PENN STATE BALLPARK

University Park, Pennsylvania

Final Senior Thesis Report

Spring 2006

Advisor: Dr. Michael Horman

Jason McFadden

Construction Management

Sponsored by Barton Malow Company, The Pennsylvania State University, and L. Robert Kimball & Associates.

Kimball
L. Robert Kimball & Associates
Architects and Engineers

2005—2006

Barton Malow

Jason McFadden

Construction Management Option

CPEP Website: www.arche.psu.edu/thesis/eportfolio/current/portfolios/jem358/

Medlar Field at Lubrano Park
University Park, Pennsylvania

PROJECT TEAM

Owner: The Pennsylvania State University

CM: Barton Malow Company

Architect: L. Robert Kimball and Associates

Structural Engineer: DLR Group

MEP Engineers: L. Robert Kimball and Associates

Interior Architect: DLR Group

Audio/Visual: The Sextant Group, Inc.

Signage & Graphics: Agnew Moyer Smith, Inc.

PROJECT OVERVIEW

Function: Sports Facility

Building Size: 152,194 S.F.

Location: University Park, PA

Estimated Project Cost: $30.8M

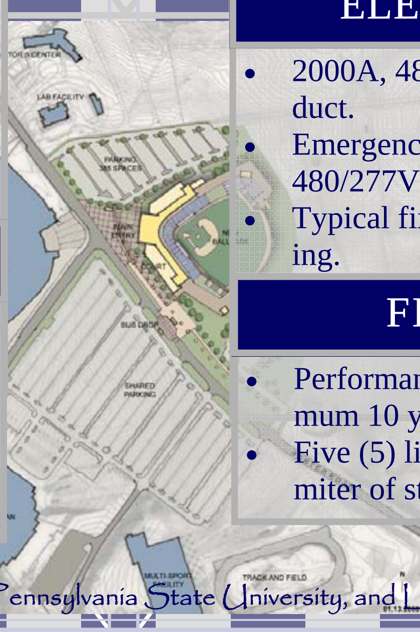
Construction Timeline: June 2005—May 2006

ARCHITECTURAL FEATURES

- 5,200 fixed spectator seating on the concourse level behind home plate, down each base line, in the outfield, and at the press/suite level.
- Home minor league and PSU locker rooms with a shared visitor locker room space.
- Separate administrative offices will be provided for each team.

PLAYING FIELD

- HUMMER Turfgrass Sand Grid Drainage System.
- By using a network of trenches and porous backfill materials, it provides a drainage system that can quickly absorb excess surface water in minutes to hours.



STRUCTURAL SYSTEM

- Typical spread and continuous footings for foundation system.
- Ordinary steel moment frames and masonry shear walls.
- Seating bowl constructed by sloping soil and pouring concrete slab-on-grade.
- Split-slab waterproofing system on the concourse level which consists of two layers of concrete with a waterproofing layer between the two layers of concrete.

MECHANICAL SYSTEM

- (3) indoor air handling units; (2) roof top units
- (2) ductless split system AC units for refrigeration.
- Climate control via a VVT damper system.
- (2) 500MBH, 600 gallon gas water heaters
- (2) 20 GPM hot water re-circulation pumps.
- Combined dry and wet sprinkler system as required by hydraulic design with pendant, concealed, and sidewall heads.

ELECTRICAL SYSTEM

- 2000A, 480/277V system with a 2500A bus duct.
- Emergency Generator: 230 kW, 287.5 kVA, 480/277V
- Typical fixtures and lamps for interior lighting.

FIELD LIGHTING

- Performance based specification with a minimum 10 year life cycle cost.
- Five (5) lighting towers located around perimeter of stadium.

Sponsored by Barton Malow Company, The Pennsylvania State University, and L. Robert Kimball & Associates.

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ACKNOWLEDGEMENTS

Most importantly, I would like to thank my family and friends for supporting me throughout my career at Penn State. Your support has been tremendous and I wish to thank you for everything.

Additionally, I would like to thank the following people for their assistance and support throughout the past year during the development of my senior thesis:

Architectural Engineering Colleagues

Mr. Bradley Hartman	*Lighting/Electrical Candidate*
Mr. Philip Mackey	*Lighting/Electrical Candidate*
Mr. Adam Senk	*Mechanical Candidate*
Mr. Michael Vergari	*Construction Management Candidate*
Mr. Abrahm Vogel	*Construction Management Candidate*

Barton Malow Company

Mr. Forrest Brewer	*Senior Superintendent*
Mr. John Elder	*Project Engineer*
Mr. Len Moser	*Project Director*
Mr. Scott Mull	*Project Manager*
Mr. Ron Sinopoli	*Assistant Project Manager*

Bettwy Electric

Mr. Tim Bettwy	*President*

Industry Professionals Who Participated in Research Interviews

L. Robert Kimball and Associates

Mr. Charles Shaw	*Project Manager*

The Pennsylvania State University

Mr. Marv Bevan	*Project Manager (Office of Physical Plant)*
Dr. Louis Geschwindner, Jr.	*AE Professor Emeritus (structural)*
Dr. Michael Horman	*AE Assistant Professor (construction)*
Dr. John Messner	*AE Assistant Professor (construction)*
Dr. M. Kevin Parfitt	*AE Assistant Professor (structural)*
Dr. David Riley	*AE Associate Professor (construction)*
Dr. Walter Schneider	*AE Instructor (structural)*

Ritner Steel, Inc.

