The Arts & Humanities Instructional Building
Howard Community College
Columbia, Maryland

FINAL REPORT

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Architectural Engineering
Construction Management 2006
Advisor: Dr. Messner
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Arts & Humanities Instructional Building
Columbia, MD

Project Overview:

Building Occupant: Howard Community College
Function: Mixed Occupancy
Classrooms, offices, theater space, gallery space.
Size: 77,800 sq.ft.
Stories above grade: 2 stories

HOWARD
COMMUNITY COLLEGE
You Can Get There From Here.

BUILDING STATISTICS:

Construction Timeline:
Start: September 2004
Completion: July 2006
Cost Information (Budgetary)
Overall Project Cost: $20 M
Delivery Method: GMP with Construction Manager at Risk

PRIMARY PROJECT TEAM:

Architect: Design Collective, Inc.
Construction Manager: Riparius Construction, Inc.
Structural Engineer: Smislova, Kehnemui & Associates
M/E/P Engineer: Mueller Associates, Inc.
Theater Architects: Wilson Butler Lodge, Inc.
Acoustical Consultants: Shen Milsom & Wilke
Lighting Consultants: Lighting Design Collaborative

ARCHITECTURAL

Brick and curtain wall façade
Primarily class rooms and offices
100 seat music and multimedia lab
3000 square foot black box theater

STRUCTURAL

Two story structural steel frame
Cast in place spread footings
Composite metal deck
Partial basement

ELECTRICAL

(2) 15 kV feeders to transformer
3000A / 480 V main switch board
Combination of standard and compact fluorescent light fixtures

MECHANICAL

Four roof top AHUs
380 ton Chiller
Two gas fired boilers
Fully sprinkled
Automatic wet pipe system

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www.arche.psu.edu/thesis/eportfolio/current/portfolios/nja115/

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EXECUTIVE SUMMARY

Howard Community College in Columbia, Maryland is constructing a new building known as the Arts and Humanities Instructional Building (AHIB). The AHIB is 77,000 square feet of classrooms, offices, musical and theatrical theaters. Additionally, the project is delivered at a GMP of $20 million in 21 months, from September 2004 to July 2006.

After the project is studied, three areas of further analysis are identified in this report to improve the sustainability and schedule of the project. The first study compares a traditional 4-ply built-up roof system to a green roof system. Another study identifies problems with the scheduling sequence of the façade in order to provide a more efficient sequence. The final analysis is used to establish a waste management plan for the project and review the associated costs.

When analyzing the different roof systems, several criteria are established for the comparison. They are installation costs, material costs and initial mechanical equipment savings. Although the green roof did offer mechanical savings, the reductions are minimal and do not result in a substantial financial gain. The high installation cost of the green roof makes the installation impractical. A 4-ply built up roof is recommended based on the lower material and installation costs.

Due to the complex footprint of the AHIB and differing façade materials, substantial coordination is required to schedule and construct the façade. Three different materials, brick veneer, curtain wall, and aluminum panels, are on all sides of the building, which presents a few scheduling concerns. After analysis, it was discovered that the curtain wall sequence is broken and does not provide a continuous construction sequence. To correct this problem, the north façade of the building is re-scheduled to phase in the construction of the curtain wall with the construction of the brick veneer. This re-sequencing will save a week of construction time, but more importantly provides a logical and more efficient sequence of construction for the curtain wall installer.

Thirdly, a waste management plan is analyzed for the AHIB. This analysis compared the cost of recycling wood, concrete, and gypsum debris created on the jobsite to the cost of not recycling them. The comparison concluded that if only 50% of the previously listed materials are recycled, a savings of about $2,500 is expected. A higher recycling rate would provide for increased cost savings.

In conclusion, the final recommendations are to construct the 4-ply built-up roof and not the green roof; follow the alternative schedule proposed for the façade construction; and implement the waste management plan. The following report presents the three phases of the analysis in greater detail.

EXISTING CONDITIONS

Project Background

The new Arts & Humanities Instructional Building (AHIB) is located on the campus of Howard Community College in Columbia, Maryland. The project is new construction consisting of 78,000 square feet of classrooms, offices, theater space and gallery space. Two above-ground stories and a partial basement comprise the AHIB building. The timeline of construction for this building is from September 2004 to July 2006. Riparius Construction Company acting as CM at risk is delivering the project. The GMP for the AHIB is approximately 20 million dollars.

Below is a summary of a few associated costs.

- Total Project Costs: $20,180,431
- Total Cost per square foot: $262.08

Major Building Systems Costs:

Item	$	$ / S.F.
Structural Steel Costs	$1,284,750	$16.69
Mechanical Costs	$3,855,000	$50.06
Electrical Costs	$1,850,200	$24.03
Masonry Costs	$1,630,601	$21.18
Plumbing Costs	$ 26,000	$ 0.34

Client Information

The owner of the new Arts and Humanities Instructional Building is the Howard Community College located in Columbia, Maryland. The largest department in the school is the Arts and Humanities Department, with a growing Business Department. Currently, Howard Community College has just over thirteen thousand students enrolled. The college has grown in recent years and has seen many new construction projects on campus. The construction manager for the AHIB, Riparius Construction, Inc., has already completed another project for the college and is familiar with the demands of working with the college as an owner.

HCC is known for its strong performing arts program, and building this facility is seen as furthering their commitment to the arts. The facility must be technologically advanced, and thus be a symbol of the schools' strength in the arts. The building will be used for the study and presentation of various forms of art, well as theatrical performances, and will serve as a showcase for the college's Arts Department. Howard Community College has also requested the building be operational by the start of the 2006 academic school year, probably the greatest requirement set forth by the owners.

Project Delivery System

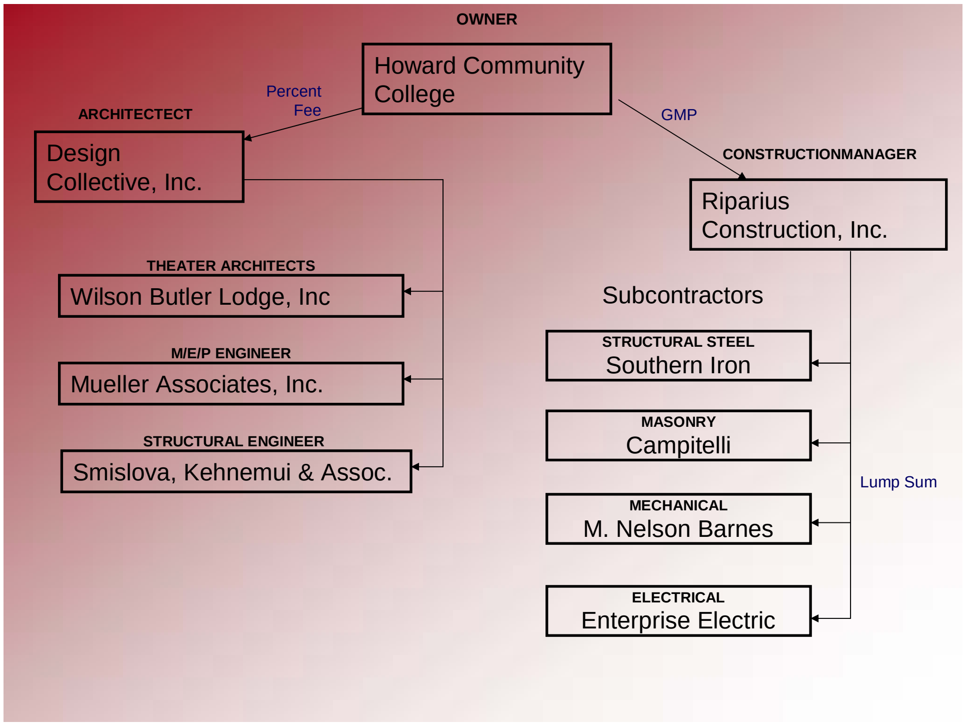
Riparius Construction, Inc. has scheduled the project to be constructed in one phase. The owner has expressed a few concerns over the construction of the new AHIB: First, the college requests the building be operational and occupied by the start of the new 2006 academic school year. Second, a high quality product is required of the project. The last major concern for this project, as for many projects, is safety. The new building is located very close to the entrance of the college campus. Keeping students away from the dangers on the construction site is a main concern being addressed by Riparius Construction, Inc.

Riparius Construction, Inc., is acting as the construction manager for this project. As stated earlier, the project is bid as a GMP with a construction manager at risk. All the subcontracts are held by the construction manager. This project delivery method is appropriate for the owner and the type of project. Although the owner, HCC, has recently completed a few other projects, it is a relatively inexperienced owner. The construction manager delivery system allows Riparius to hold all the contracts and deliver the project in an efficient manner.

Primary Project Team:

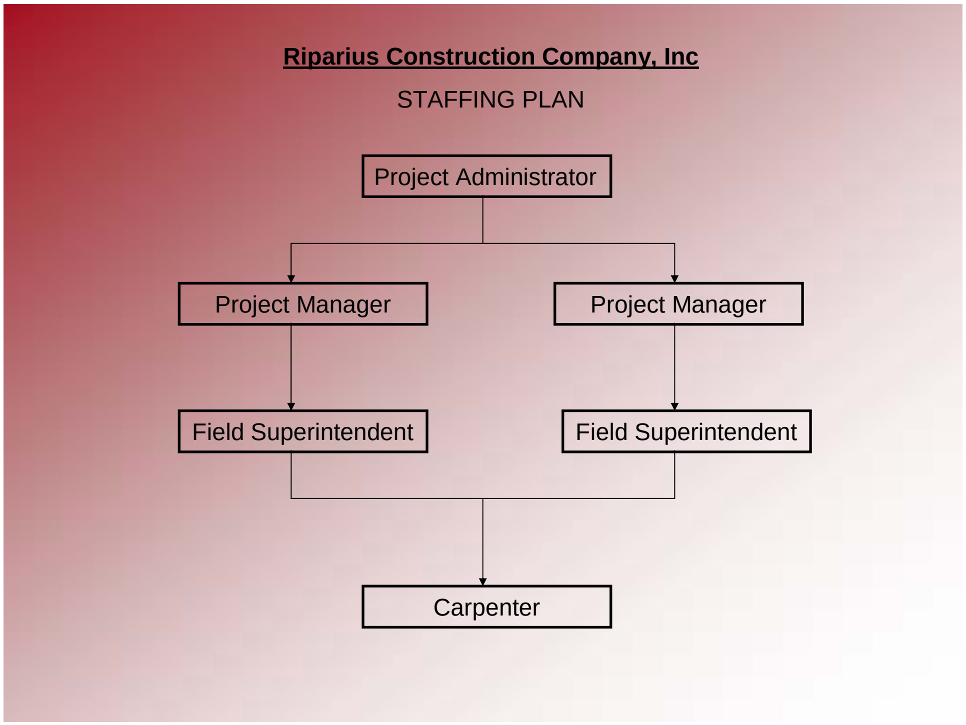
The project team and organizational chart is shown below.

- **Owner**: Howard Community College
  Website: www.howardcc.edu
- **Architect**: Design Collective, Inc.
  Website: www.designcollective.com
- **Construction Manager**: Riparius Construction, Inc.
  Website: www.ripariusconstruction.com
- **Structural Engineer**: Smislova, Kehnemui & Associates
  Website: www.skaengineers.com
- **M/E/P Engineer**: Mueller Associates, Inc.
  Website: www.muellerassoc.com
- **Theater Architects**: Wilson Butler Lodge, Inc.
  Website: www.wilsonbutlerlodge.com
- **Acoustical Consultants**: Shen Milsom & Wilke
  Website: www.smwinc.com
- **Lighting Consultants**: Lighting Design Collaborative



Staffing Plan

To complete the construction of the AHIB, Riparius Construction, Inc. has assembled a diverse project team. Riparius Construction is employing a project administrator to spend the majority of his time on the AHIB. Currently working onsite in the construction trailer are the two main project managers who are devoted solely to the AHIB project and who have two full-time field superintendents working for them. Also on the team is a full-time carpenter. Although this project is more than just a typical office or classroom building, Riparius and the project team are familiar with the constructability issues of the building, since they have already completed similar jobs.



