate, is that solar radiation rebounds back into the atmosphere before it can infiltrate the structure, therefore dissipating heat gains through the roof. However, in order to compare the cooling properties of a green roof to the reflective properties of a white roof, an "equivalent albedo" must be established. In other words, what level of reflectance is needed by a roof material to mimic the surface temperature of a green roof? A study done by Columbia University[12] concluded that the equivalent albedo of a green roof is between 70-85% (see figure A) depending on the time of year.

[12] "Energy Balance Modeling Applied to A Comparison of White and Green Roof Cooling Efficiency" Columbia University

At 85.6%, the reflectance the Duro-Last Cool Zone® roof falls within the upper range of a green roofs equivalent albedo. This indicates that both assemblies offer similar surface temperatures when exposed to direct sun. As a result, the heat flux through the roof assemblies relative to surface temperature is fairly similar for both systems. Therefore, the remaining heat transfer variable is subsurface mass with relation to material R-Value.

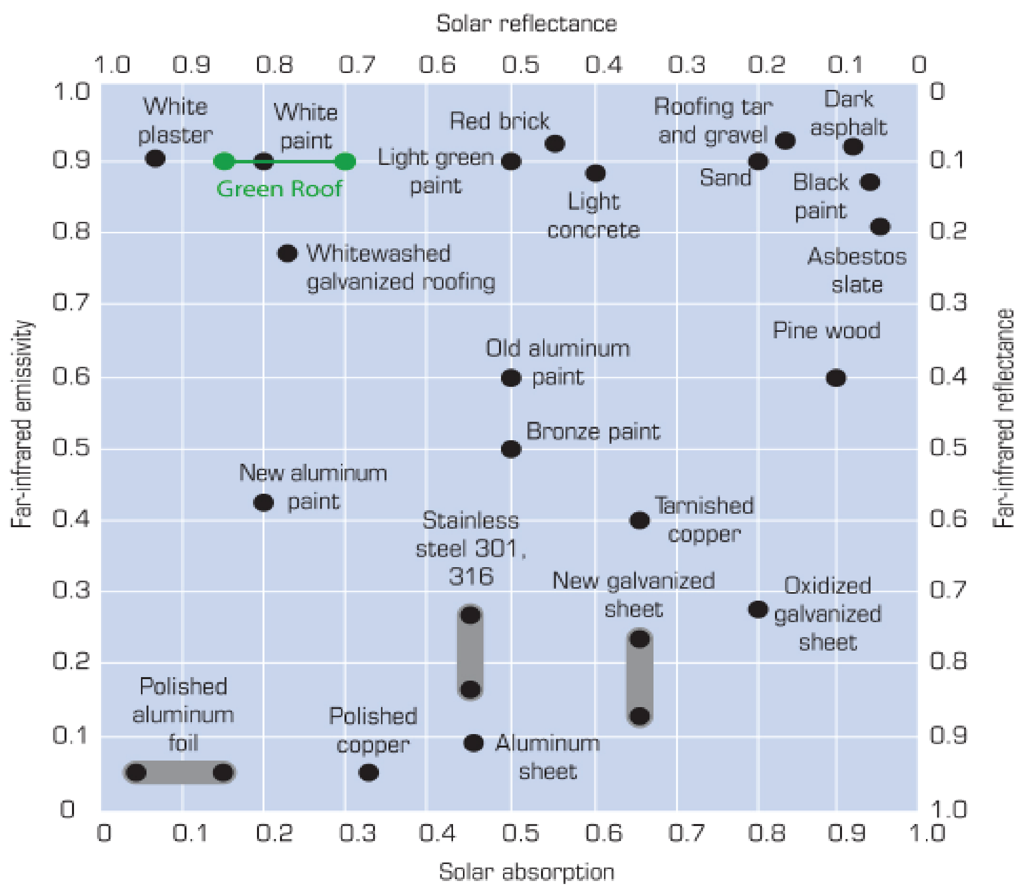


Figure A

Source: Florida Solar Energy Center

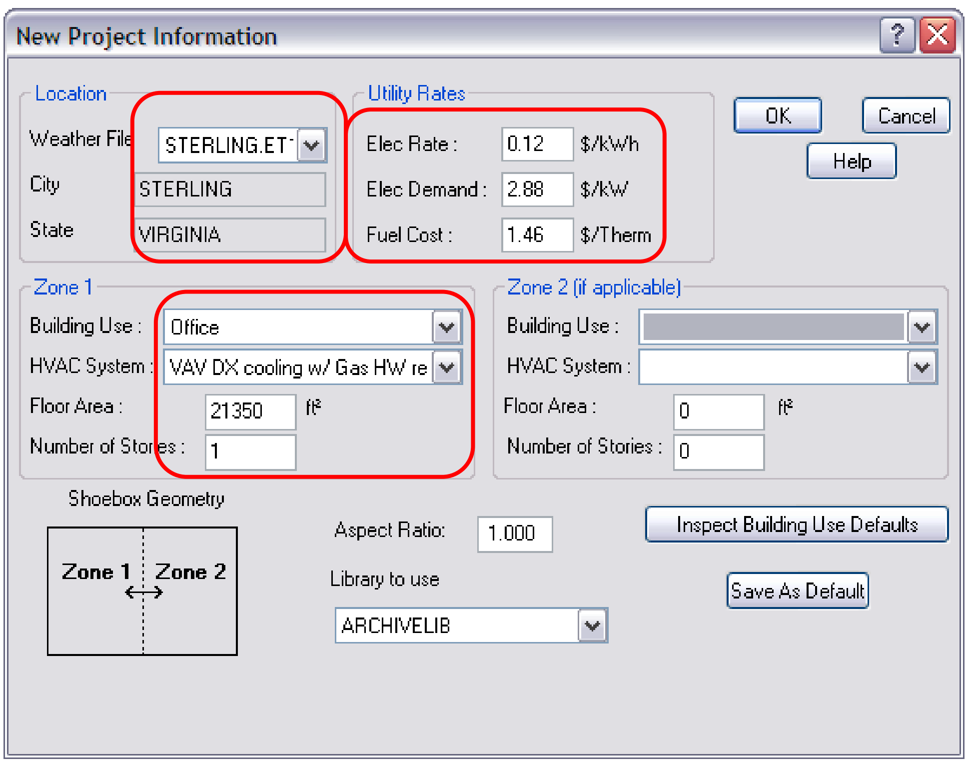
8.3 Research Goal

I intend to make a sustainability comparison between the Hydro-Tech Garden Roof® and the Duro-Last Cool Zone® and prepare a recommendation on which system is more "green". This entails an energy analysis involving the heating and cooling energy required by each system. In addition, with the savings expected from the recommended white roof, rainwater harvesting and photovoltaic systems will be investigated in order to create a self sustainable hospital laundry system to further add to the hospitals overall sustainability.