Ms. Babette Freund	*C.F.O.*

RNR Steel

Mr. Dave Edminson	*Executive*
Mr. Dale Hunt	*Superintendent*

EXECUTIVE SUMMARY

The first area of technical analysis was the structural columns that support the light fixtures design includes one (1) W14x132 columns and two (2) W14x90 columns with cross-bracing members connecting the structural bays. Because the structural steel package is on the critical path of the project and costs saving measures are often needed, I will analyze the structural columns which support the field lighting fixtures in terms of:

1. Value engineering methods to determine if an alternative structural member (ex. HSS) can be used to lessen the steel tonnage and decrease the cost while supporting the same loading.
2. Constructability methods to determine if the columns can be altered, but still achieve the aesthetic smooth appeal required by the architect.

The proposed column aesthetically looks the same as the designed members. Essentially, this method was chosen after studying the plan view of the designed column. It is apparent that the flange of the W14X132 member in the center of the tapered column does not do much structurally as depicted with a red arrow in the figure below. The alternative column design is a positive value engineering suggestion for the project. It provides an overall cost savings of $45,184.20 in labor, material, and equipment and a schedule savings of 7 days on erection of the columns.

The second area of technical analysis was proposing an electrical panel in the retail store and ticket building which is a separate building from the rest of the structure. The current design includes portions of two (2) panels which are not located within the building. One panel is 300A, 3 phase, 4 wire panel at 208V/120V for panel while the lighting is on a 225A, 3 phase, 4 wire panel at 480V/277V; both are located approximately 275' from the retail building. The proposed alternative design adds two (2) panels and a transformer. The alternative system is a positive value engineering suggestion for the project. It provides a cost savings of $8,771.38 in labor and material but most importantly the alternative system will provide the owner better electrical maintenance means during the building lifetime. Furthermore, the ease of expansion within the retail building will be much easier with the alternative system because wires and conduit do not need to be installed 275' away from the source of expansion.

The construction depth research was related to streamlining the structural steel design to construction through the implementation of computer modeling. A familiar problem in the construction industry is that a building is often designed on paper during the design phase; and then re-designed to determine "ability for construction" during the construction phase. The discussion focuses on streamlining the steel phase of a project with computer modeling along with how to take advantage of current technology to help a project team. The research methods included journal and industry article reviews, telephone interviews with steel industry professionals, and the development of a steel BIM for Penn State Ballpark. By analyzing existing practices during the steel phase of a project, a more streamline process for the steel phase of a project through computer modeling has been addressed. The above research discussion has benefited structural designers, construction managers, and steel fabrication because each entity can more effectively perform his/her job with the implementation.

Please note that all information pertaining to Penn State Ballpark is Jason McFadden's interpretation and may be different than the design and construction means and methods implemented by the project team.

SENIOR THESIS

Senior Thesis "Weight Distribution" by Breadth/Depth Study *Penn State Ballpark*					
Description	Research	Value Engineering	Constructability Review	Schedule Reduction	TOTAL
STEEL COLUMN VE	5%	25%	--	5%	35%
ELECTRICAL DIST. VE	5%	10%	5%	--	20%
STREAMLING STEEL / BIM	40%	--	5%	--	45%
TOTAL	50%	35%	10%	5%	100%

PROJECT PROPOSAL

BREADTH TOPIC #1

ANALYZE THE STRUCTURAL COLUMNS WHICH SUPPORT THE FIELD LIGHTING FIXUTRES

The *Penn State Ballpark* follows the same construction duration that has come to be accepted for sports facilities. Excavation of the 22 acre site began in June 2005 and the construction will end in May 2006 with the first game to be played in June 2006 for the minor league franchise. This means that approximately $25 million will be put in place in a twelve month time period. Furthermore, any delays in design or construction could have an immediate impact in finishing the project by May 2005.

The structural system package was released for bid in late May 2005 and bids were received by the middle of June 2005. The structural system package included 600 tons of structural steel with the interesting figure that 86 tons of that estimate was allocated to the structural columns which support the light fixtures as depicted below.