Riparius Construction Company, Inc

STAFFING PLAN

Project Administrator

Project Manager

Project Manager

Field Superintendent

Field Superintendent

Carpenter

Local Conditions

The new AHIB is located in the relatively flat and wooded area of Columbia, Maryland, which was the first planned community in the United States. Existing buildings on the HCC campus are steel structure with brick façade and curtain wall. The first buildings on campus were constructed in the late sixties and early seventies.

Upon investigation of the soil conditions, a soft weathered rock was encountered at depths of 18 to 30 feet below the ground surface. Sands and clays were found at the surface of the soil and at depths up to 28 feet. Measurable subsurface water was encountered in depths ranging from 15 to 27 feet.

Building Systems Summary

Architecture

The new Arts & Humanities Instructional Building (AHIB) is going on the small Howard Community College campus. The intent of this building is to provide the students with state-of-the-art classrooms, an auditorium, and gallery space to display art work. The architecture of the new building is consistent with the other buildings on campus with a more modern approach. The building's design is unique from the other buildings on campus because of the larger windows and a curtain wall system. The AHIB has a large 2-story lobby with a glass covered bridge located on the second floor. A 100-seat music multimedia lab with a stage is located on the first floor along with two dance studios, classrooms and a 3000-square-foot black box theater. A gallery space is located on the first floor to display student art work. The second floor consists of class rooms and music practice rooms.

Demolition

Minimal demolition is required to construct the AHIB. The AHIB will share an entrance with an existing building on campus, the Smith Theater. The existing entrance on the Smith Theater requires demolition in order to construct the new curtain wall entrance lobby. Some of the materials requiring demolition are a sloped metal panel roof overhang, a precast beam, 20 ft of storefront, and concrete pavers. Other demolition requirements include removing lighting fixtures and a payphone in the same area. This demolition is very minor compared to the entire project, and no hazardous materials are expected to be encountered during excavation.

Structural Steel Frame

The portion of the AHIB building with no basement is supported primarily by structural steel with a 3” poured concrete on a metal deck composite system. The structural steel system is comprised of approximately 28’ x 28’ bays. The roof is framed with open web steel joists. Bolted moment connections are used for the construction of the wide flange beams. The crane being used is a 100-ton rubber tire truck crane.

Cast-In-Place Concrete

The cast-in-place concrete walls for the AHIB only exist in the small basement level. The walls are not very complicated with curves, but are straight and perpendicular to each other. Also, the walls are only 15 feet high. The form selection for this wall type is a traditional reusable form. The cast-in-place concrete floor is poured on the metal deck, which acts also as the form. The concrete that will not be placed out of the truck chute will be placed with a pump.

Mechanical System

The basement of the AHIB is fully dedicated for mechanical space. There are four air handling units all located on the roof. The 12,200 cfm AHU is dedicated to serving the theater. A 40,000 cfm AHU serves the studio spaces as well as the classrooms and offices. A 9,000 cfm AHU serves only the black box theater. Another 33,500 cfm AHU serves the lobby and art gallery. A 380-ton cooling tower is located on the roof to provide chilled water. Two gas-fired boilers are located in the basement, providing heated water to the building. A fully sprinkled and automatic wet pipe system is used for fire protection.

Electrical System

The main power enters the building at the basement mechanical room and is stepped down to 480Y/277V by the primary transformer. The power is then fed to the main switchboard. The main switchboard distributes the power to the mechanical equipment and to transformers to further step the power down. The majority of the sources in the building require 208Y/120V, which is provided by the secondary transformers feeding the individual panel boards.

Masonry

The exterior wall of the AHIB is a split face CMU façade with an 8” CMU wall carrying the load. The load bearing CMU wall is tied to the spread footing foundations with steel rebar ties. The façade is attached to the CMU wall with masonry ties spaced at 16” on center. Ladder or truss-type horizontal reinforcement spaced at 16” on center is used for the construction of the masonry walls. The mason will use a hydraulic scaffold to lay the concrete block for the entire building.

Curtain Wall

A pressure-glazing system with a pre-finished extruded aluminum pipe and tube frame was selected for the curtain wall. The curtain wall uses spandrel glass throughout the entire system. The glazing is two panes separated by a 1” gap filled with an insulating gas. The entire system is self-supporting.

Project Schedule Summary

The total timeframe for construction of the Arts and Humanities Instructional Building is about 21 months. The design phase took approximately 2 years; site work on the project lasted approximately 3 weeks. The spread footing foundations have been scheduled for completion in month. The structural steel frame will be erected with final connections

taking place in just over 2 months. The building will be completely enclosed within 12 months of beginning the site work, and will take 5 months from start to completion. Finishes will last about 4 months, with final occupancy taking place the end of June.

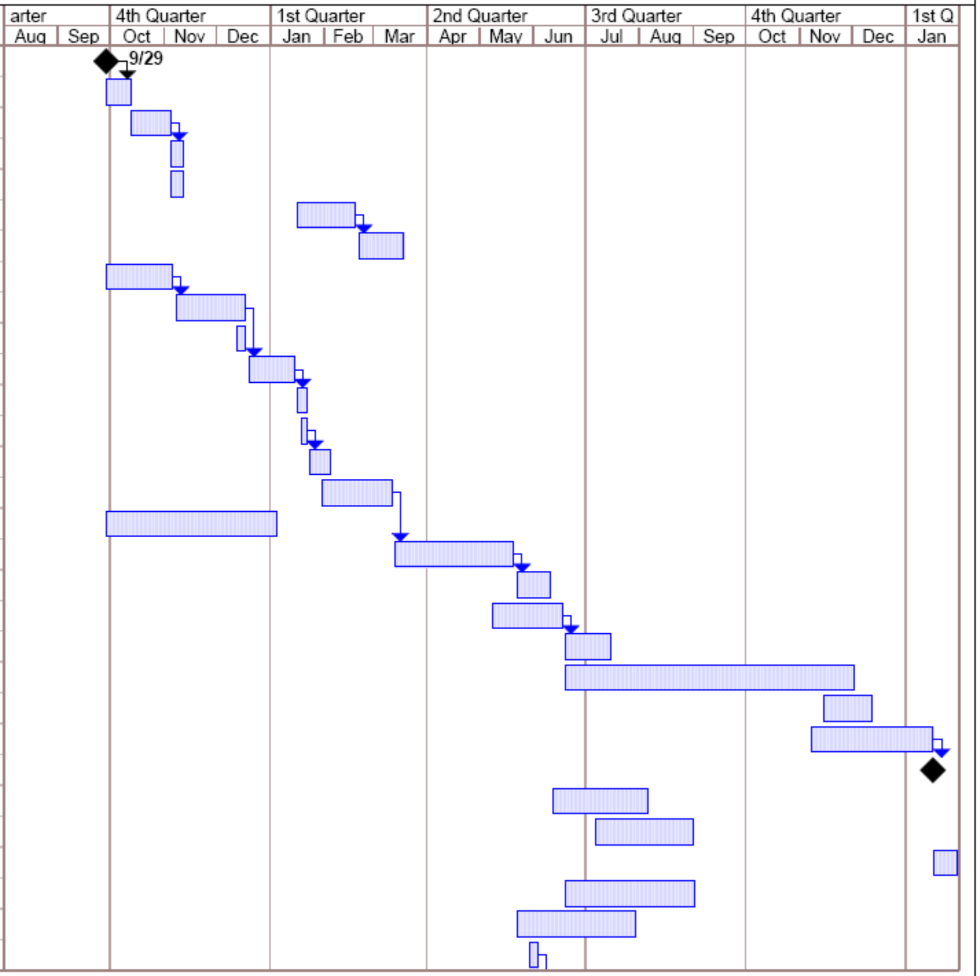
The foundation system for the majority of the building is spread footings. Although this type of construction is fairly typical, it requires some specific attention. The rebar must be procured and placed in time to keep the project on schedule. Construction managers are also concerned with the formwork, as forming and stripping the forms requires a lot of manpower, which is a potential issue.

The structural steel frame clearly is on the critical path of the job. The steel needs to be procured and delivered on site for the construction managers to shake out the steel for the job to run smoothly. Some coordination needs to be done between the construction manager and the steel fabricator to have the correct pieces on site and on time. This is especially important if a lot of beam sizes differ, because the steel fabricator will want to stay productive and produce all the same beam sizes at once, regardless of when they are needed.

The finish schedule is especially problematic for the construction manager and requires more attention. During this time, there will be many different trades on site simultaneously. It is important to know when items are being delivered, and to be prepared with lay down areas for the contractors. Construction managers must also prevent trade stacking and prepare schedules that allow subcontractors enough room to work. It is important to provide a good work plan and work sequence so that the work flows in a logical and efficient pattern. Knowing in which area of the building work will be started, and where work will go from there, is one of the most important functions of the construction manager. The following pages highlight some of the major phases of construction.

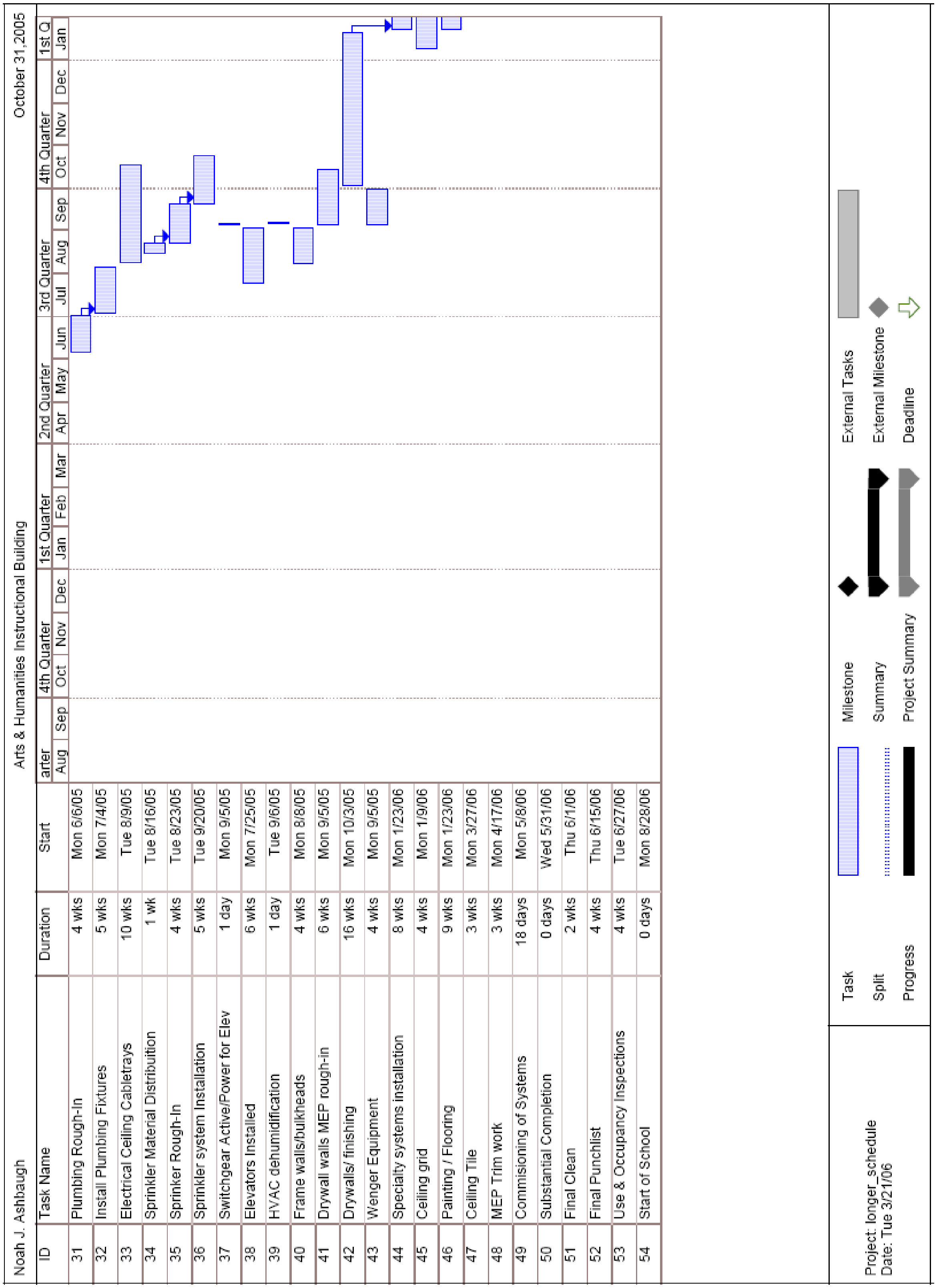
Noah J. Ashbaugh — Arts & Humanities Instructional Building — October 31,2005