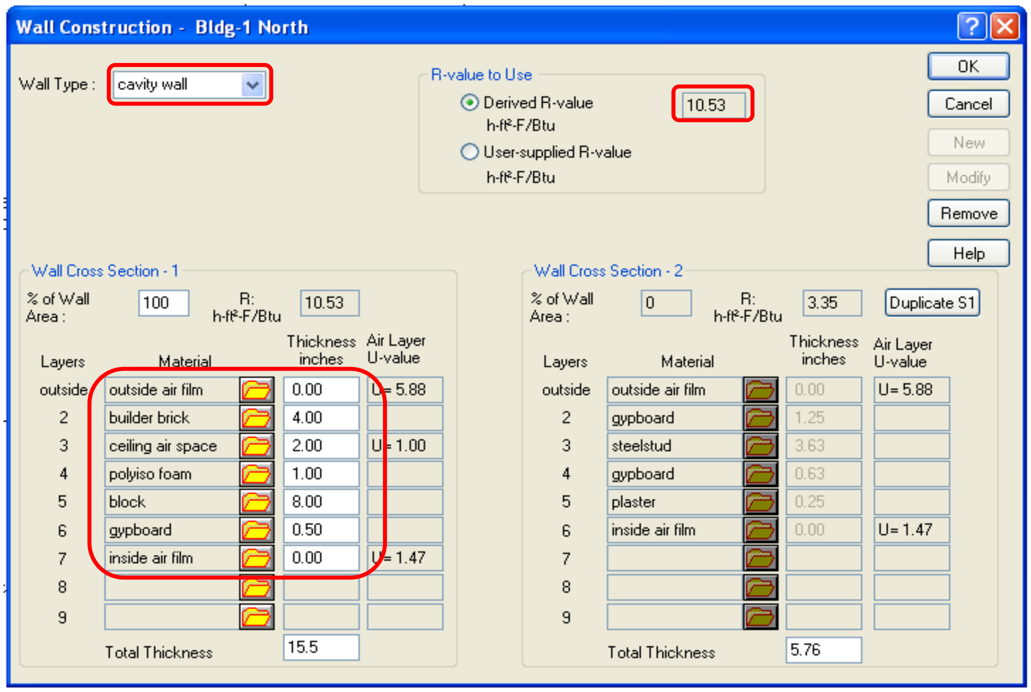
8.4 Analysis

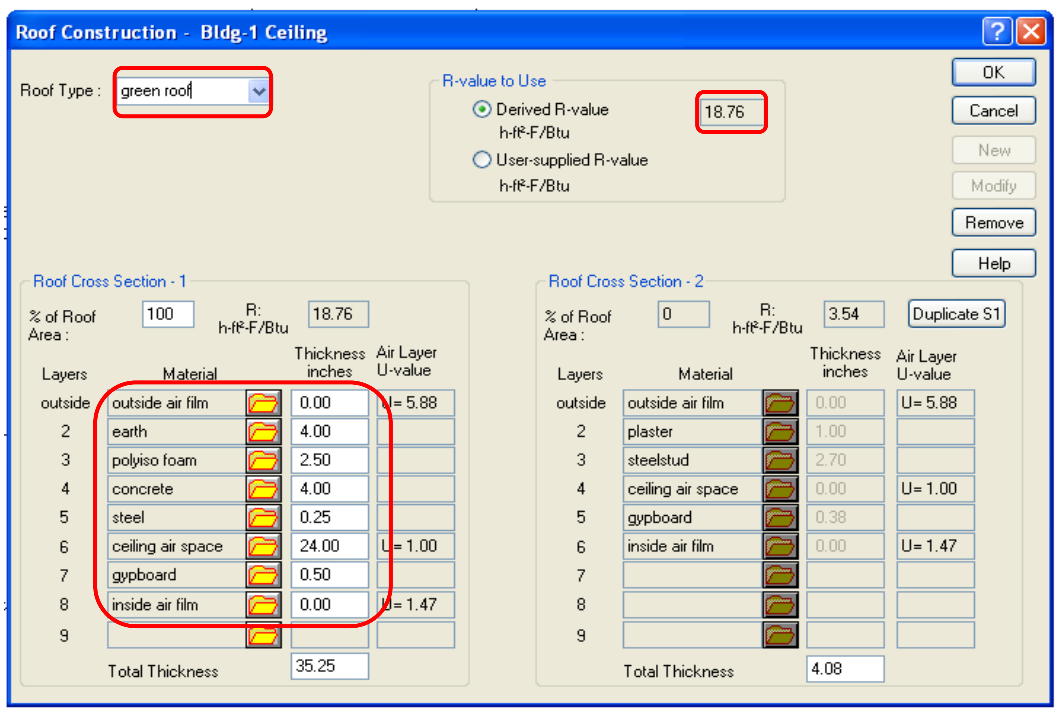
I. Energy-10 Comparison

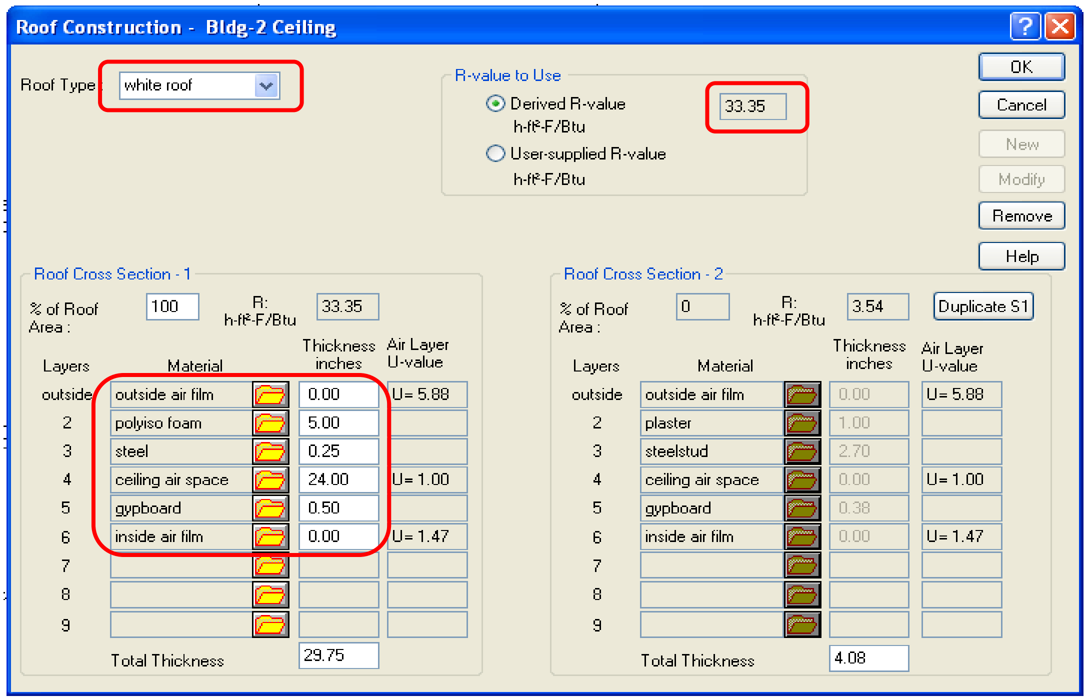
Energy-10 is a comprehensive building software that analyzes the impact of different materials on a structures overall energy consumption. In this particular instance, a simple model was created in the program that mimics the structural and thermal properties of the portion St. Elizabeth's Hospital that the green roof covered. As previously stated, this area consists of a 21,350ft^2 single story space. The space is split between mechanical rooms and staff offices and contains no windows. This data, along with the building location, HVAC system type, and local energy costs, were then entered into the program. Refer to the following images to view the interface.