Ballpark rendering with the area highlighted which will be analyzed.

The area highlighted on the first base side is typical for the third base light fixtures as well. The design includes three (3) W14x132 columns with cross-bracing members connecting the structural bays. The overall height of the W14x132 members varies between the first and third base side because there is a sixteen (16) foot elevation difference; this is due to the fact that there is a basement level on the first base side but not on the third base side. Although the rendering appears to have the same structural support for the scoreboard in left field, this is not true. The structural supports for the scoreboard are being designed in conjunction with the scoreboard manufacturer, Daktronics Inc.

Barton Malow Company, the construction manager for the project, has developed a strong niche in the sports construction market including minor league baseball facilities. Because this project is not a design-build project with the construction manager having control of the architect, Barton Malow can only advise design changes. During the bid review period and post-bid meetings, Barton Malow suggested that these columns could be altered to support the same structural loading as well as achieve the same aesthetic look for the architect. One of the concerns proposed by Barton Malow and stated earlier was the fact that this area of the project accounted for 15% of the entire structural steel package. Furthermore, from past projects of similar size, Barton Malow has learned that the columns which support the main light fixtures of the stadium can be designed under 100 lbs/ft.

Because the structural steel package is on the critical path of the project and costs saving measures are often needed, I will analyze the structural columns which support the field lighting fixtures in terms of:

1. Value engineering methods to determine if an alternative structural member (ex. HSS) can be used to lessen the steel tonnage and decrease the cost while supporting the same loading.
2. Constructability methods to determine if the columns can be altered, but still achieve the aesthetic smooth appeal required by the architect.

In order to be able to accomplish the three (3) items listed above, I will need to first understand the design process of a structural engineer and how the design relates to the architects design intent. In order to accomplish this, I will discuss the design steps taken by a structural engineer with the professors in the structural option within the architectural engineering department at Penn State University as well as discuss the design intentions with the structural designer from DLR Group. This will allow afully understand the design requirements and intent before I begin to technically critique the field lighting structural supports on the first and third base line.

Next, I will contact Barton Malow Company and ask for information about the field lighting structural supports on past minor league baseball projects. I will need to ask for the following information when talking to them:

1. Size of the structural members in the described area.
2. Shape of the structural members in the described area.

Once I receive this information, I can begin determining possible alternatives to the field lighting structural supports. Using my knowledge of AE 401 (basic steel design), I will determine the size and shapes of the steel members needed to support the field lighting fixtures for *Penn State Ballpark*. In order to determine if the aesthetic look is affected with the alternative design, I will model alternative design in AutoCAD.

Once my technical analysis has been completed and modeled, I hope to have successfully found an alternative way to design the field lighting fixture structural supports. This will ultimately allow for cost savings in the structural steel package, but might allow for a quicker erection time in this area due to lighter and less steel members. Furthermore, I will be able to use the knowledge I have learned from performing this analysis when value engineering ideas might be needed on future projects and the project team might need suggestions in how to achieve the same look with lighter steel members.

BREADTH TOPIC #2

ELECTRICAL DISTRIBUTION ANALYSIS FOR THE RETAIL STORE AND TICKET BUILDING

The electrical system design for *Penn State Ballpark* was documented rather quickly and sent out for bid without complete design documents. When the electrical package was awarded to the responsible low bidder, a new set of electrical construction documents was released. Not only did this require the electrical contractor to submit appropriate pricing for the changes, but the construction manager also had to make the necessary planning changes for the revised electrical work. Because the electrical package was assembled quickly, there is one item that I have found to give the owner, The Pennsylvania State University, a more worthwhile facility.

As depicted below, the retail store and ticket building is separate from the rest of the structure and will be used during non-operating game times.

Ballpark rendering with the area highlighted which will be analyzed.

Within the 2000 square foot structure, there is a ticket booth area, a retail store, an office, a small mechanical room, and a storage area. The spaces contain standard electrical equipment devices including light fixtures, wall receptacles, and data outlets. All of the electrical wiring for this area is designed to be run overhead through the canopy structure and into the building. Because there is no underground raceway conduits designed for this area, there is an added labor cost for running all wires through the canopy along with extra material cost for running the wires to the required panel board. Furthermore, by not designing an electrical panel within the building, electrical maintenance could become an issue. If an electrical problem arises, the maintenance crew must find an electrical panel that is not near the retail store and ticket building.

Because of the issues named above, I have decided to design an electrical panel located within the building. The current panel which is not located within the building is 300A, 3 phase, 4 wire panel at 208V/120V for panel while the lighting is on a 225A, 3 phase, 4 wire panel at 480V/277V. In order to design a new panel, I will determine all of the connected loads with the appropriate electrical design factors for lighting, receptacles, and mechanical equipment. I will also provide underground raceways to the help minimize the wires that travel through the canopy area. Lastly, I understand before beginning the electrical calculations that two electrical panels will be required and a step-down transformer will be needed for the electrical receptacles and track lighting in the area. Furthermore, I will provide a cost-benefit analysis between the designed system and the proposed re-design to help determine the value of using an alternative system.

