Structural Breadth

Analysis 1: Basement Relocation and Structural Redesign

Background

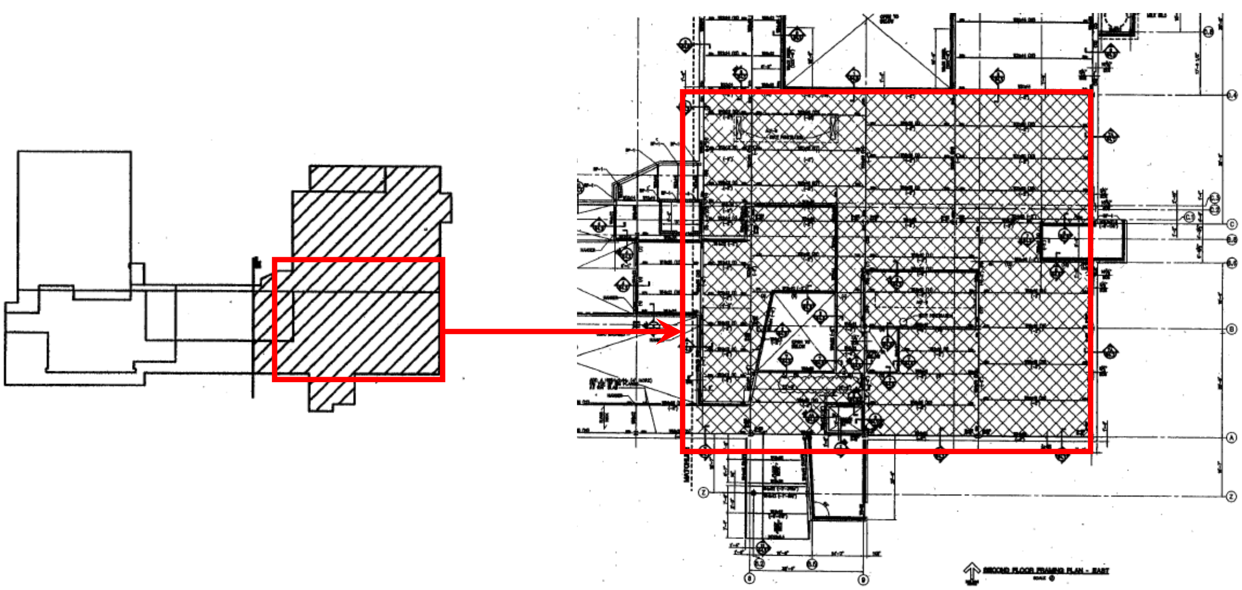
The main Production Area is located in the east part of the Food Science Building on the first floor level. The ceiling of this area (the second floor) is currently designed and installed as an 8" thick structural slab vs. the rest of the buildings' typical 6" concrete slab-on-deck. Additionally, each 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.

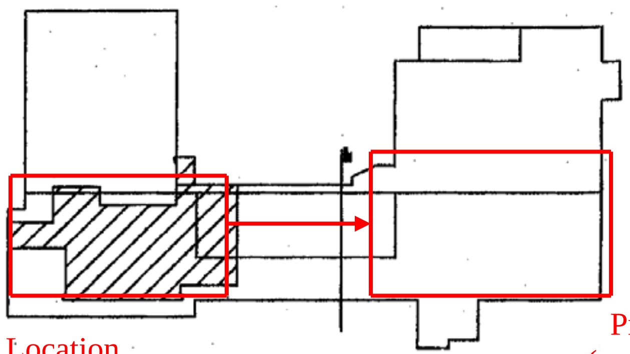
However, the large spans in the 100 ft. x 110 ft. Production Area would require some intermediate girder supports. This means that the construction sequence in this area would require additional coordination amongst the different trade contractors involved. Although, the most significant consideration 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.

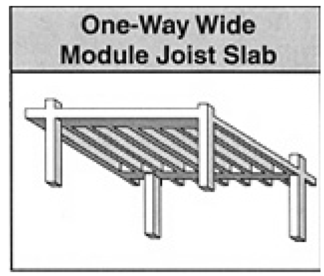


Basement Relocation Schematic

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)

