Food Science Builidng

University Park, PA

Senior Thesis 2005-06

Final Report

By Anthony Lucostic

Construction Management

Advisor: Dr. Riley

Food Science Building

University Park, PA

Architecture / History

- This building will serve as the 4th home of the PSU Creamery dating back to 1889
- Designed to make a visible statement about the importance of the Creamery Processing/Maufacuting Areas
- Organized to allow for exemplary Good Manufacturing Practice (GMPs)

Project Team

- Owner: The Pennsylvania State University
- Architect: IKM Incorporated
- Engineers: H.F. Lenz Co.
- Food Processing: Food Engineering, Inc.
- Construction Manager: Gilbane Building Co.

Structure

- Mini piles and c-i-p grade beams
- Structural steel frame and composite metal decking
- Structural slab in production area
- Precast double tee's in pilot plant

Electrical / Lighting

- Power: 12,470V / 480/277V / 208/120V
- Emergency power from PSU 4160V emergency loop

Mechanical

- VAV AHU's are utilized throughout most of the building
- CVSZ AHU's are utilized in the Production Area

Building Statistics

- Total Building Cost: $45,060,000
- Total Square Feet: 122,000 sq. ft.
- Future Square Feet: 17,600 sq. ft.
- Delivery Method: Design-Bid-Build
- Construction Schedule: Nov. 2004 - Sept. 2006

Anthony Lucostic - Construction Management
http://www.arche.psu.edu/thesis/eportfolio/current/portfolios/ajl227/

FOOD SCIENCE BUILDING
UNIVERSITY PARK, PA

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Introduction

The Food Science Building located on The Pennsylvania State University's campus at University Park, PA will most notably serve as the new home for the famous Penn State Creamery. The building contains the all new Production Facility for the Creamery, two large state of the art Pilot Plants (test labs for the Production Facility), as well as a modern Retail Area for sales. In addition, it will be the home for The Department of Agriculture's, Food Science Department which contains office space, classrooms, laboratories, and student lounge areas. Incorporating each and every one of these specific needs into one building was an immense challenge for the entire project team from design through construction. However, the end result will undeniably be a unique state-of-the-art facility that meets everyone's requirements.

The Food Science Building's project team is composed of the The Pennsylvania State University (owner), IKM Incorporated (architect), H.F. Lenz Co. (engineers), Food Engineering Inc. (food processing engineers), and Gilbane Building Co. (construction managers). It is located at the corner of Curtain Rd. and Bigler Rd. approximately three blocks west of Beaver Stadium (the PSU Football Stadium). The Food Science Building is a five story above grade structure with a partial basement level. It contains 122,000 square feet of occupiable space with the built-in capability for 17,600 square feet of future space. The project delivery method chosen was design-bid-build. Total construction duration of the project was from November 2004 to September 2006 and the project's total building cost is $45,060,000.

The following senior thesis study will centrally focus on the construction management aspect of the project during construction with special consideration given to sequencing and schedule along with constructability and cost impacts. The following analyses will review the structure and placement of the basement with regards to the production area, as well as all associated interior MEP's and exterior utilities. In addition the constructability of the interior bollard detail will be reviewed. Finally, the sustainable practices of food processing facilities will be examined. All of the above will then be assessed and a final recommendation will be made. Please note that all information pertaining to the Food Science Building is Anthony Lucostic's interpretation and may be different than the construction means and methods implemented by the project team.

History

The Food Science Building's primary use will serve as the new home for the well-known PSU Creamery. It will be the fourth home that the PSU Creamery has had since its existence dating back to 1889. In 1889 the Creamery began from a $7,000 dollar state appropriation as a one-story structure that contained everything necessary to enhance the Department of Agriculture's instruction and research in dairying. In 1904 the Creamery moved to Patterson Building and in 1932 it once again moved to Borland Laboratory where it resides today. It was determined that new construction is more efficient than a renovation and addition to Borland Laboratory. The move into their new facility, a block down Curtain Rd., will occur during the summer of 2006.

Architecture

The building architecture was designed to make a statement about the importance of the food processing and manufacturing sector. Visibility is high for the Creamery Processing/Manufacturing area and also for the Pilot Plant, emphasizing the importance of these areas to the departmental academic programs. The idea of research was therefore designed to include faculty office space, laboratory space, space for informal interactions, and joint-use research space. The idea was to encourage collaboration among faculty members, especially within groups and among graduate students.

The nature of the project is unusual with respect to the fraction of the total area that is on the first floor to accommodate the Creamery Processing/Manufacturing facility, salesroom, and pilot plant. Higher-than-normal ceilings and load bearing floors were used to accommodate this specialized equipment. Additionally, a well thought-out Creamery salesroom was designed with consideration for efficient response to periodic large influxes of customers. The new building will provide an infrastructure to allow the College of Agricultural Sciences to remain current with researchers in the food science departments in the Big Ten Conference and the Northeast.

Building Systems Overview

Building Envelope

An energy efficient wall and roof system was utilized on the Food Science Building. The exterior wall face consists of several materials and a different condition applies at each. The most typical sheathing detail holds an R 13 value. This system begins with an engineered galvanized structural stud system. A 2” wide continuous strip of 40 mil. “Textroseal” modified bitumen sealant tape is then applied to the outside flange of the stud. The next layer is a 10 mil Tyco “Film-Guard” polyethylene sheeting used as a vapor barrier. This material is continuous and all lap splices and cuts around openings, relief angles, etc. must be sealed with “Film-Guard Tuff Tape”. Next, the 2” double-sided foil faced “Thermax” polyisocyanurate sheathing (insulation board) is applied with a stainless steel washer tech screw @ 36” O.C. The insulation boards are not taped were a butt joint occurs, but the boards are simply pressed together to eliminate obvious gaps. The outer surface of the system now receives a “Tyvek” commercial grade wind and weather barrier which requires all lap splices and cuts around openings, relief angles, etc. to be taped with “Tyvek” commercial grade tape. Lastly, there is a 1-3/4” air space and then brick or 4” ground face CMU veneer is applied in a traditional manner.

The second type of wall system begins with an 8” insulated core CMU. A 1” insulation board is then applied followed by a 2” air space and a 4” ground face CMU veneer. The remaining wall systems are conventional windows, curtain wall, and aluminum panels.

There are two types of roofing systems being used on this building. The first system is located on the third floor level west side of the building. In this area the roofing is applied directly to the structural precast double tee’s located in this area. The double tee’s are being used to allow adequate support for future expansion; applying a bituminous roofing system with adhesives in this area would prove troublesome for future expansion construction. Therefore, an insulated 60 mil ballasted EPDM system is being utilized. The remaining roof of the building receives tapered insulation and a two-ply, modified bituminous membrane roof.

Structure

The structure of the building is composed of a structural steel frame with moment and shear connections. A composite metal decking along with poured in place lightweight concrete was then utilized throughout most of the building. In the production area of the building a cast-in-place 8" structural slab and beam encasements was utilized. The steel was erected with a 120 ton crawler crane.

Cast-in-place concrete was used for all grade beams, foundation walls, and slabs. All of the vertical formwork utilized reusable "Simmons" forms. The 8" structural slab used an engineered scaffolding formwork system for support. All concrete was placed using a driveable concrete pump.

There are two main areas where precast concrete is used on the building. Above the Pilot Plant area structural precast double tee's were utilized as part of the roofing system due to the long span and possible need for further expansion. As well the four stair towers are made of precast stair sections. A 180 ton mobile (all-terrain) crane was used to erect the double tee's, mainly due to reach.

Mechanical

The mechanical systems of the building tie into the PSU steam and chilled water campus loops for most heating and cooling purposes throughout the building. Steam for the heating and process loads of the Food Science Building will be routed to the building via a new steam utility tunnel that will be connected to PSU's existing steam tunnel running along Curtain Rd. The steam will be reduced to 15 psig to serve domestic hot water, heating hot water, and process steam for the Pilot Plants. In addition, the high-pressure steam will be reduced to medium pressure via a separate PRV station to serve autoclaves, steam-to-steam humidifiers, and steam kettles. The building will be provided with chilled water from the campus-wide chilled water system. Chilled water supply and return piping will enter the building in the basement level mechanical room and connected to the two main chilled water distribution pumps. Chilled water will then be distributed to each of the air handling units throughout the building. Each air handling unit (AHU) will have a two-way control valve. All offices will contain a VAV (variable

air volume) AHU including a mixing box. All laboratories will contain a VAV air handling unit that will be 100% outside air. The Production Areas and Creamery Sales Area will be served by a constant volume single zone (CVSZ) air handling unit.

Electrical

The electrical service for the facility is supplied from a radial extension of the existing campus medium voltage distribution system. The primary services will be routed to the building via underground duct banks. The building's electrical service consists of two unit substations located in the basement electrical room. Distribution voltage is 12,470V/480/277V/208/120V. Utilization voltages are 480/277V, 3 phase, 4 wire and 208Y/120V, 3 phase, 4 wire. The main distribution switchboard "HMDS" consists of two main circuit breakers and a distribution section. The switchboard is rated for 3000A, 480/277V. A sub distribution switchboard "LSDS" is fed via a 480V:208/120V transformer. Switchboard "LSDS" is rated at 208/120V.

Plumbing

There are a multitude of plumbing requirements throughout the entire building. The laboratories each have special requirements based upon the processes that are anticipated. These service connections include water, natural gas, vacuum, steam, de-ionized water, compressed air, process cooling water, etc., as required for the individual laboratories. In the Pilot and Production Areas, individual service loops will be installed around the perimeter with valves and quick disconnects to allow for flexibility within the space. In the Wet Pilot Plant and Production Areas, steam/hot water mixing valves will be installed to provide high temperature water for cleaning purposes. Water service will enter the building in the basement mechanical room. Sanitary and storm sewers will connect to the existing PSU East Subcampus lines.

Fire Protection

A fire sprinkler water service is in the basement floor mechanical room. The service consists of a double detector check valve assembly, a supervised OS&Y gate valve, and water flow switch. The water flow switch interfaces with the fire alarm system. The entire building is protected by automatic wet fire sprinkler systems.

High rack storage is located in the building and requires in-rack sprinkler systems in addition to fire sprinklers located at the ceiling. The high rack storage area sprinkler systems requires a higher water volume and pressure that needs an electric motor driven fire pump. A dedicated fire pump will be installed in the Food Science Building for this purpose. The new fire sprinkler systems installed throughout the building are designed and installed to meet NFPA and FM Global Requirements.

Telecommunications

Telecommunications service to the building originates in the new duct bank which is located in the promenade area of the site, west of the building. The service consists of fiber optic cable, 24-single mode, and 24-multi-mode strands and 200 pair copper conductor.

The MER (Main Equipment Room/MDF) houses core network electronics, a remote shelf for the PBX system, a main distribution frame for the voice system, protectors for outside cables, building backbone cable termination fields, and horizontal cable patch panels for work area outlets fed form the MER. From the MER each of the Telecommunications Closets (TC's) are fed with a variety of cables in a star configuration with backbone cables that is a home run from the TC to the MER

Project Cost Evaluation

Food Science Building – University Park, PA

Construction Cost (CC):	$32,765,261
Construction Cost per square foot (CC/SF):	$268.57 / SF
Total Project Cost(TC):	$45,060,000
Total Project Cost per square foot (TC/SF):	$369.34 / SF

Buildings Systems Cost

1) Structural System: TC: $6,574,000
TC/SF: $53.89 / SF

Includes: Piles: $1,019,000
Concrete: $2,865,000
Structural Steel: $2,690,000

2) HVAC System: TC: $4,108,000
TC/SF: $33.67 / SF

3) Electrical System: TC: $2,632,000
TC/SF: $21.57 / SF

4) Food Production / Processing System: TC: $5,338,065
TC/SF: $43.75 / SF

Includes: Food Processing: $3,518,000
Ammonia Refrigeration System: $1,040,900
Coolers & Refrigeration: $779,165

Proposal

The proposed senior thesis study of the Food Science Building in University Park, PA will concentrate its' focus on the Production Area contained within the building. There will be three different analyses performed on the Production Area along with a critical industry issues research topic pertaining to the area. These will be as follows:

- **Analysis 1:** Basement Relocation and Structural Redesign
  - Alternative 1: The use of precast double tees.
    - Proposed Benefit: Will provide a better finish while expediting schedule.
  - Alternative 2: Redesign using all c-i-p concrete in this area.
    - Proposed Benefit: Vital schedule savings while aiding in constructability.
- **Analysis 2:** MEP & Utility Relocations with Regards to Basement Relocation
  - Alternative 1: Decrease / Increase MEP & Utility Runs w/ Basement Relocation
    - Proposed Benefit: Reduce mechanical sizing and complex job coordination.
- **Analysis 3:** Stainless Steel Bollard Detail.
  - Alternative 1: Redesign a less complex structural installation detail.
    - Proposed benefit: Ease of installation will result in VE and schedule savings.
- **Research Issue:** Sustainability Designs for Production Area.
  - To develop a set of sustainable requirements for a food processing area.

The above issues will consider value engineering analysis, constructability review, schedule reduction and acceleration, along with issues research.

EXECUTIVE SUMMARY

The Food Science Building will serve as the new home for the College of Agriculture's department of Food Sciences. Additionally, it will be the new home for the well-known PSU Creamery's Production Facility and Retail Area. The current design of the building places the location of the partial basement mechanical room on the west side of the building. The majority of my senior thesis analysis is associated with the proposed relocation of the basement to the east side of the building under the Production Area. The results found are listed below:

Analysis 1: Basement Relocation and Structural Redesign

- Relocating the basement to the east side of the building under the Production Area and changing the structure to all cast in place concrete through to the second floor utilizing a wide module concrete joist slab.
  - 3 month schedule savings for Production Area
  - $190,000 cost savings
  - More aesthetically pleasing exposed concrete ceiling in Production Area
  - Increased ceiling height of 17" in Production Area

Analysis 2: MEP & Utility Relocation with Regards to Basement Relocation

- First Floor Production Area is now a cast in place structure vs. slab on grade.
  - Easier and more precise layout for critical penetrations in Production Area
  - Availability to run lines under slab and penetrate at any time
  - Maintenance and future relocation are not issues- lines always accessible.
- Interior mechanical pipe savings- Relocation places basement closer to mech. shaft
  - $48,000 cost savings
  - Decrease runs – decrease chances for future problems (leaks, maintenance)
- Exterior utility relocations to the east side of building
  - $3,000 cost savings
  - Removes utility lines from running directly under civic hardscape area

Analysis 3: Stainless Steel Bollard Detail

- Redesign to a simplified less complex installation detail
  - Value engineering idea that will aid in constructability
  - Will allow for more precise placement with surroundings

Research: Sustainable Designs for Production Areas

- Utilize a compressed ammonia refrigeration system for cooling
- Use a steam system when heating water for cleaning and equipment purposes
- Facilitate GMP's into design (Good Manufacturing Practices)
  - Use high speed quick rolling doors at coolers and freezers
  - Use HCFC-free insulated composite metal panels

Structural Breadth

Analysis 1: Basement Relocation and Structural Redesign

Background

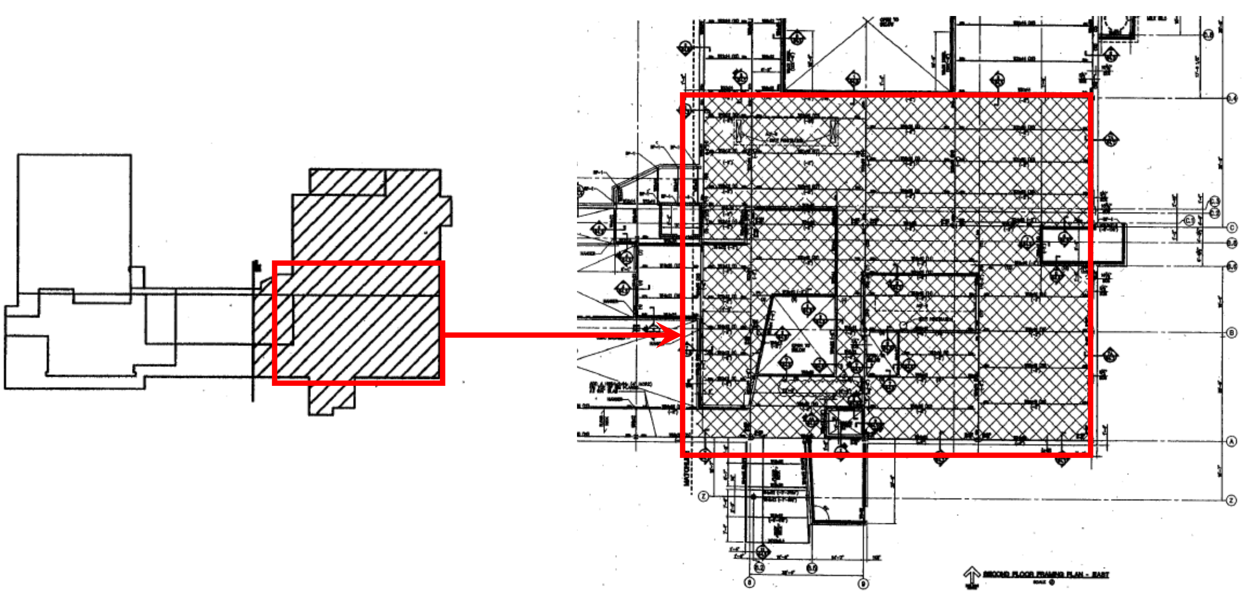
The main Production Area is located in the east part of the Food Science Building on the first floor level. The ceiling of this area (the second floor) is currently designed and installed as an 8” thick structural slab vs. the rest of the buildings’ typical 6” concrete slab-on-deck. Additionally, each structural steel beam, girder, and column in this area had to be encased with concrete which held no structural integrity; it was done simply for sanitation and cleaning purposes. This was the solution that was decided upon by the architect, engineer, and owner to solve the issues of sanitation requirements for a food processing facility. The other requirement that this solution maintained was that there was no exposed carbon steel in the area. The chemicals used weekly to clean and sanitize the area are so powerful that they would eventually corrode and eat through carbon-based structural steel.

The Food Science Building was not designed in the traditional manor that a food production facility of this level normally undergoes. The traditional process for designing a food production facility of this magnitude is to design and lay-out the production area and then build an exterior shell around it. The Food Science Building was designed with architectural aesthetics, educational use, and a retail area in mind and the production areas were worked into the design as needed; therefore the design and construction of the building is opposite of the normal procedure. The task of the construction manager to schedule, coordinate, and put in place all of the equipment and associated utilities with the production areas along with the rest of the building became an almost unbearable task at times. The most prevalent scheduling delay in the production area was the cast-in-place structural concrete slab and beam encasements. This is first activity that must take place in this area and due to its’ complexity it took three times longer than anyone had planned for.

Problem

The problem with this design was the difficult constructability and immense schedule impact that it had to the project. The start-up and useable operation of the Production facility in the Food Science Building is by far the driving task on the schedule. The sequence of the trades that has to take place and the continuous irregular and complex details of the area made management and coordination almost infeasible at times. The extensive amount of mechanical and electrical rough-in that had to take place in the slab-on-grade below before it could be poured was key. This had to be done before the shoring and scaffolding in the area could begin for the structural slab above, which was also waiting on structural steel completion in this area before it could begin. Add in that once they got to this point, no two beam encasements were the same and that after all shoring, forming, and decking was complete another sizeable amount of mechanical and electrical rough-in had to be installed before the structural slab could be poured. These delays and problems continuously pushed back the schedule as well as creating daily headaches for everyone involved.

Refer to the figures below for a structural layout showing the location of the second floor structural slab above the Production Area in the building.



Proposal

The proposed solution to the structural slab and steel beam encasement problem is a redesign to another structural system to be used in the area. There are two systems I analyzed in its' place:

Alternative #1: The elimination of the structural slab and concrete encased steel beams on the second floor and the utilization of structural precast double tee's bearing on steel girders.