CONSTRUCTION DEPTH RESEARCH

STREAMLINING THE SUPERSTRUCTURE DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

1. **Chapter 1: Introduction**
   a. In July 2005, the General Services Administration (GSA) announced that all new projects requiring their funding will need to include a building information model (BIM) as part of the project proposal.
      i. The term BIM is a relatively new term in the industry, but in the past has been noted as a project model or multi-dimensional (MD) modeling.
      ii. Essentially a building information model is a materialized 3D model meaning that everything in the building is drawn with its true properties. An example of this is with an exterior masonry wall. A typical 3D model would just draw the dimensions of the wall, whereas a BIM details the wall with its brick façade, air barrier, sheathing, studs, etc. for the wall properties.
      iii. The GSA's requirement with a BIM needed for all of their future projects is a new approach to project design and delivery. In the past, many projects have been designed in three dimensions, but have not included the object properties which would make it a BIM.
      iv. Computer aided project development has been in the industry for quite some time, however implementing it has been a hardship. Many owners, architects, and construction managers have not seen the value that these models can bring to a project mostly due to initial costs and time to develop the models.
   b. On-going Construction Industry Problems:
      i. Duplication during the steel sequence continues to be a problem in the industry. The structural engineer designs the steel structure for the building and then the structural steel contractor, upon award, re-designs the building through steel shop drawings. Because of the need to produce these shop drawings, steel cannot begin fabrication until six to eight weeks after an award is made to the steel contractor and shop drawings are approved.
   c. This research proposal will focus on a BIM of the superstructure for *Penn State Ballpark*. The goals and objectives of this research are to answer the following questions:
      i. Can the construction industry reduce the waste in the steel shop drawing process through implementing building information modeling?
   d. By analyzing existing practices (shop drawings and coordination) during the steel phase of a project, I will propose a more streamline process for the steel phase of a project.

2. **Chapter 2: Background/Literature Review**
   a. Currently, there has been a lot of research devoted to computer aided design/construction research. Most of this research is based on project case

studies and not how to effectively implement computer aided models on a construction project.

b. Most projects are documented with a 3D model which is made during the preconstruction phase of a project. These models are used to develop a rendering of the project which is mainly used for marketing purposes. Unfortunately, these models are 3D models and not building information models. Furthermore, these models are very rarely taken from the design phase of a project and implemented in the construction phase.

c. During the summer of 2005, I began my initial study of building information modeling. My research paper was tilted, “Integrating Building Models In the Construction Workplace,” and documented some of the current practices with computer modeling within the industry.

    i. The most valuable information received during the research timeline were the responses to a series of survey’s I sent to architects/engineers, owner representatives, and construction managers. The survey’s asked a series of questions relating to implementing a 3D and 4D model on the project and the value that each can bring to a project.

d. Many industry members are interested in implementing new technology on a project, but either do not know how or cannot afford the cost and time associated with developing a model. Some trades in the industry already implement 3D models to assist with pre-fabrication of systems with the steel trade being at the top of the list in terms of implementing technology.

3. Chapter 3: Objectives and Methods

a. Problem Statement

    i. Duplication of structural design delays fabrication of structural members and is a problem that affects each project in the construction industry.

b. Specific Measurable Objectives

    i. Review literature and understand current practice.
    ii. Develop a solution to implement a Structural BIM on a project.
    iii. Test and validate proposed solution.
    iv. Leave ideas for future research.

c. Methods

    i. First, I will read articles documenting projects that have implemented building information modeling and understand how the research was performed.
    ii. Next, I will find any articles relating to the shop drawing sequence of a project in order to see if there is already documented waste in this process.
    iii. Then I will find any articles relating to the steel fabrication of a project and any known documented problems that may exist.
    iv. Through building information modeling during the design phase, the time invested during the shop drawing phase can be decreased and coordination between steel material fabricators can be more easily achieved.