ID	Task Name	Duration	Start
1	Start Construction	0 days	Wed 9/29/04
2	Temporary Lots/Site prep	2 wks	Wed 9/29/04
3	Basement Excavation	17 days	Wed 10/13/04
4	Relocate Sewer Line	1 wk	Fri 11/5/04
5	Upper Level Grading	1 wk	Fri 11/5/04
6	Paving, curbs, & walks	5 wks	Mon 1/17/05
7	Landscaping	4 wks	Mon 2/21/05
8	Foundation Rebar - procurement	28 days	Wed 9/29/04
9	Concrete Foundations/Basement wall	6 wks	Mon 11/8/04
10	Elevator jack hole drilling	1 wk	Mon 12/13/04
11	Waterproofing/underslab plumbing	4 wks	Mon 12/20/04
12	Concrete Basement SOG	1 wk	Mon 1/17/05
13	Brace Basement walls	3 days	Wed 1/19/05
14	Backfilling basement walls	2 wks	Mon 1/24/05
15	Concrete ftgs & sog (1st floor)	6 wks	Mon 1/31/05
16	Steel - lead time, shop drawings	14 wks	Wed 9/29/04
17	Erect Structural Steel	10 wks	Mon 3/14/05
18	Steel Detailing	3 wks	Mon 5/23/05
19	Concrete elevated decks	6 wks	Mon 5/9/05
20	Stairs set & pour	4 wks	Mon 6/20/05
21	Masonry - shell, backup & veneer	24 wks	Mon 6/20/05
22	Punch windows	4 wks	Tue 11/15/05
23	Curtainwall & metal panels	10 wks	Tue 11/8/05
24	Building Enclosed	0 days	Mon 1/16/06
25	Roofing Field	8 wks	Mon 6/13/05
26	Roof top epuipment	8 wks	Thu 7/7/05
27	Roof perimeter after exterior walls	2 wks	Tue 1/17/06
28	Interwalls/shafts MEP Rough-In	54 days	Mon 6/20/05
29	Ductwork ceiling	10 wks	Mon 5/23/05
30	Plumbing Mat. Distribuition	1 wk	Mon 5/30/05



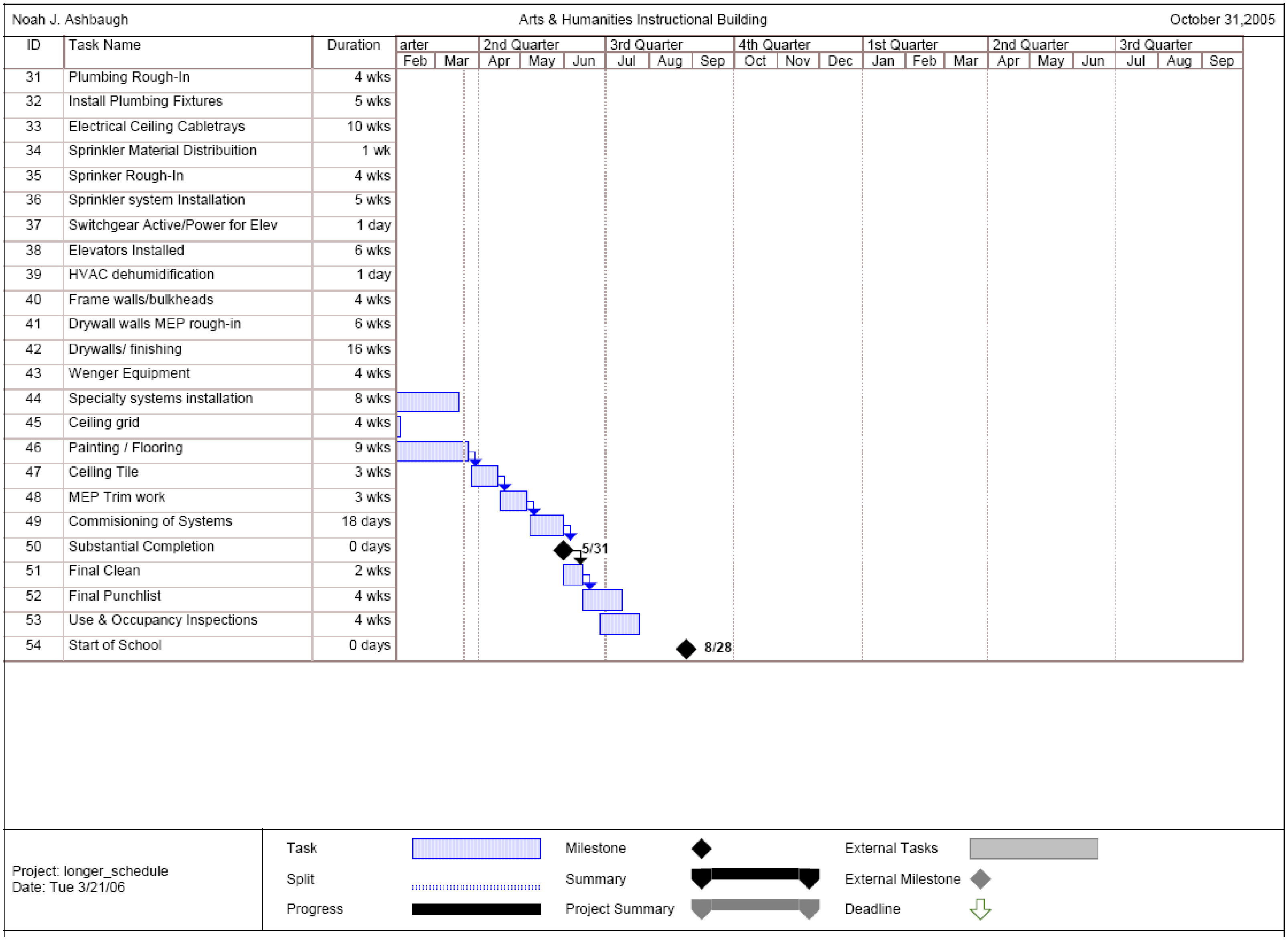
Project: longer_schedule
Date: Tue 3/21/06

Task	▨	Milestone	◆	External Tasks	▨
Split	┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩



ID	Task Name	Duration	Start
31	Plumbing Rough-In	4 wks	Mon 6/6/05
32	Install Plumbing Fixtures	5 wks	Mon 7/4/05
33	Electrical Ceiling Cabletrays	10 wks	Tue 8/9/05
34	Sprinkler Material Distribuition	1 wk	Tue 8/16/05
35	Sprinker Rough-In	4 wks	Tue 8/23/05
36	Sprinkler system Installation	5 wks	Tue 9/20/05
37	Switchgear Active/Power for Elev	1 day	Mon 9/5/05
38	Elevators Installed	6 wks	Mon 7/25/05
39	HVAC dehumidification	1 day	Tue 9/6/05
40	Frame walls/bulkheads	4 wks	Mon 8/8/05
41	Drywall walls MEP rough-in	6 wks	Mon 9/5/05
42	Drywalls/ finishing	16 wks	Mon 10/3/05
43	Wenger Equipment	4 wks	Mon 9/5/05
44	Specialty systems installation	8 wks	Mon 1/23/06
45	Ceiling grid	4 wks	Mon 1/9/06
46	Painting / Flooring	9 wks	Mon 1/23/06
47	Ceiling Tile	3 wks	Mon 3/27/06
48	MEP Trim work	3 wks	Mon 4/17/06
49	Commisioning of Systems	18 days	Mon 5/8/06
50	Substantial Completion	0 days	Wed 5/31/06
51	Final Clean	2 wks	Thu 6/1/06
52	Final Punchlist	4 wks	Thu 6/15/06
53	Use & Occupancy Inspections	4 wks	Tue 6/27/06
54	Start of School	0 days	Mon 8/28/06

Noah J. Ashbaugh — Arts & Humanities Instructional Building — October 31,2005



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50	Substantial Completion	0 days
51	Final Clean	2 wks
52	Final Punchlist	4 wks
53	Use & Occupancy Inspections	4 wks
54	Start of School	0 days

Project: longer_schedule
Date: Tue 3/21/06

ROOF SYSTEM ANALYSIS

Built-up roof vs. green roof system

Objective

The objective of the green roof analysis is to determine the impact a green roof would have on the AHIB. The main focus is to discover the structural load requirements if a green roof had been used instead of a traditional built-up roof. In addition to the structural requirements, the mechanical difference is examined to learn whether a green roof would help the efficiency of the mechanical system. The cost and scheduling comparison is made between a traditional 4-ply built-up roof and a green roof. Although other comparisons can be made, the mechanical and structural comparison is the focus of comparison between the different roof systems.

The structural area analyzed is a single bay consisting of W10x12 beams and W27x84 girders. Although the total roof area of the AHIB is approximately 25,442 square feet, a representative sample of 3,648 square feet over the theater is used for analysis. The current mechanical system in place is a 9,000 c.f.m rooftop air handling unit dedicated to only the theater. The AHU has a cooling capacity of 50 tons.

What is a Green Roof?

A green roof is an engineered roof system that allows for the propagation of roof-top vegetation. Green roof systems are widely considered to be energy savers due to their ability to remain cool even in hot summer months. Other benefits include reducing the amount of storm-water runoff. While there are many green roof manufacturers, there are only two major categories of green roof construction: intensive and extensive green roofs.

Intensive systems typically use larger plant types. These systems require a larger amount of soil, typically to a depth of at least 12 inches. Intensive systems are heavy, require more maintenance, and are more costly. Intensive green roof systems fall between the

ranges of 80-150 lb/sf. Extensive roof systems use smaller plants—typically sedums, grasses, and wildflowers. These systems are lower in weight since the plants require less soil (usually only about 4-6 inches) and fall between the ranges of 15-50 lbs/sf. Also, extensive systems do not require as much maintenance and typically are less expensive overall (www.earthpledge.org).

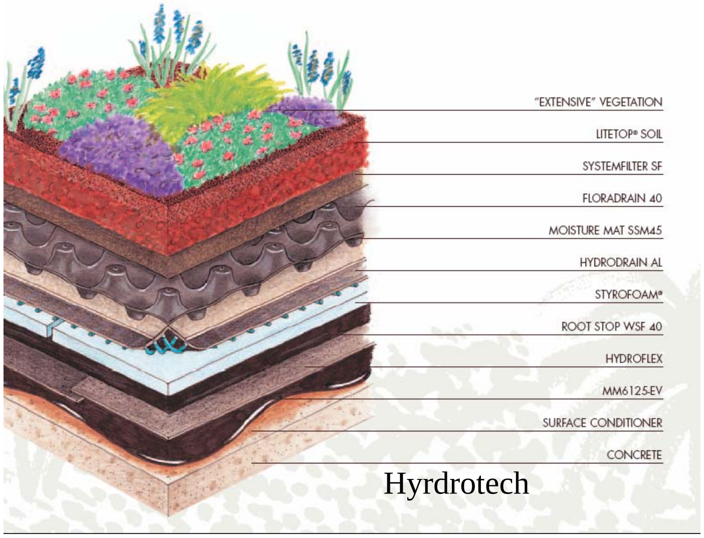
Geographic Requirements

Green roofs are not specific to any one region or area of the country. However, when designing a green roof, it is important to consider the climate in which it will be constructed and the type of plants best suited to that climate. Since some plants are more resistant to heat or cold and certain features of a particular climate, the proper plant selection is important to ensure that the green roof is capable of surviving the different seasons. According to D.C. Greenworks, a nonprofit organization that promotes sustainable design, the preferred plant types in the Maryland area are plants from the *Sedum* genus. There are several different species that are easily adaptable to green roofs. Sedums are particularly suited for use in green roof construction because they have high water-retention capability, an ability to filter pollution, and are resistant to temperature fluctuations. Also, they require minimal maintenance (www.epa.gov/heatisland).