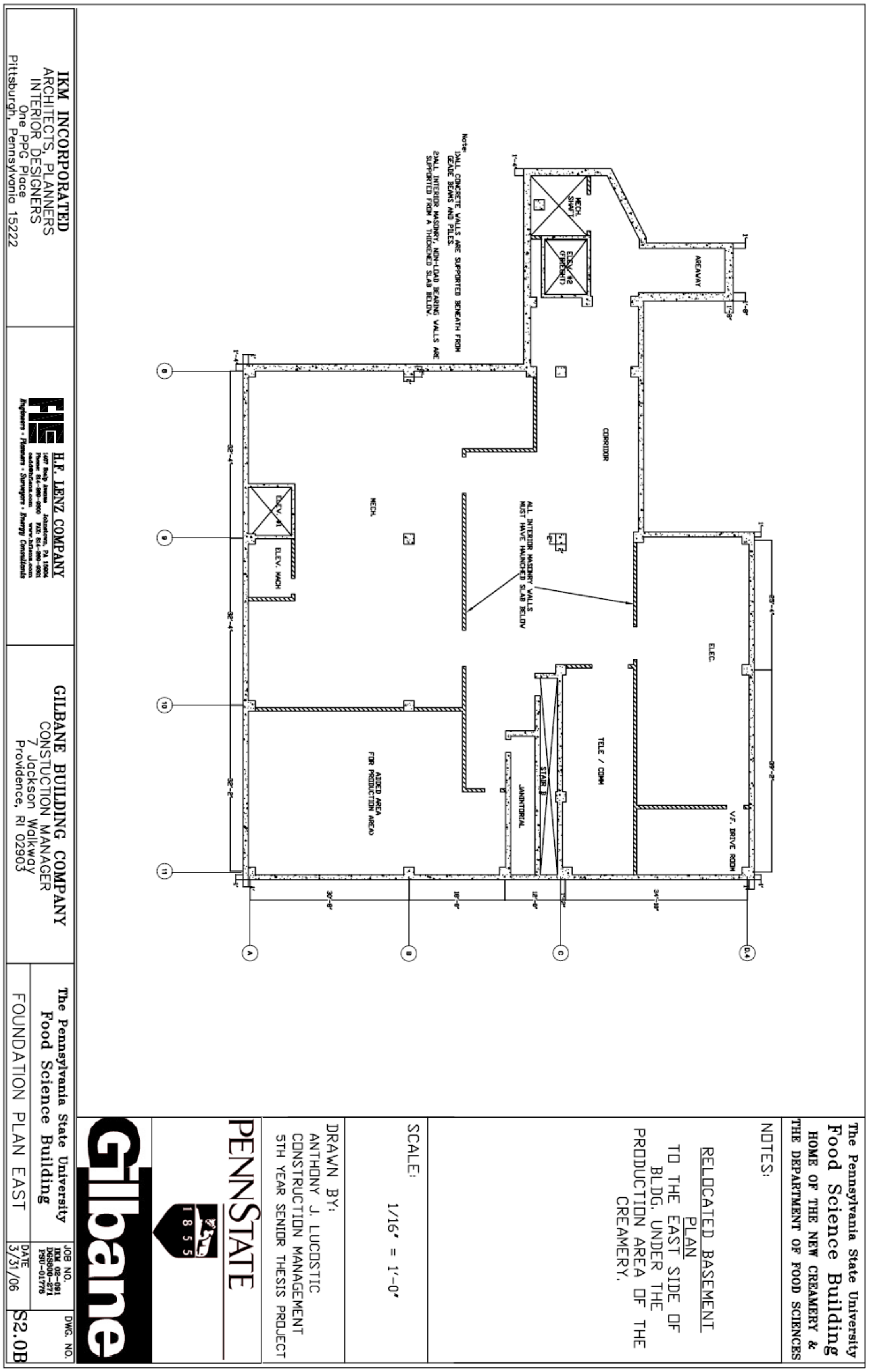
- Tabulated Capacity = 1195 plf with 33’ Clear Span
- Top Bars: #6 bars spaced @ 9” o.c.
- Bottom Bars: 2- #7 and 1- #8
- Single-leg stirrups: 17- #3 spaced @ 9” o.c.

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
CONSTRUCTION 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
Gilbane