        (1) I will make a building information model of the superstructure sequence of the project using Autodesk Revit Structure 2. This program has all of the structural members and shapes that are in the current steel manual including joists and decking which will allow me to produce an accurate model.
    v. I will then obtain a copy of the CIS/2 modeling standards which describe means of information transferred between steel computer software.
    vi. Once the computer model is made, I will contact steel industry organizations, structural engineers, steel contractors, steel detailers, and construction managers and discuss with them the items that are needed to go from design to fabrication.
    vii. By documenting the problems found in the shop drawing process, I can propose an alternative means and methods to the structural design and approval phase of a project.
    viii. Lastly, I will describe the overall affect of implementing a BIM for the structural sequence through a case study project and document the value of such a model for fabrication and design coordination.

d. Expected results / outcome / benefits
    i. In developing a BIM of the superstructure for *Penn State Ballpark*, I will be able to address better techniques in going from steel design to fabrication stage of a project. Furthermore, I will be able to address better coordination techniques between steel suppliers.
    ii. This research project will help me identify current problems and time constraints associated with the steel/structure phase of a project and allow me to suggest alternative methods to beginning the construction of a steel structure.
    iii. Because the steel phase of a project is often on the critical path, any time that might be able to be saved could result in a quicker delivery of the entire project. This research will benefit structural designers, construction managers, and steel fabricators as well as leave ideas for continued research in streamlining the design to construction of the structural sequence.

e. Timeline
    i. January 2006
        (1) Read articles about current BIM projects, studies performed with the steel sequence, and any articles with current fabrication practices.
        (2) Develop a BIM of *Penn State Ballpark's* superstructure.
    ii. February 2006
        (1) Contact steel contractors and discuss questions proposed above.
        (2) Analyze the results of the study.
    iii. March 2006
        (1) Summarize and document results of study.
    iv. April 2006
        (1) Present results of study to construction industry members.

PROJECT DESCRIPTION AND BACKGROUND INFORMATION

Penn State Ballpark is a fast-track traditional project delivery system. Barton Malow Company was hired by Penn State University to serve as the construction management agency for the project, whereas L. Robert Kimball & Associates is the lead project architect. The construction schedule for the project shows that construction began in June 2005 and will finish in time for State College Baseball's first minor league baseball game slated for June 2006. An in-depth look at the building systems shows that the stadium shell is constructed using steel and load bearing masonry walls with brick veneer. The seating bowl is shaped using a slab-on-grade approach to form the seating risers. The original project cost when construction began in June 2005 was $23.8 million; however the cost has since risen to $30.8 million.

CLIENT INFORMATION

The Pennsylvania State University

The Pennsylvania State University is a very experienced owner during the construction of a facility. Within the Office of the Physical Plant (OPP) at Penn State, there is a design and construction department solely for new and renovated projects for the University. Penn State has a set standard of procedures for procuring design and construction professionals as well as contract administration during a project. Furthermore, OPP employs construction quality representatives to perform daily on-site inspections of the work being performed.

The University is expecting a state-of-the-art facility but still maintain the overall project budget for the project. Unfortunately, the project budget has been increased significantly for the project; the budget in May 2005 was $23.8M and as of September 2005 is $30.8M. This is partly due to the fact that there are many project players with different visions for the project. For example, from Penn State there are representatives from OPP (several departments), Inter-Collegiate Athletics, Office of Telecommunications, Police Services, etc. In addition, the minor league affiliate also has a vision of the design for the project and wants to eliminate problems that have occurred at their other facility in Altoona. To help guarantee the project will be delivered safely and with good quality, Penn State University has employed two (2) construction quality representatives (CQR) for the project; this is different than past projects where only one CQR has been assigned to a project. The University employed representatives perform daily inspections of work-in-place and help to solve any issues Barton Malow is having with the L. Robert Kimball & Associates.

With the State College Baseball organization being the lessee for the project, this Stadium project becomes the first project in the country to be conceived this way. State College baseball will lease the facility as well as provide the operation of the concession stands for the events. The State College Baseball organization is an affiliate of the Altoona Curve organization, and they hope to continue to have the same success that is on-going in Altoona.

Even though this facility will be used for baseball, the major concern the University had was the affect the stadium will have on football parking. Because of this concern, Barton Malow completed the new 500 space north parking lot in August 2005 so it could be used for high-profile football parking. The only other major concern is the project must be finished by June 2006 because the minor league team will begin its season then.

Origination of the Project

- Over the past for years, Penn State has seen an increased need for a better baseball facility on campus. After setting aside money to renovate the current facility, Beaver Field, Penn State decided to entertain the idea of a first-class facility with a minor league franchise.
- After much investigation and meetings with athletic personal, OPP representatives, and the minor league affiliates, a state-of-the-art facility for both the Penn State Baseball Team and a minor league franchise was conceived.
- The baseball stadium site and design furthers the idea for Penn State to create an athletic village on the east edge of campus.
- The current baseball facility located on Park Ave. near Beaver Stadium will be demolished and become additional football parking as well as a locker room facility for the men's and women's soccer team.
- The new stadium will also serve as a recruiting tool for the Penn State Baseball team. The state-of-the-art facility will help attract prospective players to the join the Penn State Baseball team. Penn State also hopes to now be able to hold Pennsylvania state baseball championships with the new facility.
- Furthermore, the minor league affiliate (State College Baseball) will help attract more people to the University during the summer when campus is not as crowded.

