Wesley A. Brown Field House
Annapolis, Maryland

Peter Schneck
Construction Management
Final Report
Dr. Riley

Wesley A. Brown Field House

Annapolis, Maryland

UNITED STATES NAVAL ACADEMY

Project Team

Owner: NAVFAC
Architect: HKS Inc.
CM/GC: Hensel Phelps Construction Co.
Mechanical Designer: Kavocs Whitney & Assc.
Electrical Designer: M. C. Dean
Structural Engineer: Thornton Tomasetti Group

Project Overview

Size: 140,000 sqft.
Total Levels: 2 levels including the Mezzanine
Delivery Method: Design-Build
Project Cost: Approximately $45 million
Occupancy: Collegiate mulit-sport atheletic facility

Mechanical

(2) 42,000 CFM AHU to condition the Field Arena
(1) 12,000 CFM AHU for Lockers and Showers
(1) 7,850 CFM AHU for Weight Training & Sports Medicine
Wet pipe fire suppression sprinkler system

Electrical & Lighting

2 Main transformers fed from 13.8kV primary switchgear.
Secondary 480/277 volt, 3 Φ, 4 wire, 60 Hz double ended switchgear.
Pulse start metal hallide luminaires in the field arena.
Emergency and exit lighting will use batteries for back up power.

Architectural Features

The field house has a 6-lane 200m track with hyrdraullically-actuated banked curves that retract to sit flush with surrounding surface.
A roll-out Magic Carpet enables the field house to be transformed into a turf field.
Large curtainwall windows incorporated into the precast panel exterior skin overlooking the Santee Basin.

Structural

Drilled Pressure-Grouted Displacement Piles
Reinforced .25M thick concrete slab.
Structural Steel Columns supporting box trusses
60 mil felt-backed PVC membrane roofwith 4" insulation board and vapor barrier, on 3" metal deck.
Blast resistant precast concrete and curtainwall exterior.

Hensel Phelps Construction Co.

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The Pennsylvania State University
http://www.arche.psu.edu/thesis/eportfolio/2007/portfolios/PJS252/

NAVFAC Naval Facilities Engineering Command

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Executive Summary

This report is analysis of the Wesley A. Brown Field House Project in Annapolis, Maryland, and research into building materials that can be produces from Penn State's coal power plant in State College. This report is separated into six sections including:

- The Project Introduction
- The Project Team Overview
- Existing Conditions
- Project Logistics
- Fabric Ductwork vs. Steel Ductwork (Mechanical Breadth)
- Waterproofing Options
- Fly ash concrete mixes and Autoclave Aerated Concrete (Structural Breadth)
- Penn State's Power Plant and Coal Combustion Products use Building Materials

The first four sections are included to summarize work and research that was done during the fall semester. It provides information that gives a basic introduction to the Wesley A. Brown Field House project.

The following topics is work and research that was done during the spring semester. A comparison between steel and fabric ductwork was completed. Different waterproofing applications were researched for use on the Wesley A. Brown Field were also investigated.

An investigation the structural characteristics of concrete with fly ash as an aggregate was investigated. The application of a concrete mix with fly ash in the Wesley A. Brown Field House was briefly reviewed. Further investigation of Aerated Autoclaved Concrete was performed. These topics lead into the final analysis of this report.

The final analysis contains information on Penn State's Coal Fired Power Plant and its coal combustion products. These products were investigated to see if they could be used in a construction application. An application that would hopefully lead to the use of it on Penn State's campus.

Project Introduction

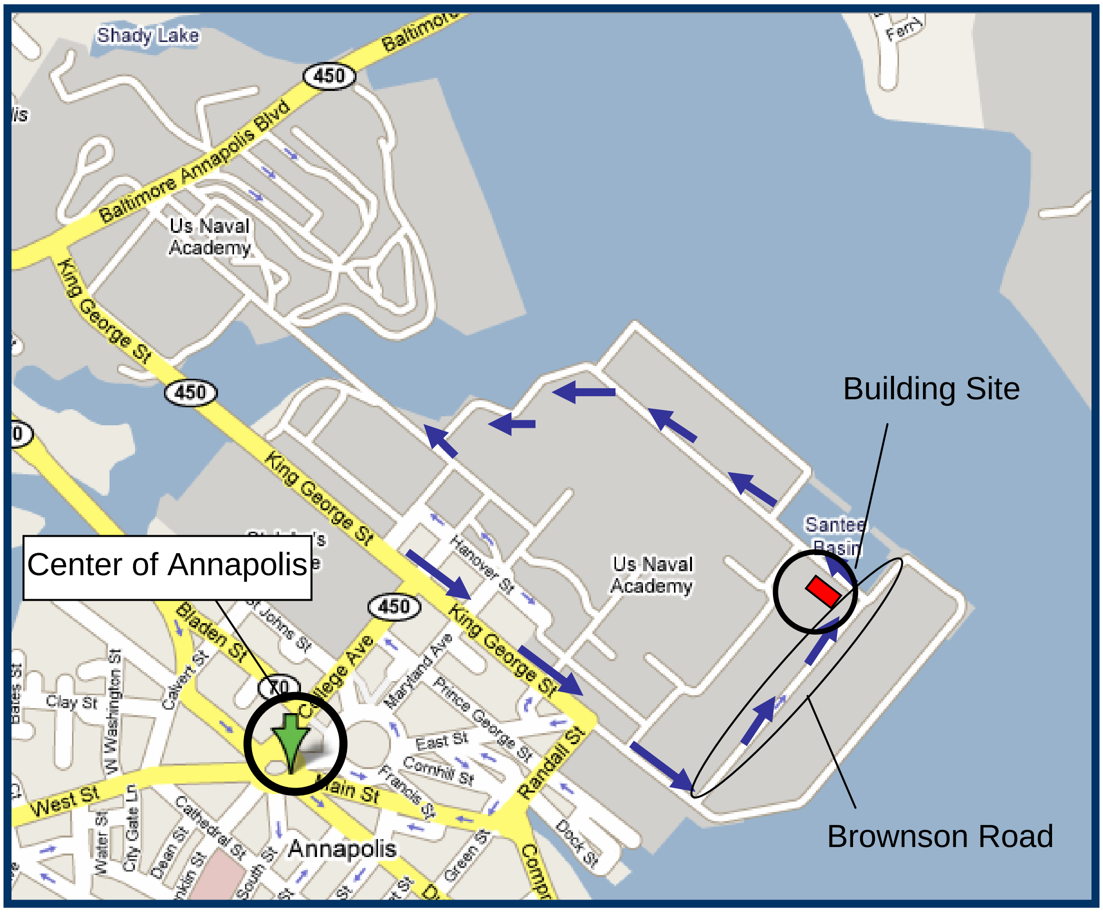
The Wesley A. Brown Field House is a state of the are $45 million dollar athletic facility. It is located on the campus of the United States Naval Academy. The project is the academy's first major project in over 10 years. The Wesley A. Brown Field House was awarded to Hensel Phelps Construction Company. The project started in February of 2006 and will finish in March of 2008.

Wesley A. Brown Field House was awarded as a Design-Build project. The owner, The Naval Facilities Engineering Command, awarded the project on a best value evaluation. Value was determined by past performance, management/technical issues, subcontracting plan, design, staffing plan. The staffing plan was of particular concern, because the government requires a large percentage of the building to be subcontracted to small businesses.

The new Field House that the NAVY intends to build, is a state-of-the-art facility. They believe that in order for the United States Naval Academy to remain one of the United States most prestigious institutions, that it needs the matching facilities for their staff, guests, and students. The project systems will highlight some of the unique features of the Field House including a hydraulic track and a roll-out turf football field.

Site Plan of Existing Conditions

The Wesley A. Brown Field House is located in Annapolis, Maryland only a few miles from the center of the city. The building is located within the United States Naval Academy's campus overlooking the Santee Basin. The site is bounded by existing buildings and two roads; Holloway Road to the Northwest, and Brownson Road to the Southeast. Due to strict regulations of vehicular access on the United States Naval Academy's Campus and the fact that Brownson Road is one way headed Northeast, there is only one viable option for construction material to get to the site. Entering the campus coming from King George Street, then taking a left on Brownson, trucks can deliver materials to the site and then leave taking Halloway Road back off campus.



Site Layout

(Please see Appendix A on page for the Steel / Concrete Phasing Site Layout)

The Site Layout Plan takes a closer look at the Steel / Concrete Placement phase of the Wesley A. Brown Field House. There is limited site access to the jobsite due to the security on the Naval Academy and the one-way streets that lead to the project's entrance. Therefore, careful planning is required for material delivery and placement of both steel and concrete. Steel staging areas will be located on the east side and northwest corner, so that picks can be made of the steel delivery trucks and placed in staging areas that minimize pick lengths. The staging locations also allows for free traffic in and out of the site for concrete trucks. Concrete pumps and hoses are located near gates will ample space for more than one concrete truck to have room to place concrete in the pump, which will prevent a stoppages in a pour. Not only does the Wesley A. Brown Field project need a well organized and functional site plan for the steel and concrete phase of construction, there will always need to be an effort to organize material delivery.

Local Conditions

Wesley A. Brown Field House is located in the center the United State Naval academy in Annapolis Maryland. The site is contained within Brownson and Santee Road on the southeast and northeast sides respectively; and Bancroft and McDonough Halls on the Southwest and Northwest sides respectively. The site is relatively level, ranging from 4 to 8 feet above sea level. Most of the trees that occupied the site have been previously removed, so that the land could be used as a staging and storage area for other construction projects on the campus. All the materials were moved prior to start of construction by Hensel Phelps.

Annapolis is located just Northeast of Washington D.C. Construction in this region have predominately been concrete structures. Although Wesley A. Brown is utilizing a steel frame, precast concrete panels are a major element in the building's envelope.

Hensel Phelps will dedicate a space, no smaller than 275 square feet, for the collection of recyclable materials. Also, at least 10% of all materials used in the construction will contain recycled content.

There is limited parking on the United States Naval Academy. Due to the limited parking availability, Hensel Phelps was only granted minimal area to park vehicles. Also, the academy is a Naval Base. Only those vehicles with proper clearance are allowed on site. Hensel Phelps, to combat the strict regulations and limited area for parking, is providing a shuttle service to a parking lot off the campus to pick up workers.

The soil on site does pose a threat to workers or others on the site, but it does contain petroleum containments. Therefore, any spoils are not allowed to be used fill and must be

disposed of properly. Also, the site stands where the basin waters use to occupy. Over time the academy has expanded its land by continuing to create sea walls further and further out. Due to the poor documentation of this process, excavation has uncovered many unforeseen material such as old bricks, blocks, and shell

Client information

The client for the Wesley A. Brown Field House is the Naval Facilities Engineering Command, and more specifically the United State Naval Academy. The Naval Academy is one of the most prestigious educational institutions in the United States. The Academy's mission first and foremost is to maintain this standing. In order to do so, the Institutional needs to provide adequate facilities to its students and staff.