Construction Materials

Every green roof system can be analyzed into five basic components. These components are:

1. Vegetation Layer
2. Soil Layer
3. Drainage Layer
4. Non-permeable Layer
5. Roof Construction



Hyrdrotech

The specific environment of the green roof dictates the design of the vegetation layer. A few considerations when choosing specific plants include: specific climates, expected rainfall, drought resistance, resistance to radiation, and resistance to snow.

The soil layer is designed following the selection of the plant types. A soil layer should retain water for the plants and control water drainage. Most important, the soil layer needs to allow for the growth of the plants.

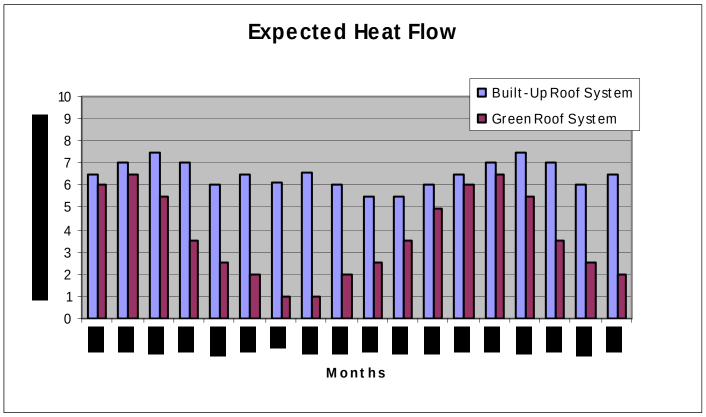
The drainage layer is important to control the flow of excess water through the green roof system. A waterproof layer is installed beneath the drainage layer to prevent moisture from damaging the roof construction. The roof construction is the structural support of the green roof system.

Structural Load Requirements

The approach taken to design the green roof involved checking the structure to understand how much additional load the existing steel roof frame could support. The goal is to avoid creating a load that will require the redesign of the structural system. First, a typical bay is selected as the area to analyze. Since the green roof’s weight is unknown at this time, the objective is to determine the maximum weight (lbs/sf) for the green roof. An unknown variable “P,” representing the weight of the green roof, is applied uniformly to the roof bay. A shear, moment and deflection check is performed on both the roof beams and girders whose size is already known and taken from the existing structural drawings. The calculations are described in the Appendix A. From the calculations found in the appendix it is determined that the maximum the green roof can weigh is 67 psf. After the weight of the green roof is determined, a decision is made to design an extensive or intensive green roof. Based on the structural requirements, an extensive green roof is selected. An extensive green roof will be approximately 15-50 psf. Based on the knowledge that green roofs typically weigh 6 psf/in when fully saturated, a good design for these requirements would be an extensive green roof with 6 inches of soil, weighting approximately 36 psf. Under this load condition, the extensive green roof meets structural load requirements.

Mechanical Implications

Green roofs are known to possess certain benefits regarding thermal efficiency. However, it is difficult to quantify the exact thermal efficiency due to a couple of factors. Currently, no R-value is calculated and assigned to green roof systems. This is because the R-value of a green roof changes when it is at different saturation levels. Also, because of the drainage requirements of a green roof, there are different soil depths at different parts of the roof. Case studies have been performed under specific conditions in an attempt to calculate exactly what thermal properties are specific to a green roof. From these case studies it is shown that, from a thermal standpoint, a green roof is most beneficial in the summer months. Additional reports conclude that the reduction of heat entering the building in the summer is greater than the reduction of heat exiting the building in the winter. These quantities may not be universal to all green roofs since each system is in a different environment, undergoes different saturation levels throughout its usage and uses different growing mediums. One such study conducted in Canada resulted in the observation that, during the summer months, the green roof reduced the roof surface temperature by 35° F and reduced the heat flow through the roof by 70% to 90%. The same roof system reduced the heat flow through the roof by 70% to 90% in the summer months. Another case study conducted at the University of Central Florida found a reduction heat flow reduction of 20% in the summer months. The green roof system used at in the University of Central Florida's case study previously mentioned is very similar in physical dimension to a portion of the green roof system proposed for the AHIB. Therefore similar thermal properties are expected and will be used as the baseline for comparison to the AHIB project, specifically the roof area above the theater. The adjacent table is an



example of the goal for the heat flow through the roof of the AHIB assuming similar results apply. The objective is to reduce the high fluctuations of heat through the roof resulting in a mechanical system that runs with less energy. Only cooling will be examined because the greatest benefits are going to be in the summer. An example of the heat flow equations is listed below:

$q_x = (T_o - T_i) * A / R$

q_x = Heat flow through the roof system, BTU / Hr

T_o = Temperature outside, °F

T_i = Temperature inside, °F

A = Area, 3,648 s.f. of roof surface area over the theater

R = R-value, thermal resistance coefficient, $hr * ft^2 * °F / BTU$

The inside and outside design temperatures are found in *Construction: Principles, Materials, and Methods*.

Built-up roof:

The r-value for the built-up roof is calculated to be 15.89

Cooling: $q_x = (91 - 68) * 3{,}648 / 15.89 = 5{,}280$ BTU / Hr

Green roof:

Based on the case study the heat flow reduction is assumed to be 20%. This is a conservative estimate since a different study resulted in a reduction of 70%-90%. The 20% reduction is also justified because the green roof system in the case study as well as the one designed for the AHIB are very similar in depth and surface area. To further justify the calculations the r-value must be calculated to determine if it falls in an appropriate range. First, the new heat flow will be calculated and the resulting r-value will be checked against the result of the case study.

Cooling: q_x = 5,280 BTU / Hr * 20% reduction = 4,224 BTU / Hr

Resulting r-value

Cooling: r-value = (91 - 68) * 3,648 / 4,224 BTU / Hr = 19.86 $hr\ ft^2 °F / BTU$

This results in a conservative r-value of 19.86 which is consistent with the expected data range of R-15 to R-60.

The conclusion is specific to the area analyzed, which in this case is limited to the theater space. The 4,224 BTU/HR heat flow reduction can be converted to cooling load reduction on the dedicated air handling unit. The AHU's cooling load is 50 tons. By reducing the heat flow 4,224 BTU/HR, the load on the AHU decreases by .352 tons. This is an insignificant amount compared to the total tonnage of the AHU and will not result in any upfront financial cost savings because the AHU can not be reduced by only .352 tons.

Material Cost Savings & Schedule Considerations

The cost comparison for the roofing system is between a 4-ply built-up roof system and a green roof system. Based on RS Means2005 data, it is determined that a 4-ply built-up roof installed will cost approximately $1.98 per square foot. In the United States green roofs systems can cost in the range of $9-$24 per square foot of roof installed. This is significantly greater than a 4-ply built up roof. A cost of $15 per square foot is used for the green roof based on case studies in the District of Columbia area. The comparison between the two systems is based on the installation of 3,648 sq. ft. of roof. The following table summarizes the furnished and installed costs for both roof systems.

<u>Material and Installation Summary Table</u>:

3,648 square ft of roof area
Built-Up Roof @ $1.98 = $ 7,223
Green Roof @ $14.43 = $ 52,640

In addition the following table summarizes the productivity rates for installation of both systems:

<u>Productivity Rates:</u>

Built-Up Roof @ 2,000 sq. ft installed per day = 2 total installation days
Green Roof @ 1,800 sq ft installed per day = 3 total installation days

Based on the previous calculations, the built-up roof system is cheaper and can be installed 1 day faster. From material and installation costs, $45,417 will be saved if the built-up roof system is chosen.

Conclusion

The recommendation for the owner is to install the built-up roof system. Although from the analysis a green roof adds no additional requirements for the structural system, the initial material costs outweigh some of the added benefits. The green roof does offer some mechanical savings by allowing the mechanical system to use less energy in the summer time, which would help reduce costs in the long run, but the initial cost savings is minimal. The analysis above focuses on the initial cost of material and installation of two different roofing systems, a green roof and a 4-ply built-up roof system. The analysis concludes that a built-up roof system is cheaper because of its lower material cost as well as lower labor cost due to faster installation.

FAÇADE SEQUENCING

Objective

The façade sequencing analysis examines alternative façade construction sequences. The goal is to determine whether one sequence is better than another. The major focus will be on the duration length and the scheduling impact each sequence has on the entire project schedule.

Façade Materials

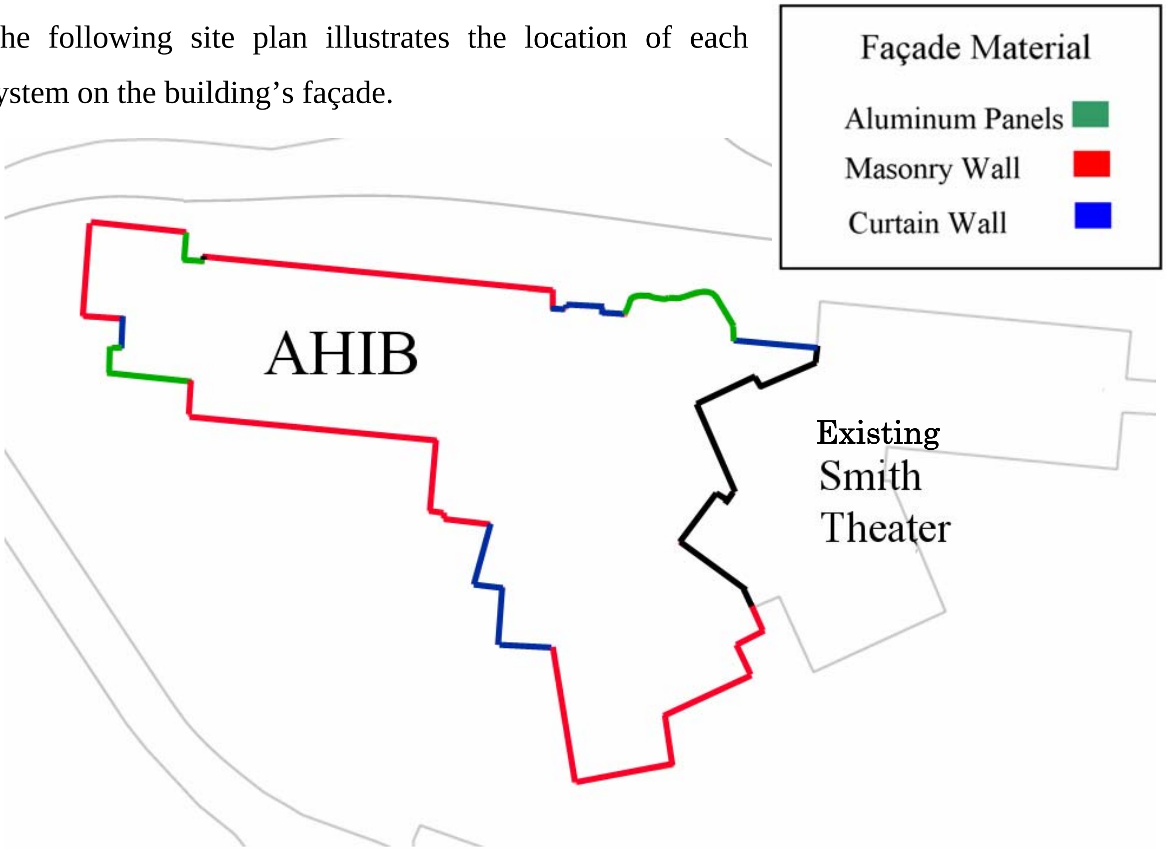
The majority of the façade surface can be broken down into three separate materials: the bulk of the façade is a brick face cavity wall; two additional façade materials are used—a curtain wall system and a pre-finished aluminum panel system.