Design Guidelines

- The Open Spaces and Natural Systems concept will be used by preserving the view of Mount Nittany and incorporating an area for grass lawn seats in the design. The surrounding area will be landscaped with trees to preserve the natural beauty of Penn State.
- The Architectural gridlines used for this building are community interface and preserving a campus community. Since the building will be used to serve both Penn State and the Minor league team there will be a strong community interface. This construction will further the idea of an "athletic village" on the eastern edge of campus.

- Penn State must embrace the heritage of the Land Grant Institution by promoting a strong agricultural image. This is embraced by maintaining a rural area surrounding the new stadium
- This stadium will have a "campus in the fields" environment due to its tree lined paths and low profile to the surroundings.

Circulation Guidelines

- A bus stop along Porter Road will transport on campus students to the stadium
- Off Campus students and visitors will be able to utilize the commuter parking or use the new 500 spaces that will be provided with the building. They will then be able to visit the campus by way of the bus systems.
- Crosswalks will be added to the area surrounding the new stadium so that the walking campus atmosphere will be maintained.

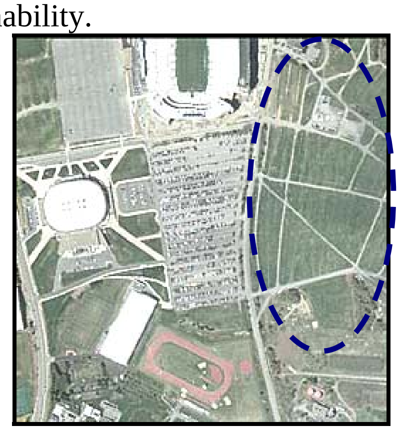
Funding

- The project budget is $30.8 million including design costs as well as FF&E.
- Penn State will contribute the land, parking, intersection improvements and five million dollars in gift funds invested by the Intercollegiate Athletics.
- Under the Pennsylvania Act 40, the State will contribute up to $12 million.
- There has also been a private donation made of $2.5 million for the project.

EXISTING AND LOCAL CONDITIONS

Site Location

- The site for the stadium is located near the intersection of Porter and Curtin Road.
- The site is surrounded by Beaver Stadium, the Bryce Jordan Center and the Multi-Sport Indoor facility.
- Also located nearby are the Visitor Centre, Meats Lab, Pig Farms, and the Center for Sustainability.



Aerial View of Athletic Area at PSU (Baseball Stadium Site Circled)

Topography

- In general, the site slopes north to south.

Soil and Groundwater Conditions

- Soil data is referenced from the United States Department of Agriculture National Resources Conservation Service Soil Data Mart.
- The following six soils types are found in the construction area: HaA, HaB, HcB, HcC, No, and OhB.
- This means that there is bedrock significantly near the surface, implying the need for blasting throughout the project.

State College Township Concerns

- Since Sewage at State College Park will flow against gravity field, a booster/ejector will be installed to pump sewage uphill to existing facility.
- The formation of a bus stop along Porter Road will allow visitors to be dropped-off and picked-up. Since there will only be 500 parking spaces added for the new stadium, bus and motor home parking will be provided by the University at another location.
- Scheduling of events at the Stadium will not conflict with University events (ex. football games).

Operating Times

- Penn State Baseball Team: March – May
- Minor League “A” Affiliate: June – September