A number of studies were taken on the facilities of the Naval Academy. These studies suggested that there was a need for a new field house facility. The Navy's intent for Wesley A. Brown Field House, is to provide a state-of-the-art multi-purpose field house for athletic competition. The design and location of the field house will project the Naval Academy's dedication to physical fitness. The project, being the first major construction project in many years, will also be sensitive to the Academy's rich past, but provide a new image for the future.

The United State Naval Academy's major priority for the Wesley A. Brown Field House, to provide quality and ample space for its sports programs. The space program, developed by NAVFAC, was determined after several meetings with athletic staff and Academy officials. The discussion not only included the need for updates of current facilities, but the potential for growth in the future. Through this, and statements included within the RFP, such as "state-of-the-art" and "world class," it is clear that the Academy's major focus is the quality of the Wesley A. Brown Field House. The Naval Academy wants the design and construction of the field house to superior and the functionality for the athletes, spectators, and broadcasters excellent.

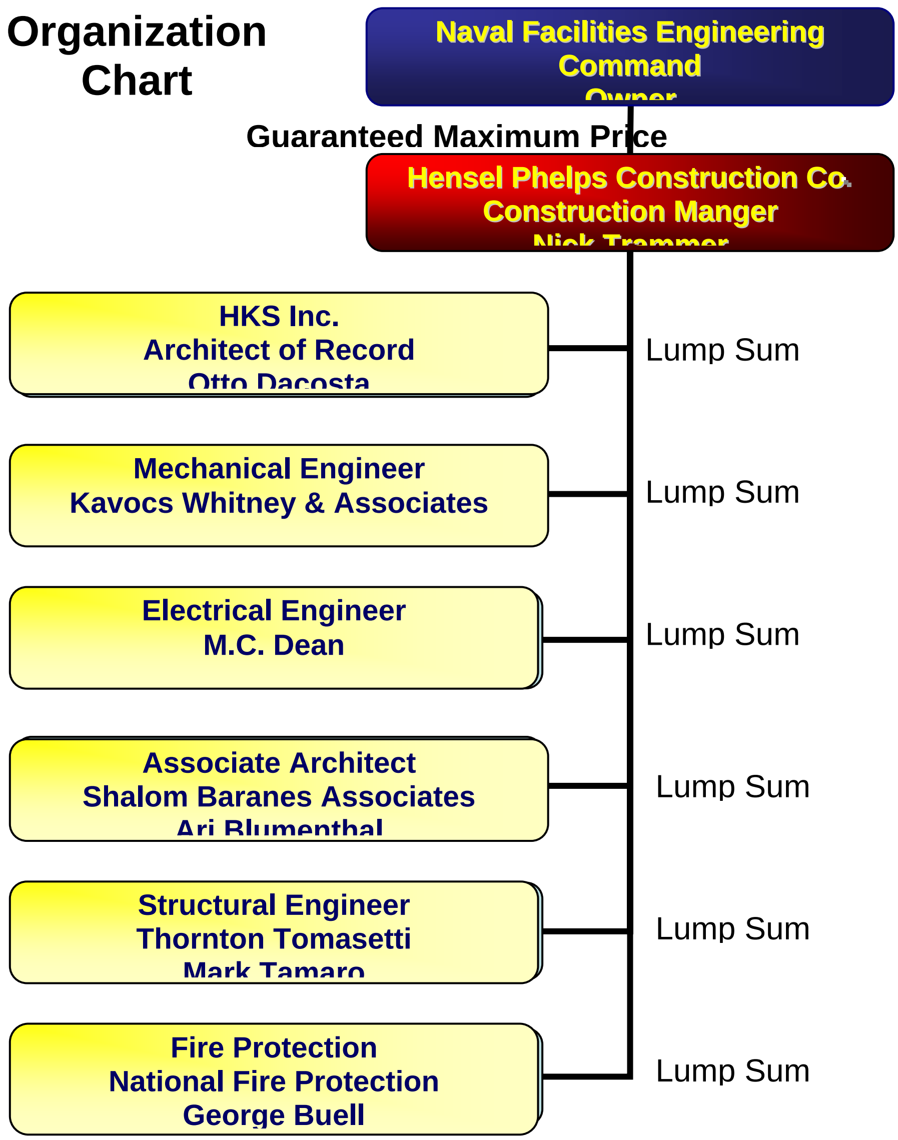
Project Delivery System

The delivery method for the Wesley A. Brown Field House is Design-Build. The United States Naval Academy pre-qualified bidders based on the past performance of highly rated competitors. Only 4 bidders, including Hensel Phelps, were pre-qualified. The pre-qualified bidders were judged on factors including past performance, technical/management factors, subcontracting plans, design, and their staffing plan. The Government selected the contractor whom they felt gave them the best value for their money.

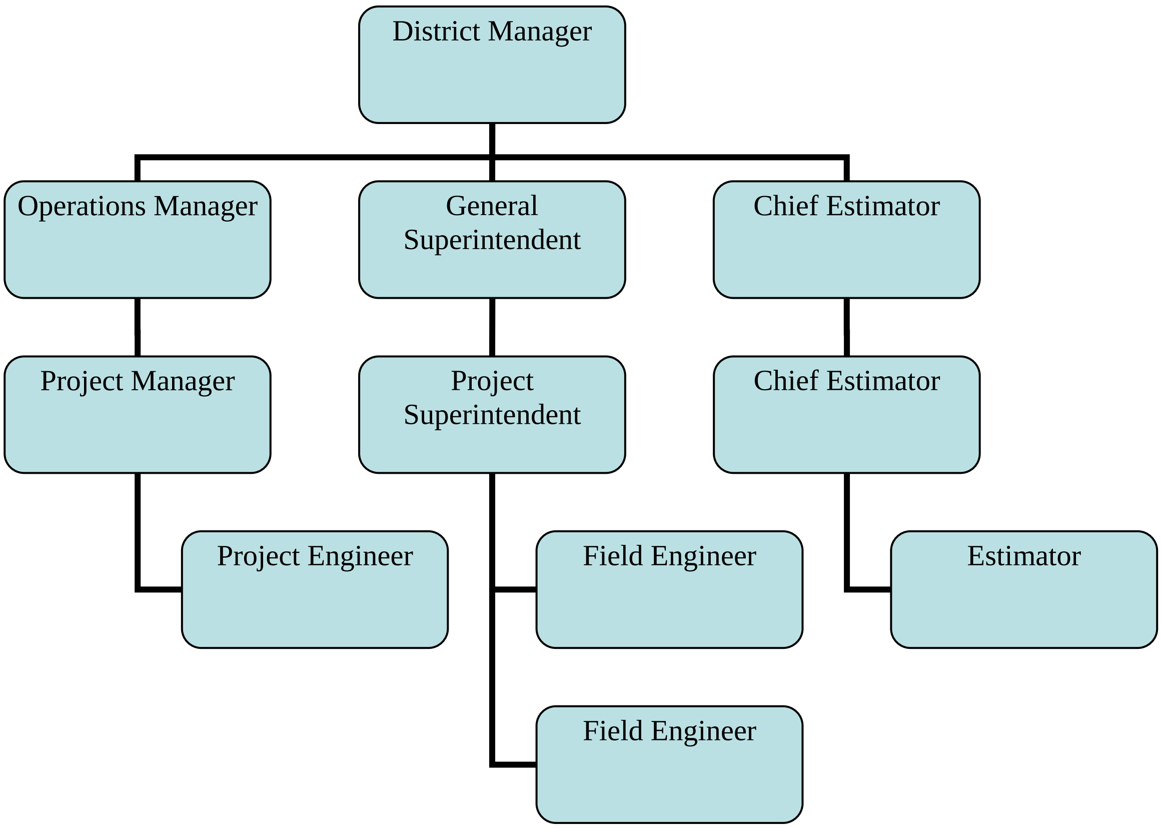
(In Reference to organization chart on next page)

Hensel Phelps holds a Guaranteed Maximum Price contract with Hensel Phelps. The United State Naval Academy is only permitted a certain budget each year. The Academy cannot and will not go over their budget, but wants to use all the available funds that it has been permitted for the Wesley A. Brown Field House. It is up to Hensel Phelps and the team of architects to deliver the best facility possible for that allocated money. Hensel Phelps holds lump sum contracts with the team of architects, engineers, and subcontractors. A major factor in the selection of the Hensel Phelps Design-Build team for Wesley A. Brown, was their past performances working with Hensel Phelps. Hensel Phelps has done at least one job with all the contractors listed on organization chart. Another important selection factor as time goes on and Hensel Phelps signs more subcontractors will be their Small Business standing. There is a strict Small Business clause, and small businesses will get a definite edge over its competition. Hensel Phelps requires any subcontractor placing work for more than $50,000 to be bonded. The a design-build job with a guaranteed maximum price contract is very appropriate for the Wesley A. Brown Field House. The NAVY wanted a world class athletic facility and had

a strict budget. With a Gauranteed Maximum Price the Government knows the project will be within budget, and the design-build delivery method allows for the best value possible by getting input from major team members early on.



Staffing Plan



The Wesley A. Brown is currently staffed by Hensel Phelps like the above plan. The District Manager oversees all projects that come through the Capitol District Office in Chantilly, Virginia. The Operations Manager ensures that numerous projects in this district have the appropriate resources to complete the projects on time and on budget. The Project Manager's job is to oversee the Wesley A. Brown Field House. He attends all meetings and is a main source of contact to the Operations Manager. The Project Engineer is the Project Manager's right-hand man making sure all materials and resources are at the job and going into place on time.

The General Superintendent oversees the construction processes of a number of jobs in the Capitol District. The Project Superintendent directs and manages all construction processes occurring in the field. He helps direct subcontractors and reports any problems that occur in the field. The field engineers perform tasks to aid the Project Superintendent track progress as well as help layout and perform other preparatory duties for the subcontractors.

The Chief Estimator is in charge of all work that comes through the Capitol District. The Wesley A. Brown Field House was assigned a Chief Estimator. The Chief Estimator has developed most all of the estimates with the help of an estimator, when help is needed.

Project System Descriptions

Primary

Construction-

Wesley A. Brown Field House is a Design-build project. Hensel Phelps pre-qualified, through past performances, along with 3 other competitors to bid the project. Hensel Phelps along with a team of architects and engineers developed a design and construction schedule to meet the needs of NAVFAC's RFP. Hensel Phelps won the job through a best value selection. The value was determined through past performance, technical/management factors, subtracting plan, design, and a staffing plan that was communicated to NAVFAC in an oral presentation. The subcontracting plan was of particular interest, because the Government required a minimum of 73.7% of the subcontracting efforts to be small business including; 15.3% SDB, 13.8% WOSB, 3.1% HUBZone Small Business, and 3% SDVOSB. More credited was given for contractors who exceeded this target. Hensel Phelps won the bid and holds a Guaranteed Maximum Price contract

Electrical-

The primary switchgear for Wesley A. Brown Field house is 13.8kV. This feeds 2 main transformers. The secondary double-ended switchgear is 480/277 volt, 3 phase, 4 wire, and 60 hertz. The switchgear distributes electricity for the electrical closets and equipment.