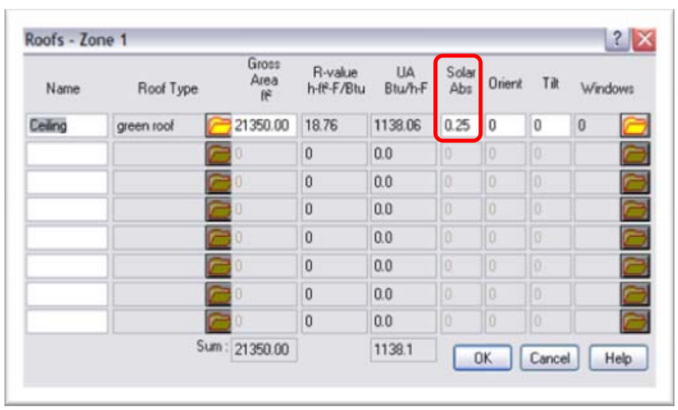
The next step was to explicitly enter the composition of the wall and roof assemblies. In order to make an energy comparison between different shell materials, the program creates two separate "buildings," a reference and a copy. You are then able to change the material setup in the copy building to other desired mediums. In this case, the reference building is the green roof assembly and the copy is the white roof. All elements remained the same in each building except for the roof assembly. This creates a single variable for evaluation, therefore producing energy data based solely on the differing roof assemblies.

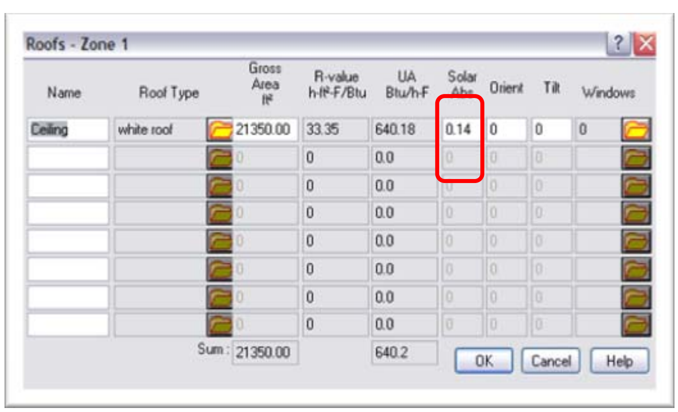






The solar absorption of the two roof surfaces, 1-.856=.14 for the white, and the equivalent albedo of 1-.75=.26 for the green roof.





After completing all entry fields, the program simulation was run and an energy analysis of the two buildings was produced. The following results were generated (see appendix for Energy-10 printouts). The percentages represent amount reduced.