Preferred Construction Methods

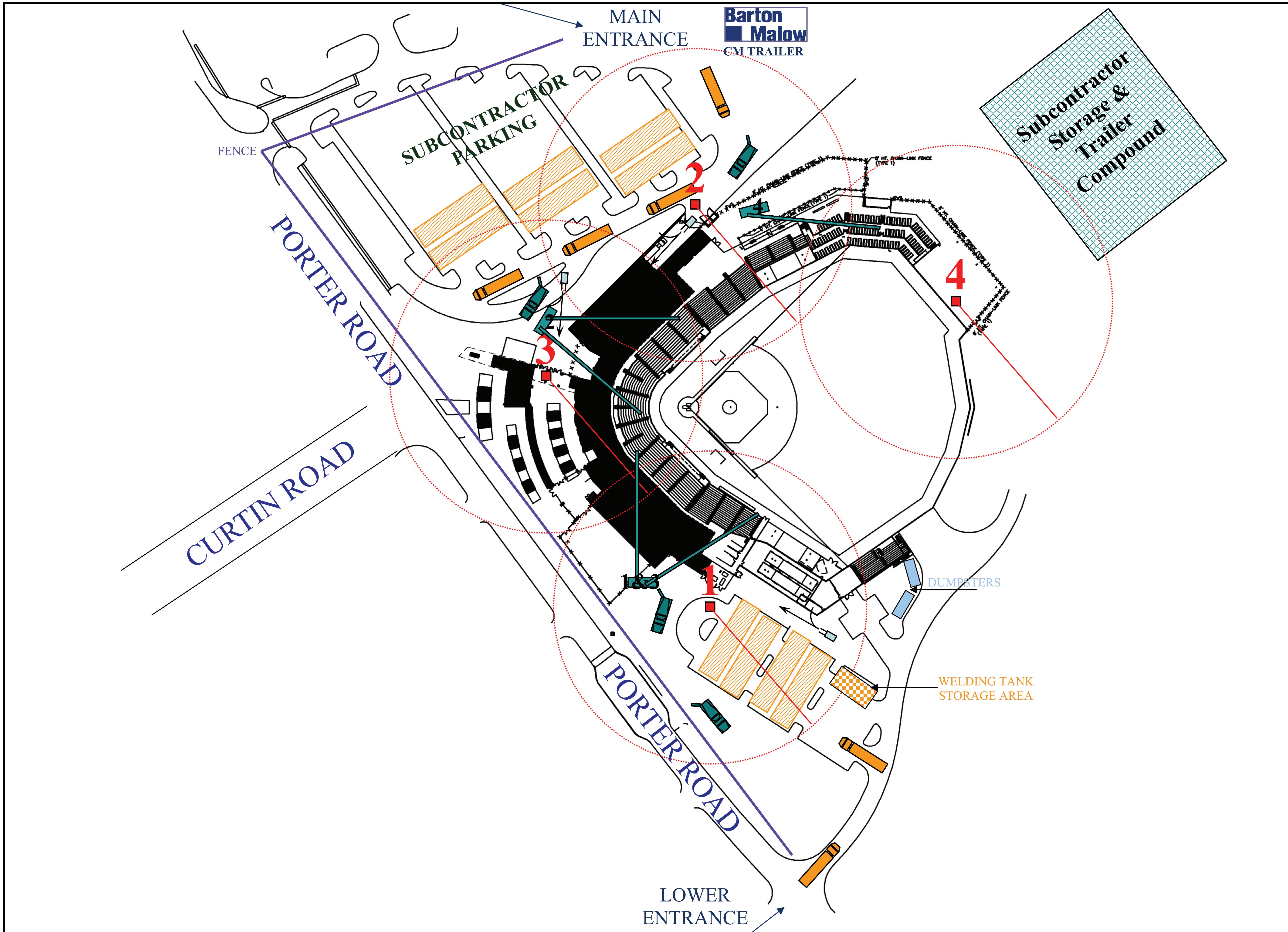
- The typical construction method Penn State using on their project is a steel structural system with concrete elevated slabs and a brick façade.

Availability of Construction Parking

- The Stadium project is unique in the fact that there is an unlimited amount of on-site parking at no cost for the project.

Available Recycling and Tipping Fees

- Penn State is hoping to acquire a LEED Certification for the project.
- Cost to dispose 1 ton of waste in Centre County is $56.



NOTE: This is Jason McFadden's Interpretation of the Site Layout Plan for the Steel/Concrete Sequence.

L. Robert Kimball & Assoc.
Frick Building
437 Grant Street
Pittsburgh, PA 15219

DLR Sports Group
7290 W. 133rd Street
Overland Park, KS 66213

Barton Malow Company
200 Mansell Court East
Suite 100
Roswell, GA 30076

KEY

- Steel Delivery Truck
- Steel Staging
- Concrete Pump & Hose
- Concrete Truck
- Forklift

SITE LAYOUT PLAN
STEEL / CONCRETE
SEQUENCE

Scale: 3/32" = 1'- 0"

C13.01

PROJECT SCHEDULE SUMMARY

Foundation Sequence

Penn State Ballpark is constructed on a conventional spread footing foundation system. Foundation construction began in area D and moved to area E and B. Concurrent construction of the field wall and area A foundation also occurred. Before foundation construction could begin, there were eight (8) weeks of mass excavation to the entire project site.