Lighting-

The main field area has pulse start metal halide lighting. The rest of the space is primarily lit by fluorescent lighting. The emergency and exit lighting is powered by backup batteries.

Mechanical-

There are two types of mechanical systems in the Wesley A. Brown Field House. One is a CAV system to condition the field arena and the other is a VAV to condition the other spaces of the Field house. The CAV system is comprise of 2 42,000 CFM AHU's. These units supply low-pressure air to the field space via exposed ductwork. The VAV system is comprised of 100% return air 12,000 CFM AHU for the lockers, a 16,830 CFM AHU for the lobby, a 7,850 CFM AHU for the weight training area, a 3,570 CFM AHU for the treatment area, and a 1,520 CFM AHU for the storage areas. The VAV systems will supply medium pressure via ceiling mounted diffusers. The return air will be collected through ceiling mounted air devices.

Structural-

The field house is comprise of two main systems acting together. The first system is a structural steel system that provides a column free athletic area. The next system is a structure that will enclose the athletic space.

The structural steel system is mainly comprised of Columns that are space 24.5ft apart along the north and south of the building. The typical size for these columns are W 360 x 134. These columns support box trusses that span 200ft. The size for a typical main member of these box trusses are W360 x 72.

The foundation system for Wesley A. Brown Field House consists of 406mm Drilled Pressure Grouted Displacement Piles. These supported a two-way .25M thick concrete slab.

The enclosure system is comprised of precast concrete panels. These panels range from 6" in thickness to 15" in thickness.

Secondary

Fire Protection-

The fire protection system is an intergrated system of suppressing fires and notifying the occupants inside the facility that there is a fire. The suppression system is a wet pipe automatic sprinkler system that completely covers all area of the field house. The standpipe system is Class I. There are mounted fire extinguishers placed within recessed cabinets in the main areas of the building, and surface mounted cabinets are provided in the support spaces. There is a electrically supervised, addressable intelligent, manual and automatic, annunciated fire alarm and detection system throughout the facility. Manual pull stations, duct smoke detectors, heat detectors, audio/visual alarms, fire alarms radio transmitter and electrical supervision of all sprinkler system alarm and supervisory devices are included in the fire alarm system

Transportation-

There are 3 elevators in Wesley A. Brown Field House. All are hydraulically operated. There are 2 passenger elevators, one located by the lobby and the other in the middle of the south elevation of the building, with two stops. The 3rd elevator is a freight elevator with two stops, located on the west side of the building in the loading dock area.

Telecommunications-

The communications system will be provided from the on campus network system facility. The voice and data services and Category V services are available throughout the building. An intercom system is in the Field Area and Weight Training area.

Hydraulic Banked Track-

A six lane 200m hydraulically banked track is to be installed in the Wesley A. Brown Field House. The track requires a bearing capacity of 500 kg/sqm in the lowered position, 200 kg/sqm in the raised position. The track is manufactured by "Mondo" and is made up of a steel frame supported by steel beams. The frame fitted with a 21mm thick plywood with a resin coat. There is a two-layer track surface that is fixed to the plywood with adhesive. Automated cylinders operated from a computer system provide progression of the curve at all angles. The track, when not inclined needs to sit flush with its surroundings.

Synthetic Surface System-

A roll-out synthetic football field is located at the east end of the Field House. The field will consist of synthetic turf knitted using nylon and a 5/8" shock pad. The field will be able to cover the field house floor without being labor intensive. Hydraulic driven winches will help pull the field into proper position. Air blowers with electric drives are required for pneumatic lift for lifting and lowering the field into its storage pit. The field meets all football and soccer playing requirements and takes no longer than 2 hours to roll-out and no more the 1 hour to place back into its storage pit.

Project Schedule Summary

(Please refer to appendix B)

It was important to procure a pile contractor as soon as possible. Test piles need to be driven and tested before the true installation of the piles can take place. If the pile contractor was not procured quickly the test piles would not be driven in time to get proper testing done. If that would have occurred the entire schedule would have been greatly affected.

It is also important to note the site is very tight. Therefore, there would not be much room for a crane to fly steel. Most likely a crawler crane will be used for this operation, so it can gradually work its way out. If something blocks the cranes path, there might be a problem getting it back out. Careful coordination will be needed to the steel placement.

The major finishes that needs to be coordinated is the hydraulic track. It is located at the end of the schedule so nothing can damage the extremely expensive item. However, moving the track in and getting everything to fit perfect will probably take some time. Hopefully, there are not mistakes, otherwise if an adjustment to a long lead item like the track, the project finish date could be set back.

Project Costs Overview

Construction Cost:

$32,000,000.00

Construction Cost/SF:

$237.69

Total Project Cost:

$45,500,000.00

Total Project Cost/SF:

$336.50

Major Building System Costs

Mechanical:

$7,700,000.00

Electrical:

$4,600,000.00

Structural:

$7,500,000.00

Analysis 1 (Mechanical Breadth) – Ductwork Comparison: Steel Ductwork vs. Fabric Ductwork

Background Information:

The Naval Academy specifies in the RFP of the Wesley A. Brown Field House project that they want a state of the art athletic facility that allows athletics to perform at their highest potential. In order to provide such a facility the environment needs to meet certain specifications to allow the air to be comfortable and clean. This requires a highly functional air distribution system. However, the functionality of the distribution system is not the Naval Academies sole concern. The athletic field area will have exposed ductwork, so the aesthetics are also design consideration for this new Field House.

The project specifications call for the mechanical ductwork system in the athletic field area to be G90 galvanized steel. The ductwork needs to be preinsulated with at least 1 inch thick fiberglass insulation. The system needs to prevent condensation from forming in all conditions including startup in a humid building during full cooling. The ductwork also needs to be installed as high as possible, which make the installation height between 40 and 50 feet. The ductwork needs to be aesthetically integrated into the design of the exposed structural elements of the field house. This includes painting the ductwork with glossy alkyd enamel paint.

Problem:

Steel ductwork, although common in field house applications, poses many concerns during the construction process. First and probably most apparent is the cost of the material. Galvanized steel can be a costly material for ductwork. Especially now with steel price escalation, steel ductwork is not the best selection of ductwork if a contractor is trying to keep costs down. There are also space concerns. Steel ductwork needs to have lay down area to store and organize. Wesley A. Brown has limited site space, and

therefore space that is available should be used as most effectively as possible. The ductwork that is being installed in the Wesley A. Brown Field House is as big as 58 inches in diameter. A run of that ductwork takes up a large chunk of space onsite before it is installed. Also, being such a large steel ductwork system, extra load is applied to the roof structure. Another concern is the environment that the ductwork is stored. The ductwork needs to be kept in a place that does not allow for moisture to get in the ductwork, so that there won't be bacterial or mold growth. After the system is installed, there is still concern of bacteria and mold growth. Dust will also collect in the system, which will then be distributed to the occupants of the field house and affect the quality of the air that they breathe. To combat these problems regular cleaning of the system will have to be performed. Cleaning these ducts can be costly and dangers, especially at heights of 40 feet.

Goal:

The goal is to provide a comparison between the Steel Ductwork that is specified for the Wesley A. Brown Field House and a Fabric System. The comparison will look at cost, constructability, and other advantages and disadvantages of each system. The comparison will illustrate which system would be a better application in the Wesley A. Brown Field House.

Methodology and Tools:

An alternative system to the steel ductwork will be investigated and analyzed. The system will be a fabric ductwork system. An investigation of cost, constructability, maintenance, and other system pros and cons with be used to compare the two different systems. The fabric ductwork system will be sized to the building needs to provide a more accurate comparison.

Tools that will help the comparison are phone interviews with fabric duct suppliers, testimonials of projects that have used a fabric ductwork system, R.S. Means, Ductsox's online design guide, and Architectural Engineering students.

Analysis

The first step of the analysis is to design the fabric ductwork system. This design process is outline by Ductsox's design guide and includes:

1. Selecting Series and Shape
2. Design layout
3. Fabric Selection
4. Air Dispersion
5. Suspension selection

Selecting the series-

The mechanical ductwork system in the Wesley A. Brown Field House is an exposed application that will hang from the ceiling. The fabric needs to resist condensation and be a color to match the exposed structural elements. The Cylindrical series is available in all fabric styles and is able to be support in an open ceiling application.

Design Layout-

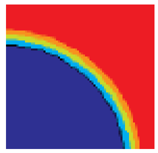
The next step is to size and design the ductwork. The Wesley A. Brown Field House has to two Air handlers that serve the athletic field area. Each Air handler is providing 42,000 cfm to this space. The design layout for the fabric ductwork will be four straight runs, two running off of each air handler. The runs will be 190 feet long. This design is simple, economical, and efficient.

The maximum velocity at an Inlet with fittings is 1400 FPM. However, the system was design at 1200 FPM for reduced stress, noise, and a better balanced system. The duct size selection was a 58" diameter for a 21,000 CFM inlet according to the Ductsox design guide.

Diameter	Inlet Velocity			
	1,000	1,200	1,400	1,600
50	13,635	16,362	19,090	21,817
52	14,748	17,698	20,647	23,597
54	15,904	19,085	22,266	25,447
56	17,104	20,525	23,946	27,367
58	18,348	22,017	25,687	29,356
60	19,635	23,562	27,489	31,416

Fabric Selection-

The different fabrics available for use in the a ductwork system have different properties that lend themselves to different applications. The application in the Wesley A. Brown Field House is one that is most similar to a gymnasium. The Ductsox Design guide recommends three different types of fabric for a gymnasium application. These fabrics include porous and non-porous fabrics. The porous materials purpose is to eliminate the threat of condensation. The porous materials allow some conditioned air through the porous material, creating a small layer of tempered air preventing warm moist air from getting to the ductwork and forming condensate. The two figures below from Ductsox Condensation Evaluation of Permeable and Impermeable Materials for Air Distribution illustrate the temperature gradients of impermeable and permeable fabrics.



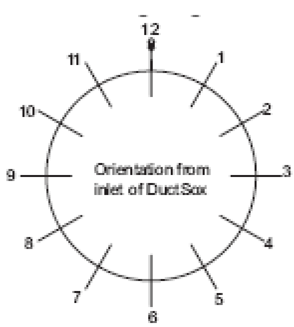
Temperature Gradient
For Impermeable fabrics

Temperature Gradient
For Permeable Fabrics

Permeable Fabrics can be considered the direct alternative to double walled mechanical ductwork. The Wesley A. Brown Field House is such an application, so the fabric should be porous. This narrows the selection to the Sedona-Xm and Verona fabrics. The Sedona-Xm was selected for this analysis for its 10year warranty and custom color capability.