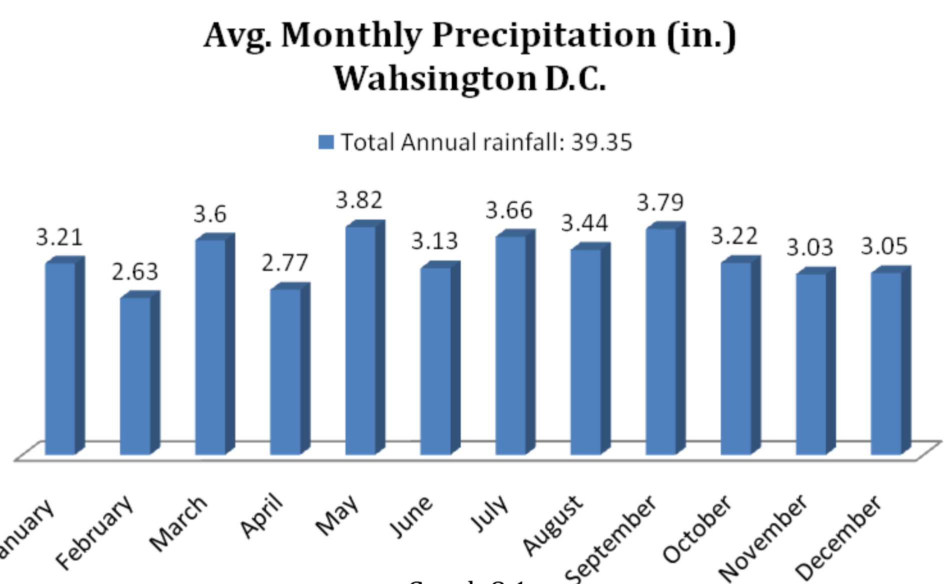
- *Annual Energy Use (kBTU/ft²)*
  - Heating- White - 20%
  - Cooling – 0%
  - Other – White -1%
  - **Total- White - 7.4%**
- *Annual Energy Cost ($/ft²)*
  - Fuel- White-17.7%
  - kWh- White - .7%
  - Demand- Green- 2.4%
  - **Total- White - 6.13%**
- *Emissions (lbs.)*
  - $S0_2$ - White - 1.2%
  - $N0_x$ – White – 1.8%
  - $C0_2$ – White - 3.5%
  - **Total – White – 6.5%**

Clearly the Duro-Last Cool Zone® roof assembly performed better in all three major categories relating to energy consumption. The values produced were expressed in percent reduction rather than actual hard numbers to account for the fact that the model produced is not a perfect representation. This simulation's main purpose was to make a relative comparison rather than produce actual energy/cost/emissions data. The hospitals energy cost lies at about $4.00/*ft²*. With a projected savings of 6.13%, this equates to a $.25 savings/*ft²* and at 21,350 *ft²* this portion of the hospital is looking at an annual energy **savings of $5,300.00.**

II. Rainwater Harvesting System

So far, replacing the green roof with the white roof assembly has been looking rather attractive. However, one of the most influential reasons for installing a green roof is for its storm water management advantages. Through absorption and evaporation by the vegetative medium, green roofs are able to reduce runoff by 50 to 90%[13]. Ecologically speaking, this process naturally transports water back into the environment. With water becoming a scarcity in certain regions, this process, rather than producing additional waste water, returns it back to the earth for reuse. Ultimately, process this prevents additional energy consumption for retreatment in already overburdened water facilities as well as reducing times of peak volume intake by the local sewer system. But, rather than sending the water back into the sky, why not capture it and reuse locally within the building system.

The 21,350 ft^2 of proposed white roof surface could now be used as an enormous collection surface for rainwater. Washington D.C. has an average rainfall of 39.35" that historically falls fairly evenly over a year (see graph 8.1)[14].



Graph 8.1

This presents an interesting opportunity to integrate this run off back into a local building system. After conducting some preliminary calculations to determine the volume of water

[13] *American Hydrotech:* http://www.hydrotechusa.com/benefits.htm

[14] http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmpcp.txt

available, the hospitals laundry service was selected as the target system to explore incorporating this technology into.

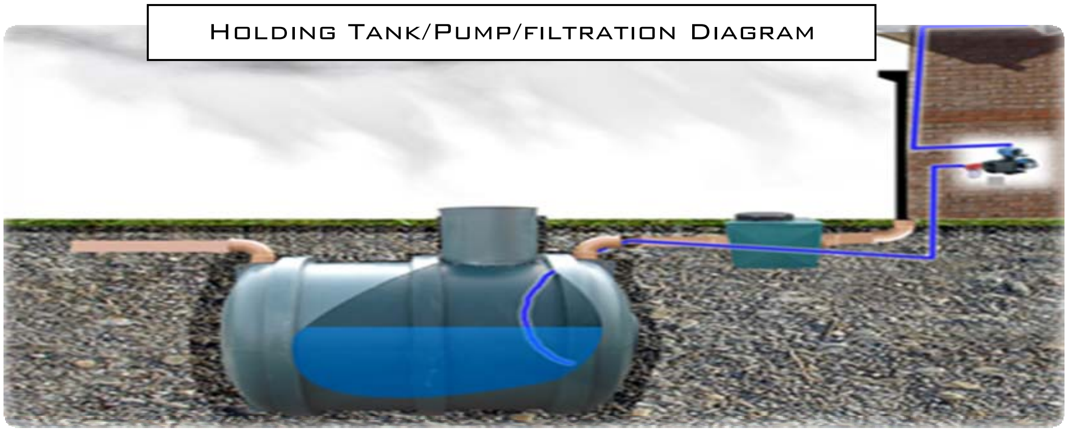
LAUNDRY WATER AND ELECTRICAL DEMANDS

Commercial	Quantity	Cycles/Year	Hours/Cycle	Water Use/Cycle (gal.)	Water Use/Year (gal.)	kW	kWh/Year
Washers	24	1300	0.5	13.9	433680	5	78000
Dryers	12	1300	0.666	~	~	21	218181.6
Residential							
Washers	2	1300	0.5	10	26000	1	1300
Dryers	2	1300	0.833	~	~	2	4331.6
				Total	**459,680.00**	**Total**	**301,813.20**