A summary of the material quantities is listed below:

Masonry:	20,492 square feet
Curtain Wall:	6,492 square feet
Aluminum Panels:	6,044 square feet

Although the building's façade can be broken down into three distinct components, the placement of each material on the façade is awkward for constructability. All three of the materials can be found on all sides of the building, creating a difficult sequencing problem during erection.

The following site plan illustrates the location of each system on the building’s façade.



Why Re-sequence?

The major reason to examine the façade sequencing is to determine the most logical and cost-effective process of construction for the façade. There is a trade-off with any construction process between time, money, quality, and safety. There is a potential for speeding up the installation of the façade by simply adding more workers to the job, but this will cost more money for additional crews, add potential overtime, and possibly additional equipment. In addition, constructing the facade too hastily may result in a loss of quality or possibly safety. On the other hand, if the installation takes a little longer, the length of the project increases. Increasing the schedule length may reduce the amount of money spent on labor if fewer crews are used, but it may also increase the amount spent on general conditionals costs. An evaluation of all these factors needs to be considered

before selecting the best sequence for the AHIB project. It is important to implement a good plan early in the process. Attempting to make up time on a construction schedule during the construction process can prove to be more costly than if the plan is established early and the necessary arrangements are made.

What is the Current Sequence?

A summary of the current construction sequence is as follows:

- Masonry Veneer
  - Tech Theater & Black Box
  - Music Multimedia
  - Stair 1
  - South Façade of West Teaching Wing
  - West Façade of West Teaching Wing
  - North Façade of West Teaching Wing
- Curtain Wall is installed as follows...
  - South Lobby 105 and Vestibule (followed Masonry Veneer at Tech Theater/Black Box and Music Multimedia)
  - North Lobby & 2nd Floor Offices (followed Masonry Veneer at Stair 1)
  - Stair 2 & West End Corridor (followed Masonry Veneer at South and West)
  - Stair 1 (followed Masonry Veneer at North Façade)
  - Light Monitors CW4 (followed Masonry Veneer at North Façade)
  - North Lobby 105 Vestibule
  - Smith Theater Lobby 104 CW5
- Aluminum Panel
  - South Façade (followed Curtain Wall)
  - West Façade (followed Curtain Wall)
  - North Façade (followed Curtain Wall)

Possible Alternatives

After examining the construction sequence, it looks as though there is room for improvement. A few key observations are listed below:

- The masonry crew jumps from the south façade to a small portion on the north façade and then back to the south façade.

  Problem:
    - This sequence requires the masonry contractor to move from one side of the building to the other and then back again. This takes time to set up the scaffolding, resulting in a longer duration.
- The curtain wall installation does not follow an easy construction flow either. The same pattern of south façade to north façade back to south façade is used.

  Problem:
    - The same broken flow as the masonry veneer results in extra time to set up and remobilize.
- The curtain wall is erected in short spurts of activity with weeks of inactivity between.

  Problem:
    - This particular sequence is also inefficient. It requires the curtain wall installer to man the job for a few weeks, leave the job for another few weeks and return to complete the installation. This process at the current sequence happens twice.
- The aluminum panels follow a continuous flow of construction, starting at the south façade and working continuously to the west façade, and finally the north façade.

  Problem:
    - The installation of the aluminum panels follows the most logical flow of working in a continuous direction. This construction is not as crucial to the schedule since the building is already watertight

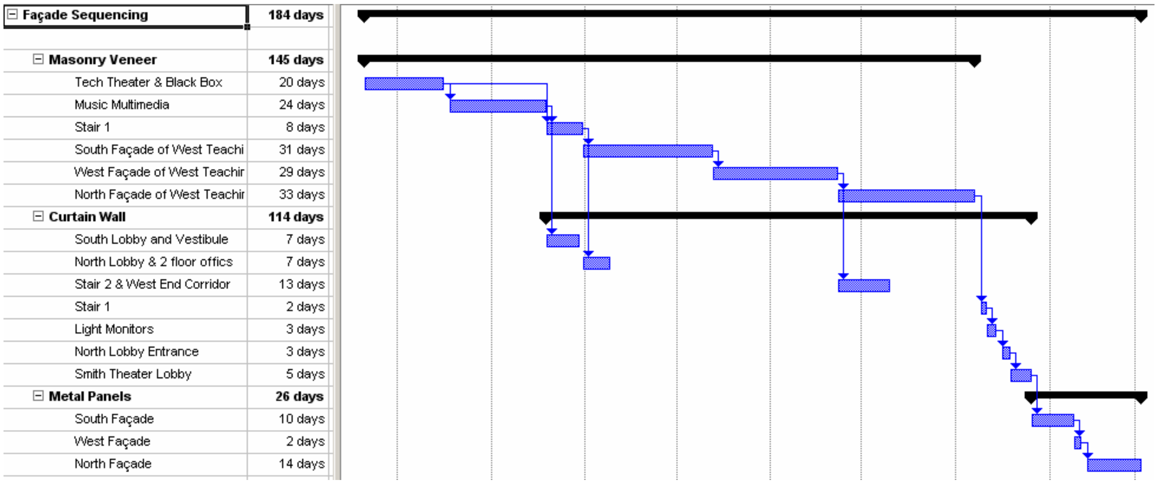
by the time the aluminum panels are installed. Therefore, the aluminum panels are not delaying the interior construction.

After reviewing the observations, specific goals are made to improve the scheduling sequence.

- Find a continuous work flow for the masonry veneer and curtain wall.
- Find a continuous work flow for the curtain wall.
- Group the curtain wall construction activities together.

The objective is to develop a continuous flow to make a more efficient construction schedule. Several alternatives are listed below.

The original sequence is the baseline for which all other alternatives will be compared. The original bar schedule is the following:

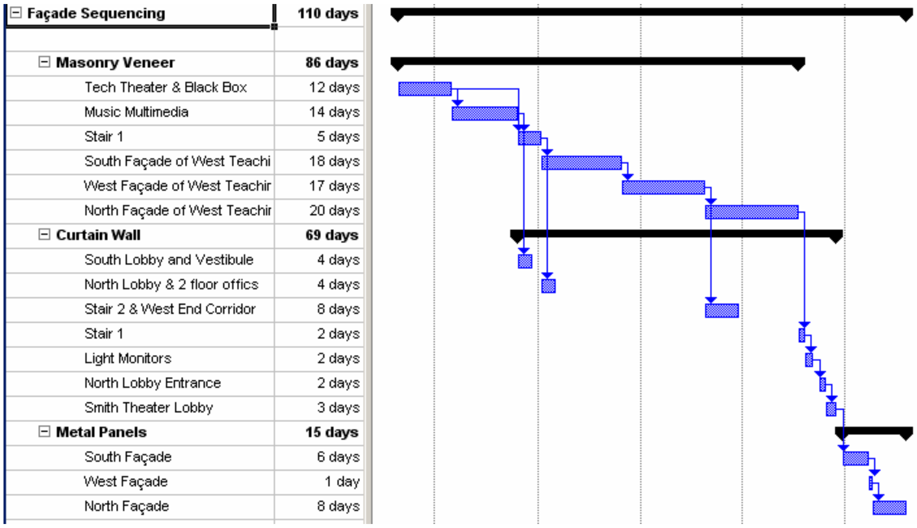


⊟ **Façade Sequencing**	**184 days**
⊟ **Masonry Veneer**	**145 days**
Tech Theater & Black Box	20 days
Music Multimedia	24 days
Stair 1	8 days
South Façade of West Teachi	31 days
West Façade of West Teachir	29 days
North Façade of West Teachir	33 days
⊟ **Curtain Wall**	**114 days**
South Lobby and Vestibule	7 days
North Lobby & 2 floor offics	7 days
Stair 2 & West End Corridor	13 days
Stair 1	2 days
Light Monitors	3 days
North Lobby Entrance	3 days
Smith Theater Lobby	5 days
⊟ **Metal Panels**	**26 days**
South Façade	10 days
West Façade	2 days
North Façade	14 days

Alternative A

One possible alternative is to add additional construction crews to the project. The additional crews will compress the schedule, with the objective being to bring the curtain wall construction activities closer together. With additional crews, the façade will be constructed faster, but not at double the rate. Adding workers to the crew does have a few drawbacks. A loss of productivity will be encountered when there are too many members in the crew. The loss of productivity will be

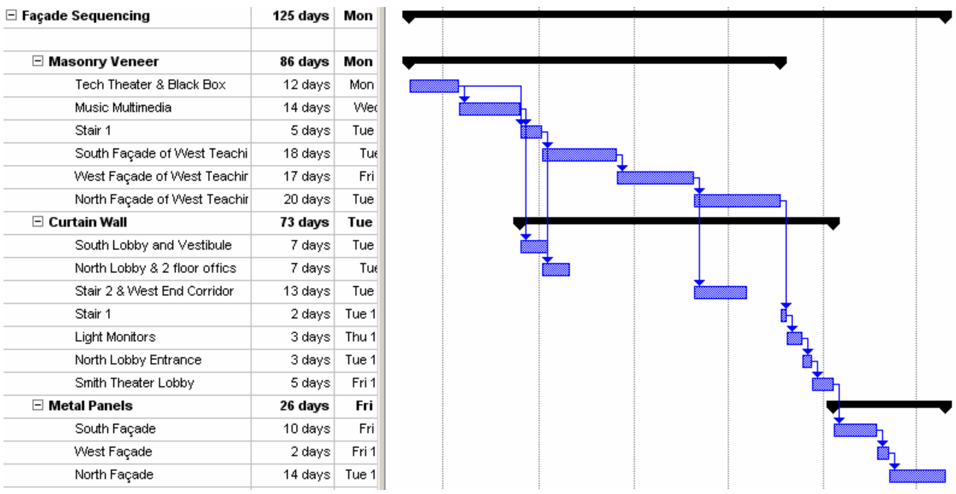
compensated for when calculating the construction duration by reducing the daily output by 15%. Detailed estimates of all associated costs and durations can be found in Appendix B. The following schedule is developed from Alternative A.



Façade Sequencing	**110 days**
Masonry Veneer	**86 days**
Tech Theater & Black Box	12 days
Music Multimedia	14 days
Stair 1	5 days
South Façade of West Teachi	18 days
West Façade of West Teachir	17 days
North Façade of West Teachir	20 days
Curtain Wall	**69 days**
South Lobby and Vestibule	4 days
North Lobby & 2 floor offics	4 days
Stair 2 & West End Corridor	8 days
Stair 1	2 days
Light Monitors	2 days
North Lobby Entrance	2 days
Smith Theater Lobby	3 days
Metal Panels	**15 days**
South Façade	6 days
West Façade	1 day
North Façade	8 days

Alternative B

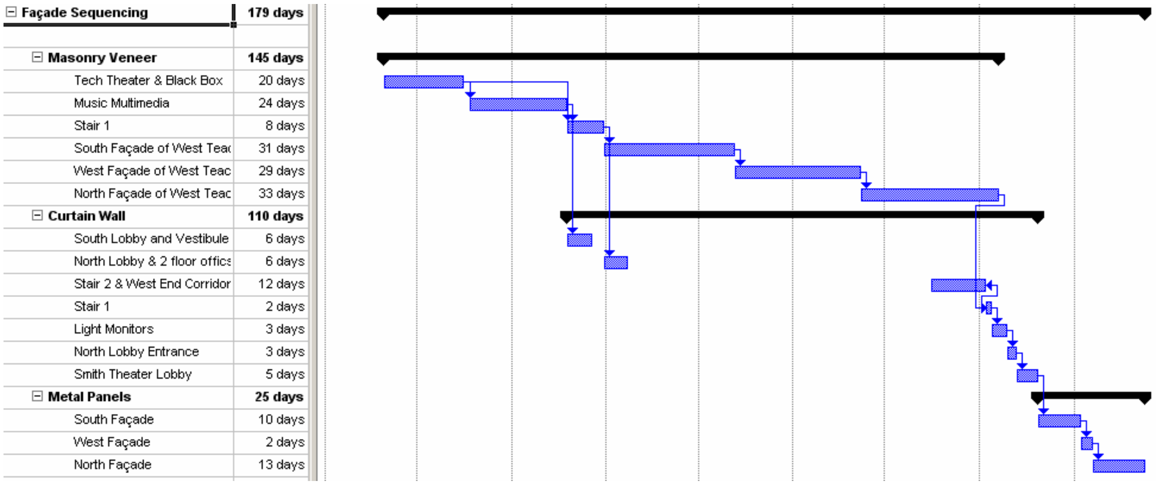
Another alternative is to add an additional construction crew to the masonry veneer crew only. The construction will work in the same sequence. The previous alternative only compressed the schedule at the same rate, while leaving the construction of the curtain wall still broken. Additional masonry crews will shorten the schedule, with the objective being to bring the curtain wall construction activities closer together. The same loss of productivity will be applied to the masonry crews as the previous alternative.