Air Dispersion-

A High-throw system is the best for the Wesley A. Brown Field House because the height of the duct is 40ft high. The Only 2” and 3” diameters are available for High Throw systems with Sedona-Xm fabric. A 6 o’clock location for the orifices in the duct was designed to minimize the Throw require the formula for required throw for 6 o’clock openings is : (Height – 6) x 1.00 = Throw required. Therefore, the required throw is (40-6) x 1= 34’



2” and 3” orifices are the only opening that are offered in Sedona-Xm fabric. Using the orifice sizing chart at 0.5 static pressure, Distance to Velocity at 100, and required throw of 34’, the orifice spacing is 83.52 CFM each.

ORIFICE Size	AP (in w.g.)	Airflow (CFM/ea)	Distance (ft) to Velocity (FPM)		
			150	100	50
3" SG3	0.25	59.06	16	24	48
	0.50	83.52	23	34	68
	0.75	102.29	28	42	83
	1.00	118.11	32	48	96
	1.25	132.06	36	54	108

Therefore,

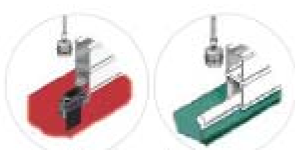
21,000/83.52 = 252 orifices are required.

The minimum space allowed is 6".

190'/252orfices = approximately 9" so the spacing is okay.

The Suspension Selection –

A two row suspended H-track system was designed for the is application, because the diameter of the duct is greater than 32" and has the ability to vary vertically in height.



Aluminum H-Track
with Snap Tab or Cord-In

Cost Analysis-

After designing the Fabric System and Cost and Construction Analysis was performed to compare the Galvanized Steel Ductwork with the Fabric ductwork.

Mechanical Ductwork Comparison				
	LNFT	AVG $/LNFT	COST ($)	DAYS
Ductsox	760	40	30400	14
Galvanized Steel	966	46.76	45171	66

The numbers were based of Ductsox's Installation Estimator, Ductsox's Cost Analysis, and R.S. Means.

For a complete list of assumptions and further cost analysis refer to Appendix. C

Conclusion-

There is a clear advantage in using the Ductsox system. The system has a lower intial cost and its saves time on the schedule. Futhermore, there is no need to worry about denting the ducts with balls and other flying objects in the Wesley A. Brown Field House. The duct comes in custom colors, which satisfies the Naval Academy's need for an aesthetically pleasing ductwork. Maintenance time is also shorter and cheaper. The fabric system is easily removed and laundered in commercial washers for cleaning. Fabric ductwork also does not demand as much site space for storage on the project. It arrives in boxes and can be stored more efficiently than large steel ductwork. This provides a value to this product that cannot be measured, but benefits the project by allowing more access for workers and more storage for other materials. The Naval Academy may however, want the look of similar building materials when one looks up. If that is the case than the steel ductwork would be preferred. However, this analysis demonstrates that a Fabric Ductwork System is an excellent application in the Wesley A. Brown Field House.

Analysis 2 – Waterproofing

Background Information

The Wesley A. Brown Field House is located on the Santee Basin. There are pits that penetrate below the slab on grade 3 feet into the ground. These pits contain highly specialized and expensive systems used for the hydraulic track, roll out football turf system, and elevators. It is imperative that these systems are not damaged by water. The cost to replace these specialized system would be very expensive and timely to replace. Therefore waterproofing is required on the pits that penetrate below grade. The specifications for the waterproofing in the Wesley A. Brown Field House call for an asphalt system with fiber.

Problem

An asphalt based waterproofing system is an effective waterproofing system, but there are new technologies and materials available that might be a better choice for the Wesley A. Brown Field House.

Goals-

To investigate other forms of waterproofing including Bituminous modified polyurethane fluid applied, 3-ply glass fiber membrane, and a Bentonite waterproofing. A cost analysis as well as a constructability review will be made on each material to determine which one is the best fit for the Wesley A. Brown Field House application.

Methodology and Tools

Using R.S. Means and waterproofing construction information graphs will be used to compare all the waterproofing types in cost and constructability.

Tools include:

RS Means

Excel

The Manual of Below-Grade Waterproofing Systems by Justin Henshell

Analysis

The first step in the analysis was to takeoff the waterproofing surface and create a cost and schedule comparison chart.

Waterproofing Type	SQFT	Dailyoutput	Manhours	$/SQFT	Cost
Bituminous Asphalt with Fiber	23143	0.02	462.86	0.91	21060
Elastomeric Bituminous Modied Polyethleyene Fluid	23143	0.024	555.43	1.4	32400
Bentonite	23143	0.013	300.86	1.41	32632

RS Means was the source for numbers above

For a takeoff concrete at pits and a list of assumptions please refer to appendix D

Next is to analyze the advantages and disadvantages of each application:

Asphalt Coating with Fibers:

Advantages

Fast and easy to install

Inexpensive

Adaptable to complex shapes

Good for concrete with penetrations

Disadvantages

Slightly Temperature Sensitive

Hard to get uniform application on vertical surfaces

Defective Flashing

Needs 24 hours to dry between coats

Limited crack spanning ability

Bituminous modified polyurethane fluid applied:

Advantages-

More flexibility and breaking strain than built-up membranes

Resists acid soils and organic growth

Improved resilience, self-healing property, and bond-ability

Easier joint seaming

Improved resistance to vapor flow

Enhanced crack bridging

Improved bond adhesion

Disadvantages-

Unsuitable for blindside applications

Does not adhere to slabs on ground when applied to a mud slab

Poor ultraviolet-radiation (should not be exposed to the atmosphere)

Application is limited to temperatures of 25 degrees F and higher

Bentonite waterproofing:

Advantages

Fast and Easy Installation

No VOC restrictions

Safe applications in extreme temperatures

Easy Leak Detection

Bridge gaps up to 1/4”

Adaptability to complex shapes

Disadvantages

Needs constant hydrostatic pressure to maintain integrity

Lack of dependable resistance to vapor migration

Limited options for repair and replacement

(Advantages and disadvantages were found in The Manual of Below-Grade Waterproofing Systems)

Conclusion

It is clear by looking at the cost and construction graph that there is a question whether cost of schedule is more important in the Wesley A. Brown Field House. This is a fast-tracked project with a tight budget, so both are important. The asphalt waterproofing system provides the cheapest option for waterproofing while the Bentonite is the fastest and saves time on the schedule. The elastomeric bituminous modied polyethleyene fluid does not provide an advantage in cost or schedule. The advantages and disadvantages of this material also do not set it apart from either the asphalt with fibers or the bentonite. Looking at the advantages of the asphalt and bentonite it is easy to see that both have benefits that lend themselves to the application of the Wesley A. Brown Field House. However looking at the disadvantages some flags go up. First, the asphalt is slightly temperature sensitive. The pits are being poured in the months of March, April, and May when the average low in Annapolis is no lower than 34 degrees F(refer to schedule and chart in appendix). Therefore, the concern is nullified. The bentonite allows vapor migration. The Wesley A. Brown Field House has wooden basketball courts that are sensitive to humidity. Vapor migration increases the chances for higher humidity. An increase in humidity would have to be accounted for in the design on the mechanical system, therefore possibly leading to cost increases of the mechanical equipment and operation. Bentonite should be used if schedule is paramount and the occupancy is not humidity-sensitive. For the Wesley A. Brown Field House the asphalt coating with fibers is an effective choice.

Analysis 3 – Concrete Strength Characteristics of Fly Ash mixes and Autoclaved Aerated Concrete

Background

The Naval Academies Request for Proposal allows for concrete mixes to have up to 25% fly ash in the mixture as long as it is approved by the structural engineer. The concrete in the pits as well as the slab on grade is specified to be 4000 psi concrete. Concrete mixtures with fly ash can add strength, workability, and durability to concrete. Fly ash is a recycled coal product that is pozzolanic in nature, and can be used a partial replacement for Portland cement. Fly ash is a much cheaper material than Portland cement, and therefore could save money on the project while adding desirable properties to the concrete .

There are also other applications of fly ash in concrete products. Autoclave Aerated Concrete (AAC) utilizes fly ash as a cementious material as well. AAC has different properties than typical concrete mixes. It is a lightweight material that has strong compressive properties with ability to be screwed into and cut by standard construction equipment.

Problem

The Wesley A. Brown Field House has a concrete mix that does not utilize Fly Ash. Using Fly Ash in the mixture could reduce cost, increase workability, and increase durability.

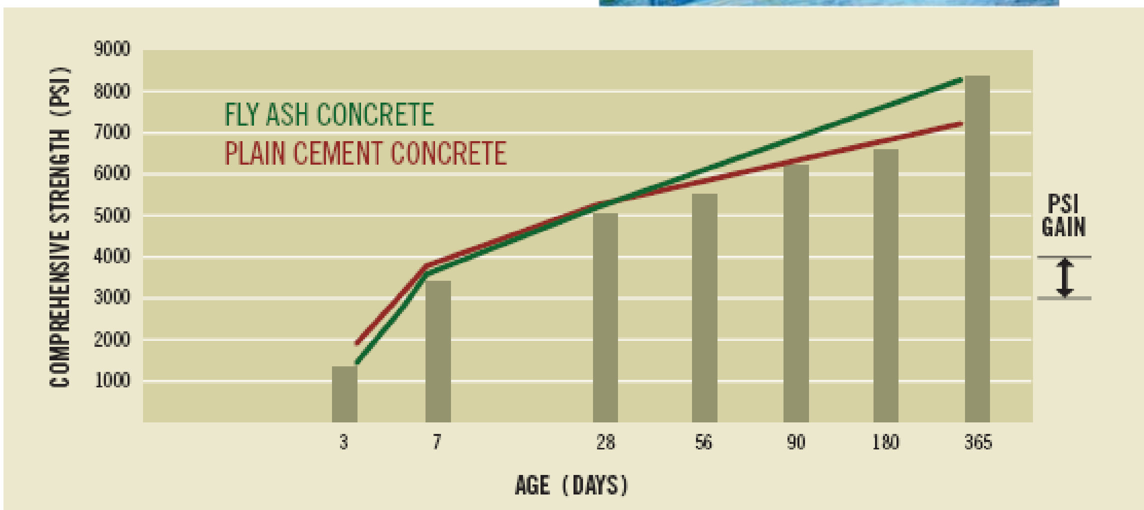
Other applications of Fly Ash in concrete have also been overlooked. One such application is Autoclaved Aerated Concrete in use of non-loading bearing wall where CMU has been specified.

Goal

To research concrete mixes with Fly Ash aggregate to see if the strength properties are within the specifications of the structural design, and to determine if Autoclave Aerated Concrete is an acceptable alternative to CMU block.