Both the water *and* electrical demands of the system were calculated in order to investigate the possibility of photovoltaics later on. However, focusing on just the water demand, it is shown that hospital requires 459,680 gal. to serve the 26 washer machines. A quick calculation of annual rain capture capability revealed that the roof area can produce 523,047 gal. annually, which exceeds the needed volume to run the system.

The next step was to find a tank system with the capacity to retain the runoff at a volume that would roughly match the outgoing wash loads while also considering periods of drought. Draco Inc., an underground water tank manufacturer, offered some insight on these situations and recommended a 10,000 gal. underground fiberglass tank. This accounts for two (2) weeks of storage capacity. The pumping and filtration system was the next consideration. A representative from Martin Water Conditioning put together a quote for a system that would suit the volume and purity levels required to supply the washers.

HOLDING TANK/PUMP/FILTRATION DIAGRAM



http://www.water-tanks.net/acatalog/2800H-RWHsm.jpg

Fig. 8.1

Rain Water Recovery System Components

- Darco Inc. 10,000 gal. Fiberglass Tank & Plumbing Hookups — $17,599 (Mat. & Lab.)
- ½ HP Shallow Well Jet Pump
- Sediment Filter
- CAHT 10 Filter w/ 5 Micron Filter
- 6 gal. Pressure Tank
- Power Star Endless Water Heater

(½ HP Shallow Well Jet Pump through Power Star Endless Water Heater) — $ 4,600 (Mat. & Lab.)

Total Up-front investment = **$22,199**

A life cycle savings estimate was then created:

Laundry System Water Usage

- Annual Laundry H_20 Usage: 424,320 gallons
- Annual Rainwater Capture Capability: 523,047 gallons
- Water Rate: $2.14 per CCF (WASA)
- 1 US gallon = 0.13368 ft^3

(459,680) x (0.13368 ft^3) = 61,460 ft^3

61,460 ft^3 / 100 = 614.60 CCF

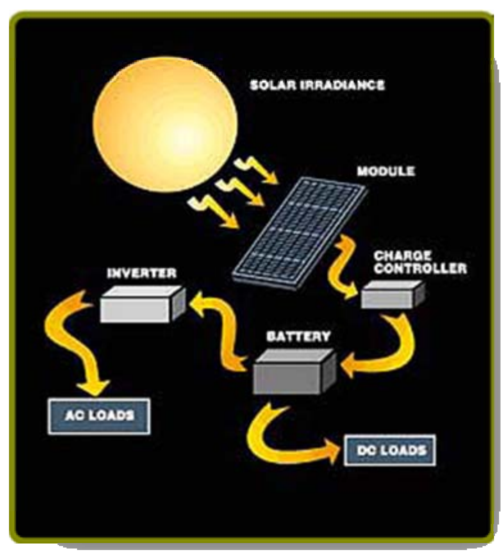
(614.60 CCF) x ($2.14) = **$1315/year**

50 year projected building life = **$65,761 Savings**

III. Photovoltaic Investigation

In order to make the laundry system completely independent of the hospital's power grid, a basic evaluation of a photovoltaic system was also investigated. After calculating the washer and dryer electrical demands, as shown above, it was determined that the laundry system requires 301,813 kWh/year to operate. Capitol Sun Group Inc., based in Maryland put together an estimate for a system that would meet this demand.

Fig. 8.2



http://www.gammasolar.com/upload/PV_Cell_System_Diagram2.png

Capitol Sun Group Photovoltaic Estimate:

- Laundry Demand: 301,813 kWh/year
- Size of System Required: 223kW
- System Coverage: 19,800ft^2
- 20^0 Panel Orientation
- Total Material & Installation: **$1,780,000**

Cost Analysis of Photovoltaic System

(301,813 kWh/year) $ .12kWh = $36,218/year

$1,780,000 / $36,218/year ≈ **49 year payback**

8.5 Conclusions & Recommendation

The Energy-10 analysis produced favorable results for the Duro-Last Cool Zone® roof system over that of the Hydro-Tech Garden Roof® in most every relevant energy comparison. Due to the fact the equivalent reflectance's are relatively similar, the greater R-Value provided by the 5" poly-iso insulation most likely generated the savings advantages. Additionally, by negating the storm water advantages of the green roof with the laundry harvesting system, the white roof maintains its comparability. Not only does this system make use of naturally available rainwater, it also produces an additional small annual savings, that, over a projected 50 year lifecycle, amounts to **$65,761**. Although this may seem like a relatively small dollar amount, it's still money that would have been spent purchasing water from an already stressed city water system.