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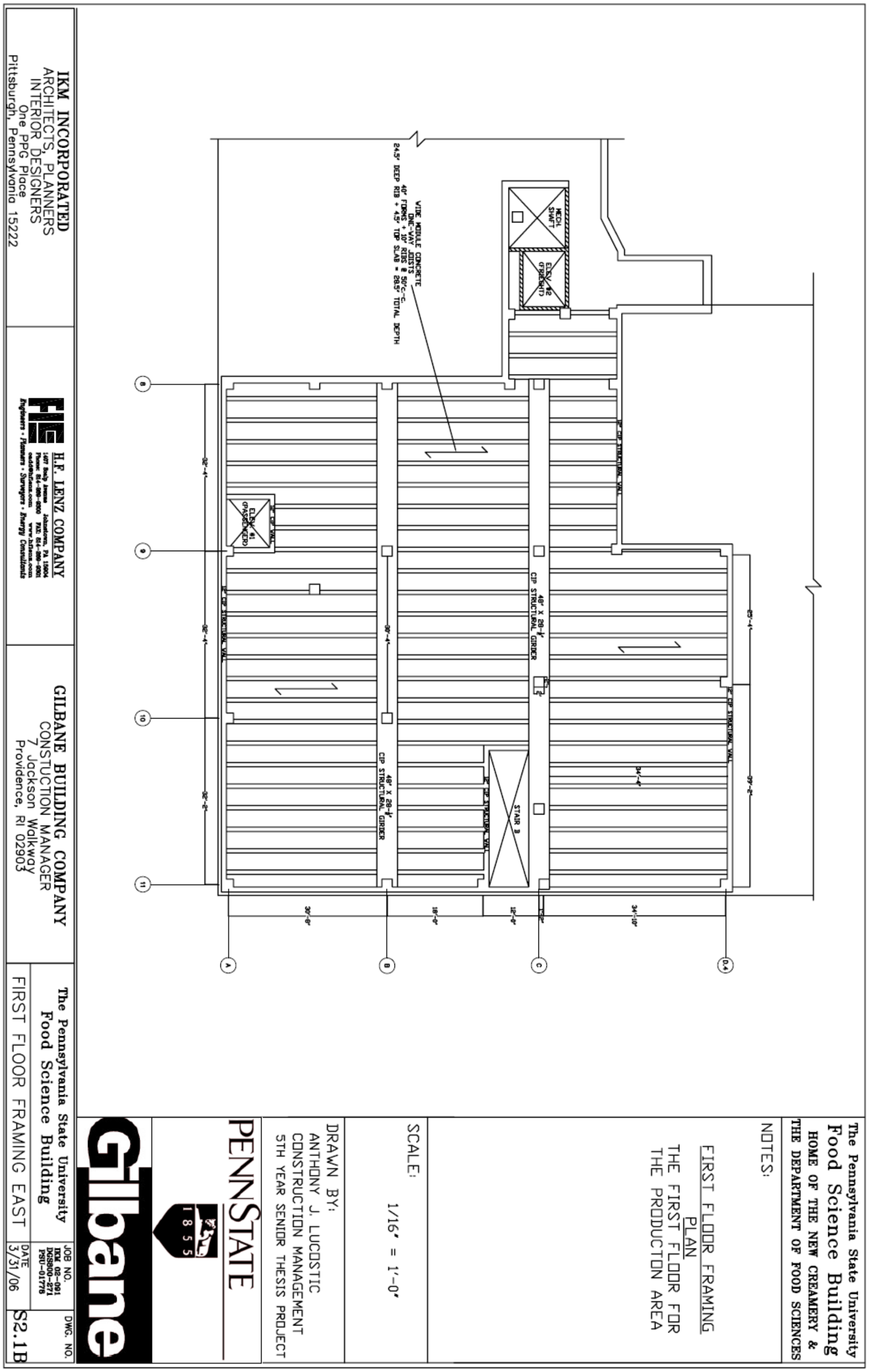
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CONSTUCTION MANAGER
7 Jackson Walkway
Providence, RI 02903
The Pennsylvania State University
Food Science Building
FIRST FLOOR FRAMING EAST
DATE
3/31/06
DWG. NO.
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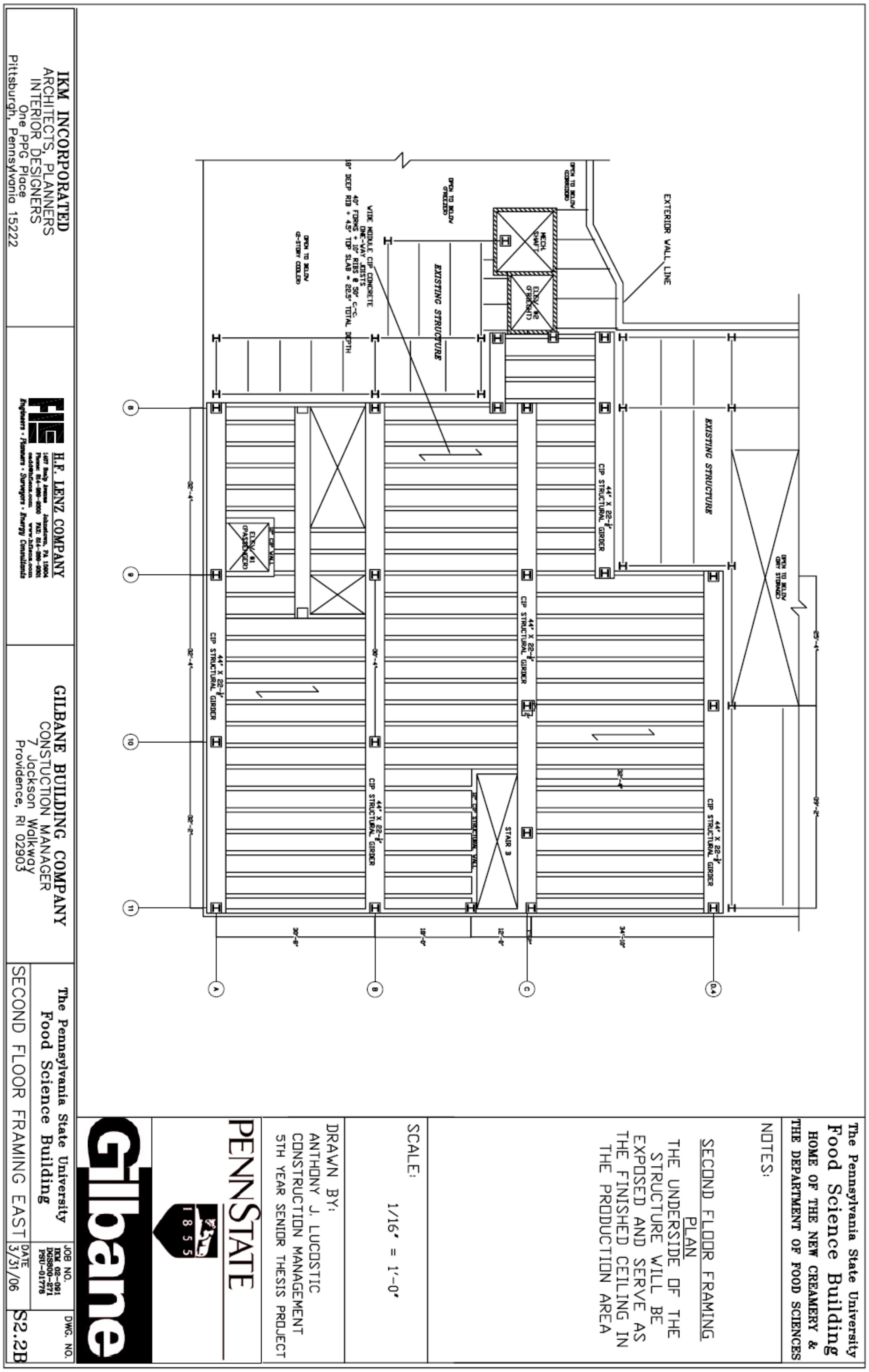
PENNSTATE
1 8 5 5
DRAWN BY:
ANTHONY J. LUCOSTIC
CONSTRUCTION MANAGEMENT
5TH YEAR SENIOR THESIS PROJECT
SCALE:
1/16" = 1'-0"
NOTES:
FIRST FLOOR FRAMING PLAN
THE FIRST FLOOR FOR THE PRODUCTON AREA
The Pennsylvania State University
Food Science Building