⊟ **Façade Sequencing**	**125 days**	**Mon**
⊟ **Masonry Veneer**	**86 days**	**Mon**
Tech Theater & Black Box	12 days	Mon
Music Multimedia	14 days	Wed
Stair 1	5 days	Tue
South Façade of West Teachi	18 days	Tue
West Façade of West Teachir	17 days	Fri
North Façade of West Teachir	20 days	Tue
⊟ **Curtain Wall**	**73 days**	**Tue**
South Lobby and Vestibule	7 days	Tue
North Lobby & 2 floor offics	7 days	Tue
Stair 2 & West End Corridor	13 days	Tue
Stair 1	2 days	Tue 1
Light Monitors	3 days	Thu 1
North Lobby Entrance	3 days	Tue 1
Smith Theater Lobby	5 days	Fri 1
⊟ **Metal Panels**	**26 days**	**Fri**
South Façade	10 days	Fri
West Façade	2 days	Fri 1
North Façade	14 days	Tue 1

Alternative C

This alternative sequence attempts to group the curtain wall in a more continuous construction pattern. The activity of constructing the curtain wall at stair tower #2 and the west corridor is moved to later in the project. This results in the curtain wall construction being less intermittent. Now, a longer work period exists at the end of the process, instead of a 4-week stoppage. In addition, a phased construction sequence of the north façade is proposed. If the curtain wall construction on the north façade is phased-in with masonry veneer on the north façade, the efficiency of the curtain wall construction is improved.



⊟ **Façade Sequencing**	**179 days**
⊟ **Masonry Veneer**	**145 days**
Tech Theater & Black Box	20 days
Music Multimedia	24 days
Stair 1	8 days
South Façade of West Teac	31 days
West Façade of West Teac	29 days
North Façade of West Teac	33 days
⊟ **Curtain Wall**	**110 days**
South Lobby and Vestibule	6 days
North Lobby & 2 floor offics	6 days
Stair 2 & West End Corridor	12 days
Stair 1	2 days
Light Monitors	3 days
North Lobby Entrance	3 days
Smith Theater Lobby	5 days
⊟ **Metal Panels**	**25 days**
South Façade	10 days
West Façade	2 days
North Façade	13 days

Alternative D

The final alternative investigated is to remove the aluminum panels from the stair towers and replace with masonry veneer. This is chosen because it provides for a continuous flow of masonry veneer. By eliminating the aluminum panels at the stair tower, the masonry crew can work in a more logical sequence from the south façade to the west façade and finally the north façade.

Re-sequencing Results & Costs

Detailed calculations can be found in Appendix B.

The results from re-sequencing demonstrate the following financial and logistical changes.

		Additional	Additional	
	Duration	Labor Costs	General Conditions Costs	Total Difference
Original Design	37 weeks	$ -	$ -	$ -
Alternative A	22 weeks	$71,208	($203,160)	($131,952)
Alternative B	25 weeks	$50,565	($162,528)	($111,963)
Alternative C	36 weeks	$ -	$ -	$ -
Alternative D	39 weeks	$23,058	$27,088	$50,146

Original Design

This sequence doesn't allow for a continuous flow of work causing an inefficient construction process.

Alternative A

Alternative A focused on productivity rates, and although the construction schedule was faster, the sequence is no better than the original design. Also, it is unknown whether the subcontractor is able to even provide the additional crews required.

Alternative B

Alternative B is problematic for the same reason as Alternative A. The sequence is not improved and the possibility of additional crews is unknown.

Alternative C

This schedule provides the most logical sequence of construction. The curtain wall activities are grouped closer together although not completely sequential. A more efficient and practical sequence is followed with this proposed schedule. Some drawbacks include the fact that the curtain wall crew is closely following the masonry crew, which could be a problem if the masonry slows down during the construction of the north façade.

Alternative D

Although this option is explored, it is not the most practical of alternatives. The addition of face brick drove up the cost compared to the aluminum panels. See Appendix B. Also, the aesthetics are altered, which would require owner approval to accept this change.

Conclusion

Although some alternative methods for constructing the façade exist, there may be a few reasons not to shorten the schedule. One possible reason is the lead time of construction materials. The façade materials may not be at the jobsite in time for a faster construction sequence. Other construction materials in the next phase of construction such as interior materials may have a long lead time and accelerating the schedule too much will only leave an idle site while the materials are still being delivered. Also, a condensed schedule may not leave enough float days in the schedule incase of bad weather or unforeseen circumstances.

The most logical sequence of construction to recommend is Alternative C. This sequence adds no additional costs and even reduces the façade schedule by a week. Alternative C is good choice because the sequencing of construction makes sense. The curtain wall construction is grouped for a better continuous flow. Phasing the northern façade is concluded to be the most reasonable and logical solution.

WASTE MANAGEMENT

Objective

The objective is to develop a waste management plan for the AHIB that would use construction materials more efficiently and recycle the scrap material generated onsite. An effective plan promotes a more efficient use of construction materials during installation, reduces the amount of debris being sent to landfills, and helps the environment. For the AHIB project, a 50% recycling goal is set.

What is Waste Management?

Waste management is the practice of waste reduction that includes prevention, salvage, deconstruction, and recycling (Construction Waste Management Guide). For the purpose of this analysis, the majority of the focus will be on recycling, which entails the separation and recycling of recoverable waste materials generated during construction and remodeling. Packaging, new material scraps, old materials, and debris all constitute potentially recoverable materials (www.greenbuilder.com).

A good waste management plan is implemented very early in the project's life, typically in the design phase. However, to be effective, a good plan is constantly being monitored during the construction phase as well. It is very important to set waste reduction goals for each project, to monitor the goals, and set new goals as they become necessary.
Nonresidential construction accounts for approximately 57% of the debris generated in the United States. The following table summarizes the generation of building-related construction and demolition debris.

Source	Residential		Nonresidential		Totals	
	Thou Tons	%	Thou Tons	%	Thou Tons	%
Construction	6,560	11	4,270	6	10,830	8
Renovation	31,900	55	28,000	36	59,900	44
Demolition	19,700	34	45,100	58	64,800	48
Totals	58,160	100	77,370	100	135,530	100
Percent	43		57		100	

Source: Franklin Associates

Typically, wood is the material that generates the most debris on construction and renovation sites. Commonly, the debris from a construction site is taken to a landfill. An estimated 35 to 40 percent of construction debris was discarded in landfills in 1996.

Why do it?

There are several important reasons why an owner may ask for a waste management plan or a construction management team may implement one. Most good construction management companies would want to implement a waste management plan on their site to promote the efficient use of material. Salvaging construction material that can be used for another project or even the same project will reduce the cost of material by using pieces that in the past may have been thought of as scrap material. As the owner and operator of the AHIB, Howard CC wants to have a building of which they can be proud. Using environmentally friendly construction methods can go a long way to improve the public perception of the building and its owners. Also, tax credits are available to the owner if certain requirements are fulfilled involving green construction such as recycling (www.aicpa.org). Recycling material also provides some benefits in cost savings. It can be cheaper to send certain materials to recycling centers than to send them to a landfill.

What can be recycled?

The most common materials that are recovered and recycled are concrete, asphalt, metals and wood. However, many more construction-generated materials can be recycled. There are many recycling centers located in Maryland, and each one specializes in recycling different materials.

Materials that are commonly recycled include:

- Bricks
- Cardboard
- Carpet
- Concrete
- Drywall
- Paint
- Wood
- Window Glass
- Metals

For this analysis, wood, concrete and gypsum board will be the main focus of materials that are recycled. The LEED (Leadership in Energy and Environmental Design) requirements specify different levels of recycling rates for achieving points. One, two, or three points may be earned for achieving a 50%, 75%, or 90% recycling rate, respectively. Additional points may be earned for salvaged, refurbished, or reused materials.

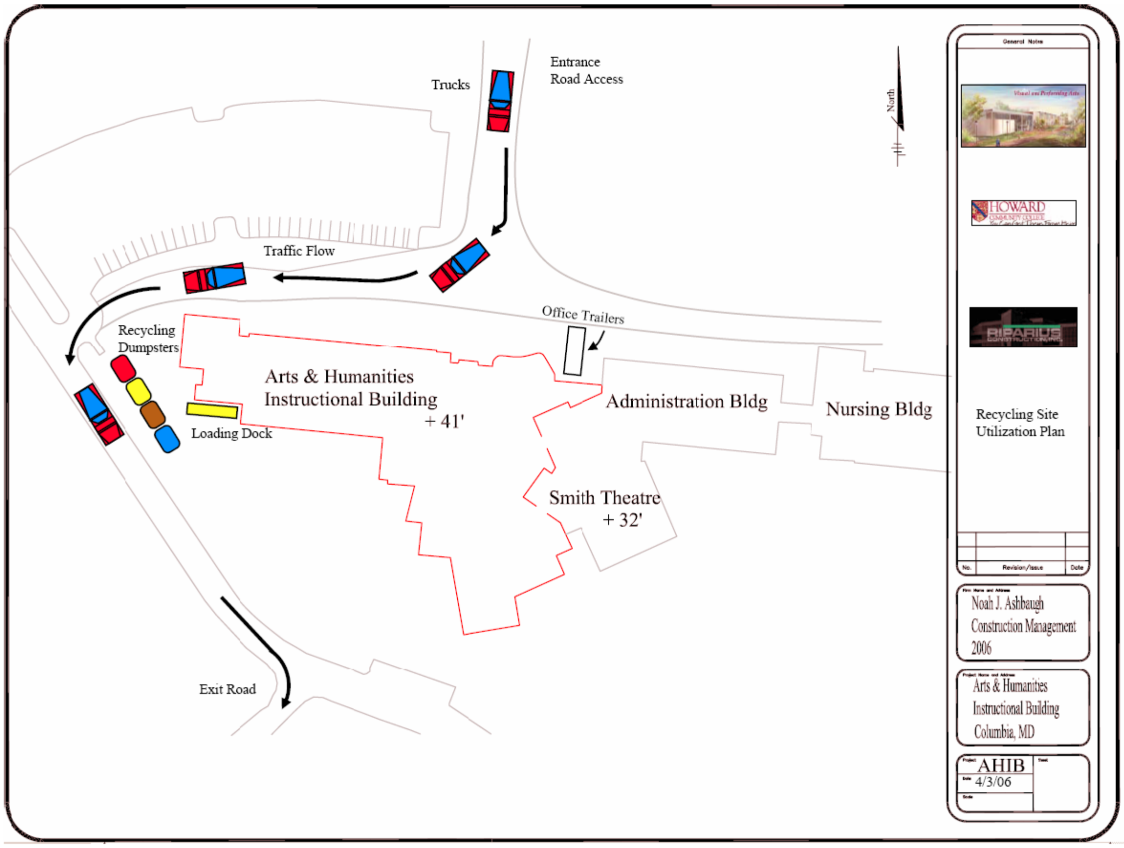
Where can it be recycled?