Alternative #2: The relocation of the Basement Mechanical Area to the East side of the building under the Production Area and using structural cast-in-place concrete columns, beams, and slab for the building's structure from the basement through to the second floor.

Goals: Both alternatives will aid constructability and schedule. They will improve the overall quality of the Production Area while saving money and significant time in the schedule. Additionally, during the construction process the flow of job-site coordination, staging, and sequencing amongst trades will be notably improved.

Analysis

Alternative#1

The first alternative design consideration with regards to the replacement of the structural slab and concrete encased steel beams and girders was to use structural precast double tee's bearing on steel girders in its' place.

The greatest benefit that the use of structural precast concrete double tee's would provide is the unquestionable savings in shoring, framing, and pouring; which were the most significant reasons for the schedule delay on the project. Additionally, the underside of the double tee's would have a smoother, more finished aesthetic look when compared to the cast in place concrete using custom built wood formwork.

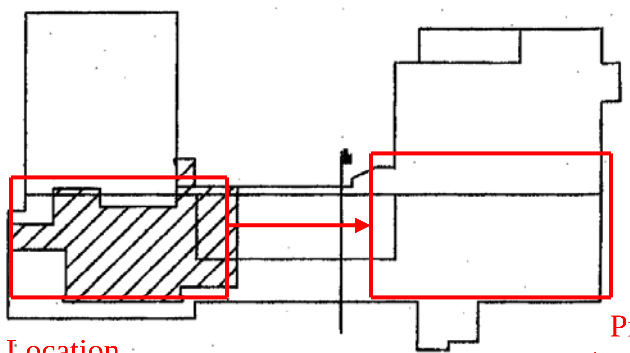
However, the large spans in the 100 ft. x 110 ft. Production Area would require some intermediate girder supports. This means that the construction sequence in this area would require additional coordination amongst the different trade contractors involved. Although, the most significant consideration to review is how the work on the underside of the slab will tie together and meet the requirements for the Production Area.

The need of intermediate steel girder supports in the Production Area creates a problem due to the fact that you can not have exposed carbon steel in this area. Thus they must be covered. A cast in place concrete encasement at this point is now impossible to construct and the use of any other material would create finishing and aesthetic problems below. Additionally, the precast double tee's will have an exposed joint on the underside of the slab were two planks meet. This joint is typically sealed by caulking, but the commercial grade caulk typically used would not be acceptable in a Production Area. However, they do make a food process caulking approved for such areas but this would require continuous maintenance issues and accessibility to these areas would be extremely difficult.

After initially researching this idea it was decided that it would actually not be the best solution to the Production Areas' problems. Although, it would undoubtedly save forming time and schedule it creates an entire set of new issues within itself mainly with regards to Production Area requirements, finishes, and maintenance.

Alternative #2

The second alternative design considers multiple aspects of the project. The proposed alternative includes relocating the current basement mechanical room from the west side of the building, were it currently resides to the east side of the building under the Production Area. In addition, this alternative changes the structure in this area to a cast in place concrete structure from the basement level through to the second floor. This means that the basement foundation, walls, and columns will all be c-i-p concrete structure. As well, the first floor level (Production Area floor) and columns along with the second floor level (Production Area Ceiling) will be c-i-p concrete structure.

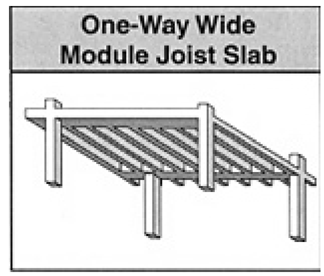


Basement Relocation Schematic

The idea was to relocate the basement mechanical room area from the west side of the building to the east side of the building under the Production Area. This would place the buildings' mechanical piping closer to the mechanical shaft that is located on the buildings' east side. Furthermore, the most significant change would be the added accessibility to the Production Area for MEP's from below. This would mean that the immense amount of rough-in that had to take place before the slab on grade was poured could now be done from below and would not slow down the progress of the structure. Additionally, the layout of critical penetration for connections to production equipment, etc. could now be done with drastically more precision. This is due to the working platform that will be created for the c-i-p concrete slab that the mechanicals can layout from vs. before when they were trying to work from a gravel base for the slab on grade trying to place penetrations within inches of the necessary locations shown. An added feature would be the accessibility for future maintenance and repairs to all production utilities from below. Therefore if a pipe line or fitting would wear-out it could be easily fixed. Also, this would allow for a great deal more freedom to the owner to be able to rearrange or add equipment in the future.

Structural Redesign

The design chosen for the cast in place concrete structure was a wide module concrete one-way joist system that frames into cast in place girders and columns. The CRSI (Concrete Reinforcing Steel Institute 2001) Handbook was utilized to choose the concrete system that was correct for the situation. It was determined that the load on the first floor level would be the most significant due to the Production Facility in this area, a factored load of 436 psf. All live load considerations were taken from IBC (International Building Code) 2000. In addition some special considerations were taken into account for the uniqueness of the area; for example the traditional pipe hanging support of 15 psf was doubled due to the amount of mep's that are planned to be hanging from the structure below in the basement.



Choosing the system that worked for the extreme situation of the first floor level was challenging. Although, after considering all other systems, one way and two slabs with different arrangements of beams and girders, the wide module joist slab held the most load and worked the best for the situation. Likewise, a similar but smaller wide modular joist slab was chosen for the second floor due to the decrease in load from the first floor level. After the joist slabs were chosen the girders were then calculated by hand to size and chose the reinforcing. The girders was designed on the basis that the ultimate flexural strength will be greater than the design moment. The reinforcing was spaced evenly through out the girders win a minimum 2" cover. The concrete joist slab construction will also decrease the overall structural floor height (bottom of beam to top of slab) for the first floor by 2" and by 17" for the second floor. The additional 17" of ceiling height gained by the Production Area would be vital benefit in providing increased ceiling height as well as giving the mechanicals above more room. The two floor systems chosen are:

Proposed Structure

First Floor Level:

Wide Module Concrete One-Way Joists

40” Forms + 10” Ribs @ 50” c.-c.

24.5” Deep Rib + 4.5” Top Slab = 28.5” Total Depth

End Span: (Use @ all locations)

- Tabulated Capacity = 1894 plf with 37’ Clear Span
- Top Bars: #8 bars spaced @ 11.5” o.c.
- Bottom Bars: 1- #10 and 1- #11
- Single-leg stirrups: 21- #4 spaced @ 9” o.c.

Interior Span:

- *Tabulated Capacity = 3095 plf with 37’ Clear Span*
- *Top Bars: #9 bars spaced @ 10.5” o.c.*
- *Bottom Bars: 1- #10 and 1- #11*
- *Single-leg stirrups: 21- #5 spaced @ 9” o.c*

Girder

- 48” x 28.5”
- w/ 20- #9 bars spaced @ 1-1/8” o.c. on Top
- w/ 17- #8 bars spaced @ 1.5” o.c. on Bottom

Second Floor Level:

Wide Module Concrete One-Way Joists

- 40” Forms + 10” Ribs @ 50” c.-c.
- 18” Deep Rib + 4.5” Top Slab = 22.5” Total Depth

End Span: (Use @ all locations)

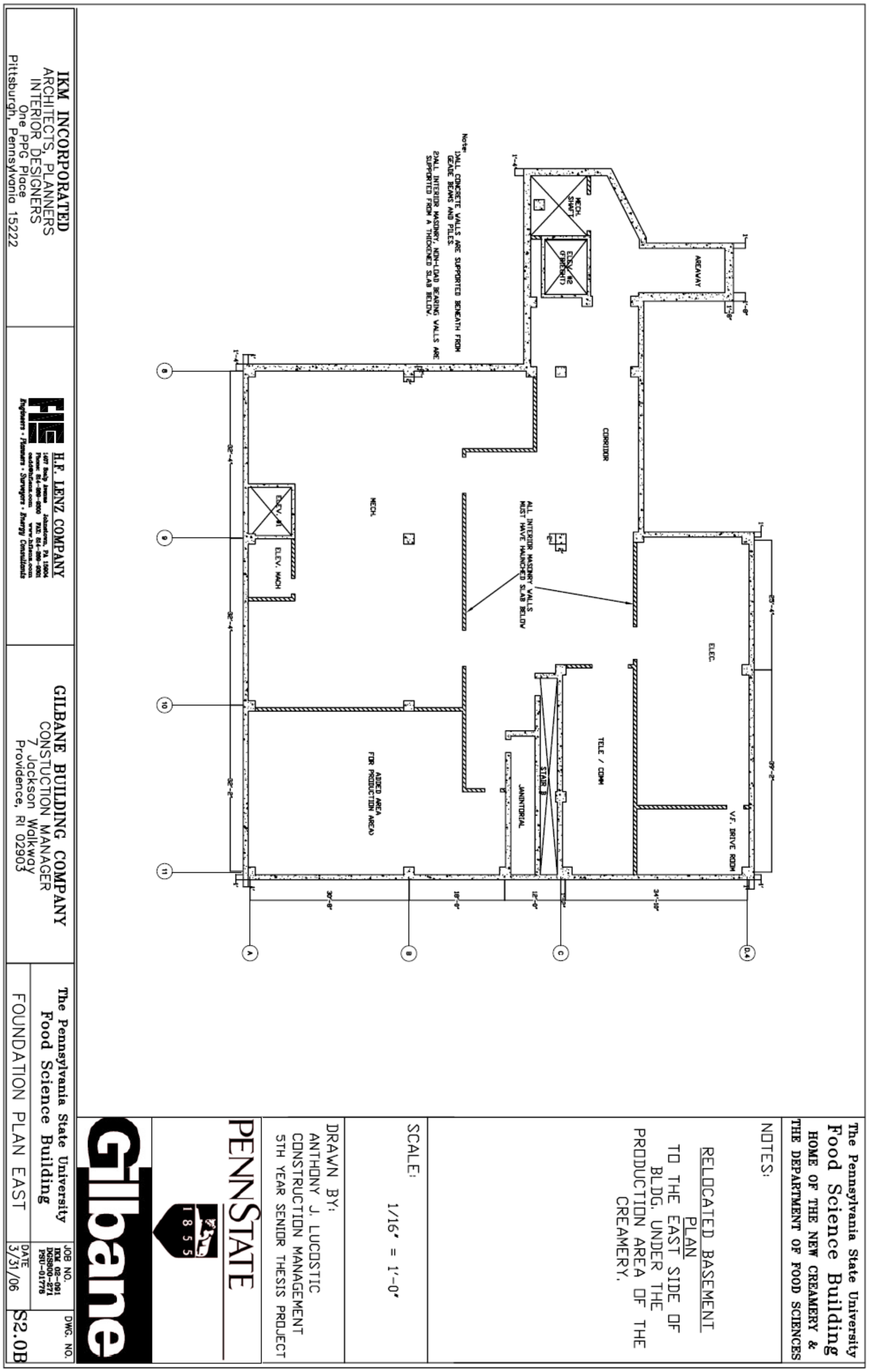
- Tabulated Capacity = 1195 plf with 33’ Clear Span
- Top Bars: #6 bars spaced @ 9” o.c.
- Bottom Bars: 2- #7 and 1- #8
- Single-leg stirrups: 17- #3 spaced @ 9” o.c.

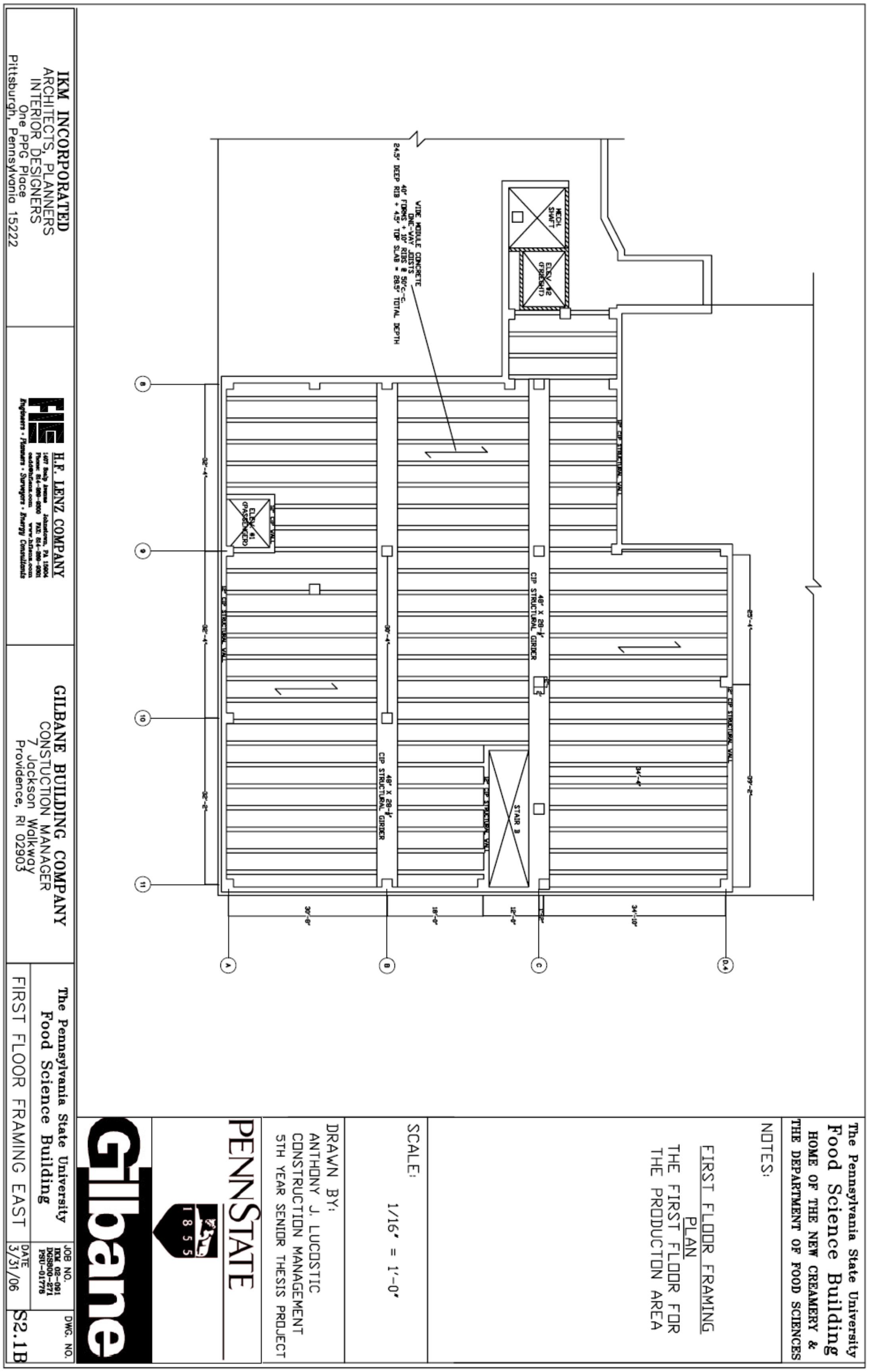
Interior Span:

- *Tabulated Capacity = 2025 plf with 33’ Clear Span*
- *Top Bars: #7 bars spaced @ 9” o.c.*
- *Bottom Bars: 2- #7 and 1- #8*
- *Single-leg stirrups: 17- #3 spaced @ 9” o.c*

Girder

- 44” x 22.5”
- w/ 18- #9 bars spaced @ 1-1/8” o.c. on Top
- w/ 16- #8 bars spaced @ 1.5” o.c. on Bottom


IKM INCORPORATED
ARCHITECTS, PLANNERS
INTERIOR DESIGNERS
One PPG Place
Pittsburgh, Pennsylvania 15222
H.F. LENZ COMPANY
GILBANE BUILDING COMPANY
CONSTUCTION MANAGER
7 Jackson Walkway
Providence, RI 02903
The Pennsylvania State University
Food Science Building
FOUNDATION PLAN EAST
DATE 3/31/06
S2.0B
The Pennsylvania State University
Food Science Building
HOME OF THE NEW CREAMERY &
THE DEPARTMENT OF FOOD SCIENCES
NOTES:
RELOCATED BASEMENT PLAN
TO THE EAST SIDE OF BLDG. UNDER THE PRODUCTION AREA OF THE CREAMERY.
SCALE:
1/16" = 1'-0"
DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT
PENNSTATE
1 8 5 5
Gilbane
CORRIDOR
MECH.
ELEC.
TELE / COMM
JANITORIAL
STAIR B
V.F. DRIVE ROOM
AREAWAY
ELEV. #1
ELEV. MACH
ADDED AREA FOR PRODUCTION AREA
ALL INTERIOR MASONRY WALLS MUST HAVE HAUNCHED SLAB BELOW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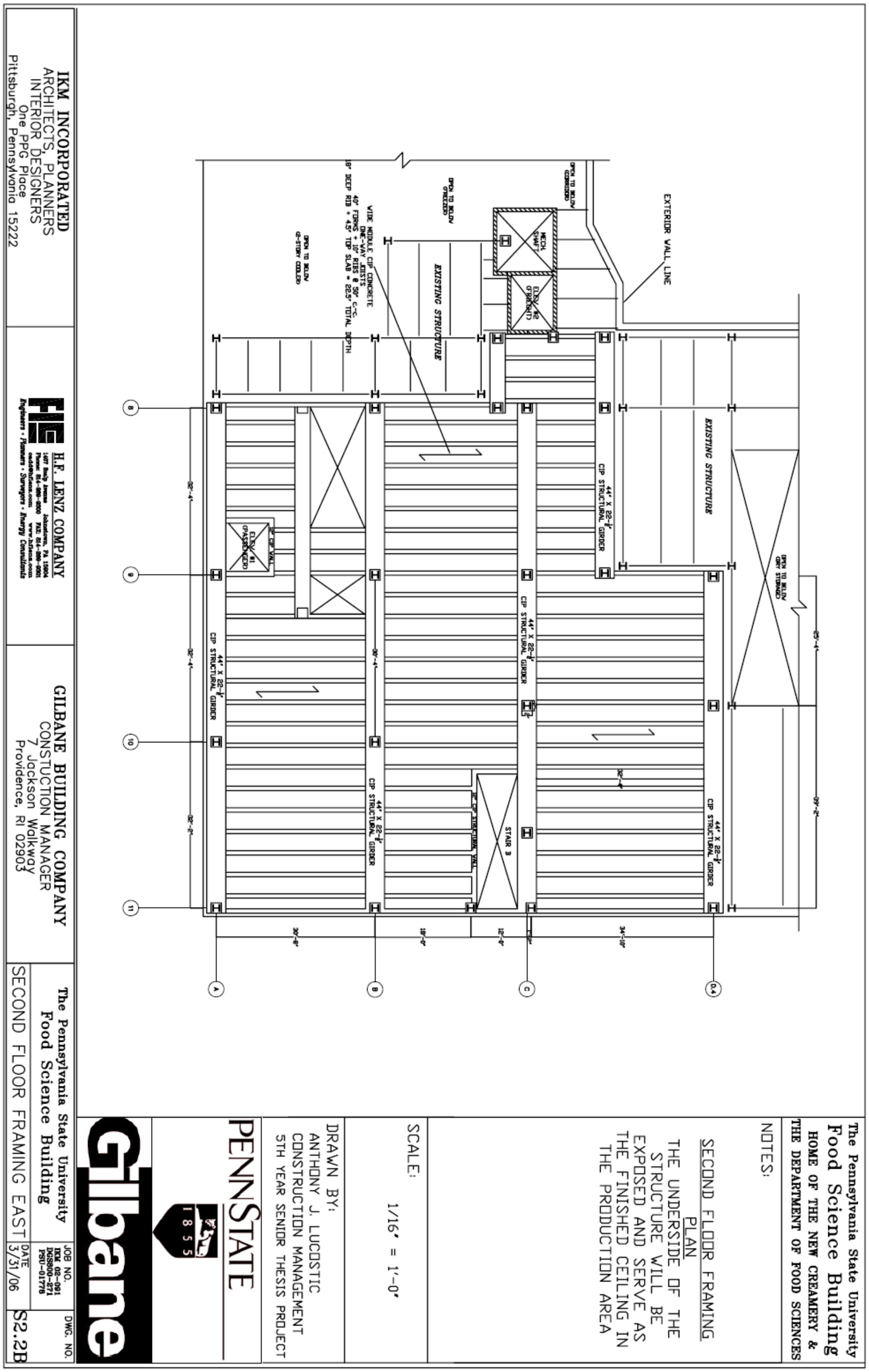
FIRST FLOOR FRAMING EAST
DATE
3/31/06
DWG. NO.
S2.1B
The Pennsylvania State University
Food Science Building
HOME OF THE NEW CREAMERY &
THE DEPARTMENT OF FOOD SCIENCES
NOTES:
FIRST FLOOR FRAMING PLAN
THE FIRST FLOOR FOR THE PRODUCTION AREA
SCALE:
1/16" = 1'-0"
DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT
PENNSTATE
1855
Gilbane
STAIR B
CIP STRUCTURAL GIRDER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The Pennsylvania State University
Food Science Building
SECOND FLOOR FRAMING EAST
DATE 3/31/06
DWG. NO. S2.2B
The Pennsylvania State University
Food Science Building
HOME OF THE NEW CREAMERY &
THE DEPARTMENT OF FOOD SCIENCES
NOTES:
SECOND FLOOR FRAMING PLAN
THE UNDERSIDE OF THE STRUCTURE WILL BE EXPOSED AND SERVE AS THE FINISHED CEILING IN THE PRODUCTION AREA
SCALE:
1/16" = 1'-0"
DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT
PENNSTATE
Gilbane
EXTERIOR WALL LINE
EXISTING STRUCTURE
44" X 22-1/2" CIP STRUCTURAL GIRDER
STAIR B

-

Schedule Savings / Constructability

A major benefit of the joist slab is the repetitive procedure savings in formwork cost and the use of the metal pans to form the joists structure. This will significantly aid in the constructability of this area of the building when compared to the custom formed wrap of each steel beam and girder. The other factor that plays a role in this particular situation is the types of contractors in the area and the typical type of construction performed in central PA area. In the central PA area the typical type of superstructure built is a structural steel frame with concrete slab on metal decking. A c-i-p concrete elevated structural slab type of construction is not at all typical practice in this area and therefore there are not any specialty contractors available to perform this type of work. This makes the constructability of a structure such as this even more difficult to a contractor that does not typically perform this type of work. Thus, any repetitive design that incorporates prefabricated formwork panels would notably aid the constructability of an area such as this.