HOME OF THE NEW CREAMERY &
THE DEPARTMENT OF FOOD SCIENCES
STAIR B
CIP STRUCTURAL GIRDER


EXTERIOR WALL LINE
EXISTING STRUCTURE
WIDE MODULE CIP CONCRETE ONE-WAY JOISTS
44" X 22-1/2" CIP STRUCTURAL GIRDER
STAIR B
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
1 8 5 5
Gilbane
IKM INCORPORATED
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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
DATE
3/31/06
DWG. NO.
S2.2B

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.

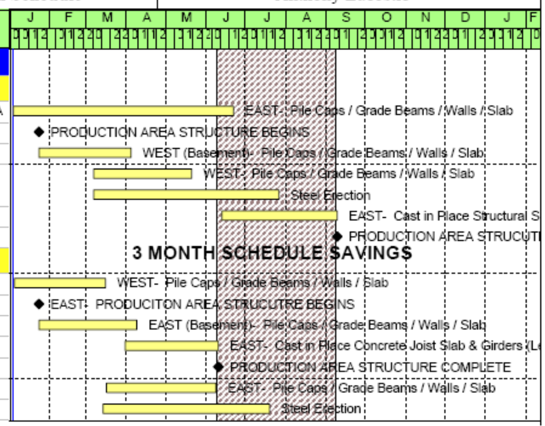
Concrete Joist Construction

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 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.