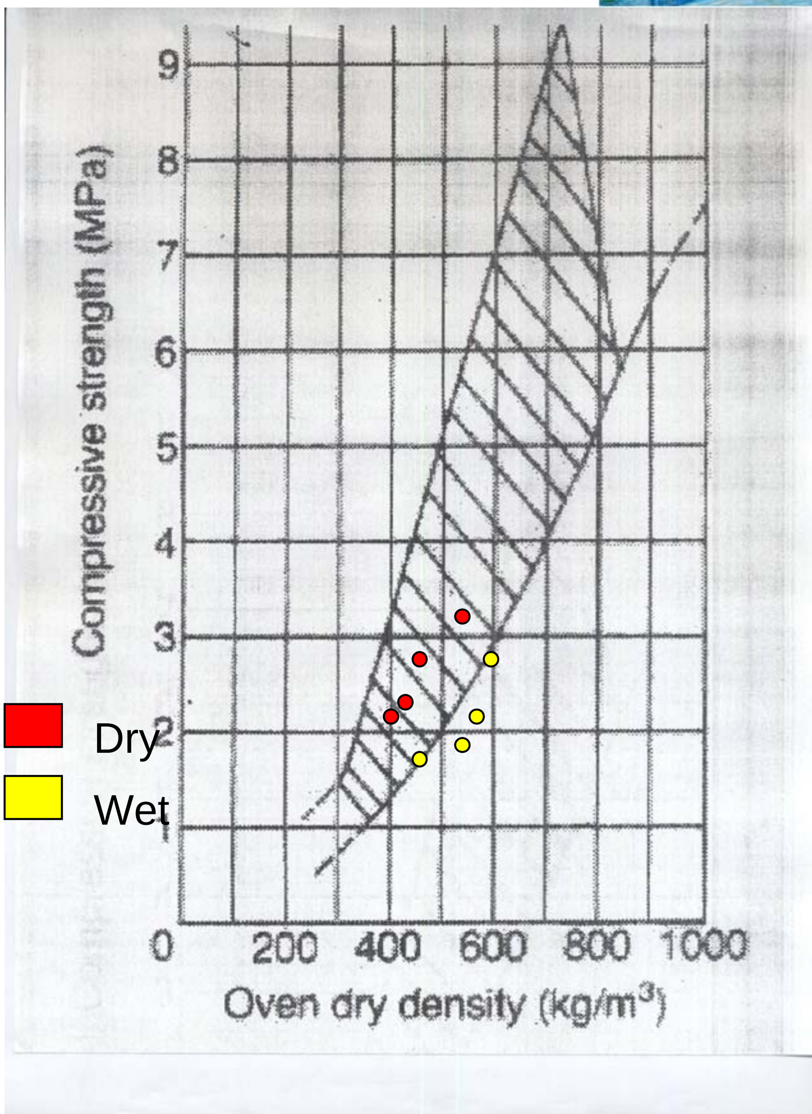
Analysis

To begin the investigation of Fly Ash the acceptability of Fly Ash mixes in concrete, an understanding of the chemical reactions must be understood. Fly Ash is a coal combustion product. This material is what flies up in the air after the coal has been burned up. Because it is created at high temperatures, fly ashes are glassy spheres. These glassy spheres are high in silica, alumina, and calcium. It is both the shape and chemical makeup that give concrete different properties when include in mixes. The chemical makeup of Fly Ash reacts with lime, calcium hydroxide, to form Calcium Silicate Hydrate (CSH). CSH is the strong and durable portion of the paste in concrete. Strong concrete has good aggregates with the proper amount of paste with as much CSH as possible and as little lime as possible. In a regular Portland cement mix, up to ¼ lb of lime is in the concrete for every pound of Portland cement. The lime that is in concrete is drawn out through capillaries in the concrete when water is introduced to the concrete. If Fly Ash is present, this lime will react will the fly ash creating more CSH and therefore closing off capillaries in the concrete. Because of this property concrete with fly ash often has less strength than Portland cement concretes at 7 days, similar strengths at 28 days, and much more strength at year. A graph from Headwaters Resources brochure for Fly Ash shows this relationship



Also, the as more CSH is produces and capillaries are being filled, the concrete becomes more durable to chemicals and freeze thaw cycles. Not only is the strength and durability increased, but workability increases. Due to the spherical shape of fly ash, it creates a ball-bearing effect which allows the concrete to flow more easily.

Aerated Autoclaved Concrete (AAC) utilizes the unique characteristics of Fly Ash to produce a lightweight high strength construction material. AAC mixes combine Fly Ash, Portland cement, and aluminum together under regulated pressure and temperature. The mixes are poured into form and then placed into an autoclave. The aluminum reacts with calcium hydroxide and water to provide hydrogen bubbles in the concrete. The hydrogen eventually escapes and the bubbles are left. In some mixes, 80% of the volume of the concrete is air. These bubbles give AAC excellent thermal and sound transmission properties. Eventually the calcium hydroxide reacts to form CSH, which provides the strength in AAC. AAC can be cut into blocks and panels. The following graph shows the industries acceptable strength vs. oven dry density for AAC. The plots on the graph were samples created from Penn State Fly Ash. Refer to appendix D for mix proportions and strength information.



The Wesley A. Brown Field House has CMU block that located in the locker room walls. AAC block could be used as an alternative to CMU block. AAC would decrease sound transmission as well as adding thermal resistance.

Conclusion-

The inclusion of Fly Ash in the concrete mixes for the Wesley A. Brown Field House would increase strength, durability, and workability. Savings would be evident in

using a cheaper cementitious material as well as saving cost on future repairs to concrete for damaged concrete. The use of AAC block in the Wesley A. Brown Field House as an alternative to CMU block is not feasible. AAC block would be more expensive and sound and thermal transmission is not critical for locker rooms. If there were offices or rooms that required sound control, AAC would be a good application.

Analysis 4 (Depth) – Penn State's Coal Fired Power Plant and its Waste Products

Background

Penn State University power is supplied from an on campus coal fired power plant. From this operation between 6,000 and 9,000 tons of coal waste product is produce in the form of Fly Ash and Bottom Ash each year. 10% of this waste is in the form of Fly ash, which is approximately 600 to 800 tons. The other 90% of the waste is bottom ash which is accounts for between 6,000 and 8,000 tons. Penn State currently is paying around $35 a ton to dispose of the Fly Ash in a landfill in accordance with Pennsylvania regulations. The bottom ash that Penn State produces currently is being disposed of in a few different manners. The Bottom Ash is either being placed in landfills or being dumped on local roads.

Problem

Penn State is paying both money and time to dispose of the Fly Ash and Bottom Ash that the coal fired power plant is producing on campus. This process is both time consuming and expensive. Pennsylvania has deemed acceptable applications for both these coal by products. The bottom ash that is being spread as anti-skid material is upsetting the locals. This dumping occurs often and creates a build up of material on the road. It also ties up Penn State trucks and employees for long periods of time.

Goal

The goal of this analysis is to find acceptable applications for Penn State's coal combustion products. There are two types of combustion products that Penn State produces, each with different chemical properties. The differing properties are beneficial to different applications and are different enough that they will each need a different application to be applied. The ultimate goal is to find an application for both Fly Ash and

Bottom Ash to be recycled here on campus projects, and therefore utilizing all the coal we purchase and minimizing transportation costs of trucking the ash to other places.

Methodology and Tools

Investigating the Penn State Coal Fired Power Plant and its coal combustion product will provide information about the source of the problem and shed light on to help solve the problem. Research in the library and the internet on coal combustion products will help discover and define applications for the coal combustion products that Penn State produces.

Tools include:

Personal Interviews
Site Visits
Phone interviews
Materials Research
Lab Work
Books
Internet

Analysis

The first step to the analysis was to learn how Penn State produces the Coal Combustion Products. A visit to Penn State's coal plant and meeting with superintendent of steam services was used to explain the Coal Plant's system. Penn State has been producing steam power in this plant for many years, and because of the age of the plant, it does not use many of the new technologies that other coal plants utilize. One technology on many other plants that is not utilized in Penn State's plant that is of particular interest, is that the coal is not pulverized before it enters into the stoves. This

effects the coal combustion products that are produced. Penn State's stoves are Stoker stoves that are fed coal by a gravity system. The coal rolls along the top of the stoves until it eventually reaches the end where the rest is collected in bins. The idea is to have all the coal burned up by the time it reaches the end where the rest is collected. Along the way some of the coal is turned into ash which flies up and is collected in filters. This ash is called the fly ash. The material that makes it to the end of the stove that is collected is the bottom ash. Both these products make up the coal combustion products that Penn State Produces. On average 90% of the material is bottom ash and 10% of this material is fly ash. On newer stoves the ratios are reserved due to the fact that the coal is pulverized before it enters the stoves.

After understanding the coal-fired power plant, an investigation into the problem that faces Penn State in disposing of these products was conducted. Again, the site visit to the power plant and meeting with the superintendent of steam services was able to illustrate the problem at hand. Both products were of no use to the Power Plant and needed to be removed from the site due to the limit amount of space that is available to the operation. Pennsylvania regulates the disposal of coal combustion products, and it is therefore difficult to get rid of these two products. Currently the fly ash is placed in special landfills at a cost of $35 a ton. The bottom ash is being placed in landfills or dump on local streets as anti-skid material. Both uses are costing Penn State time, resources, and money that could be better used elsewhere if other ways to use bottom ash were utilized.

Research was conducted to investigate the uses of Coal Combustion Products that are acceptable in Pennsylvania. Pennsylvania residual waste management allow coal combustion products can be used in beneficial uses. These acceptable beneficial uses are:

1. As a structural fill upon approval from the Department if the person proposing the use complies with specified requirements. (Any other use as a structural fill requires a disposal permit.);
2. As a soil substitute or soil additive if the person proposing the use complies with specified requirements;
3. For reclamation at an active surface coal mine site, a coal refuse reprocessing site, or a coal refuse disposal site if the use complies with all specified requirements under 25 Pa. Code §287.663, the Clean Streams Law and regulations promulgated thereunder, the Surface Mining Conservation and Reclamation act (52 P.S. §§1396.1-1396.19a), the Coal Refuse Disposal Control Act (52 P.S. §§30.51-30.66), and the applicable provisions of Chapters 86-90;
4. For reclamation at an abandoned coal or an abandoned noncoal (industrial mineral) mine site if the reclamation work is approved by the Department or is performed under a contract with the Department and the use complies with 25 Pa. Code §287.664, and the applicable environmental statutes and regulations promulgated thereunder;
5. In the manufacture of concrete;
6. For the extraction or recovery of one or more materials and compounds contained within the coal ash;
7. As an anti-skid material or road surface preparation material, if the use is consistent with Department of Transportation specifications or other applicable specifications. (This use applies to bottom ash or boiler slag only. The use of fly ash as an anti-skid material or road surface preparation material is not deemed to be a beneficial use.);

8. As a raw material for a product with commercial value, including the use of bottom ash in construction aggregate. (Storage of coal ash prior to processing is subject to specific requirements.)
9. For mine subsidence control, mine fire control and mine sealing, if the person or municipality proposing the use gives advance written notice to the Department, the pH of the coal ash is in a range that will not cause or allow the ash to contribute to water pollution, and use of the coal ash in projects funded by or through the Department is consistent with applicable Department requirements;
10. As a drainage material or pipe bedding, if the person or municipality proposing the use has first given advance written notice to the Department, and has provided to the Department an evaluation of the pH of the coal ash and a chemical analysis of the coal ash that meets the specific chemical waste analysis requirements;
11. As a stabilized product where the physical or chemical characteristics are altered prior to use or during placement if the person or municipality proposing the use has first given advance written notice to the Department, the coal ash is not mixed with solid waste, unless otherwise approved in writing by the Department prior to use, and the use of coal ash results in demonstrated reduction of the potential of the coal ash to leach constituents into the environment.