Concrete Joist Construction

The proposed construction sequence would also change with the new structural sequence. The current structural phase of the project was performed from east to west through the building. The new sequence with the proposed structural changes would actually be opposite, from west to east. The reasoning would be that the piles, caps, & grade beams would start on the west and work east. Once the concrete contractor reaches the east side of the building he can increase his crew size and work the c-i-p structure for the relocated basement and through the Production Area up to the second floor. At the same time steel erection can begin on the west side and by the time steel erection reaches the east side of the building the c-i-p structure of the Production Area will be complete. Therefore steel erection can continue above the Production Area and work there way around to finish the remainder of the building. This new schedule arrangement is found to have saved 3 months of construction time in the Production Area.

Food Science Building Schedule Comparison

Current Schedule vs. Proposed Relocation Schedule

Food Science Building	Compared Relocation Schedule		Anthony Lucostic
Activity Name	Original Duration	Start	Finish
Food Science Building	315	05-Jan-05 A	09-Sep-05
Current Project Schedule	302	05-Jan-05 A	09-Sep-05
EAST- Pile Caps / Grade Beams / Walls / Slab	1	05-Jan-05 A	22-Jun-05 A
PRODUCTION AREA STRUCTURE BEGINS	0	24-Jan-05*	
WEST (Basement)- Pile Caps / Grade Beams / Walls / Slab	51	24-Jan-05*	04-Apr-05
WEST- Pile Caps / Grade Beams / Walls / Slab	55	07-Mar-05*	20-May-05
Steel Erection	100	07-Mar-05*	26-Jul-05
EAST- Cast in Place Structural Slab & Beam Encasement	63	13-Jun-05*	09-Sep-05
PRODUCTION AREA STRUCUTRE COMPLETE	0	09-Sep-05*	
Proposed Relocation Schedule	138	05-Jan-05	19-Jul-05
WEST- Pile Caps / Grade Beams / Walls / Slab	50	05-Jan-05*	15-Mar-05
EAST- PRODUCITON AREA STRUCUTRE BEGINS	0	24-Jan-05*	
EAST (Basement)- Pile Caps / Grade Beams / Walls / Slab	55	24-Jan-05*	08-Apr-05
EAST- Cast in Place Concrete Joist Slab & Girders (Levels 1&2)	51	31-Mar-05*	10-Jun-05
PRODUCTION AREA STRUCTURE COMPLETE	0	10-Jun-05*	
EAST- Pile Caps / Grade Beams / Walls / Slab	59	17-Mar-05*	08-Jun-05
Steel Erection	90	14-Mar-05*	19-Jul-05

3 MONTH SCHEDULE SAVINGS

**3 Month Schedule Savings in Production Area*

Food Science Building Cost Comparison

Current Design vs. Proposed Relocation

Take-Off Summary

Current Design Deletion

Area	Deletion	Addition	Associated Cost
WEST SIDE (Basement Area)			
Basement Level			
Piles, Caps, Grade Beams, Foundation Walls, Slab on Grade	X		$276,845.00
First Floor Level			
W Shape, Composite Deck, Slab on Deck	X		$197,912.00
EAST SIDE			
First Floor Level			
Piles, Caps, Grade Beams, Walls, Slab on Grade, Concrete Encased Steel Columns	X		$161,346.00
Second Floor Level			
Composite Beams & Cast in Place Slab	X		$348,416.00
Total Savings			$984,519.00

Proposed Relocation Addition

Area	Deletion	Addition	Associated Cost
WEST SIDE			
First Floor Level			
Slab on Grade		X	$60,488.00
EAST SIDE (Basement / Production Area)			
Basement Level			
Sheet Piles, Caps, Grade Beams, Foundation Walls, Slab on Grade, CIP Concrete Columns		X	$315,680.00
First Floor Level			
CIP Concret Joist Slab & Columns		X	$241,290.00
Second Floor Level			
CIP Concrete Joist Slab		X	$173,418.00
Total Savings			$790,876.00

Total Cost Impact of Relocation	Savings of:	**$193,643.00**

**Apprx. $190,000 Savings in Structural Redesign*

Estimate / Cost Comparison

The cost comparison performed on the Food Science Building considers the structural systems involved when looking at the existing, compared to the new proposed relocation and design. A take-off was performed on the current basement, first floor, and second floor structural systems which were estimated and calculated as a complete deletion and savings to the project. Another take-off was then performed on the complete redesign which was estimated and calculated as a complete added cost to the project. The numbers were then subtracted and a savings of approximately $190,000 dollars was found with the use of the new system. Detailed take-off sheets can be found in Appendix A.

Conclusion

The relocation of the basement to the east side of the building under the mechanical room and the use of all cast in place structure from the basement level through to the second level, utilizing wide module concrete joist is the suggested alternative to use. This alternative will significantly aid in constructability with regards to the regions specific construction techniques while providing a more aesthetically pleasing exposed concrete finished ceiling for the Production Area. The 17” height saving in the ceiling of the Production Area will increase ceiling height while giving mechanicals added room. Everything considered, the relocation of the basement and the concrete joist system will save approximately $190,000 dollars of the total structure cost while saving 3 months of critical schedule time for the Production Area.

Mechanical Breadth

Analysis 2: MEP & Utility Relocations with Regards to Basement Relocation

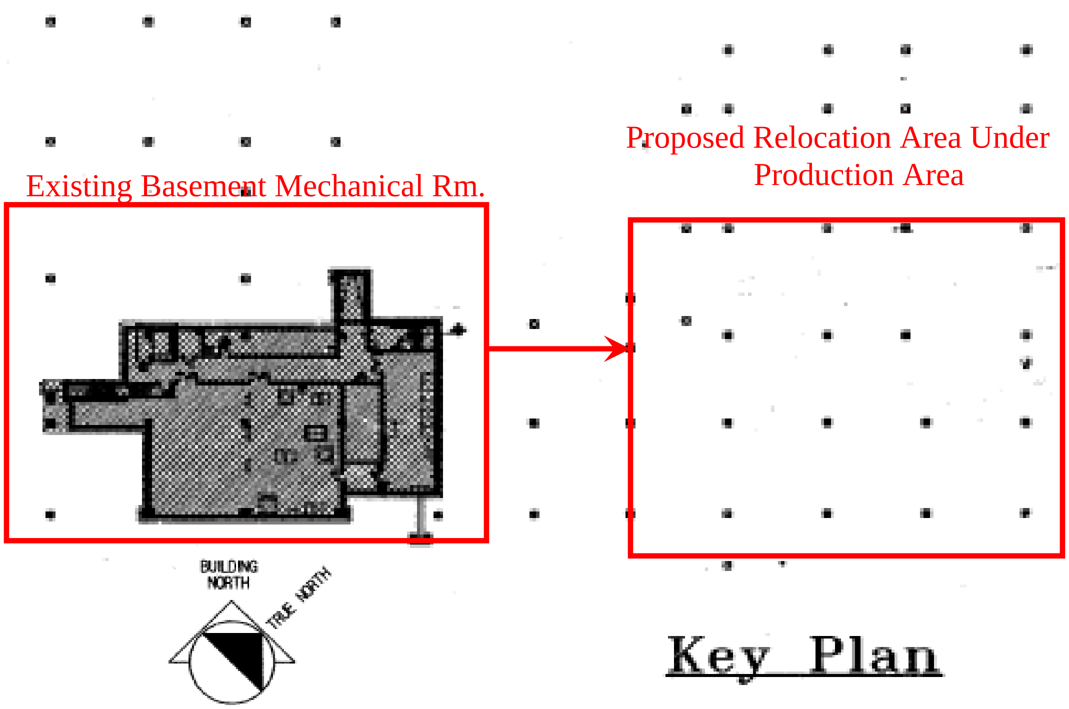
Background & Problem

The Production Area is a highly mechanically driven area of the building. A huge part of the sequencing and schedule delays was due to all of the rough-ins that had to occur in the slab-on-grade before pouring. This held up shoring, which held up structural slab that intern kept continuously pushing the schedule back for the Production Area. Additionally, the same situation occurred in the above structural slab area, although the rough-ins in this area contained an added factor. Due to the vast amount of conduit, pipes, and penetrations a close watch had to constantly be kept on the coverage and structural integrity of the concrete structural slab. All of this work was performed with the idea to keep the least amount of piping exposed in the Production Area itself. Thus, keeping the least amount of exposed piping hanging in the ceiling, the less of a chance there is for bacteria, etc. to grow up there. In spite of the design efforts there still ended up being a significant amount of piping exposed in the Production Area's ceiling. Also, all of the mechanical and electrical piping running in the Production Area ceiling meant that there needed to be time allowed in the schedule for this work to be done before flooring could begin. Intern, equipment installation, connections, and start-up could not begin until flooring is complete. Refer to the picture to the right showing a portion of the ceiling in the Production Area while current installation and construction in the area is not even complete.

The Food Science Building contains a partial basement level; meaning that only the west side of the building has a basement level below the first floor level. This basement area serves solely as the buildings mechanical and electrical rooms. A majority

of the services coming from this mechanical and electrical room serve the Production Area which is located at the opposite end of the building on the east side. Therefore, a lot of mechanical and electrical coordination was necessary to route all of the piping through the building to get it to where it was needed. As well, a good deal of extra piping was necessary to make these runs.

Refer to the figures below of the building layout to show the locations of the basement level mechanical room and the location of the Production Area.



Proposal

The proposal of this mechanical analysis will directly relate to structural analysis 1 performed earlier, relocating the basement mechanical and electrical rooms to the east side of the building under the Production Area. I will investigate all associated MEP relocations and conflicts that may arise with this relocation, positive and negative.

Analysis

Interior Piping

My initial considerations were that the relocation of the basement to the east side places all the starting points for the MEP's closer to the Production Area and closer to the mechanical shaft on the east side of the building. My thinking was that a majority of the runs from the basement ran to the Production Area and to the mechanical shaft nearby which would save a significant portion of piping.

The further I examined the drawings and pipe runs the more confused I became. The building houses a production facility, commercial labs, classrooms, teaching and food processing labs, and a retail area. Moreover, each specific type of facility was not organized into like clusters. Therefore, you had all different types of piping running back and forth across the entire building on each floor feeding all of the specific needs. Consequently, despite my earlier wish the amount of interior piping I was planning to save was not as significant as had hoped.

However, I was able to remove approximately 800 linear feet of piping due to the basement relocation. The basement now being directly next to the east mechanical shaft which feeds through the building to the penthouse, enabled me to remove many horizontal runs from the existing basement on the west side to the particular shaft. These include 6" low pressure steam supply and return lines, 8" chilled water supply and return lines, and 6" hot water perimeter supply and return lines along. In addition four 90^{o} elbows on each run were eliminated.

Using a pipe sizing and computational head loss chart from the ASHRAE Handbook I performed some calculations to determine the decrease in head pressure lost from removing the lines discussed above. Knowing the pipe size and pump size from the HVAC Schedule I was able to utilize the charts and find a head loss per unit length. In addition, a length of 30' was added to my run length for each 90^{o} elbow fitting encountered; from 'HVAC Analysis and Design, Fifth Edition'. The decreases in head pressures lost ranged from 10ft/100ft to 14ft/100ft. These losses were considered negligible and would only help to increase the efficiency of the pumps. Below find the take-off of the deleted pipe and associated costs:

Food Science Building

Interior Piping Take-Off

Description	Savings	Addition	Quantity	Cost: Piping	Cost: Insulation	Total Cost
Low Pressure Steam / Return						
4" LPS	X		120'	$2,520.00	$2,106.00	$4,626.00
4" LPR	X		120'	$2,520.00	$2,106.00	$4,626.00
4" 90° Elbows	X		4	$1,024.00	$0.00	$1,024.00
Chilled Water Supply / Return						
8" CHWS	X		120'	$5,700.00	$3,900.00	$9,600.00
8" CHWR	X		120'	$5,700.00	$3,900.00	$9,600.00
8" 90° Elbow	X		8	$5,200.00	$0.00	$5,200.00
Hot Water Permieter Supply / Return						
6" HWPS	X		120'	$3,960.00	$3,120.00	$7,080.00
6" HWPR	X		120'	$3,960.00	$3,120.00	$7,080.00
6" 90° Elbows	X		8	$3,440.00	$0.00	$3,440.00
Total Cost Impact				**Savings of:**		**$48,836.00**

Food Science Building

Utility Relocation Take-Off

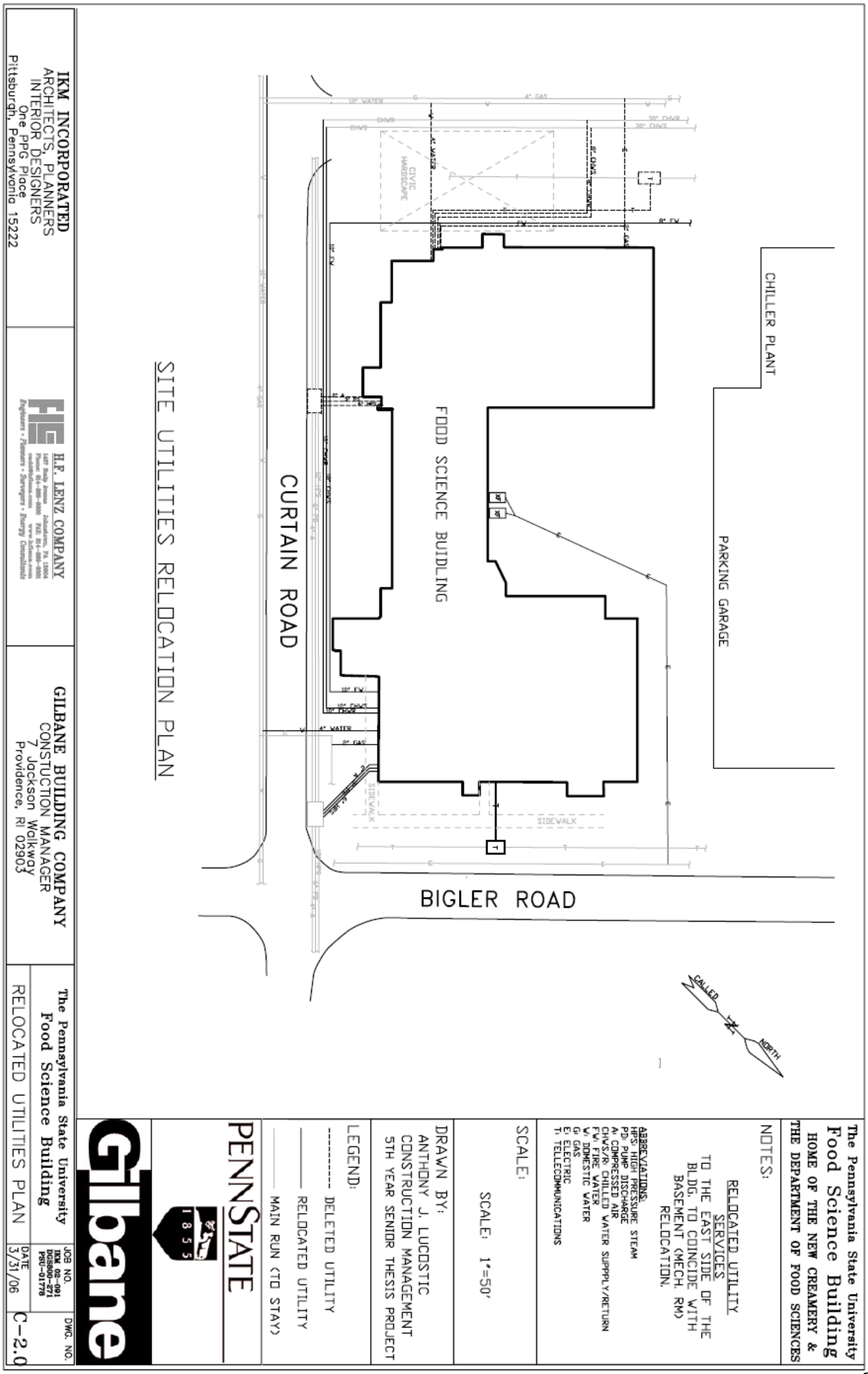
Description	Savings	Addition	Quantity	Cost: Piping	Cost: Excavation	Total Cost
Steam						
6" HPS (High Pressure Steam)	No Cost Impact		0	$0.00	$0.00	$0.00
3" PD (Pump Discharge,Condensate)	No Cost Impact		0	$0.00	$0.00	$0.00
2" A (Compressed Air)	No Cost Impact		0	$0.00	$0.00	$0.00
Chilled Water						
10" CHWS (Chilled Water Supply)		X	200'	$426.00	$1,088.10	$1,514.10
10" CHWR (Chilled Water Return)		X	200'	$426.00	$1,088.10	$1,514.10
10" 90° Elbow	X		2	$930.00	$0.00	$930.00
Fire Protection						
10" FW (Fire Water)		X	350'	$710.00	$2,176.20	$2,886.20
10" 90° Elbow		X	1	$465.00	$0.00	$465.00
Natural Gas						
2" G (Gas)	X		200'	$2,140.00	$1,088.10	$3,228.10
8" 90° Elbow	X		1	$256.00	$0.00	$257.00
Domestic Water						
4" W (Water)	No Cost Impact		0	$0.00	$0.00	$0.00
Electric						
E (Electric Ductbank)	No Cost Impact		0	$0.00	$0.00	$0.00
Telecommunications						
T (Telecom. Ductbank)						
4- 5" PVC Conduit	X		80'	$1,680.00	$627.75	$2,307.75
5" 90° Elbow	X		4	$314.00	$0.00	$314.00
Reinforcing Rods	X		1 Ton	$1,575.00	$0.00	$1,575.00
Concrete In Place	X		7 CY	$1,211.00	$0.00	$1,211.00
Total Cost					Savings	$9,822.85
Total Cost					Addition	$6,379.40
Total Cost Impact				**Savings of:**		**$3,443.45**

Utility Relocation

The exterior utilities would also need to be moved to accommodate the associated basement relocation. All utilities were considered when reviewing the tie-ins into the building and locations of the main runs. After review it was found that the following utilities needed to be routed to the basement: Steam, Chilled Water, Fire Water, Natural Gas, Domestic Water, Electric, and Telecommunications. Utilizing the existing site utilities plan I located the main runs for the services and also found some additional branch lines that might be of some use.