Several recycling centers have been identified near the location of the project. (www.mdrecycles.org)

Name of Center	Distance from jobsite	Materials Accepted
Baltimore Scrap Corporation	40 miles	Scrap Metals
Better Composting, Inc.	42 miles	Gypsum Board
Benjer, Inc.	37 Miles	Concrete, Wood, Brick

Site Plan

The site of the AHIB is a little congested, making planning for waste removal an important step in the waste management process. A site plan is developed for the flow of waste material and truck logistics through the site. Specific recycling bins are established for different materials that are encountered and are to be recycled. An area on the site is designated for the recycling bins. The bins need to stay easily accessible to both the pick up trucks as well as the construction workers who will be depositing the material into the bins. Therefore, the bins are kept close to the construction road as well as to the loading dock at the rear of the building.



Recycling Costs?

Several factors are associated with the cost of removing construction debris from the job site. They include: a tipping fee, which is the cost of either cubic yards or tons of material for a recycler or landfill to accept the material; a hauling fee, the cost of picking up the debris and hauling it back to the landfill or recycling plant; and the dumpster rental fee. Recycling plants are set up to accept one material or another, and because of this, separate dumpsters need to be designated at the jobsite for easy and efficient separation of materials. Having multiple dumpsters, each designated for a certain material, takes up room on the jobsite, making site planning an important task. Also, some additional time is required for separating the materials as opposed to just putting all the debris in one dumpster. However, this labor cost is not explored in the study. The major focus of the analysis is to determine the material and hauling costs of recycling versus not recycling.

The exact material cost of recycling the specified materials is listed in a cost evaluation table in Appendix C. In summary, recycling 50% of the wood, gypsum, and concrete will save approximately $2,500 compared to not recycling.

Conclusion

Although the AHIB project currently has no recycling or waste management plan established, implementing a plan could be easily achieved. Not only will a waste management plan reinforce the idea of minimizing construction waste, it promotes recycling materials. It was shown that recycling 50% of the wood, gypsum and concrete could actually save approximately $2,500 over the length of the project. Because recycling costs less per total tonnage of material, the more material that is recycled, the more money will be saved. From the waste management analysis, a well-planned program will save money and is therefore recommended for the AHIB project.

FINAL CONCLUSION

ROOF SYSTEM ANALYSIS

The analysis of the roof systems compared two different roof systems: a 4-ply built-up roof system and a green roof system. The analysis compared the structural load requirements and the potential mechanical systems savings. Installation costs and material costs are an important part of the comparison. As shown in the final report, the structural and mechanical requirements of the two systems are too similar to result in any significant financial savings. However, the installation costs of the built-up roof are substantially less than the green roof system. The final recommendation is to construct the AHIB with a traditional 4-ply built-up roof. From material and installation costs, $45,417 will be saved if the built-up roof system is chosen. This amount represents only the difference when comparing a small portion of the roof area. The total difference would be larger, approximately $316,748, if the costs are compared for the entire roof.

FAÇADE SEQUENCING

The complex shape of the AHIB and the multiple materials of the façade make coordination and planning especially important when constructing the façade. After analysis, it is concluded that the sequencing of the façade installation can be improved. Several alternatives are explored, each with their own advantages and disadvantages. Ultimately, one sequence is chosen above the others based on the efficiency and the continuous work flow it provides. Although only one week of construction is saved in using an alternative schedule, the sequence will provide more flexibility for the installer of the curtain wall. The final conclusion and recommendation based on the analysis is to select Alternative C.

WASTE MANAGEMENT

Waste management is becoming increasingly more important in the construction industry. This analysis demonstrated that when recycling even a small portion, only 50% of certain construction materials, an owner can expect to incur a financial savings. The waste management plan proposed for the AHIB recycled wood, concrete, and gypsum, and identified recycling centers to recycle the waste instead of taking it to a landfill. The savings for the AHIB is expected to be $2,500 if the plan is followed. However, if a stricter recycling plan is adopted and a higher percentage of materials are recycled, the savings will increase. The waste management plan proposed would be effective and should be implemented in the AHIB project.

Appendix A

Uniform green roof and weight of beam: w = 5’P + 12 lb/ft

W 10 x 12 Beam 17ft in length

Shear $V_{max} = \frac{wL}{2} = 8.5\text{'}w$

ΦV_n comes from the AISC LRFD Manual of Steel Construction, 3rd Edition

$\Phi V_n = 50.6 \text{ k} \geq V_u = 8.5\text{'} \, w$

Solving for w:

$w \leq 5.95 \text{ k/ft}$

Moment $M_{max} = \frac{wL^2}{8} = 36.125\text{'}w$

ΦM_{rx} comes from the AISC LRFD Manual of Steel Construction, 3rd Edition

$\Phi M_{rx} = 32.7 \text{ `k} \geq M_u = 36.125\text{'} \, w$

Solving for w:

$w \leq 0.905 \text{ k/ft}$

Deflection

$$\frac{L}{240} \geq \frac{5}{384}\frac{wL^4}{EI_x}$$

Solving for w:

$$w \leq 0.705 \text{ k/ft}$$

W 27 x 84 Girder 40ft in length

Shear

$$V_{max} = \frac{17w \times 7 + 84x40}{2} = 59.5w + 1680 \text{ lbs}$$

ΦV_n comes from the AISC LRFD Manual of Steel Construction, 3rd Edition

$$\Phi V_n = 332 \text{ k} \geq V_u = 59.5\text{ w} + 1.680$$

Solving for w:

$$w \leq 5.55 \text{ k/ft}$$

$w' = 7*17w / 40 = 2.975\text{ w}$

Moment

$$M_{max} = \frac{w'L^2}{8} + \frac{w'L^2}{8} = 595w + 16800\text{'lb}$$

ΦM_{rx} comes from the AISC LRFD Manual of Steel Construction, 3rd Edition

$$\Phi M_{rx} = 915\text{ 'k} \geq M_u = 595w + 16800\text{'lb}$$

Solving for w:

$$w \leq 1.50 \text{ k/ft}$$

Deflection

$$\frac{L}{240} \geq \frac{5}{384}\frac{wL^4}{EI_x}$$

Solving for w:

$$w \leq 2.86 \text{ k/ft}$$

The limiting factor in this case is the deflection for the beam. The next step is to solve for P, the maximum load of the green roof.

$$w \leq 0.705 \text{ k/ft}$$

$$705\text{lb/ft} \geq 5'P + 12 \text{ lb/ft}$$

$$P \leq 138.6 \text{ psf}$$

From the structural steel drawings, the design loads are noted to be 30 psf for live and 19.3 for snow. With the appropriate factors applied, the following equation must be solved for the green roof load being treated as a dead load.

$$138.6 \text{ psf} \geq 1.6\ (30) + .5\ (19.3) + 1.2\ x$$

$$x \leq 67 \text{ psf}$$

Howard Community College
Arts & Humanities Instructional Building
Assemblies Estimate Details
April 3, 2005

Noah J. Ashbaugh
Construction Management

UNIT COST DETAILS

Roof, 4ply built up roof

		Unit Costs			Total Costs		
	Unit	Mat.	Inst	Total	Mat.	Inst	Total
3,648 sf of 4ply built up roof	sf	0.62	1.09	1.71	$ 2,261.76	$ 3,976.32	$ 6,238.08
	Total				$ 2,261.76	$ 3,976.32	$ 6,238.08
					Tax	5%	$ 6,549.98
					Overhead	7%	$ 7,008.48
					Profit	3.50%	$ 7,253.78
							$ 7,253.78

Cost is to supply and install
includes location factor

Scheduling Information

Daily Output	2,000	sf

Duration = Total SF / Daily Output

Duration	2	days
	0.4	wks

UNIT COST DETAILS

Extensive Greenroof

		Unit Costs			Total Costs		
	Unit	Mat.	Inst	Total	Mat.	Inst	Total
3,648 sf of Extensive Greenroof	sf			14.43	$ -	$ -	$ 52,640.64
	Total				$ -	$ -	$ 52,640.64

Cost is to supply and install
includes overhead, profit, location factor and general conditions and tax

Scheduling Information

Daily Output	1,800	sf

Duration = Total SF / Daily Output

Duration	3	days
	0.6	wks

Appendix B

Activity Duration Calculations

Original Design	SF	Production Rate	Days to complete
Masonry Veneer		sf/day	
Tech Theater & Black Box	2,800	145	20
Music Multimedia	3,344	145	24
Stair 1	1,122	145	8
South Façade of West Teaching Wing	4,382	145	31
West Façade of West Teaching Wing	4,064	145	29
North Façade of West Teaching Wing	4,780	145	33
Curtain Wall	-		
South Lobby and Vestibule	1,096	180	7
North Lobby & 2 floor offics	1,140	180	7
Stair 2 & West End Corridor	2,220	180	13
Stair 1	320	180	2
Light Monitors	480	180	3
North Lobby	480	180	3
Smith Theater Lobby	756	180	5
Metal Panels	-		
South Façade	2,376	250	10
West Façade	340	250	2
North Façade	3,328	250	14

Alternative A			
Original Design, crew size x 2	SF	Production Rate	Days to complete
Masonry Veneer, 2 crews		sf/day	
Tech Theater & Black Box	2,800.00	246.50	12.00
Music Multimedia	3,344.00	246.50	14.00
Stair 1	1,122.00	246.50	5.00
South Façade of West Teaching Wing	4,382.00	246.50	18.00
West Façade of West Teaching Wing	4,064.00	246.50	17.00
North Façade of West Teaching Wing	4,780.00	246.50	20.00
Curtain Wall, 2 crews	-		
South Lobby and Vestibule	1,096.00	306.00	4.00
North Lobby & 2 floor offics	1,140.00	306.00	4.00
Stair 2 & West End Corridor	2,220.00	306.00	8.00
Stair 1	320.00	306.00	2.00
Light Monitors	480.00	306.00	2.00
North Lobby	480.00	306.00	2.00
Smith Theater Lobby	756.00	306.00	3.00
Metal Panels, 2 crews	-		
South Façade	2,376.00	425.00	6.00
West Façade	340.00	425.00	1.00
North Façade	3,328.00	425.00	8.00

Alternative B			
Original Design	SF	Production Rate	Days to complete
Masonry Veneer, 2 crews		sf/day	
Tech Theater & Black Box	2,800.00	246.50	12.00
Music Multimedia	3,344.00	246.50	14.00
Stair 1	1,122.00	246.50	5.00
South Façade of West Teaching Wing	4,382.00	246.50	18.00
West Façade of West Teaching Wing	4,064.00	246.50	17.00
North Façade of West Teaching Wing	4,780.00	246.50	20.00
Curtain Wall	-		
South Lobby and Vestibule	1,096.00	180.00	7.00
North Lobby & 2 floor offics	1,140.00	180.00	7.00
Stair 2 & West End Corridor	2,220.00	180.00	13.00
Stair 1	320.00	180.00	2.00
Light Monitors	480.00	180.00	3.00
North Lobby	480.00	180.00	3.00
Smith Theater Lobby	756.00	180.00	5.00
Metal Panels	-		
South Façade	2,376.00	250.00	10.00
West Façade	340.00	250.00	2.00
North Façade	3,328.00	250.00	14.00

Alternative D			
Redesign	SF	Production Rate	Days to complete
Masonry Veneer		sf/day	
Tech Theater & Black Box	2,800.00	145.00	20.00
Music Multimedia	3,344.00	145.00	24.00
Stair 1	1,122.00	145.00	8.00
South Façade of West Teaching Wing	6,482.00	145.00	45.00
West Façade of West Teaching Wing	4,404.00	145.00	31.00
North Façade of West Teaching Wing	5,380.00	145.00	38.00
Curtain Wall, 2 crews	-		
South Lobby and Vestibule	1,096.00	180.00	7.00
North Lobby & 2 floor offics	1,140.00	180.00	7.00
Stair 2 & West End Corridor	2,220.00	180.00	13.00
Stair 1	320.00	180.00	2.00
Light Monitors	480.00	180.00	3.00
North Lobby	480.00	180.00	3.00
Smith Theater Lobby	756.00	180.00	5.00
Metal Panels, 2 crews	-		
South Façade	-	250.00	-
West Façade	-	250.00	-
North Façade	3,004.00	250.00	13.00

Production Rate Calculations

One Crew:

Production rates and the associated labor for each system is the following, based on one crew.