There are many different applications that are acceptable for both fly ash and bottom, but only a few were investigated. The fly ash and bottom ash have different properties and therefore both are not suitable for all applications. The search for uses of Fly Ash and Bottom Ash should be considered separate investigations.

Penn State's Fly Ash-

The focus of this portion of the report is the use of Penn State's Fly Ash was use of this coal combustion product in the manufacture of a concrete product. More specifically, is the use of fly ash in Autoclave Aerated Concrete. Autoclaved Aerated Concrete is a lightweight concrete that uses Fly Ash as a partial Portland Cement substitute. The mix is placed in autoclaves where the reaction between aluminum and the cementitious materials is accelerated causing hydrogen bubbles to form and the concrete to expand up to 5 times its original volume. The product that is produce is a lightweight closed-cell structure that can be use as non-load bearing or loading bearing blocks or panels.

AAC mixes were created with varying amounts of Aluminum and dryness at the Penn State Materials Laboratories. These mixes were poured into cubes forms and placed in autoclaves. The blocks were removed and tested for strength. The results can be seen in Appendix E.

When the results were plotted on a graph showing the industry acceptable strength vs. oven dry density, the blocks that were dry landed in the accepted region and the wet test blocks did not yield high enough strengths. The Plot can be seen in appendix E.

Bottom ash-

The focus for finding a use for the bottom ash was as a structural fill material or pipe bedding. An important property of aggregate for structural fill and pipe bedding is the consistency and gradation of the material. Penn State's Bottom Ash gradation is :

Screen Test	%	Cumulative % Down	Cumulative % Up
+ 1/2"SQ	7.64	7.64	100.00
1/2"SQ X 1/4"SQ	73.40	81.03	92.36
1/4"SQ X 8M	17.00	98.03	18.97
8M X 0	1.97	100.00	1.97
	100.00 %		

MOISTURE AS RECEIVED	2.93%	
CARBON AS RECEIVED	54.55%	DRY BASIS 56.20%
LOSS ON IGNITION	65.03%	

Unfortunately, Penn State's bottom ash gradation is not acceptable for either application. The grains are to large for these applications. Gradation of Fly Ash and Bottom can be seen in Appendix F.

Conclusion-

Penn State's coal fired power plant produces coal combustion products. These products, fly ash and bottom, can be recycled and used for construction applications. The fly ash has been tested and proved to be a useful aggregate in the composition of an AAC block. These blocks need to have further tests performed on them to demonstrate their thermal and sound transmission properties. After those tests, Penn State may want to use these AAC blocks in future Construction projects.

The bottom ash is still a problem. Another application will have to be found for this coal combustion product. Maybe a none construction application, such as a soil stabilizer. Otherwise a feasibility study on purchasing and running a grinder or screen system will have to be performed to see if that equipment would help solve Penn State's bottom ash disposal problem.

Summary and Conclusion

The Wesley A. Brown Field House is a prestigious project on one of America's finest universities. The United States Naval Academy wants to have a state of the are facility, so that their athletics can perform at their highest level. It is located on the waterfront so the project can be seen by many. The function and the appearance of this field house are very important to the owner.

Analyses were done to investigate possible systems that could have enhanced Wesley A. Brown Field House. Not all investigations were successful. The first investigation compared a Steel Ductwork System to a Fabric Ductwork system. The researched reveal many benefits to the fabric ductwork system. If this system were in lieu the steel ductwork, both time and money would have been saved.

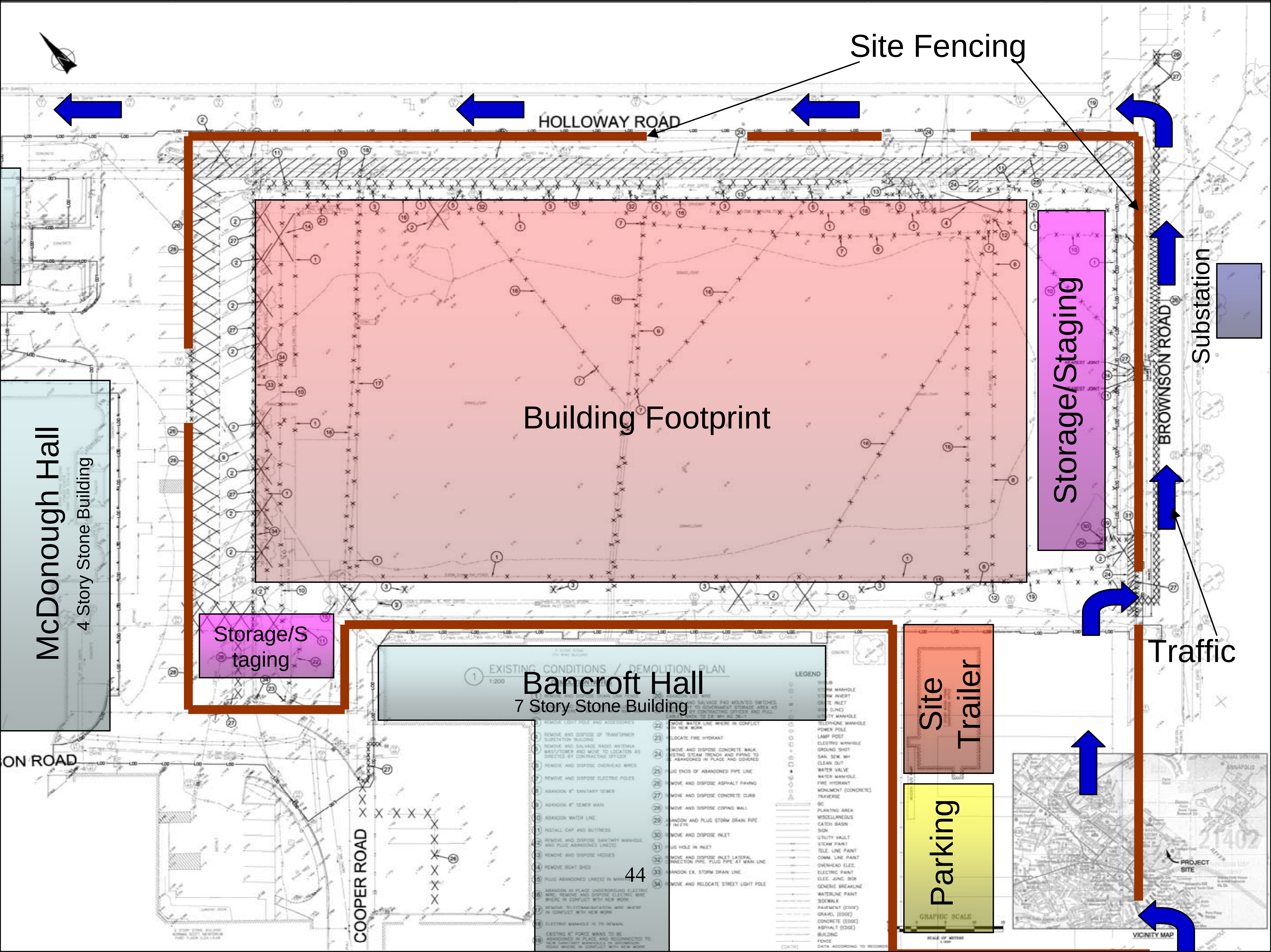
The second analysis was to determine if the waterproofing system in the Wesley A. Brown Field was the best choice. Other systems were investigated, but the waterproofing system designed for the Field seemed to be the best answer.

The third analysis was performed on concrete with fly ash as an aggregate. The investigation revealed that strength, durability, and workability were all positively effected by fly ash if used properly. The project seems to be a good application for this concrete mix. Further investigation was done on AAC as a non-load bearing replacement for CMU walls. Block made from Penn State Fly Ash proved to be an acceptable material, but Wesley A. Brown Field House is not the proper application for this block.

The last investigation was performed on Penn State's Coal fired power plant combustion products. The use of these products in construction materials were investigated. It was found that Penn State's fly ash can be used in an AAC application to create block that might be used as an alternative to CMU block. The bottom ash however proved to be more of a problem. The gradation of the material made it tough to use in a construction application. Further investigation is needed to find a use for Penn State's bottom ash.