The drawing on the following page will show the placement of the existing utilities compared to the proposed relocation. You can see were the proposed utilities tap of the main compared to were they used too. The results found are shown in the table above with there associated costs to the project. The steam line, domestic water, and electric ductbank relocations were a zero cost impact because no length change was necessary. The chilled water was an added cost due to the 200 ft. of added line and the pipe increase from and 8" to 10" to maintain the correct pressure in the line due to the added length. Similarly, the same thing was found for the added 350 ft. of pipe for the fire water; and an increase from an 8" line to a 10" line was necessary. On the over hand, the natural gas line provided could be shortened by 200 ft. and the telecommunication's ductbank could be shortened by 80 ft. The conclusion was that the utility relocation provided an overall savings to the project.

To determine the need for an increase in pipe size a similar calculation was performed as used in the interior piping above. The change in head loss from the existing run to the new proposed run was calculated. By increasing the pipe size of the new proposed line to a 10" from an 8" it was found that I could maintain the similar pressures that were needed. In addition, due to the fact that the chilled water and fire water are supplied from Penn State's campus loops there is ample pressure necessary to boost it up if necessary.


SITE UTILITIES RELOCATION PLAN
CURTAIN ROAD
BIGLER ROAD
FOOD SCIENCE BUIDLING
CHILLER PLANT
PARKING GARAGE
CIVIC HARDSCAPE
SIDEWALK
NORTH
IKM INCORPORATED
ARCHITECTS, PLANNERS
INTERIOR DESIGNERS
One PPG Place
Pittsburgh, Pennsylvania 15222
H.F. LENZ COMPANY
GILBANE BUILDING COMPANY
CONSTUCTION MANAGER
7 Jackson Walkway
Providence, RI 02903
The Pennsylvania State University
Food Science Building
RELOCATED UTILITIES PLAN
DATE 3/31/06
DWG. NO. C-2.0
The Pennsylvania State University
Food Science Building
HOME OF THE NEW CREAMERY &
THE DEPARTMENT OF FOOD SCIENCES
NOTES:
RELOCATED UTILITY SERVICES TO THE EAST SIDE OF THE BLDG. TO COINCIDE WITH BASEMENT (MECH. RM) RELOCATION.
ABBREVIATIONS:
HPS: HIGH PRESSURE STEAM
CHWS/R: CHILLED WATER SUPPLY/RETURN
FW: FIRE WATER
W: DOMESTIC WATER
G: GAS
E: ELECTRIC
T: TELECOMMUNICATIONS
SCALE:
SCALE: 1"=50'
DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT
LEGEND:
DELETED UTILITY
RELOCATED UTILITY
MAIN RUN (TO STAY)
PENNSTATE
1855
Gilbane

-

Conclusion

Relocating the basement mechanical and electrical rooms from the existing west side of the building to the east side under the Production Area will improve constructability, coordination, and maintenance. It will shorten some of your pipe runs while also reducing the conflicts that may occur along the way. Though, the most noteworthy benefit that will arise from relocating the basement will be that all of the rough in that had to go in the slab-on-grade below the Production Area could now be run overhead in the basement and stub-upped through the first floor slab. This will greatly ease constructability and future maintenance along with a huge schedule savings. The huge schedule savings will come because now the progress of the structural slab above is no longer in conflict with anything below! Additionally, the layout for all of the stub-ups for equipment that won't even be on-site for months to come is insignificant because you can now stub-up through the basement ceiling anytime, anywhere creating perfect layout the first time!

Overall, the mechanical relocations inside and out will provide a cost savings to the project of approximately $52,000 dollars with zero schedule impact to the project. In addition, with concern to the lines on the inside of the building anytime you decrease or remove the length of pipe run it is considered good practice. This decreases the chance of a leak occurring throughout these building systems just due to the fact that they are simply no longer there. Thus, creating lower maintenance cost in the future.

Analysis 3: Stainless Steel Bollard Detail

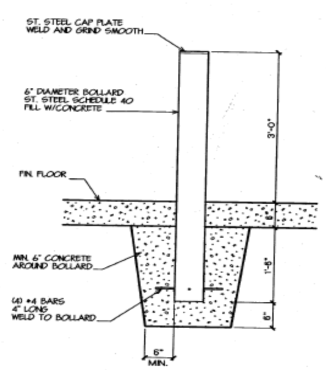
Background

The Production Area contains fifty-six 6" stainless steel bollards that are set in 2' of concrete below a 6" slab-on-grade with #4 bars welded to the bottom of the bollard. These bollards are located sporadically throughout the first floor level of the Production Area for protection of equipment, doors, and entrances for when a forklift is moving around the area.

Problem

In order to place these bollards per the detail below with a 6" slab-on-grade in 2' of concrete with #4 bars welded to the bottom of them, they need to be installed before the slab-on-grade is poured. Therefore, you are trying to layout the exact location of these bollards before the equipment, doors, and entrances are located or placed. Additionally, you don't even have a concrete slab to place marks on and chalk lines down. Hence, you are left trying to layout these bollards in the gravel base of the slab while working around the underground rough-in: conduit, pipes, drains, etc. Even then, if you are able to locate and place them correctly the first time, once the slab-on-grade is poured and all of the walls, equipment and doors are being installed hopefully there was not a change that relocated any of them because the amount of work necessary to remove one of these bollards and place it even a couple inches to the side is tremendous. It is my initial hypothesis that the bollards were structurally over designed to meet the requirements of withstanding a "fork-lift carrying milk cartons at 1mph" *(a logical guess)*.

Refer to the figure to the right to view the bollard design detail:



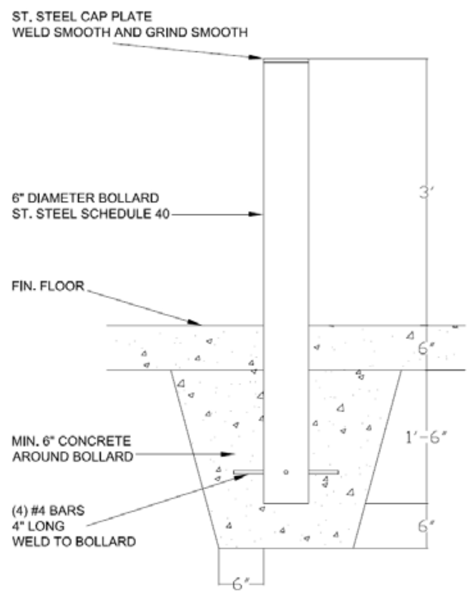
11 / A8.6 Typical Bollard
1 1/2"=1'-0"

Proposal

The redesign of a bollard detail that is less complex. A design that is more easily installed while maintaining the necessary structural requirements would allow for a more feasible installation detail. Intern, this would provide easier installation during construction while maintaining the necessary structural requirements. The proposed solutions will offer value engineering to the project by providing the same quality with a simpler installation that may result in a cost savings on labor to the project. Also, this would help to expedite the schedule during this phase of the project.

Analysis

I began my investigation into the bollard detail by first talking with the architect and engineer. The first question asked was why the need for such a complex and structurally solid bollard detail. The answers received were astonishing. The engineer had not even seen the bollard detail. The complex structural detail was not even approved by the structural engineer on the project. The architect used a typical detail found from some place not known to even them. Through the course of the interview I found that the architect did not even give any serious consideration to the detail which was one of the most difficult on the project for sequencing and constructability.



Current Bollard Detail

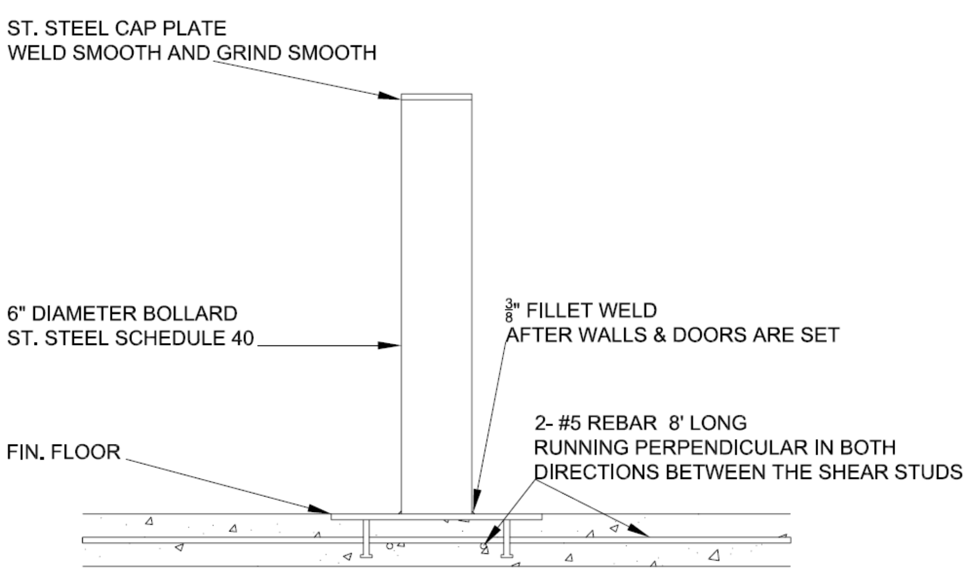
The next part of the investigation was to determine the load the bollard needs to resist to provide an acceptable redesign. Even this question raised some interesting discoveries. The architect, whom designed the detail, did not know what resistance it would have to withstand. The engineer however, even though he was not asked to review the detail, was helpful in this matter. After speaking with a few of his colleagues he found that there is not always a good way to design a bollard. Typically, an engineer would have an understanding of where the

bollards where going to be located on the project and what there intended use was for. Using this information, a logical engineering judgment is made to base the design upon.

From these results the next step was to go to the user group of the Production Area and review their needs. The information found here was invaluable. It was discovered, through an extremely easy conversation with the Production Facility Manager, what their desired needs were in the area with regards to the bollards.

During our walk, through the on going construction in the Produciton Area, it was determined that for the most part the facility has no desire to drive a fork-lift through the Production Area. Standing there and looking at all the equipment set and piping run it would be almost impossible to get a fork lift through there. Likewise the facility never had a desire to run a fork lift through the area, mainly the only thing the fork-lift will be used for is to get product form the loading dock to the storage areas and to move product in and out of the coolers and freezers. In the Production Area itself everything is manageable by hand and a small hand truck or pallet lift.

Therefore, through simple investigation and questioning it was determined the requirements for the bollards in the Production Area were considerably less than originally perceived. A detail was later issued by the engineer, whom worked considerably with the construction manager to provide a better detail, which was used for the installation of the last 10 bollards. This detail is shown below:



Proposed Bollard Detail

Conclusion

The new proposed bollard detail should be used in place of the current detail at all locations. The new proposed detail allows for the 12” x 12” stainless steel plate w/ shear studs to be imbedded and set in the concrete with the adequate reinforcing during the concrete pour. With the flexibility of now having a 12” x 12” area to weld the bollard to later will allow for more accurate placement. This is due to the fact that the plates can be set then all other work in the area can be done; including walls, doors, equipment, etc. The bollards can then be welded onto the plate in there exact locations.

In addition, now because the first floor level will be a cast-in-place structure the layout of the plates can be placed more accurately by laying-out off of the plywood as a work surface. The required 8 ft. long #5 bars was decided upon so that if the bollard is hit the force is distributed to two joists in the slab, regardless of its placement.

The new proposed design will ultimately provide a better finish with a considerable amount of ease added to the constructability of the design. In addition, the good judgment engineering reasoning behind the design provided a value engineering idea that will not increase the cost.

Research Issue: Sustainability Design for Production Area

Goals

The research issue I will investigate pertains to the sustainable design of production facilities. I will utilize the availability I already have to the Food Science Building's Production Area as my case study that I will evaluate. Through examination of the Food Science Building's Production Facility I can evaluate its' sustainability. Including these results with others that I will discover through the course of my research I hope to compile a list of useable guidelines that may be applied to production facilities in general.

I will utilize all resources available to myself to perform the most well rounded research possible. Some initial considerations I will use include the U.S. Department of Health and Human Services, FDA (Food & Drug Administration) Manuals, and job-site contacts I have made through my on-site internship with Gilbane Building Co. (the CM) on the Food Science Project. I anticipate that the most beneficial research performed will come from the on-site project contacts I will make. The food processing engineer and food production contractor will be the first two people I will begin my investigation with. In addition, I may interview the mechanical and possibly the plumbing contractor to find their views on the situation.

Next, I will talk with Penn State University's project manager, whom was involved in the project from the initial design phase until now. I feel that this would be a good place to begin the initial investigation of the design. After that, I will move on to the user group and interview with the man in charge of the PSU Creamery.

I feel that through reviewing the manuals mentioned above I will have a good understanding of the minimum requirements necessary for a production facility. Next, I will combine these minimum requirements with the good practice techniques I hope to reveal through talking with the on-site experts that build these facilities everyday. A compilation of all this information into a chart, advantage / disadvantage format will then be produced showing all of the results found.

Analysis

The preliminary investigation into the Production Area uncovered some unexpected results. The Production Area in the Food Science Building can not be classified as a typical Production Area. It is classified as a Milk Processing Facility which holds significantly stricter standards. A milk processing facility actually has an entirely different set of guidelines and minimum standards it must maintain.

However, the same study as mentioned above can still take place and the same results can be produced just for a more limited set of facilities as you will find out below. A set of sustainable guidelines can be developed specifically for milk processing facilities and/or for production facilities and areas that are required to be 'cold areas', for example large loading docks that must be maintained a certain cold temperature or large storage cooler and freezers. In addition, facilities that require extreme heat for cleanliness purposes, etc. can benefit from the results found below.

Reutilization of left-over 'By Product'

The first issue investigated was the reutilization of the left-over by product of the facility. At the beginning I reviewed the food processing drawings and began to understand the multiple systems uses and flows: clean in place system, batch plant, homogenizer and separator, pasteurization, flavor vats and ingredient feeders, ice cream tanks, milk filling, cream vats, and cheese vats. Each of these systems quickly became complicated and difficult to follow. At this point, is when I began my discussion with the food processing engineer. The end result of the discussion was: in a milk processing facility there is very little left-over 'by product' waste that is not used in the production of some milk based product. Nevertheless, the minimal left-over 'by product' can not even be considered for any other use due to the fact of how quickly milk spoils.

Refrigeration / Cooling Systems

The second concern found is choosing the correct type of refrigeration / cooling system in your facility. Dependant upon the needs of your facility some exceptionally large areas may need to be kept at extremely low temperatures. For example, the

Production Facility at the PSU Creamery contains a 20'x55' x 30'high freezer that must maintain a temperature of -20^{o}, a 20'x25' x30'high freezer @ -25^{o}, and a 25'x60' x30'high cooler @ +34^{o}. In addition to these areas there are also a few smaller cooler and freezers that require the same temperatures as the bigger ones mentioned above. The cooling costs in these areas are an extremely significant cost in the operation of the facility.

There are mainly three different fluids that can be used when considering cooling loads such as these: water, freon, and ammonia. Water is the least desirable due to the amount of energy required to cool the fluid to achieve the desired temperatures. Additionally, if you wish to cool an area below freezing such as a freezer, water is unable to so based upon the simple fact that the water in your lines will freeze at 32^{o} (if you are even able to achieve the incredible amount of energy necessary to keep flowing water at 32^{o}). The next alternative is well known to everyone, freon. Freon, when considering energy required too cool is drastically more efficient than water. However, when considering sustainability freon is considered awful for the obvious reasons of its extremely negative affect on the environment. Lastly, ammonia is currently the best choice out there to use for such cooling situations; due to its chemical make-up it requires the least amount of energy to cool and can become just about as cold as necessary. The downside to ammonia is if you would have a leak in your system the concentration of ammonia in some facilities could be fatal if inhaled for an extended period of time. Therefore, ammonia detectors must be put in with the installation of your ammonia cooling system. Another positive to an ammonia system is that if a leak occurs and the ammonia needs to be discarded it can be processed and spread on farming fields for fertilization. Additionally, specialized ammonia cooling contractors are becoming more prevalent thus costs of these systems are becoming cheaper through competitive bidding.

Heating Systems

Subsequently, the next cost that may become significant for a processing facility is the heating costs. The heating costs considered in this instance though are not the costs associated with heating the area to an acceptable working temperature. The heating costs in this consideration is the cost to heat the water to a required temperature for the necessary equipment or for cleanliness purposes. For example, at Food Science 160^{o}+ water is required for the continuous pasteurizer and 180^{o}+ water is required for the clean in place machine used to sanitize all tools, etc.

There are also three main ways to heat the water in these types of facilities to the required temperatures: electricity, heating hot water, or steam. Electricity, is entirely energy inefficient to heat the continuous water supply to the necessary temperature for a facility such as this. Utilizing your buildings heating hot water source to provide this service is actually sometimes logical with the right upgrades but still not the cheapest solution. Steam is the cheapest alternative to suffice your facilities extreme hot water needs. Steam is the cheapest and cleanest heat to produce and through a heat exchanger you can acquire any hot water temperature necessary. Although, steam is not always a readily available utility source such as it is at the Penn State Campus steam loop. In this case the cost of the boiler at your facility would have to be compared to the duration of your facility's intended operations life and an individually based cost analysis would have to be performed. It is possible in such situations it could be best to use a basic heating hot water system.

GMP's (Good Manufacturing Practices)

The PSU Creamery facility was designed to allow for exemplary Good Manufacturing Practices (GMPs). Service connections and ease of equipment egress and ingress was carefully studied. As well provisions were made with great consideration for the pick-up and delivery of both the Creamery and the Pilot processing facilities. The provisions include the flow of work inside being coordinated with the placement of the multiple loading dock zones around the buildings north side and the loading zones being easily accessible by tractor-trailer. Independent air-handling systems were also required to eliminate concerns of possible contamination of the Creamery Processing/Manufacturing area by the microbiology research and teaching laboratories.

Additional considerations that were accounted for at the PSU Creamery facility were high speed quick rolling overhead doors and some redundancy in critical materials such as insulation. As stated above a substantial cost that a facility such as this incurs is the cooling costs for the large coolers and freezers. Each time that one of the doors in those areas are opened for a fork-lift, etc. an excessive amount of cold air is lost. To boot, say that the fork lift operator is moving in and out of the area each day and not getting off of the machine each time he goes in and out and closes the door behind them. Consider the amount of energy lost throughout the course of one day just by this one action, not closing a door. Thus at the PSU Creamery they installed high speed quick rolling doors at each location such as this. These doors are all sensory or sound operated so that the operator never has to leave the machine. For example, when the forklift breaks the laser beam, the door opens at a speed of 100 in./sec. and as soon as the laser beam is whole again (when he leaves the door closing area) the door closes behind him, thus increasing production and decreasing the amount of cold air lost through the entrance.