Masonry: 145 square feet daily output = 141 days = 28 weeks

Curtain Wall: 180 square feet daily output = 36 days = 8 weeks

Aluminum Panels: 250 square feet daily output = 25 days = 5 weeks

The curtain wall and aluminum panels are scheduled to start after 85% of the masonry was is complete. For one crew on the job 85% completion will be at about week 24. This will cause an estimated overlap of four weeks. With this four week overlap the total duration of the façade erection is 37 weeks.

General conditions costs = $13,544 / wk x 37 wks = $ 501,128

Man hours:

Masonry = 5 man crew x 8 hr work day x 142 days = 5,680 man hours

Curtain Wall = 4 man crew x 8 hr work day x 37 days = 1,184 man hours

Aluminum Panels = 4 man crew x 8 hr work day x 25 days = 800 man hours

Labor Costs:

Masonry = 5,680 man hours x $48.62 / mh = $276,162

Curtain Wall = 1,184 man hours x $59.08 / mh = $69,951

Aluminum Panels = 800 man hours x $46.31 / mh = $37,048

Total labor costs = $383,160

Total cost (general conditions + labor costs) = $884,288

Two Crews:

Production rates and the associated labor for each system is the following, based on two crews each. A 15% loss of productivity is applied to all output.

Masonry: 247 square feet daily output = 83 days = 17 weeks
Curtain Wall: 306 square feet daily output = 21 days = 4 weeks
Aluminum Panels: 425 square feet daily output = 14 days = 3 weeks

The curtain wall and aluminum panels are scheduled to start after 85% of the masonry was is complete. For one crew on the job 85% completion will be at about week 15. This will cause an estimated overlap of two weeks. With this two week overlap the total duration of the façade erection is 22 weeks.

General conditions costs = $13,544 / wk x 22 wks = $ 297,968

Man hours:

Masonry = 10 man crew x 8 hr work day x 83 days = 6,650 man hours
Curtain wall = 8 man crew x 8 hr work day x 21 days = 1,357 man hours
Aluminum Panels = 8 man crew x 8 hr work day x 14 days = 910 man hours

Labor Costs:

Masonry = 6,640 man hours x $48.62 / mh = $323,350
Curtain wall = 1,344 man hours x $59.08 / mh = $80,219
Aluminum Panels = 896 man hours x $46.31 / mh = $42,149

Total labor costs = $445,718

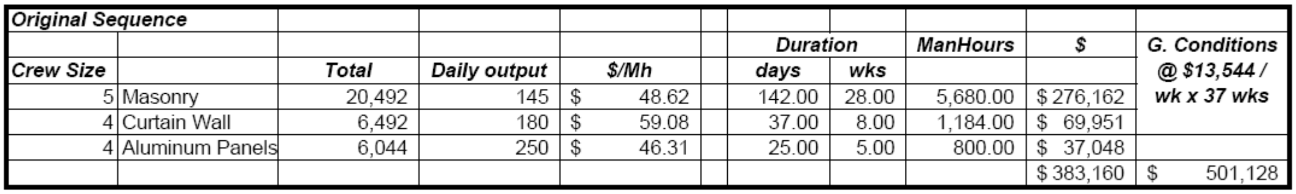
Total cost (general conditions + labor costs) = $743,686

Conclusion:

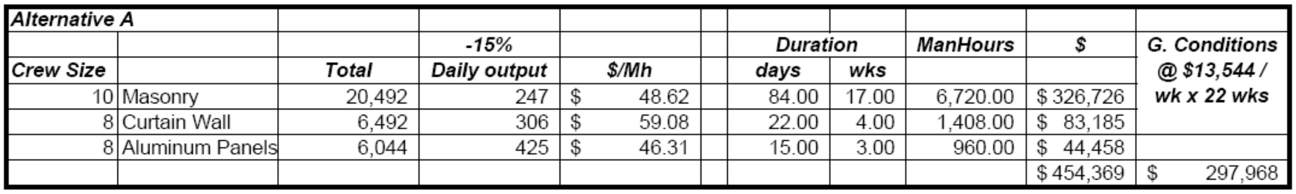
Additional cost of labor for two crews: $ 62,558
Savings from general conditions: $ 203,160

Total Savings: $140,602 and 15 weeks on the construction schedule

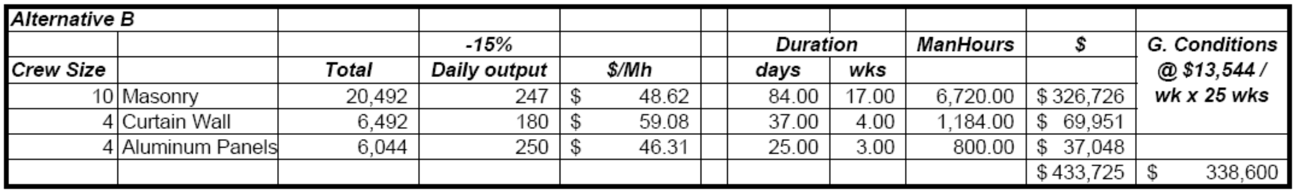
Cost Calculations



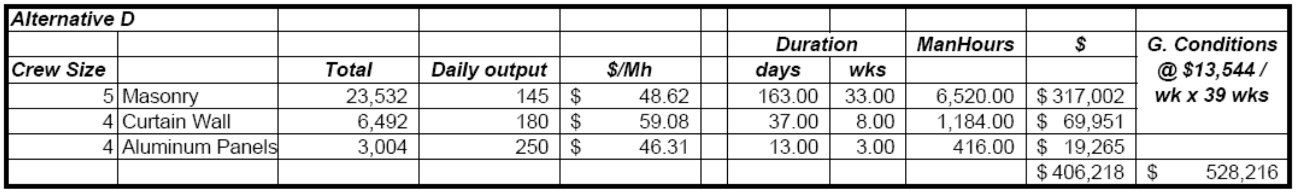
Original Sequence										
						Duration		***ManHours***	***$***	***G. Conditions***
Crew Size		***Total***	***Daily output***	***$/Mh***		***days***	***wks***			***@ $13,544 /***
5	Masonry	20,492	145	$ 48.62		142.00	28.00	5,680.00	$ 276,162	***wk x 37 wks***
4	Curtain Wall	6,492	180	$ 59.08		37.00	8.00	1,184.00	$ 69,951	
4	Aluminum Panels	6,044	250	$ 46.31		25.00	5.00	800.00	$ 37,048	
									$ 383,160	$ 501,128



Alternative A										
			-15%			***Duration***		***ManHours***	***$***	***G. Conditions***
Crew Size		***Total***	***Daily output***	***$/Mh***		***days***	***wks***			***@ $13,544 /***
10	Masonry	20,492	247	$ 48.62		84.00	17.00	6,720.00	$ 326,726	***wk x 22 wks***
8	Curtain Wall	6,492	306	$ 59.08		22.00	4.00	1,408.00	$ 83,185	
8	Aluminum Panels	6,044	425	$ 46.31		15.00	3.00	960.00	$ 44,458	
									$ 454,369	$ 297,968



Alternative B										
			-15%			***Duration***		***ManHours***	***$***	***G. Conditions***
Crew Size		***Total***	***Daily output***	***$/Mh***		***days***	***wks***			***@ $13,544 /***
10	Masonry	20,492	247	$ 48.62		84.00	17.00	6,720.00	$ 326,726	***wk x 25 wks***
4	Curtain Wall	6,492	180	$ 59.08		37.00	4.00	1,184.00	$ 69,951	
4	Aluminum Panels	6,044	250	$ 46.31		25.00	3.00	800.00	$ 37,048	
									$ 433,725	$ 338,600



Alternative D										
						Duration		***ManHours***	***$***	***G. Conditions***
Crew Size		***Total***	***Daily output***	***$/Mh***		***days***	***wks***			***@ $13,544 /***
5	Masonry	23,532	145	$ 48.62		163.00	33.00	6,520.00	$ 317,002	***wk x 39 wks***
4	Curtain Wall	6,492	180	$ 59.08		37.00	8.00	1,184.00	$ 69,951	
4	Aluminum Panels	3,004	250	$ 46.31		13.00	3.00	416.00	$ 19,265	
									$ 406,218	$ 528,216

Assembly Estimate Summary

Howard Community College
Arts & Humanities Instructional Building
Assemblies Estimate Breakdown
April 3, 2006

Noah J. Ashbaugh
Construction Management

Comparison Table

ORIGINAL DESIGN				Costs		
	No. of Units			Mat.	Inst.	Total
Curtain Wall	6,492	sf	Total	$ 101,794.6	$ 43,171.8	$ 144,966.4
Masonry Wall	20,492	sf	Total	$ 135,247.2	$ 342,216.4	$ 477,463.6
Prefinished Aluminum Panels	6,044	sf	Total	$ 20,428.7	$ 26,291.4	$ 46,720.1
			Total Cost	$ 257,470.5	$ 411,679.6	$ 669,150.1

REDESIGN				Costs		
	No. of Units			Mat.	Inst.	Total
Curtain Wall	6,492	sf	Total	$ 101,794.6	$ 43,171.8	$ 144,966.4
Masonry Wall	23,532	sf	Total	$ 155,311.2	$ 392,984.4	$ 548,295.6
Prefinished Aluminum Panels	3,004	sf	Total	$ 10,153.5	$ 13,067.4	$ 23,220.9
			Total Cost	$ 267,259.3	$ 449,223.6	$ 716,482.9

	Total Cost	Difference
Original Design	$ 669,150	$ (47,333)
Redesign	$ 716,483	

Appendix C

Construction Debris Generation

Total Building Size	77,000	s.f.
Debris Generation	3.89	lbs/s.f.
Estimated Construction Debris	299,530	lbs
LEED Requirements	50	% Diversion
Goal of Construction Debris to be	149,765	lbs to be diverted

Construction Debris	Generation Rates	Recyclable Material	
Concrete	50%	74,883	lbs
Wood	25%	37,441	lbs
Drywall	10%	14,977	lbs

Recycling Economics Worksheet - Sample

Commercial Hauler

Cost of Recycling

Material	Tons or Yards	Tip Fee	Subtotal 1	# Loads	Hauling Fee	Subtotal 2	# of months	Container Rental	Subtotal 3	Total Cost
Concrete	38	$ 50.00	$ 1,900.00	13	$ 50.00	$ 650.00	13	$ 30	$ 390.00	$ 2,290.00
Wood	19	$ 30.00	$ 570.00	4	$ 50.00	$ 200.00	4	$ 30	$ 120.00	$ 890.00
Drywall	8	$ 45.00	$ 360.00	5	$ 37.50	$ 187.50	5	$ 30.00	$ 150.00	$ 697.50
			$ -			$ -			$ -	$ -
			$ -			$ -			$ -	$ -
			$ -			$ -			$ -	$ -
			$ -			$ -			$ -	$ -
Totals			$ 2,830.00			$ 1,037.50			$ 660.00	$ 3,877.50

Cost of Not Recycling

Material	Tons or Yards	Tip Fee	Subtotal 1	# Loads	Hauling Fee	Subtotal 2	# of Months	Container Rental	Subtotal 3	Total Cost
Construction Debris	65	$ 70.00	$ 4,550.00	22	$ 55.00	$ 1,210.00	$ 22	$ 30.00	$ 660.00	$ 6,420.00

Savings or Cost of Recycling

Cost of Not Recycling	Cost of Reyclcing	**Total Savings**
$ 6,420.00	$ 3,877.50	**$ 2,542.50**

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