The Capitol Sun Group Photovoltaic System definitely adds to the green appeal of the roof system. However, because of the extremely high cost of the photovoltaic system relative to the price of city electricity it seems a bit unrealistic at this time. When faced with an almost 50 year payback period, it's not hard to believe that cheaper alternative energy solutions will be developed much before then.

Taking these energy issues into consideration, it is again recommended that the Duro-Last Cool Zone® roof system replace the Hydro-Tech Garden Roof®. It is also recommended that the rainwater harvesting system be installed. However, due to the extremely high cost of the photovoltaic system, it is recommended this not be installed.

Bottom Line Cost Breakdown of White Roof Recommendation

Duro-Last Cool Zone® Construction Savings:	$380,022.00
Rainwater Harvesting System Cost:	- $22,200.00
TOTAL:	**$357,822.00**
Annual Projected Lifecycle Savings	
Energy:	$5,300.00
Water:	$1,315.00
Maintenance:	- $500.00
TOTAL:	**$6,115.00**

Ultimately, the Duro-Last Cool Zone® and rainwater harvesting system is a more environmentally and economically sustainable design both in construction and lifecycle as compared to the Hydro-Tech Garden Roof®.

APPENDIX A

Detailed Schedule

General Conditions Estimate

VI.I GENERAL CONDITIONS ESTIMATE

ST. ELIZABETH'S HOSPITAL

Schedule:	36 months
Estimated Volume:	$ 140,000,000
Gross Area:	450,000 SF

ITEM No.	CONSTRUCTION		TOTAL
01110	MOBILIZATION		$638,100
01120	DEMOBILIZATION		$273,471
01130	JOB OFFICE		$27,720
01300	TEMP UTILITIES		$360,000
01310	DAILY CLEANUP		$50,000
01320	FINAL CLEANUP		$100,000
01320	SITE SINAGE		$8,000
01601	OFFICE SUPPLIES		$3,312
01602	OFFICE EQUIPMENT / FURNITURE		$5,508
01603	TELEPHONE / FAX		$8,064
01605	SCHEDULE MAINTENANCE & SUBMITTAL		$200,000
01700	PROJECT STAFF - BASE		$1,941,613
01810	PROJECT STAFF - FRINGES and BENEFITS		$485,403
01840	BUILDERS RISK INSURANCE		$508,000
01860	BONDS: PERFORMANCE, LABOR AND MATERIAL		$1,617,337
	CONSTRUCTION SUBTOTAL		$5,314,957
	TOTAL GENERAL CONDITIONS		$5,315,000
	FEE	4.00%	$5,600,000
	TOTAL		$10,915,000