Another sustainable GMP is to use HCFC-free insulated composite metal panels. These types of insulated metal panels are among the best building materials for freezer and cooler wall panels and are accepted as a sustainable product by the U.S. Green Building Council's LEED Rating System. Sustainable benefits include recyclability of metal, reuse of entire panels, can be refinished, energy saving efficiency of isocyanurate insulation, long term panel durability, minimal landfill waste, minimal job site impact, low maintenance requirement.

Conclusion

In the beginning of my analysis I soon found that a few of my initial considerations were incorrect. The PSU Creamery's Production Facility which I used for the basis of my case study in some ways can not be compared to all production facilities. The fact that it is a milk processing facility varies it significantly from other facilities. Although, the issues that I investigated can be directly related to and applied to any facility which requires cold storage and extreme cleanliness requirements.

The reutilization of any 'left-over' by product from a milk processing facility is impossible due to the fact that milk spoils so easily.

Thus, the next most significant issue for a sustainable production facility is the systems chosen for the cooling of the freezers and coolers and the heating for the water cleanliness and equipment requirements. The most sustainable fluid and system to be used for refrigeration / cooling is a compressed ammonia system. Ammonia has the best properties for efficiency when cooling to such cold temperatures with significant loads. It is also the most environmentally friendly system readily available right now. The most sustainable system to use for heating is a steam system due to its high efficiency and cleanliness manner in which it produces heat.

A few good GMP's (Good Manufacturing Practices) that can be incorporated into a sustainable design are the use of high speed quick rolling doors and HCFC-free insulated composite metal panels. High speed quick rolling doors drastically decrease the amount of energy loss each time the cooler/freezer is entered. It decreases the amount of time the door is open and cold air is lost and eliminates the reliability to the workers. The HCFC-free insulated composite metal panels are the best sustainable material choice for a cooler / freezer wall as suggested by the U.S. Green Building Council's LEED Rating System.

Recommendation

The recommendation I have for the Food Science Building incorporates all of the results from my analyses and justifications I have shown throughout this report.

The basement mechanical and electrical room on the west side of building should be relocated to the east side of the building under the PSU Creamery's Production Area. The structure in this area shall be changed to all cast in place concrete utilizing wide module concrete joist construction with girders and columns for the first and second floor levels of this area. This work will be performed simultaneously with the steel erection on the west side of the building. The joist slab construction will create a typical repetitive layout which can utilize the metal pan formwork easing constructability significantly when compared to the old system. In addition, it will provide a more aesthetically pleasing similar finish for the exposed concrete ceiling in the Production Area while increasing the overall ceiling height by 17". The deletion of the old structure and the addition of the new proposed structure provides a total cost savings to the project of $190,000 dollars while in addition completely the structure of the Production Area 3 months ahead of schedule.

While the basement relocation works out positively for the structure you must now consider which utilities where affected. On the interior of the building six horizontal pipe runs can now be deleted because they are moved with the basement to the east side of the building placing them directly next to the mechanical shaft. The deletion of these pipe runs results in a project savings of $48,000 dollars. On the exterior of the building most utilities will also have to be relocated. As well, a few of the lines had to be resized from 8" to 10" due to the increased length. Overall, the exterior utility relocation resulted in a project savings of $3,000 dollars. However, the most notable benefit of the basement relocation with regards to the mechanicals is the ease of constructability because mechanicals can now layout off of plywood deck or penetrate the slab later from above in the basement. In addition, it allows for easier relocation of equipment in the future for the production area.

The utility relocation also provides another future benefit to the owner because it removes the current placement of all underground utilities from directly under a civic hardscape area. Thus if there were ever be a problem in the future were a utility line

would need to be dug-up it would not require the complete removal and rebuilding of the civic hardscape area. The new proposed utilities will only run directly under a 6' wide sidewalk.

The last recommendation is the proposal for the simplified bollard detail. This detail will provide a greater ease of constructability and sequencing. In addition, this detail will provide a higher quality more aesthetically pleasing finish product for the same cost.

The Production Facility already contains all sustainable guidelines that I have discovered for a milk processing facility. It has a compressed ammonia cooling system, steam heating, quick rolling high speed doors, and HCFC-free insulated composite metal panels.

Utilizing all of the above newly proposed solutions will provide a more aesthetically pleasing higher quality production facility for The Pennsylvania State University's PSU Creamery Production Facility. In addition to all of the added benefits discussed above the recommended changes to the project would save approximately $241,000 dollars while also opening up the PSU Creamery's Production Facility 3 months ahead of schedule.

Credits & Acknowledgements

I would like to take this opportunity to thank everyone that has assisted me in my senior thesis research on the Food Science Building. I would like to thank the Pennsylvania State University for allowing me to use the Food Science Building for my research. In addition, I would like to thank everyone from the Office of Physical Plant that provided me with all the information needed. Thanks to Gilbane Building Company for providing me with the contacts, detailed project info, and in depth construction knowledge necessary to understand this projects specific requirements. Thanks to all of the projects subcontractors that helped me in so many ways. Thanks to H.F. Lenz Company for providing me with detailed project engineering advice. Thanks to IKM Incorporated for aiding in the design phase of my thought process. Thanks to Sweetland Engineering for their aid with all my site and utility inquiries. Thanks to the AE faculty that helped me through some of the difficult calculations and engineering. I appreciate all of your help and I could not have done it with out you.

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Appendix A

Schedules
- Current Schedule
- Proposed Relocation Schedule
- Compared Schedule

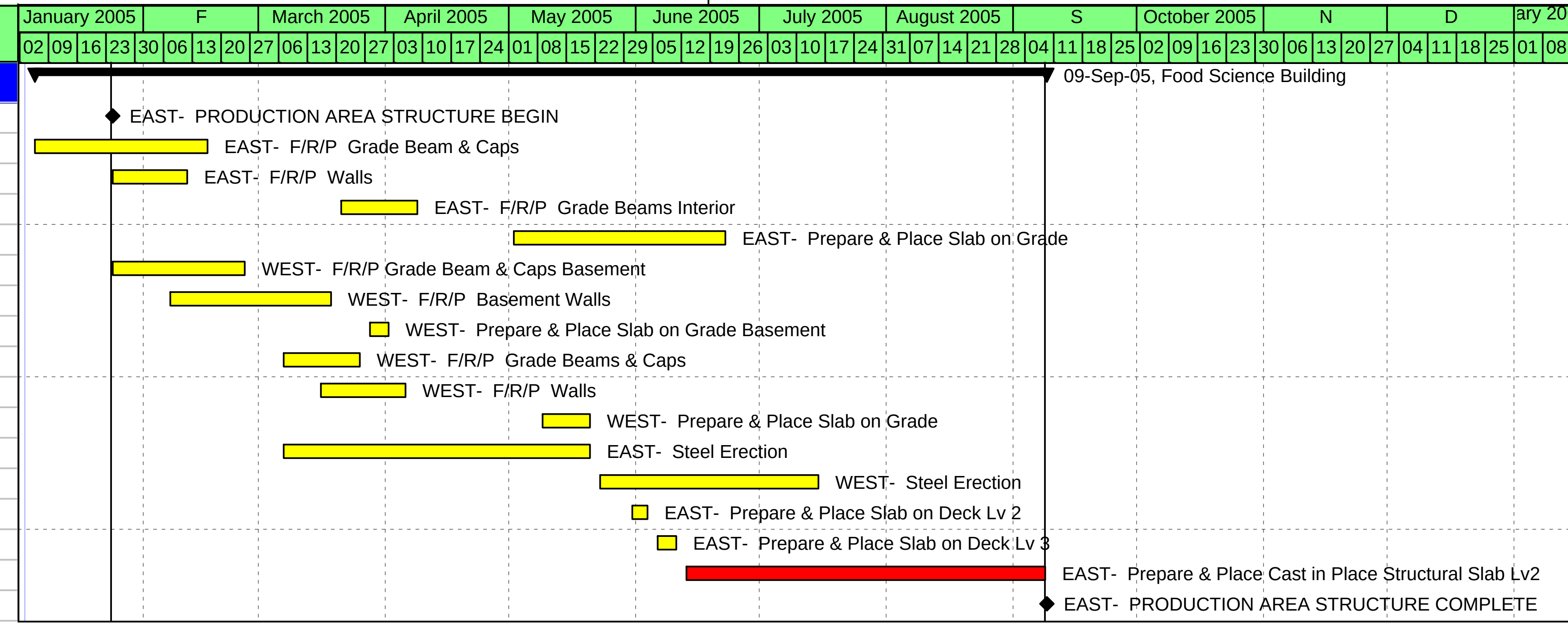
Estimates
- Existing Take-Off / Detailed Estimate
- Proposed Relocation Take-Off / Estimate
- Cost Comparison Estimate

Structural Drawings
- S2.0B- Foundation Plan East
- S2.1B- First Floor Framing Plan
- S2.2B- Second Floor Framing Plan

Structural Calculations
- First Floor Level
- Second Floor Level

Food Science Building	Current Project Schedule	Anthony Lucostic

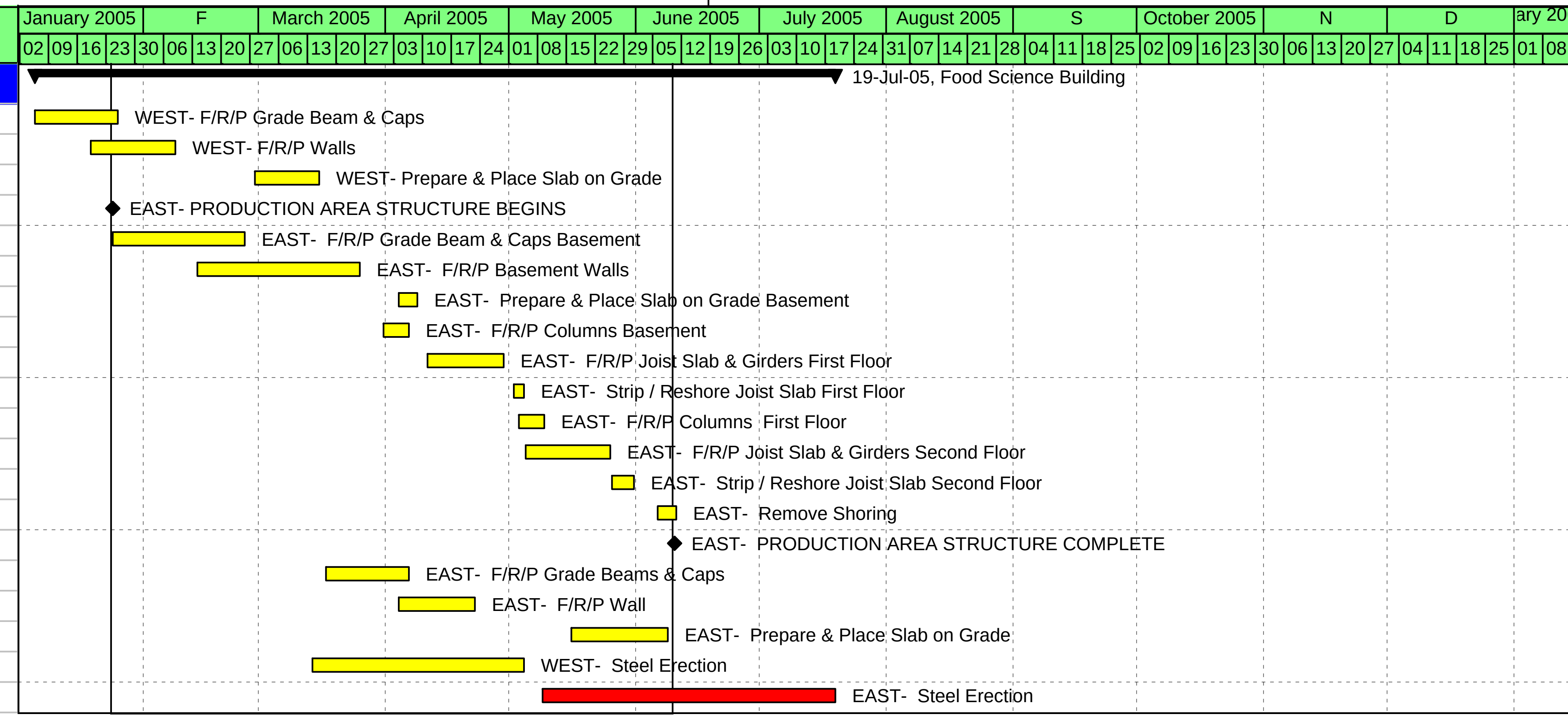
Activity ID	Activity Name	Original Duration	Start	Finish
Food Science Building		174	05-Jan-05	09-Sep-05
A0990	EAST- PRODUCTION AREA STRUCTURE BEGIN	0	24-Jan-05*	
A1000	EAST- F/R/P Grade Beam & Caps	31	05-Jan-05*	16-Feb-05
A1010	EAST- F/R/P Walls	15	24-Jan-05*	11-Feb-05
A1020	EAST- F/R/P Grade Beams Interior	15	21-Mar-05*	08-Apr-05
A1030	EAST- Prepare & Place Slab on Grade	37	02-May-05*	22-Jun-05
A1050	WEST- F/R/P Grade Beam & Caps Basement	25	24-Jan-05*	25-Feb-05
A1060	WEST- F/R/P Basement Walls	30	07-Feb-05*	18-Mar-05
A1065	WEST- Prepare & Place Slab on Grade Basement	5	28-Mar-05*	01-Apr-05
A1070	WEST- F/R/P Grade Beams & Caps	15	07-Mar-05*	25-Mar-05
A1075	WEST- F/R/P Walls	15	16-Mar-05*	05-Apr-05
A1080	WEST- Prepare & Place Slab on Grade	10	09-May-05*	20-May-05
A1110	EAST- Steel Erection	55	07-Mar-05*	20-May-05
A1120	WEST- Steel Erection	38	23-May-05*	15-Jul-05
A1130	EAST- Prepare & Place Slab on Deck Lv 2	4	31-May-05*	03-Jun-05
A1140	EAST- Prepare & Place Slab on Deck Lv 3	5	06-Jun-05*	10-Jun-05
A1150	EAST- Prepare & Place Cast in Place Structural Slab Lv2	62	13-Jun-05*	08-Sep-05
A1151	EAST- PRODUCTION AREA STRUCTURE COMPLETE	0	09-Sep-05*	



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

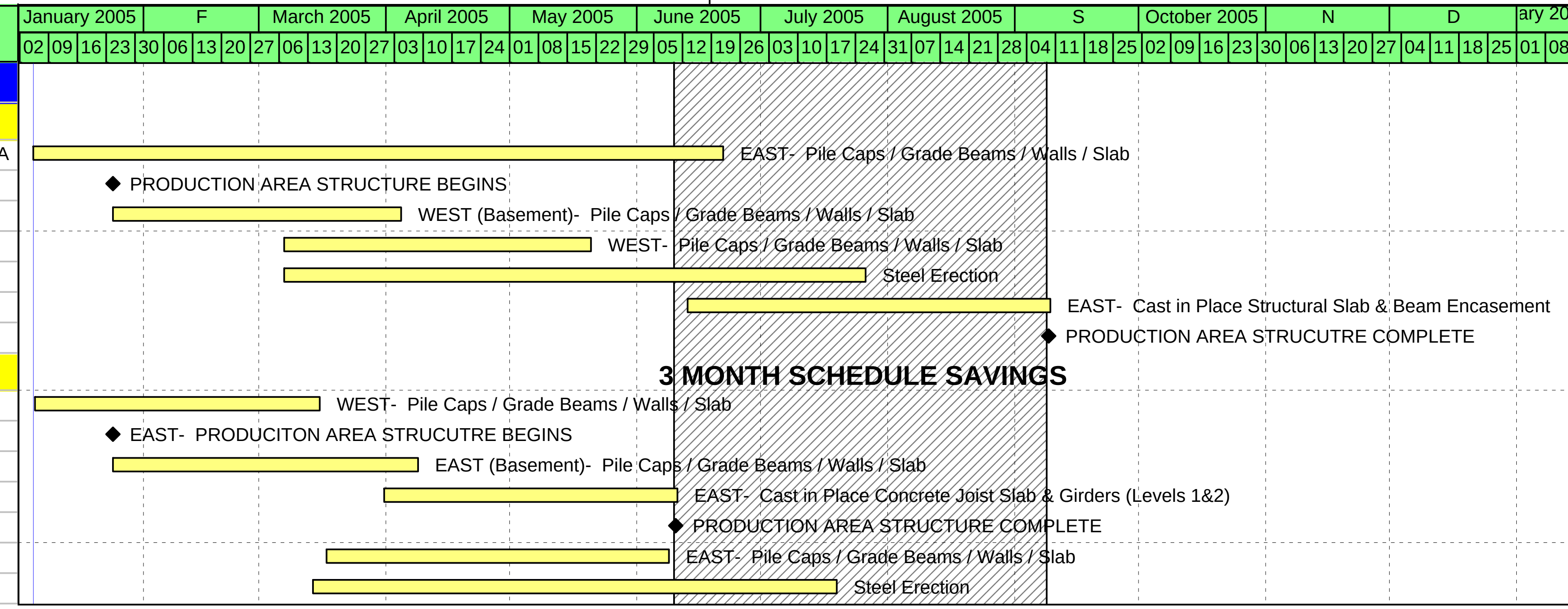
Food Science Building	Proposed Relocation Schedule	Anthony Lucostic

Activity ID	Activity Name	Original Duration	Start	Finish
Food Science Building		138	05-Jan-05	19-Jul-05
A1000	WEST- F/R/P Grade Beam & Caps	15	05-Jan-05*	25-Jan-05
A1010	WEST- F/R/P Walls	15	19-Jan-05*	08-Feb-05
A1020	WEST- Prepare & Place Slab on Grade	12	28-Feb-05*	15-Mar-05
A1025	EAST- PRODUCTION AREA STRUCTURE BEGINS	0	24-Jan-05*	
A1030	EAST- F/R/P Grade Beam & Caps Basement	25	24-Jan-05*	25-Feb-05
A1040	EAST- F/R/P Basement Walls	30	14-Feb-05*	25-Mar-05
A1050	EAST- Prepare & Place Slab on Grade Basement	5	04-Apr-05*	08-Apr-05
A1051	EAST- F/R/P Columns Basement	5	31-Mar-05*	06-Apr-05
A1052	EAST- F/R/P Joist Slab & Girders First Floor	15	11-Apr-05*	29-Apr-05
A1053	EAST- Strip / Reshore Joist Slab First Floor	3	02-May-05	04-May-05
A1054	EAST- F/R/P Columns First Floor	5	03-May-05*	09-May-05
A1055	EAST- F/R/P Joist Slab & Girders Second Floor	15	05-May-05*	25-May-05
A1056	EAST- Strip / Reshore Joist Slab Second Floor	3	26-May-05*	31-May-05
A1057	EAST- Remove Shoring	5	06-Jun-05*	10-Jun-05
A1058	EAST- PRODUCTION AREA STRUCTURE COMPLETE	0	10-Jun-05*	
A1059	EAST- F/R/P Grade Beams & Caps	15	17-Mar-05*	06-Apr-05
A1060	EAST- F/R/P Wall	15	04-Apr-05*	22-Apr-05
A1070	EAST- Prepare & Place Slab on Grade	17	16-May-05*	08-Jun-05
A1080	WEST- Steel Erection	38	14-Mar-05*	04-May-05
A1090	EAST- Steel Erection	50	09-May-05*	19-Jul-05



Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

Activity ID	Activity Name	Original Duration	Start	Finish
Food Science Building		315	05-Jan-05 A	09-Sep-05
Current Project Schedule		302	05-Jan-05 A	09-Sep-05
A1010	EAST- Pile Caps / Grade Beams / Walls / Slab	1	05-Jan-05 A	22-Jun-05 A
A1015	PRODUCTION AREA STRUCTURE BEGINS	0	24-Jan-05*	
A1050	WEST (Basement)- Pile Caps / Grade Beams / Walls / Slab	51	24-Jan-05*	04-Apr-05
A1070	WEST- Pile Caps / Grade Beams / Walls / Slab	55	07-Mar-05*	20-May-05
A1090	Steel Erection	100	07-Mar-05*	26-Jul-05
A1110	EAST- Cast in Place Structural Slab & Beam Encasement	63	13-Jun-05*	09-Sep-05
A1190	PRODUCTION AREA STRUCUTRE COMPLETE	0	09-Sep-05*	
Proposed Relocation Schedule		138	05-Jan-05	19-Jul-05
A1030	WEST- Pile Caps / Grade Beams / Walls / Slab	50	05-Jan-05*	15-Mar-05
A1120	EAST- PRODUCITON AREA STRUCUTRE BEGINS	0	24-Jan-05*	
A1130	EAST (Basement)- Pile Caps / Grade Beams / Walls / Slab	55	24-Jan-05*	08-Apr-05
A1140	EAST- Cast in Place Concrete Joist Slab & Girders (Levels 1&2)	51	31-Mar-05*	10-Jun-05
A1145	PRODUCTION AREA STRUCTURE COMPLETE	0	10-Jun-05*	
A1150	EAST- Pile Caps / Grade Beams / Walls / Slab	59	17-Mar-05*	08-Jun-05
A1160	Steel Erection	90	14-Mar-05*	19-Jul-05



Food Science Building

Existing Take-Off

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
WEST SIDE (Existing Basement Area)								
Basement Level								
Piles & Pile Caps (for Steel Columns)	NO Cost Impact							$0.00
Supportive of columns above. Need to stay. Will be rasied to the First Floor Level Elevation.								
						Ton	$ / Ton	$
Steel Columns (Basement Level)	X		A-2	W12x170	14'	1.19	$2,725.00	$3,242.75
			A-3	W12x152	14'	1.064	$2,725.00	$2,899.40
			A-4	W12x152	14'	1.064	$2,725.00	$2,899.40
			B-2	W12x230	14'	1.61	$2,725.00	$4,387.25
			B-3	W14x211	14'	1.477	$2,725.00	$4,024.83
			B-4	W14x211	14'	1.477	$2,725.00	$4,024.83
			B-5	W14x193	14'	1.351	$2,725.00	$3,681.48
			C-2	W12x70	14'	0.49	$2,725.00	$1,335.25
			C-3	W12x70	14'	0.49	$2,725.00	$1,335.25
			C-4	W12x152	14'	1.064	$2,725.00	$2,899.40
			C.2-5	W12x70	14'	0.49	$2,725.00	$1,335.25
Total								$32,065.08
						V.L.F.	$ / V.L.F.	$
Concrete Encasement-Steel Columns (Basement Level)	X		A-2	24"x24"	14'	14	$129.00	$1,806.00
			A-3	24"x24"	14'	14	$129.00	$1,806.00
			A-4	24"x24"	14'	14	$129.00	$1,806.00
			B-2	24"x24"	14'	14	$129.00	$1,806.00
			B-3	24"x24"	14'	14	$129.00	$1,806.00
			B-4	24"x24"	14'	14	$129.00	$1,806.00
			B-5	24"x24"	14'	14	$129.00	$1,806.00
			C-2	24"x24"	14'	14	$129.00	$1,806.00
			C-3	24"x24"	14'	14	$129.00	$1,806.00
			C-4	24"x24"	14'	14	$129.00	$1,806.00
			C.2-5	24"x24"	14'	14	$129.00	$1,806.00
Total								$19,866.00
Grade Beams								
Exterior Wall Perimeter GB's	NO Cost Impact							$0.00
Supportive of Exterior Wall. Need To stay. Will be raised to the First Floor Level Elevation.								
						L.F.	$ / L.F.	$

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
Interior Partiton GB's	X		GB 5	40"x16"	8'4"	8.33	$105.00	$874.65
			GB 8	40"x16"	8'4"	8.33	$105.00	$874.65
			GB 31	24"x16"	9' 8"	9.67	$62.00	$599.54
			GB 32	24"x16"	22' 6"	22.5	$62.00	$1,395.00
			GB 33	24"x16"	22' 7"	22.58	$62.00	$1,399.96
			GB 25	40"x20"	22' 4"	22.33	$105.00	$2,344.65
			GB 26	24"x16"	8' 8"	8.67	$62.00	$537.54
Total								$8,025.99
						L.F.	$ / L.F.	$
Foundation Walls	X		CIP Conc.	12" (14'High)	336'	336	$207.50	$69,720.00
			CIP Conc.	16" (14'High)	82'	82	$231.50	$18,983.00
			CIP Conc.	20" (14'High)	30'	30	$255.50	$7,665.00
Total								$96,368.00
						L.F.	$ / L.F.	$
Foundation Waterproofing	X		Found.Walls	14' High	448'	448	20.2	$9,049.60
Total								$9,049.60
						L.F.	$ / L.F.	$
Foundation Drain	X		Perf. PVC	6"	448'	448	8.2	$3,673.60
Total								$3,673.60
						Ea.	$ / Ea.	$
Piles (Interior Partition GB's, CMU)	X		250 Kip		<60'	5	$1,995.00	$9,975.00
Total								$9,975.00
						S.F.	$ / S.F.	$
Masonry Walls (Int. Partion Walls)	X		8" CMU	13'-6"	332'	4482	$6.73	$30,163.86
Total								$30,163.86
Slab-on Grade	X					S.F.	$ / S.F.	$
6" SOG W/ 4X4 W4.0 x W4.0 WWF ON VAPOR BARRIER			6" SOG		6394S.F.	6394	$9.46	$60,487.24
Total								$60,487.24
Precast Concrete Stairs	X						$	$
Stair C - Single Width (1st floor - Basement)							$3,000.00	$3,000.00
Stair D - Double Width (1st floor - Basement)							$4,170.00	$4,170.00
Total								$7,170.00
First Floor Level								
						S.F.	$ / S.F.	$
W Shape / Composite Deck / Slab	X				6394S.F.	6394	$30.25	$193,418.50
Total								$193,418.50
						S.F.	$ / S.F.	$

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
Fireproofing (Steel Beams and Girders)	X		1	W21x48	24' 8"	75	$1.40	$105.00
			1	W18x35	24' 8"	75	$1.40	$105.00
			16	W18x35	32' 4"	1536	$1.40	$2,150.40
			1	W12x14	3' 6"	11	$1.40	$15.40
			4	W10x12	8' 0"	96	$1.40	$134.40
			3	W21x44	32' 4"	288	$1.40	$403.20
			1	W21x44	22' 0"	66	$1.40	$92.40
			1	W21x44	2' 0"	6	$1.40	$8.40
			1	W14x22	25' 4"	75	$1.40	$105.00
			2	W12x14	13' 8"	84	$1.40	$117.60
			5	W12x14	8' 4"	135	$1.40	$189.00
			8	W12x14	10' 0"	240	$1.40	$336.00
			1	W12x14	24' 0"	72	$1.40	$100.80
			4	W24x62	30' 0"	360	$1.40	$504.00
			1	W24x55	29' 4"	90	$1.40	$126.00
Total								$4,492.60
Total Cost						**Savings**		**$474,755.47**
EAST SIDE (Existing Production Area)								
First Floor Level								
Piles & Pile Caps (for Columns)	NO Cost Impact							$0.00
Supportive of columns throughout bldg. Need to stay. Will be lowered to the Basement Level Elevation.								
Steel Columns (First Floor Level)	X					Ton	$ / Ton	$
			A-9	W12x96	16'	0.768	$2,725.00	$2,092.80
			A-10	W12x79	16'	0.632	$2,725.00	$1,722.20
			A-11	W12x96	16'	0.768	$2,725.00	$2,092.80
			B-9	W12x190	16'	1.52	$2,725.00	$4,142.00
			B-10	W12x170	16'	1.36	$2,725.00	$3,706.00
			B-11	W12x96	16'	0.768	$2,725.00	$2,092.80
			B.6-11	W12x58	16'	0.464	$2,725.00	$1,264.40
			C-8	W12x136	16'	1.088	$2,725.00	$2,964.80
			C-9	W12x136	16'	1.088	$2,725.00	$2,964.80
			C-9.8	W12x152	16'	1.216	$2,725.00	$3,313.60
			C-10.5	W12x96	16'	0.768	$2,725.00	$2,092.80
			C-11	W12x58	16'	0.464	$2,725.00	$1,264.40
			C.3-7.6	W12x65	16'	0.52	$2,725.00	$1,417.00
			C.7-7	W12x170	16'	1.36	$2,725.00	$3,706.00
Total								$34,836.40
						V.L.F.	$ / V.L.F.	$
Concrete Encasement-Steel Col. (First Floor Level)	X		B-9	24"x24"	14'	14	$129.00	$1,806.00
			C-8	24"x24"	14'	14	$129.00	$1,806.00
			C-9	24"x24"	14'	14	$129.00	$1,806.00
			C-9.8	24"x24"	14'	14	$129.00	$1,806.00

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
Total								$7,224.00
Fireproofing (Steel Columns)	X					V.L.F.	$ / V.L.F.	$
			A-9	W12x96	16'	16	$12.69	$203.04
			A-10	W12x79	16'	16	$13.69	$219.04
			A-11	W12x96	16'	16	$14.69	$235.04
			B-10	W12x170	16'	16	$15.69	$251.04
			B-11	W12x96	16'	16	$16.69	$267.04
			B.6-11	W12x58	16'	16	$17.69	$283.04
			C-10.5	W12x96	16'	16	$18.69	$299.04
			C-11	W12x58	16'	16	$19.69	$315.04
			C.3-7.6	W12x65	16'	16	$20.69	$331.04
			C.7-7	W12x170	16'	16	$21.69	$347.04
Total								$2,750.40
Grade Beams								
Exterior Wall Perimeter GB's	NO Cost Impact							$0.00
Supportive of Exterior Wall. Need To stay. Will be raised to the First Floor Level Elevation.								
						L.F.	$ / L.F.	$
Interior Partiton GB's	X		GB 117	24"x12"	15'0"	15	$62.00	$930.00
			GB 118	24"x12"	7'0"	7	$62.00	$434.00
			GB 119	24"x12"	8'0"	8	$62.00	$496.00
			GB 120	24"x16"	35'0"	35	$62.00	$2,170.00
			GB 121	24"x16"	22'0"	22	$62.00	$1,364.00
			GB 109	48"x24"	24'0"	24	$105.00	$2,520.00
			GB 122	24"x16"	36'0"	36	$62.00	$2,232.00
			GB 123	24"x16"	22'0"	22	$62.00	$1,364.00
			GB 126	24"x16"	28'0"	28	$62.00	$1,736.00
			GB 127	24"x12"	12'0"	12	$62.00	$744.00
			GB 128	24"x16"	28'0"	28	$62.00	$1,736.00
			GB 130	24"x12"	12'0"	12	$62.00	$744.00
			GB 131	24"x12"	18'0"	18	$62.00	$1,116.00
			GB 132	30"x20"	28'0"	28	$62.00	$1,736.00
			GB 133	42"x24"	28'0"	28	$105.00	$2,940.00
			GB 134	30"x20"	10'0"	10	$62.00	$620.00
			GB 138	24"x12"	25'0"	25	$62.00	$1,550.00
			GB 139	24"x12"	28'0"	28	$62.00	$1,736.00
			GB 140	30"x14"	30'0"	30	$62.00	$1,860.00
			GB 141	24"x12"	22'0"	22	$62.00	$1,364.00
Total								$10,146.00
						Ea.	$ / Ea.	$
Piles (Interior Partition GB's, CMU)	X		250 Kip		<60'	7	$1,995.00	$13,965.00
Total								$13,965.00

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
Slab-on Grade	X					S.F.	$ / S.F.	$
6" SOG W/ 2 Layers 6x6, W2.9 x W2.9 WWF			6" SOG		9770S.F.	9770	$9.46	$92,424.20
Total								$92,424.20
Second Floor Level								
Composite Beam & Cast In Place Slab	X					S.F.	$ / S.F.	$
					10737S.F.	10737	$32.45	$348,415.65
Total								$348,415.65
Total Cost						**Savings**		**$509,761.65**

TOTAL COSTS (East&West Sides) *Structural System Deletion (for replacement with new system)*	**Savings**	**$984,517.12**

Food Science Building

Proposed Relocation Take-Off

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
WEST SIDE (Retail Sales & Cafe Area)								
First Floor Level								
Piles & Pile Caps (for Steel Columns)	NO Cost Impact							$0.00
Relocated and rasied to the First Floor Level Elevation.								
Grade Beams								
Exterior Wall Perimeter GB's	NO Cost Impact							$0.00
Supportive of Exterior Wall. Need To stay. Will be raised to the First Floor Level Elevation.								
Slab-on Grade		X				S.F.	$ / S.F.	$
6" SOG W/ 4X4 W4.0 x W4.0 WWF ON VAPOR BARRIER			6" SOG		6394S.F.	6394	$9.46	$60,487.24
Total								$60,487.24
Total Cost						**Added**		**$60,487.24**

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
EAST SIDE (Basement / Production Area)								
Basement Level								
Piles & Pile Caps (for Columns)	NO Cost Impact							$0.00
Relocated and lowered to the Basement Level Elevation.								
						Ton	$ / Ton	$
Sheet Piling		X	Along Bigler	100'	15	15	$1,250.00	$18,750.00
Total								$18,750.00
Grade Beams								
Exterior Wall Perimeter GB's	NO Cost Impact							$0.00
Relocated and lowered to the Basement Level Elevation.								
						L.F.	$ / L.F.	$
Foundation Walls		X	CIP Conc.	12" (14'High)	393'10"	393.833	$207.50	$81,720.35
			CIP Conc.	16" (14'High)	123'1"	123.083	$231.50	$28,493.71
			CIP Conc.	20" (14'High)	28'7"	28.583	$255.50	$7,302.96
Total								$117,517.02
						L.F.	$ / L.F.	$
Foundation Waterproofing		X	Found.Walls	14' High	545'6"	545.5	20.2	$11,019.10
Total								$11,019.10

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
						L.F.	$ / L.F.	$
Foundation Drain		X	Perf. PVC	6"	545'6"	545.5	8.2	$4,473.10
Total								$4,473.10
CIP Concrete Columns (Basement Level)		X	A-8	26"x26"	14'	14	$151.50	$2,121.00
			A-9	26"x26"	14'	14	$151.50	$2,121.00
			A-10	26"x26"	14'	14	$151.50	$2,121.00
			A-11	26"x26"	14'	14	$151.50	$2,121.00
			A-8.6	26"x26"	14'	14	$151.50	$2,121.00
			A.2-8.6	26"x26"	14'	14	$151.50	$2,121.00
			A.2-9	26"x26"	14'	14	$151.50	$2,121.00
			A.5-8	26"x26"	14'	14	$151.50	$2,121.00
			A.5-8.7	26"x26"	14'	14	$151.50	$2,121.00
			A.5-9	26"x26"	14'	14	$151.50	$2,121.00
			A.5-9.3	26"x26"	14'	14	$151.50	$2,121.00
			B-8	26"x26"	14'	14	$151.50	$2,121.00
			B-9	26"x26"	14'	14	$151.50	$2,121.00
			B-10	26"x26"	14'	14	$151.50	$2,121.00
			B-11	26"x26"	14'	14	$151.50	$2,121.00
			B.6-10.5	26"x26"	14'	14	$151.50	$2,121.00
			B.6-11	26"x26"	14'	14	$151.50	$2,121.00
			B.8-7.6	26"x26"	14'	14	$151.50	$2,121.00
			B.8-8	26"x26"	14'	14	$151.50	$2,121.00
			C-8	26"x26"	14'	14	$151.50	$2,121.00
			C-9	26"x26"	14'	14	$151.50	$2,121.00
			C-9.8	26"x26"	14'	14	$151.50	$2,121.00
			C-10.5	26"x26"	14'	14	$151.50	$2,121.00
			C-11	26"x26"	14'	14	$151.50	$2,121.00
			C.3-7.6	26"x26"	14'	14	$151.50	$2,121.00
			C.7-7	26"x26"	14'	14	$151.50	$2,121.00
			D-7.6	26"x26"	14'	14	$151.50	$2,121.00
			D-8	26"x26"	14'	14	$151.50	$2,121.00
			D-9	26"x26"	14'	14	$151.50	$2,121.00
			D.4-9	26"x26"	14'	14	$151.50	$2,121.00
			D.4-9.8	26"x26"	14'	14	$151.50	$2,121.00
			D.4-11	26"x26"	14'	14	$151.50	$2,121.00
Total								$67,872.00
						Ton	$ / Ton	$
Steel Columns (Basement Level)		X	B.8-7	W12X190	14'	1.33	$2,725.00	$3,624.25
Total								$3,624.25
Slab-on Grade		X				S.F.	$ / S.F.	$
6" SOG W/ 2 Layers 6x6, W2.9 x W2.9 WWF			6" SOG		9770S.F.	9770	$9.46	$92,424.20
Total								$92,424.20

Description	Deletion	Addition	Designation	Member	Size	Quantity / Unit	Cost / Unit	Total Cost
First Floor Level								
						S.F.	$ / S.F.	$
CIP Structural Joist Slab		X			9770S.F.	9770	$17.75	$173,417.50
Total								$173,417.50
CIP Concrete Columns (First Floor Level)		X	A-8	26"x26"	14'	14	$151.50	$2,121.00
			A-9	26"x26"	14'	14	$151.50	$2,121.00
			A-10	26"x26"	14'	14	$151.50	$2,121.00
			A-11	26"x26"	14'	14	$151.50	$2,121.00
			A-8.6	26"x26"	14'	14	$151.50	$2,121.00
			A.2-8.6	26"x26"	14'	14	$151.50	$2,121.00
			A.2-9	26"x26"	14'	14	$151.50	$2,121.00
			A.5-8	26"x26"	14'	14	$151.50	$2,121.00
			A.5-8.7	26"x26"	14'	14	$151.50	$2,121.00
			A.5-9	26"x26"	14'	14	$151.50	$2,121.00
			A.5-9.3	26"x26"	14'	14	$151.50	$2,121.00
			B-8	26"x26"	14'	14	$151.50	$2,121.00
			B-9	26"x26"	14'	14	$151.50	$2,121.00
			B-10	26"x26"	14'	14	$151.50	$2,121.00
			B-11	26"x26"	14'	14	$151.50	$2,121.00
			B.6-10.5	26"x26"	14'	14	$151.50	$2,121.00
			B.6-11	26"x26"	14'	14	$151.50	$2,121.00
			B.8-7.6	26"x26"	14'	14	$151.50	$2,121.00
			B.8-8	26"x26"	14'	14	$151.50	$2,121.00
			C-8	26"x26"	14'	14	$151.50	$2,121.00
			C-9	26"x26"	14'	14	$151.50	$2,121.00
			C-9.8	26"x26"	14'	14	$151.50	$2,121.00
			C-10.5	26"x26"	14'	14	$151.50	$2,121.00
			C-11	26"x26"	14'	14	$151.50	$2,121.00
			C.3-7.6	26"x26"	14'	14	$151.50	$2,121.00
			C.7-7	26"x26"	14'	14	$151.50	$2,121.00
			D-7.6	26"x26"	14'	14	$151.50	$2,121.00
			D-8	26"x26"	14'	14	$151.50	$2,121.00
			D-9	26"x26"	14'	14	$151.50	$2,121.00
			D.4-9	26"x26"	14'	14	$151.50	$2,121.00
			D.4-9.8	26"x26"	14'	14	$151.50	$2,121.00
			D.4-11	26"x26"	14'	14	$151.50	$2,121.00
Total								$67,872.00
Second Floor Level								
						S.F.	$ / S.F.	$
CIP Structural Joist Slab		X			9770S.F.	9770	$17.75	$173,417.50
Total								$173,417.50
Total Cost						**Added**		**$730,386.67**

TOTAL COSTS (East&West Sides) **Added** **$790,873.91**

Relocated basement to east side with new structural system.