APPENDIX A

Site Plan

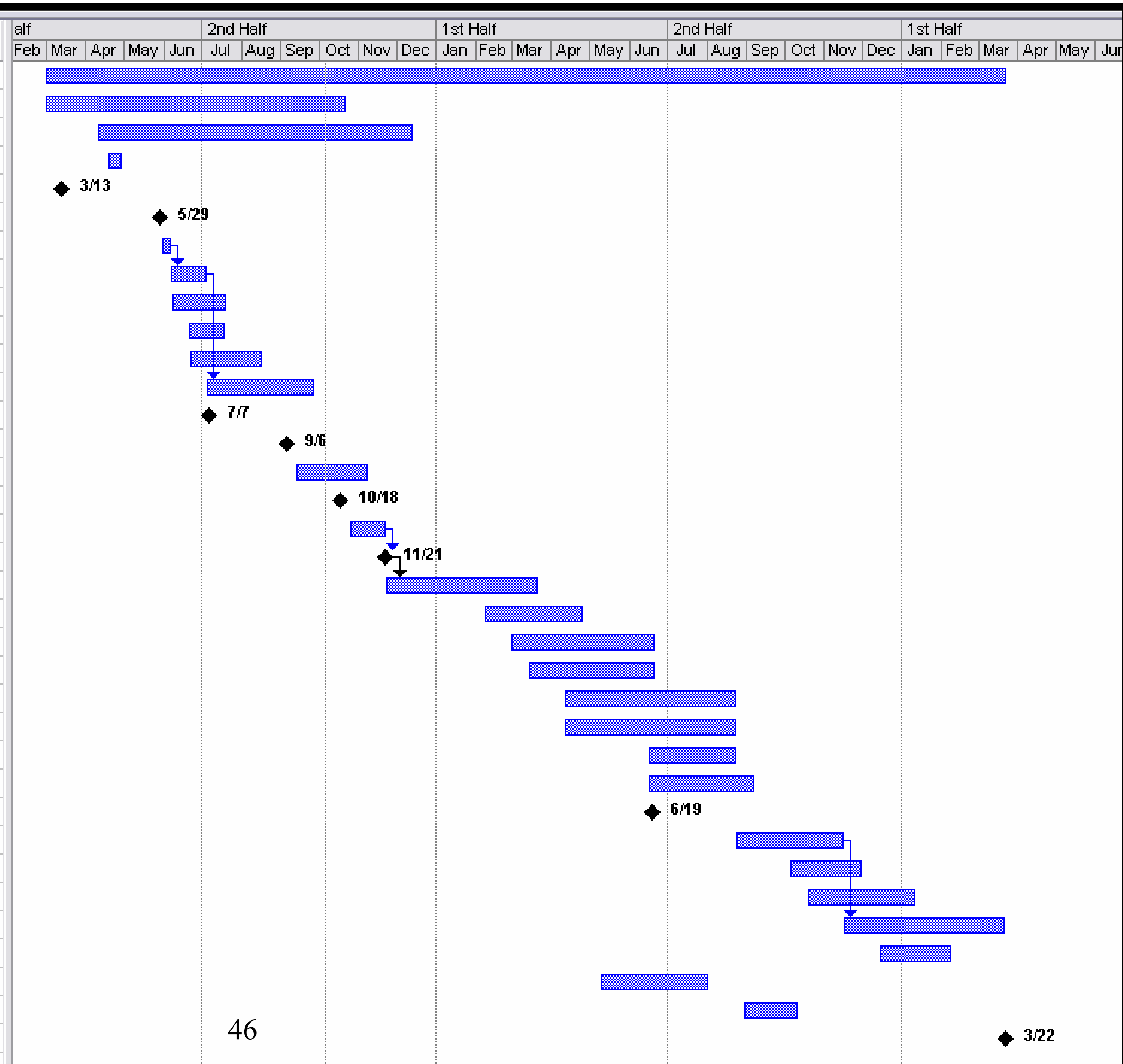

Site Fencing
HOLLOWAY ROAD
Building Footprint
Storage/Staging
BROWNSON ROAD
Substation
McDonough Hall
4 Story Stone Building
Storage/Staging
Bancroft Hall
7 Story Stone Building
EXISTING CONDITIONS / DEMOLITION PLAN
LEGEND
Site Trailer
Parking
Traffic
COOPER ROAD
PROJECT SITE
VICINITY MAP

APPENDIX B

Schedule

Wesley A. Brown Field House Schedule

	Task Name	Duration	Start	Finish
1	Contract Duration	539 days?	Tue 2/28/06	Fri 3/21/08
2	Design	169 days?	Tue 2/28/06	Fri 10/20/06
3	Procurement & Fabrication	177 days?	Mon 4/10/06	Tue 12/12/06
4	Mobilization	9 days?	Tue 4/18/06	Fri 4/28/06
5	Concept Design Complete	0 days	Mon 3/13/06	Mon 3/13/06
6	Commence Construction	0 days	Mon 5/29/06	Mon 5/29/06
7	Install Erosion Controll	5 days?	Tue 5/30/06	Mon 6/5/06
8	Site Demo	20 days?	Tue 6/6/06	Mon 7/3/06
9	Utility Relocation	30 days?	Wed 6/7/06	Tue 7/18/06
10	Site Prep for Piles	20 days?	Tue 6/20/06	Mon 7/17/06
11	New Utility Install	40 days?	Wed 6/21/06	Tue 8/15/06
12	Install Perimeter & Pit	61 days?	Tue 7/4/06	Tue 9/26/06
13	Design Development	0 days	Fri 7/7/06	Fri 7/7/06
14	100% Design Complete	0 days	Wed 9/6/06	Wed 9/6/06
15	Import Fill	40 days?	Wed 9/13/06	Tue 11/7/06
16	Final Design Complete	0 days	Wed 10/18/06	Wed 10/18/06
17	Install Piers	20 days?	Wed 10/25/06	Tue 11/21/06
18	Stand Steel	0 days	Tue 11/21/06	Tue 11/21/06
19	Install Structural Steel	85 days?	Wed 11/22/06	Tue 3/20/07
20	F/R/P Structural Slab	55 days?	Wed 2/7/07	Tue 4/24/07
21	Install Exterior Skin	80 days?	Wed 2/28/07	Tue 6/19/07
22	Install Roofing	70 days?	Wed 3/14/07	Tue 6/19/07
23	Mechanical System Rough	97 days?	Wed 4/11/07	Thu 8/23/07
24	Electrical System Rough-In	97 days?	Wed 4/11/07	Thu 8/23/07
25	Special System Rough-In	50 days?	Fri 6/15/07	Thu 8/23/07
26	Install Interior Walls	60 days?	Fri 6/15/07	Thu 9/6/07
27	Dried-In	0 days	Tue 6/19/07	Tue 6/19/07
28	Paint Interior	60 days?	Fri 8/24/07	Thu 11/15/07
29	Install Flooring	40 days?	Fri 10/5/07	Thu 11/29/07
30	Track & Field Special	60 days?	Fri 10/19/07	Thu 1/10/08
31	Punchlist	90 days?	Fri 11/16/07	Thu 3/20/08
32	Equipment	40 days?	Fri 12/14/07	Thu 2/7/08
33	Exterior Sitework	60 days?	Wed 5/9/07	Tue 7/31/07
34	Paint Exterior	30 days?	Wed 8/29/07	Tue 10/9/07
35	Project Complete	0 days	Sat 3/22/08	Sat 3/22/08



APPENDIX C

Mechanical Takeoff, Assumptions, Graph

Mechanical Ductwork Comparison					
	LNFT	$/LNFT	$	Hours	Days
Ductsox					
58"	760	40	30400	114	14
Total			30400		14
Galzinized Steel					
58"	44	72.5	3190	26	3
52"	64	65	4160	38	5
50"	118	62.5	7375	71	9
44"	204	55	11220	122	15
38"	32	47.5	1520	19	2
36"	168	45.15	7585.2	101	13
24"	336	30.12	10120.32	146	18
Total			45170.52		66

Assumptions:

Costs used for metal ductwork was only for single walled. Therefore, the price is low

Prices for duct of 36" were interpolated

Production Rates for Steel duct over 36" was assumed to be the same as 36" to be conservative

Mechanical Ductwork Comparison				
	LNFT	AVG $/LNFT	COST ($)	DAYS
Ductsox	760	40	30400	14
Galvanized Steel	966	46.76	45171	66

Installation Estimator for Ductwork Calculations
Inlet Diameter = 58"
1hr per Inlet Diameter of 41"-60"
4 inlets
4hrs
2 hours for each straight section + 1.5 hours per 25'
4 Straight Sections
760' of double track
8 + 2 x 1.5(760/25) = 91.2
Add 20% for ductwork betwee n 41"-60"
1.2 x 91.2 = 109.44
109.44 + 4 = 113.44

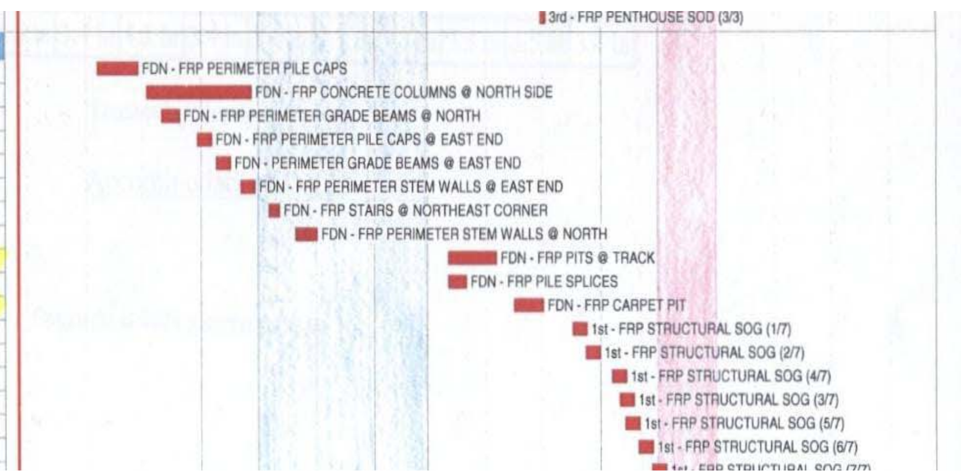
APPENDIX D

Concrete Pit Takeoff, Concrete Pit Schedule, and Annapolis Weather

Surface Area of concrete at Track, Elevator, and Carpet Pits		
	SQFT	SQFT
Track Pit		
Vertical Surface Area	7180	
Horizontal Surface Area	11207	
Total		18387
Elevator Pit 1		
Vertical Surface Area	722	
Horizontal Surface Area	145	
Total		867
Elevator Pit 2		
Vertical Surface Area	295	
Horizontal Surface Area	78	
Total		373
Carpet Pit		
Vertical Surface Area	1246	
Horizontal Surface Area	2270	
Total		3516
Total		23143

Waterproofing Type	SQFT	Dailyoutput	Manhours	$/SQFT	Cost
Bituminous Asphalt with Fiber	23143	0.02	462.86	0.91	21060
Elastomeric Bituminous Modied Polyethleyene Fluid	23143	0.024	555.43	1.4	32400
Bentonite	23143	0.013	300.86	1.41	32632

3rd - FRP PENTHOUSE SOD (3/3)	3	04/30/07 *	05/02/07
FDN - FRP PERIMETER PILE CAPS	16	09/07/06 *	09/28/06
FDN - FRP CONCRETE COLUMNS @ NORTH	40	10/03/06 *	11/27/06
FDN - FRP PERIMETER GRADE BEAMS @	8	10/11/06 *	10/20/06
FDN - FRP PERIMETER PILE CAPS @ EAST END	6	10/30/06 *	11/06/06
FDN - PERIMETER GRADE BEAMS @ EAST END	6	11/09/06 *	11/16/06
FDN - FRP PERIMETER STEM WALLS @ EAST	6	11/22/06 *	11/29/06
FDN - FRP STAIRS @ NORTHEAST CORNER	4	12/07/06 *	12/12/06
FDN - FRP PERIMETER STEM WALLS @ NORTH	8	12/21/06 *	01/01/07
FDN - FRP PITS @ TRACK	20	03/12/07 *	04/06/07
FDN - FRP PILE SPLICES	8	03/12/07 *	03/21/07
FDN - FRP CARPET PIT	12	04/16/07 *	05/01/07
1st - FRP STRUCTURAL SOG (1/7)	6	05/17/07 *	05/24/07
1st - FRP STRUCTURAL SOG (2/7)	6	05/24/07 *	05/31/07
1st - FRP STRUCTURAL SOG (4/7)	6	06/07/07 *	06/14/07
1st - FRP STRUCTURAL SOG (3/7)	6	06/11/07 *	06/18/07
1st - FRP STRUCTURAL SOG (5/7)	6	06/14/07 *	06/21/07
1st - FRP STRUCTURAL SOG (6/7)	6	06/21/07 *	06/28/07