APPENDIX B

Roofing Industry Letter

U.S. Department of Labor Data

APPENDIX C

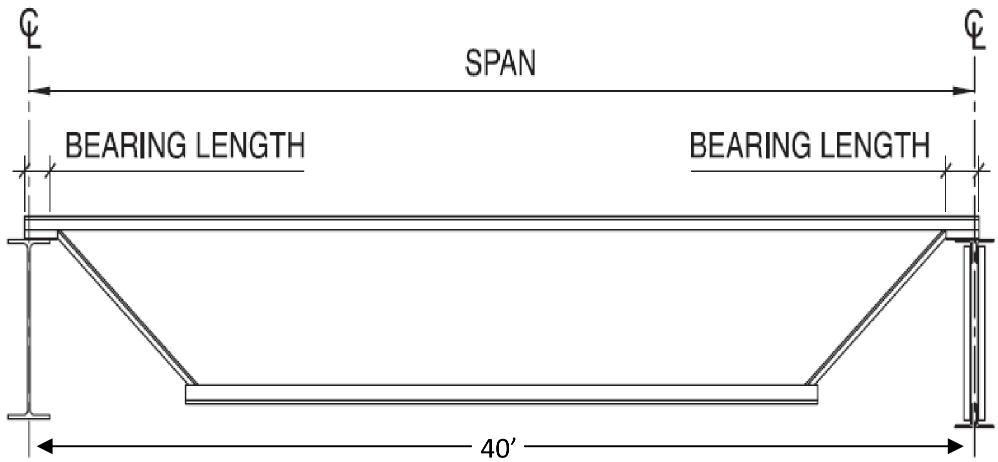
Representative Joist Load Calculation

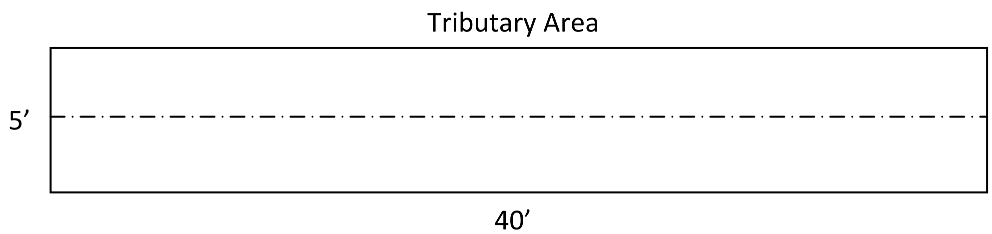
Vulcraft Economy Joist Table

United Steel Deck Tables

Original Roofing Schedule

Representative Joist Load Calculation (Green Roof Longest Span)





Dead Load

- 20 G. Composite B-Lock 1.9 *psf*
- Lightweight Slab 29 *psf*
- Green roof Assembly 35 *psf*
- Ceiling 2 *psf*
- Utilities 10 *psf*
- Drainage/Insul. 5 *psf*
    - *Total D.L.* ***82.9 psf***

Live Load

- Snow w/ Drift 25 *psf*

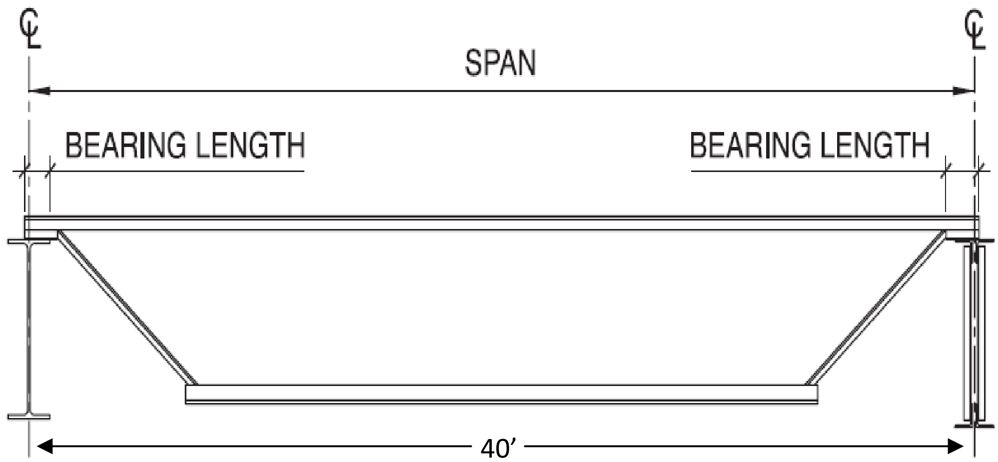
Factored Loads

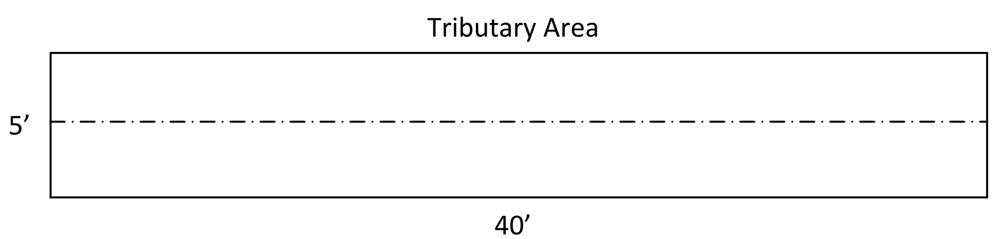
1.2(82.9) + 1.6(25) = 139.5 *psf*

Line Load

139.5(5') ≈ **740plf**

Representative Joist Load Calculation (White Roof Longest Span)





Dead Load

- 22 G. B-W.R. Roof Deck 1.7 *psf*
- 5" Polyiso Insulation 2.5 *psf*
- 50mil Duro-last Mem. .25 *psf*
- Ceiling 2.0 *psf*
- Utilities 10 *psf*
- Drainage/Insul. 5.0 *psf*
    - *Total D.L.* ***19.45 psf***

Live Load

- Snow w/ Drift 25 *psf*

Factored Loads

1.2(19.45) + 1.6(25) = 63.82 *psf*

Line Load

139.5(5') ≈ **320plf**