Food Science Cost Comparison

Current Design vs. Proposed Relocation

Take-Off Summary

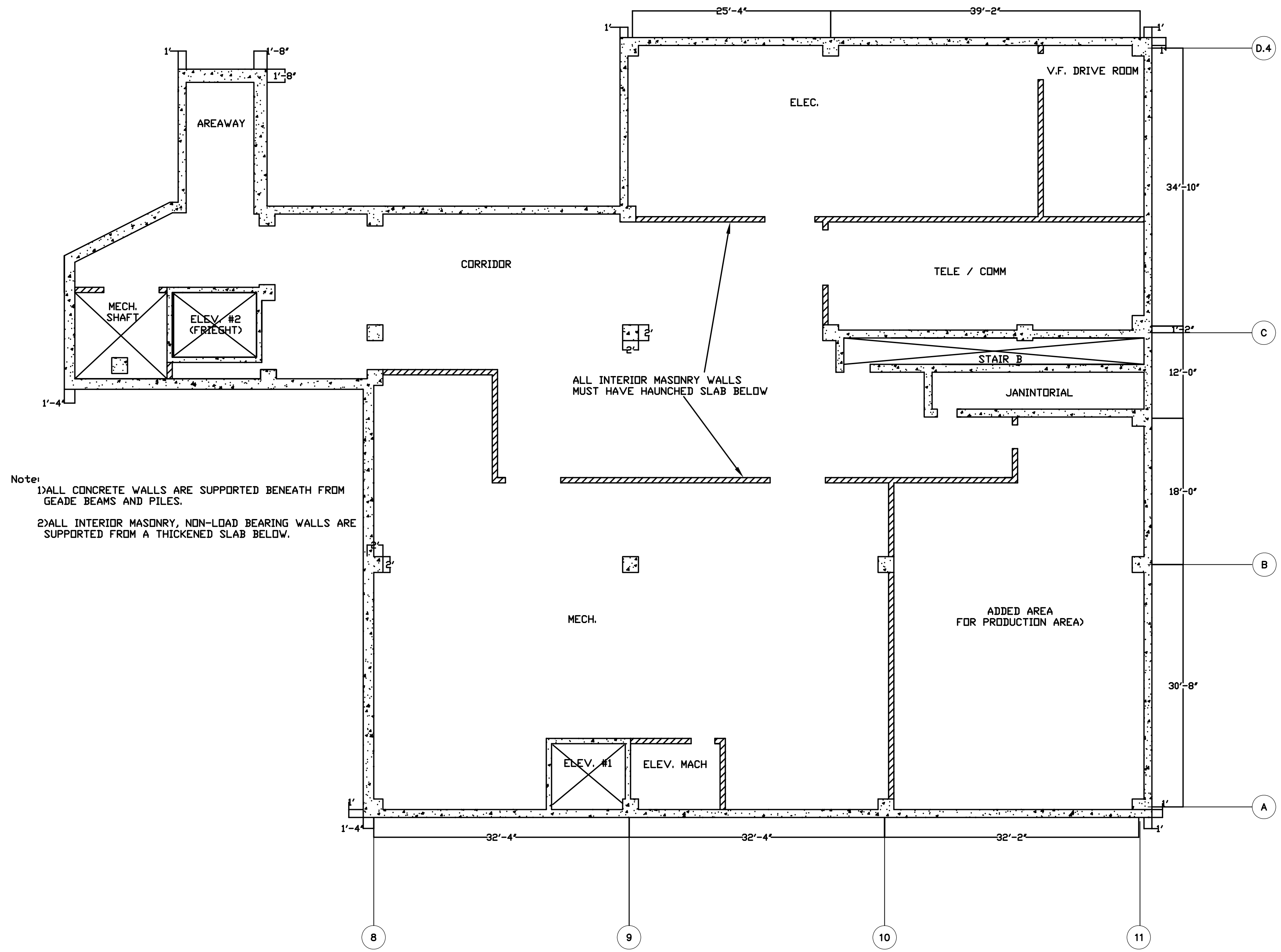
Current Design Deletion

Area	Deletion	Addition	Associated Cost
WEST SIDE (Basement Area)			
Basement Level			
Piles, Caps, Grade Beams, Foundation Walls, Slab on Grade	X		$276,845.00
First Floor Level			
W Shape, Composite Deck, Slab on Deck	X		$197,912.00
EAST SIDE			
First Floor Level			
Piles, Caps, Grade Beams, Walls, Slab on Grade, Concrete Encased Steel Columns	X		$161,346.00
Second Floor Level			
Composite Beams & Cast in Place Slab	X		$348,416.00
Total Savings			$984,519.00

Proposed Relocation Addition

Area	Deletion	Addition	Associated Cost
WEST SIDE			
First Floor Level			
Slab on Grade		X	$60,488.00
EAST SIDE (Basement / Production Area)			
Basement Level			
Sheet Piles, Caps, Grade Beams, Foundation Walls, Slab on Grade, CIP Concrete Columns		X	$315,680.00
First Floor Level			
CIP Concret Joist Slab & Columns		X	$241,290.00
Second Floor Level			
CIP Concrete Joist Slab		X	$173,418.00
Total Savings			$790,876.00

Total Cost Impact of Relocation	Savings of:	**$193,643.00**



The Pennsylvania State University
Food Science Building
HOME OF THE NEW CREAMERY &
THE DEPARTMENT OF FOOD SCIENCES

NOTES:

RELOCATED BASEMENT PLAN
TO THE EAST SIDE OF BLDG. UNDER THE PRODUCTION AREA OF THE CREAMERY.

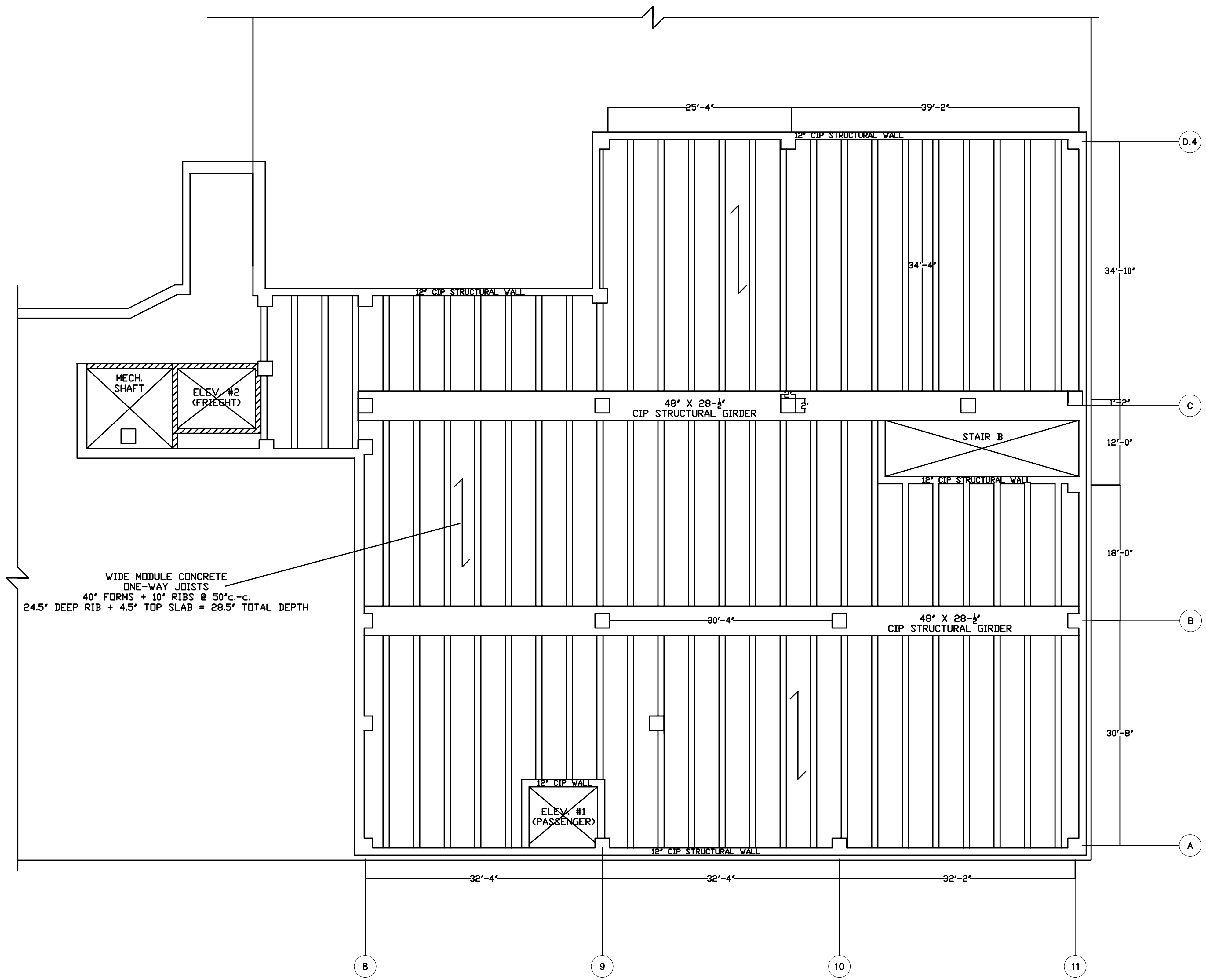
SCALE:
1/16" = 1'-0"

DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT

PENNSTATE
1855

Gilbane

IKM INCORPORATED ARCHITECTS, PLANNERS INTERIOR DESIGNERS One PPG Place Pittsburgh, Pennsylvania 15222	H.F. LENZ COMPANY 1407 Scalp Avenue Johnstown, PA 15904 Phone: 814-269-9300 FAX: 814-269-9301 cadd@hflenz.com www.hflenz.com Engineers • Planners • Surveyors • Energy Consultants	GILBANE BUILDING COMPANY CONSTUCTION MANAGER 7 Jackson Walkway Providence, RI 02903	The Pennsylvania State University Food Science Building FOUNDATION PLAN EAST	JOB NO. IKM 02-091 DGS800-271 PSU-01778 DATE 3/31/06	DWG. NO. S2.0B



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NOTES:

FIRST FLOOR FRAMING PLAN
THE FIRST FLOOR FOR THE PRODUCTON AREA

SCALE:
1/16" = 1'-0"

DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT

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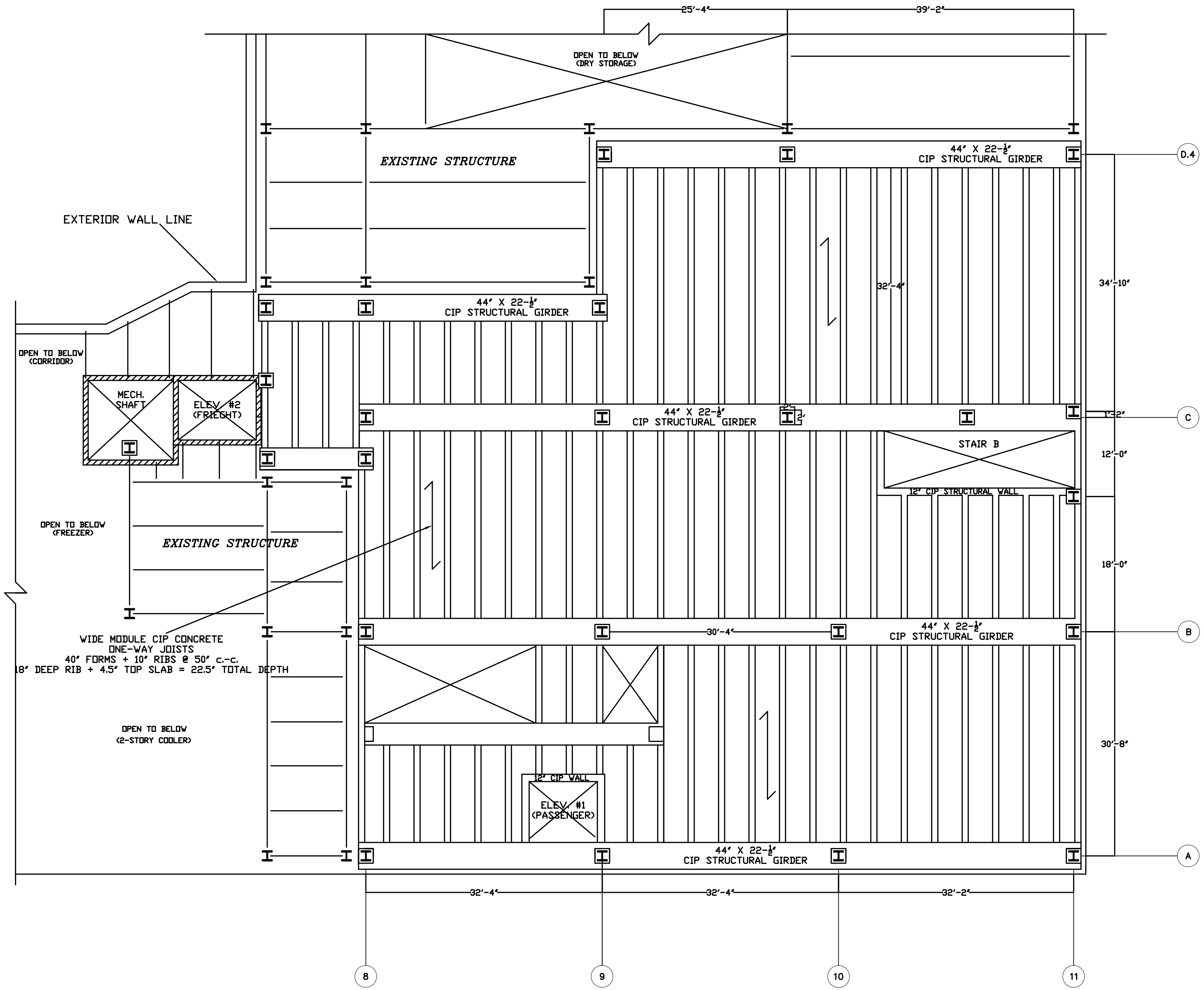

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Food Science Building
HOME OF THE NEW CREAMERY & THE DEPARTMENT OF FOOD SCIENCES

NOTES:

SECOND FLOOR FRAMING PLAN
THE UNDERSIDE OF THE STRUCTURE WILL BE EXPOSED AND SERVE AS THE FINISHED CEILING IN THE PRODUCTION AREA

SCALE:
1/16" = 1'-0"

DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT

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GILBANE BUILDING COMPANY
CONSTUCTION MANAGER
7 Jackson Walkway
Providence, RI 02903

The Pennsylvania State University
Food Science Building
SECOND FLOOR FRAMING EAST

JOB NO.
IKM 02-091
DGS800-271
PSU-01778

DATE
3/31/06

DWG. NO.
S2.2B

First Floor Wide Module Concrete Joist Slab & Girder Design

IBC: LL 250 psf Mech Rm / Heavy Storage
DL 15 psf Pipe Hanging Support

$1.2(15 \times 2) + 1.6(250) = \underline{436\ psf}$

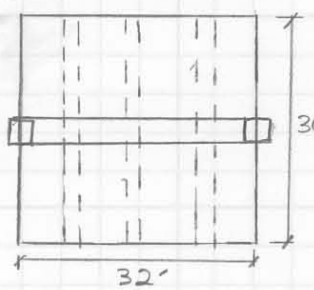
CRSI Handbook: Use Wide Module Concrete Joist Slab Tables

Use* Try 40" Forms + 10" Ribs @ 50" c.c. → 28.5" overall depth

50" c.-c. = 4.167′   436 psf × 4.167′ = 1816.81 plf w/ 33′ Clear Span] Design Parameters

→ End Span 37′ 1894 plf > 1816.81 ∴ OK
Int. Span 37′ 3095 plf

Girder Design



span = 32′
trib. width = 30′

Joist slab self weight = 0.86 $\frac{cf}{sf}$
↳ $0.86 \frac{cf}{sf} \times 150 \frac{lb}{cf} = 129\ psf$

$w = (436\ psf + 129\ psf)\,30' = 16{,}950\ plf$

Try beam: $28.5'' \times 48'' = 9.5\ ft^2$

$w = (436\ psf + 129\ psf)\,30' + (9.5\ ft^2)(150\ lb/ft^2)$
$= 16950\ plf + 1425\ plf$
$= 18{,}375\ plf$

Reinforcing Design

Btm: $M = \frac{18{,}375(32)^2}{14} = 16{,}128\ in\cdot k$

use 17-#8 w/ 1.5" spacing leaving 3.5" on ea. side

$a = \frac{(17)(0.79)(60)}{(.85)(4)(48)} = 4.9375$

$M_n = 17(0.79)(60)(0.9)\left(26 - \frac{4.9375}{2}\right) = 17{,}066\ in\cdot k > 16{,}128\ in\cdot k$ ∴ OK

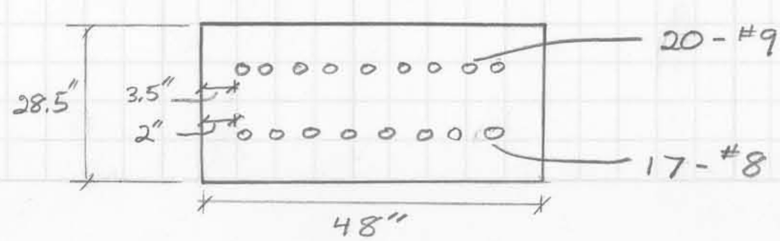
Top: $M = \frac{18{,}375(32)^2}{10} = 22{,}580\ in\cdot k$

use 20-#9 w/ $1\frac{1}{8}''$ spacing leaving $2\frac{1}{16}''$ cover ea. side

$a = \frac{20(1)(60)}{(.85)(4)(48)} = 7.35$

$M_n = 20(1)(60)(0.9)\left(26 - \frac{7.35}{2}\right) = 24{,}110\ in\cdot k > 22{,}580\ in\cdot k$ ∴ OK

Use:



Second Floor Wide Module Concrete Joist Slab + Girder Design

IBC: LL 150 psf Air Handling Equip. Rms
DL 15 psf Pipe Hanging Support

$1.2(15 \times 2) + 1.6(150) = 276$ psf

CRSI Handbook: Use Wide Module Concrete Joist Slab Tables

Use * Try 40" + 10" Ribs @ 50" c.c. → 22.5" overall depth

50" c.-c. = 4.167'   276 psf × 4.1667' = 1150 plf w/ 33' Clear Span] Design Parameters

→ End Span: 33' 1195 plf > 1150 ∴ OK
Int. Span: 33' 2025 plf

Girder Design

Span: 32'
Trib. Width: 30'

Joist Slab self weight = 0.72 cf/sf
↳ 0.72 cf/sf × 150 lb/cf = 108 psf

$w = (276\text{ psf} + 108\text{ psf}) \times 30' = 11{,}520$ plf

Try beam: $22.5'' \times 44'' = 6.875\ ft^2$

$w = 11{,}520\text{ plf} + (6.875\ ft^2)(150\ lb/cf)$
$= 12{,}552$ plf

Reinforcing Design

Top: $M = \frac{12{,}552(32^2)}{10} = 15{,}424$ "K   use 18 - #9 w/ 1⅛" spacing leaving 2 5/16" cover ea. side

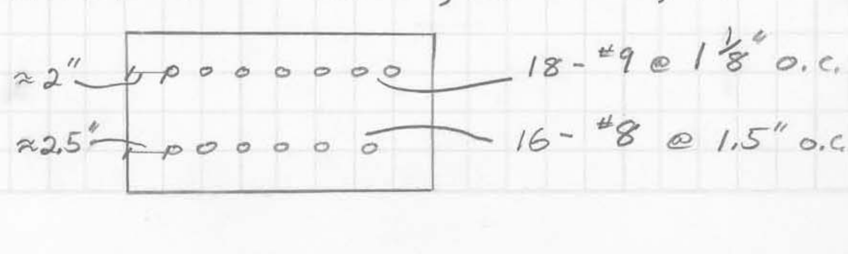
$a = \frac{18(1)(60)}{0.85(4)(44)} = 7.219$