Annapolis Weather

US Geography / US Weather / Maryland Weather / Annapolis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	42°	45°	55°	65°	75°	84°	87°	86°	80°	68°	57°	47°
Avg. Low	24°	26°	34°	44°	54°	62°	67°	66°	60°	47°	38°	28°
Mean	34°	36°	45°	55°	65°	74°	78°	76°	70°	58°	48°	38°
Avg. Precip.	3.3 in	3.3 in	3.6 in	3.4 in	4.1 in	3.4 in	3.6 in	3.9 in	3.3 in	3.3 in	3.5 in	3.4 in

Degrees in Fahrenheit

Accommodations

APPENDIX E

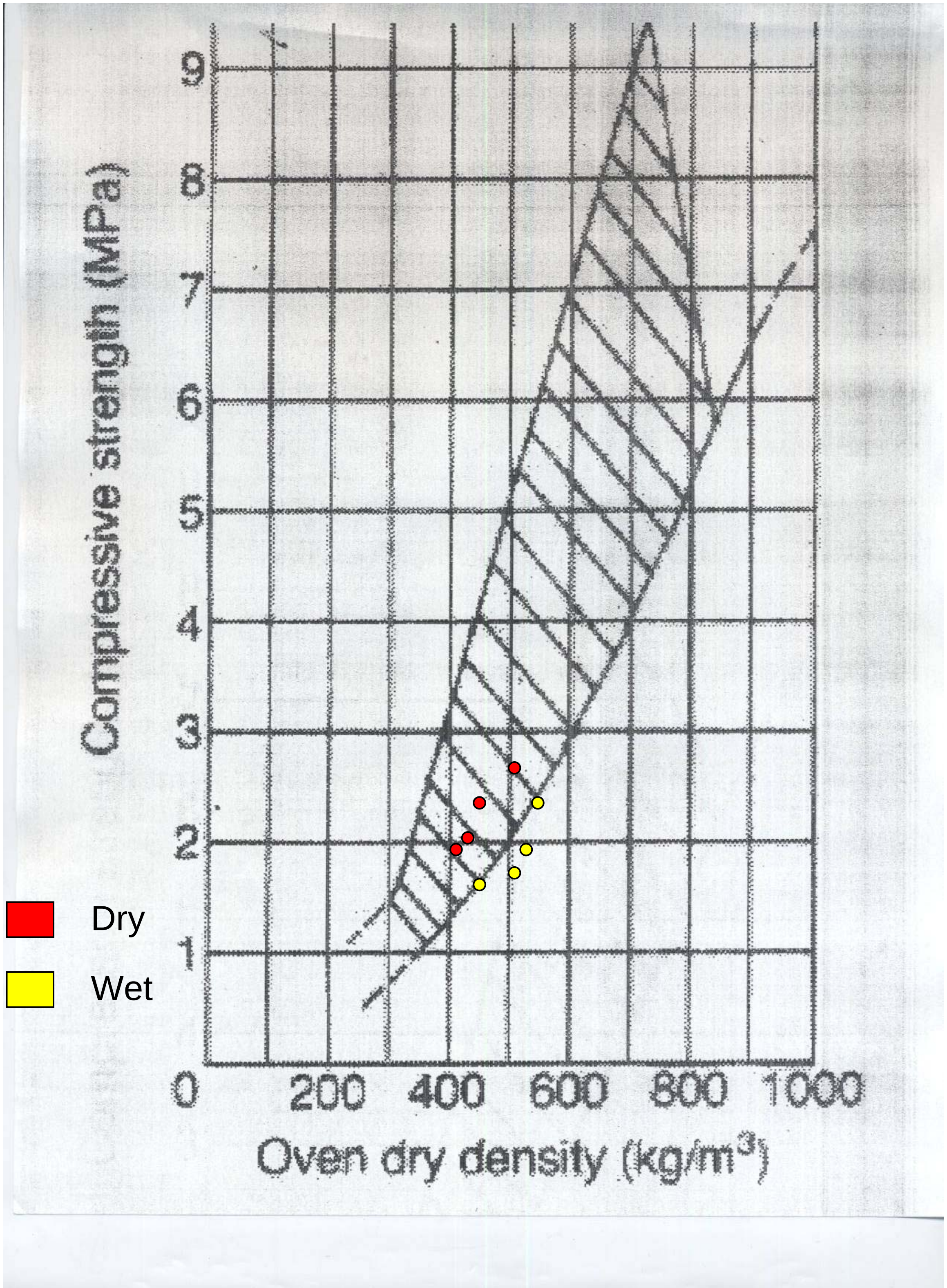
Penn State Fly Ash Chart and Acceptable AAC Plot

PSU fly ash ongoing test

Nominal 4 in cube testing: 10.16 cm

Sample	Number	Mass (both if app)		H2O mass	% mass	Density	g/cm3	Load	PSI	Mpa	ave load	ave density
		Room	Dry	lost	lost	Room	Dry	lbs				
A51	1	690.90	558.00	132.90	0.19	0.65877	0.532051	7120	445	3.068164	392.9167	0.5295717
	2	686.00	554.80	131.20	0.19	0.654098	0.529	6500	406.25	2.800992		
	3	645.80	553.40	92.40	0.14	0.615768	0.527665	5240	327.5	2.258031		
	4	639.20				0.609475	0.609475	5900	368.75	2.542439	322.5	0.6008932
	5	661.00				0.630261	0.630261	5540	346.25	2.387307		
	6	590.40				0.562944	0.562944	4040	252.5	1.740924		
A52	1	638.30	549.50	88.80	0.14	0.608616	0.523946	6580	411.25	2.835466	401.25	0.5284593
	2	673.40	554.00	119.40	0.18	0.642084	0.528237	7160	447.5	3.085401		
	3	662.20	559.20	103.00	0.16	0.631405	0.533195	5520	345	2.378689		
	4	627.00				0.597842	0.597842	6100	381.25	2.628623	362.0833	0.5925978
	5	598.90				0.571049	0.571049	5520	345	2.378689		
	6	638.60				0.608903	0.608903	5760	360	2.48211		
A71	1	617.70	494.80	122.90	0.20	0.588974	0.47179	5440	340	2.344215	319.5833	0.4639076
	2	613.70	464.00	149.70	0.24	0.58516	0.442422	5700	356.25	2.456255		
	3	618.70	500.80	117.90	0.19	0.589928	0.477511	4200	262.5	1.809872		
	4	578.90				0.551979	0.551979	4580	286.25	1.973622	257.5	0.5484191
	5	568.30				0.541872	0.541872	3580	223.75	1.5427		
	6	578.30				0.551407	0.551407	4200	262.5	1.809872		
A72	1	613.60	492.20	121.40	0.20	0.585065	0.469311	4200	262.5	1.809872	239.7917	0.4699464
	2	605.40	494.90	110.50	0.18	0.577246	0.471885	3090	193.125	1.331549		
	3	618.70	491.50	127.20	0.21	0.589928	0.468643	4220	263.75	1.81849		
	4	578.40				0.551502	0.551502	3240	202.5	1.396187	254.5833	0.5476881
	5	565.70				0.539393	0.539393	4340	271.25	1.870201		
	6	579.10				0.55217	0.55217	4640	290	1.999478		
A91	1	623.80	471.40	152.40	0.24	0.594791	0.449478	4720	295	2.033951	292.9167	0.4524656
	2	630.80	480.00	150.80	0.24	0.601465	0.457678	5000	312.5	2.154609		
	3	632.70	472.20	160.50	0.25	0.603277	0.450241	4340	271.25	1.870201		
	4	565.70				0.539393	0.539393	4100	256.25	1.76678	254.5833	0.5426981
	5	568.50				0.542062	0.542062	4080	255	1.758161		
	6	573.30				0.546639	0.546639	4040	252.5	1.740924		
A92	1	618.40	455.60	162.80	0.26	0.589642	0.434413	4480	280	1.93053	280	0.4365423
	2	615.90	462.80	153.10	0.25	0.587258	0.441278	4400	275	1.896056		
	3	615.70	455.10	160.60	0.26	0.587067	0.433936	4560	285	1.965004		
	4	586.70				0.559416	0.559416	3320	207.5	1.430661	217.5	0.5572866
	5	584.20				0.557032	0.557032	3380	211.25	1.456516		
	6	582.50				0.555411	0.555411	3740	233.75	1.611648		

Penn State AAC



Penn State AAC

APPENDIX F

Bottom Ash and Fly Ash Gradation

FAIRWAY LABORATORIES, INC.

2019 Ninth Avenue
P.O. Box 1925
Altoona, Pennsylvania 16603

(814) 946-4306 FAX. (814) 946-8791

Penn State University Office of Physical Plant	Project: Biosolids	Reported:
Wastewater Treatment Plant	Project Number: 8	07/28/04 07:45
University Park PA. 16802	Collector: -	
Project Manager: Charlie Railis	Number of Containers: 2	

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
FLY ASH	4G13010-01	Ash	07/09/04 00:00	07/12/04 16:40
BOTTOM ASH	4G13010-02	Ash	07/09/04 00:00	07/12/04 16:40

4G13010-01

Bulk Density 19.05 lbs. per cubic foot

Screen Test	%	Cumulative % Down	Cumulative % Up
+ 8M	0.00	0.00	100.00
8M X 16M	0.06	0.06	100.00
16M X 30M	0.13	0.19	99.94
30M X 50M	1.23	1.42	99.81
50M X 100M	6.95	8.37	98.58
100M X 200M	23.33	31.70	91.63
200M X 325M	27.83	59.54	68.30
325M X 0	40.46	100.00	40.46
	100.00 %		

MOISTURE AS RECEIVED 13.25%
CARBON AS RECEIVED 16.32% DRY BASIS 18.49%
LOSS ON IGNITION 24.72%

4G13010-02

Fairway Laboratories, Inc.

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Reviewed and Submitted by:

Michael P. Tyler
Laboratory Director

FAIRWAY LABORATORIES, INC.
2019 Ninth Avenue
P.O. Box 1925
Altoona, Pennsylvania 16603
(814) 946-4306 FAX: (814) 946-8791

Penn State University Office of Physical Plant	Project:	Biosolids	Reported:
Wastewater Treatment Plant	Project Number:	8	07/28/04 07:45
University Park PA, 16802	Collector:	-	
Project Manager: Charlie Rallis	Number of Containers:	2	

Bulk Density 22.48 lbs. per cubic foot

	%	Cumulative % Down	Cumulative % Up
Screen Test			
+ 1/2"SQ	7.64	7.64	100.00
1/2"SQ X 1/4"SQ	73.40	81.03	92.36
1/4"SQ X 8M	17.00	98.03	18.97
8M X 0	1.97	100.00	1.97

	100.00 %		

MOISTURE AS RECEIVED 2.93%
CARBON AS RECEIVED 54.55% DRY BASIS 56.20%
LOSS ON IGNITION 65.03%

Fairway Laboratories, Inc.

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Reviewed and Submitted by:

Michael P. Tyler
Laboratory Director