$M_n = (18)(1)(60)(0.9)(20 - \frac{7.219}{2}) = 15{,}932$ "K > 15,424 "K ∴ OK

Bottom: $M = \frac{12{,}552(32)^2}{14} = 11{,}018$ "K   use 16 - #8 w/ 1.5" spacing leaving 2¾" cover ea. side

$a = \frac{16(0.79)(60)}{0.85(4)(14)} = 15.93$

$M_n = 16(0.79)(60)(0.9)(20 - \frac{15.93}{2}) = 11{,}921$ "K > 11,018 "K ∴ OK



Appendix B

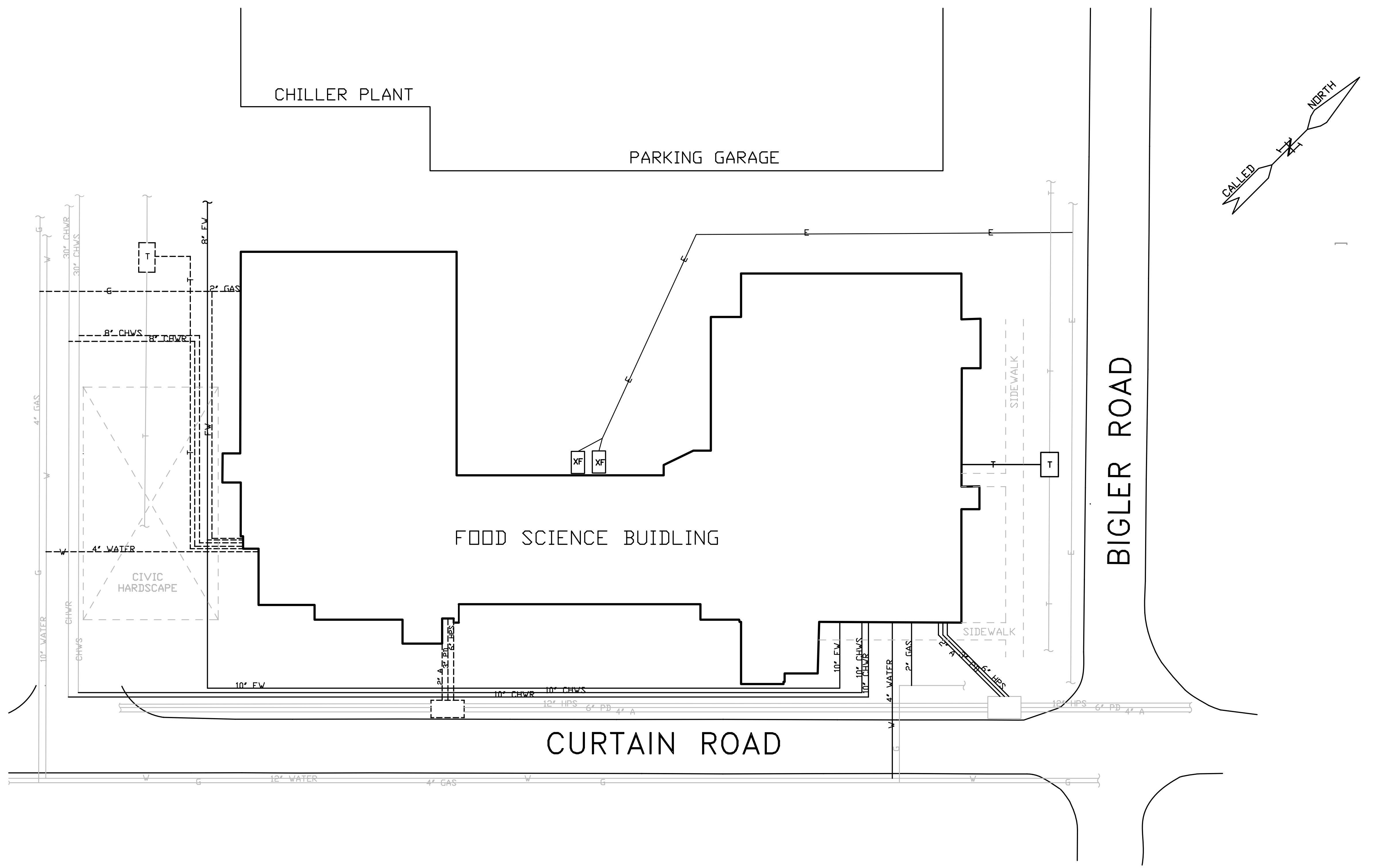
Utility Relocation Drawing

Estimates

- Utility Relocation Take-Off / Estimate
- Interior Piping Take-Off / Estimate

Mechanical Calculations

- Interior Piping
- Utility Piping Relocations



SITE UTILITIES RELOCATION PLAN

The Pennsylvania State University
Food Science Building
HOME OF THE NEW CREAMERY &
THE DEPARTMENT OF FOOD SCIENCES

NOTES:

RELOCATED UTILITY SERVICES
TO THE EAST SIDE OF THE BLDG. TO COINCIDE WITH BASEMENT (MECH. RM) RELOCATION.

ABBREVIATIONS:
HPS: HIGH PRESSURE STEAM
PD: PUMP DISCHARGE
A: COMPRESSED AIR
CHWS/R: CHILLED WATER SUPPPLY/RETURN
FW: FIRE WATER
W: DOMESTIC WATER
G: GAS
E: ELECTRIC
T: TELLECOMMUNICATIONS

SCALE:

SCALE: 1"=50'

DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT

LEGEND:
---------- DELETED UTILITY
——— RELOCATED UTILITY
——— MAIN RUN (TO STAY)

PENNSTATE
1855

Gilbane

IKM INCORPORATED
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INTERIOR DESIGNERS
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Engineers • Planners • Surveyors • Energy Consultants

GILBANE BUILDING COMPANY
CONSTUCTION MANAGER
7 Jackson Walkway
Providence, RI 02903

The Pennsylvania State University
Food Science Building
RELOCATED UTILITIES PLAN

JOB NO.
IKM 02-091
DGS800-271
PSU-01776

DATE
3/31/06

DWG. NO.
C-2.0

Food Science Building

Utility Relocation Take-Off

Description	Savings	Addition	Quantity	Cost: Piping	Cost: Excavation	Total Cost
Steam						
6" HPS (High Pressure Steam)	No Cost Impact		0	$0.00	$0.00	$0.00
3" PD (Pump Discharge,Condensate)	No Cost Impact		0	$0.00	$0.00	$0.00
2" A (Compressed Air)	No Cost Impact		0	$0.00	$0.00	$0.00
Chilled Water						
10" CHWS (Chilled Water Supply)		X	200'	$426.00	$1,088.10	$1,514.10
10" CHWR (Chilled Water Return)		X	200'	$426.00	$1,088.10	$1,514.10
10" 90° Elbow	X		2	$930.00	$0.00	$930.00
Fire Protection						
10" FW (Fire Water)		X	350'	$710.00	$2,176.20	$2,886.20
10" 90° Elbow		X	1	$465.00	$0.00	$465.00
Natural Gas						
2" G (Gas)	X		200'	$2,140.00	$1,088.10	$3,228.10
8" 90° Elbow	X		1	$256.00	$0.00	$257.00
Domestic Water						
4" W (Water)	No Cost Impact		0	$0.00	$0.00	$0.00
Electric						
E (Electric Ductbank)	No Cost Impact		0	$0.00	$0.00	$0.00
Telecommunications						
T (Telecom. Ductbank)						
4- 5" PVC Conduit	X		80'	$1,680.00	$627.75	$2,307.75
5" 90° Elbow	X		4	$314.00	$0.00	$314.00
Reinforcing Rods	X		1 Ton	$1,575.00	$0.00	$1,575.00
Concrete In Place	X		7 CY	$1,211.00	$0.00	$1,211.00
Total Cost					Savings	$9,822.85
Total Cost					Addition	$6,379.40
Total Cost Impact				**Savings of:**		**$3,443.45**

Food Science Building

Interior Piping Take-Off

Description	Savings	Addition	Quantity	Cost		Total Cost
				Piping	Insulation	
Low Pressure Steam / Return						
4" LPS	X		120'	$2,520.00	$2,106.00	$4,626.00
4" LPR	X		120'	$2,520.00	$2,106.00	$4,626.00
4" 90° Elbows	X		4	$1,024.00	$0.00	$1,024.00
Chilled Water Supply / Return						
8" CHWS	X		120'	$5,700.00	$3,900.00	$9,600.00
8" CHWR	X		120'	$5,700.00	$3,900.00	$9,600.00
8" 90° Elbow	X		8	$5,200.00	$0.00	$5,200.00
Hot Water Permieter Supply / Return						
6" HWPS	X		120'	$3,960.00	$3,120.00	$7,080.00
6" HWPR	X		120'	$3,960.00	$3,120.00	$7,080.00
6" 90° Elbows	X		8	$3,440.00	$0.00	$3,440.00
Total Cost Impact				**Savings of:**		**$48,836.00**

Anthony Lucostic | Senior Thesis '06 | 3/31/06

Utility Piping Calculations

CHW:

Existing: 8" Sch 40, 170', 2 ftg

(assumed from chart)

$6 \, ft/100' \, (170') + 2(30')(6 \, ft/100')$
$10.2 + 3.6$
13.8 ft of head

Proposed: 8" Sch 40, 370', 1 ftg

$6 \, ft/100' \, (370') + 1(30')(6 \, ft/100')$
$22.2 + 1.8$
$13.8 < 24$ ft of head
∴ Too much
Can't use

Use: 10" Sch 40, 370', 1 ftg

$2.5 \, ft/100 \, (370') + 1(30')(2.5 \, ft/100)$
$9.25 + 0.75$
$13.8 > 10$ ft of head
∴ ok

FW: Existing: 8" Sch 40, 150', 1 ftg

$6 \, ft/100' \, (150') + 1(30')(6 \, ft/100)$
$9 + 1.8$
10.8 ft of head

Use: Proposed: 10" Sch 40, 400', 1 ftg

$2.5 \, ft/100' \, (400') + 1(30')(2.5 \, ft/100)$
$10 + 0.75$
$10.8 \approx 10.75$ ft of head
∴ ok

Interior Piping Calculations

LPS: 4" Sch 40
120' in length (Removed)
4- 90° elbow fittings (Removed)

Supplied by PSU steam / no inside pump ∴ OK

CHW: 8" Sch 40
120' in length (Removed)
4- 90° elbow fittings (Removed)

Use Figure 10-22 from HVAC Analysis & Design 5th Edition
Friction loss due to flow of water in commercial steel pipe (Sch 40)
↳ From ASHRAE Handbook, Fundamentals Volume, 1989

From Dwg. Schedule: Pump 2000 gpm
from chart Fig. 10-22 ↳ 4.5 ft/100 ft = 4.5 ft wg / 100 ft

$4.5\ \text{ft}/100' \times (120') + 4\ \text{ftg}\ (30')\ (4.5\ \text{ft}/100)$
↳ from figure 10-24a for 90° elbows

5.4 + 5.4
10.8 ft head loss (decrease in head pressure)
75 ft head @ pump → ≈14% decrease
∴ Stay as is

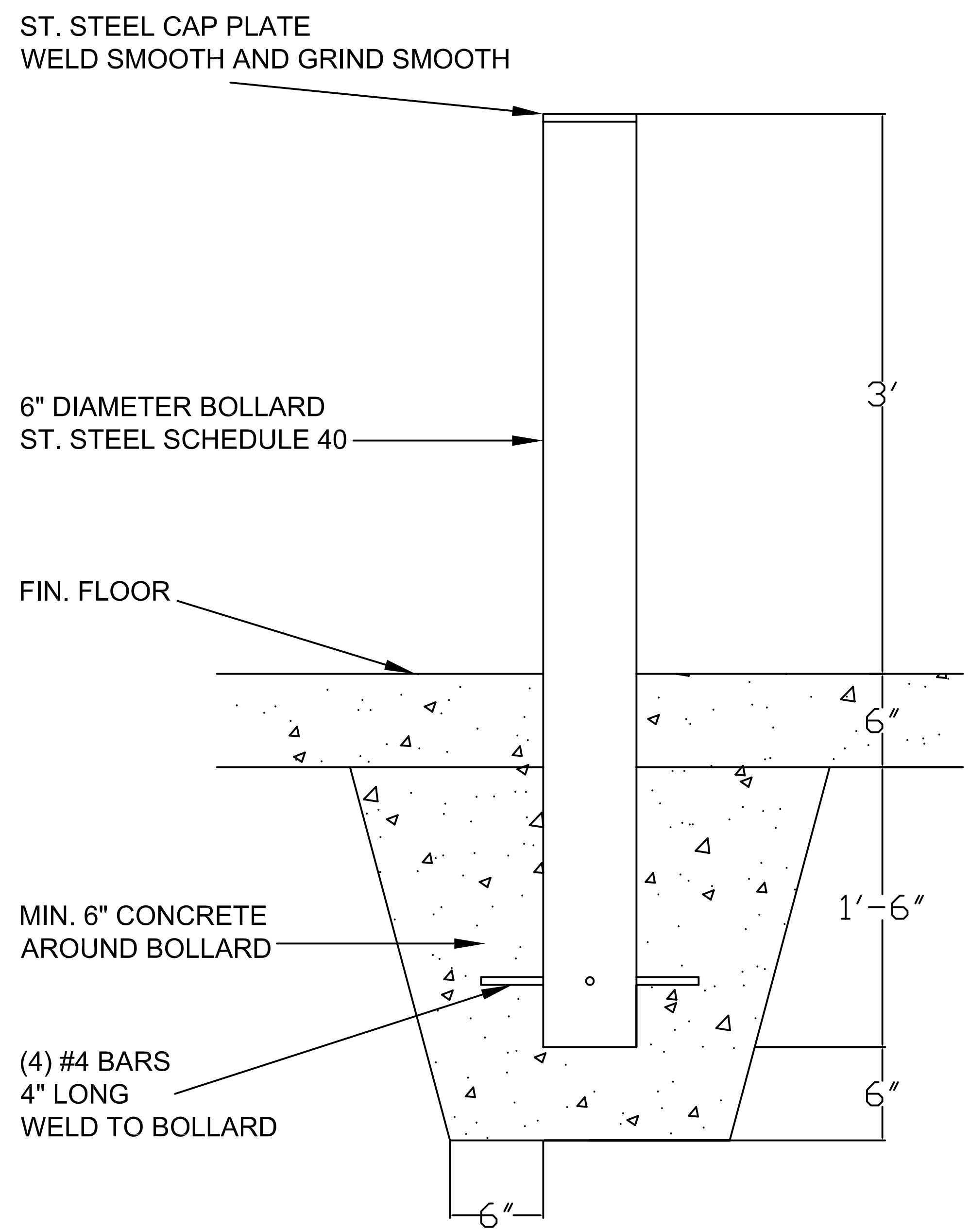
HWP: 6" Sch 40
120' in length (Removed)
4- 90° elbow fittings (Removed)

From Dwg. Schedule: Pump 900 gpm
↳ 6 ft/100' from chart

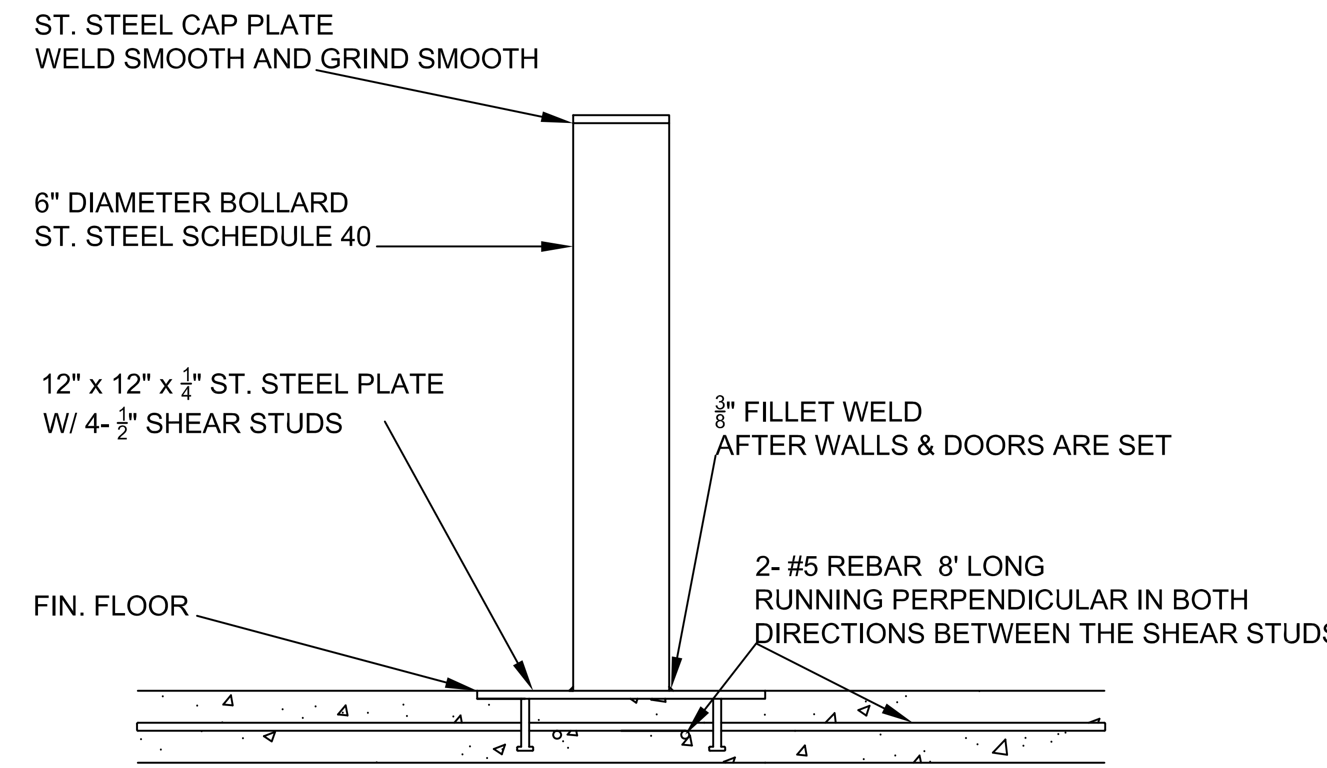
$6\ \text{ft}/100' \times (120') + 4\ (30')\ (6\ \text{ft}/100)$
7.2 + 7.2
14.4' head loss
72' head @ pump → ≈ 20% decrease
∴ Stay as is

Appendix C

Bollard Detail Drawing



CURRENT BOLLARD DETAIL



PROPOSED BOLLARD DETAIL

The Pennsylvania State University
Food Science Building
HOME OF THE NEW CREAMERY &
THE DEPARTMENT OF FOOD SCIENCES

NOTES:

BOLLARD DETAILS
CURRENT
VS.
PROPOSED

SCALE:

SCALE: 1"=1'

DRAWN BY:
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LEGEND:

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IKM INCORPORATED ARCHITECTS, PLANNERS INTERIOR DESIGNERS One PPG Place Pittsburgh, Pennsylvania 15222	H.F. LENZ COMPANY 1407 Scalp Avenue Johnstown, PA 15904 Phone: 814-269-9300 FAX: 814-269-9301 cadd@hflenz.com www.hflenz.com Engineers • Planners • Surveyors • Energy Consultants	GILBANE BUILDING COMPANY CONSTUCTION MANAGER 7 Jackson Walkway Providence, RI 02903	The Pennsylvania State University Food Science Building BOLLARD DETAILS	JOB NO. IKM 02-091 DGS800-271 PSU-01778 DATE 3/31/06	DWG. NO. C-2.0