Structural/Exterior Phases

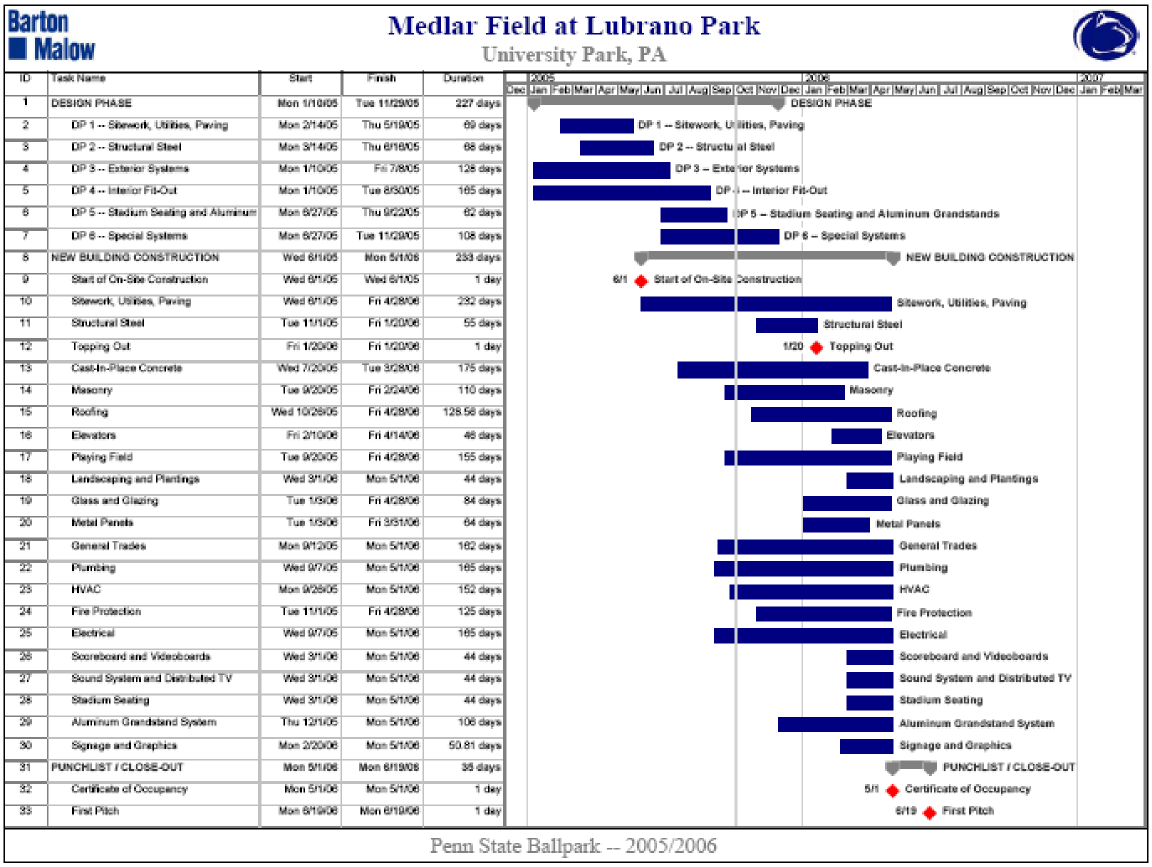
The current steel erection sequence is divided into seven (7) phases by areas of the stadium; the stadium is divided into areas A, B, C, D, and E which are arranged in a counter-clockwise direction around the building. Steel erection will begin in area D, and then move to area B, followed by area C, and then finish with area A and E. Steel erection will finish with the erection of the light towers and scoreboard structure. The concrete floor slab construction will follow the structural steel erection sequence. The masonry sequence begins with construction of load bearing walls in areas B and E and then will follow with areas C and D.

Finish Sequence

Finishes were sequenced through the building from area D to C and finishing in area B. The majority of finishes in area D are in the basement level while area B and C are at the suite level.

After HVAC and other major overhead equipment were in place, the finishes will be phased in the following manner:

- Metal studs
- MEP Rough-In
- Ceiling Grid
- Insulation
- Gypsum Board
- Ceiling Grid
- Electrical Fixtures and Diffusers
- Ceiling Tiles
- Painting
- Carpeting and Other Floor Installations
- Furniture



ID	Task Name	Start	Finish	Duration
1	DESIGN PHASE	Mon 1/10/05	Tue 11/29/05	227 days
2	DP 1 -- Sitework, Utilities, Paving	Mon 2/14/05	Thu 5/19/05	69 days
3	DP 2 -- Structural Steel	Mon 3/14/05	Thu 6/16/05	68 days
4	DP 3 -- Exterior Systems	Mon 1/10/05	Fri 7/8/05	128 days
5	DP 4 -- Interior Fit-Out	Mon 1/10/05	Tue 8/30/05	165 days
6	DP 5 -- Stadium Seating and Aluminum	Mon 6/27/05	Thu 9/22/05	62 days
7	DP 6 -- Special Systems	Mon 6/27/05	Tue 11/29/05	108 days
8	NEW BUILDING CONSTRUCTION	Wed 6/1/05	Mon 5/1/06	233 days
9	Start of On-Site Construction	Wed 6/1/05	Wed 6/1/05	1 day
10	Sitework, Utilities, Paving	Wed 6/1/05	Fri 4/28/06	232 days
11	Structural Steel	Tue 11/1/05	Fri 1/20/06	55 days
12	Topping Out	Fri 1/20/06	Fri 1/20/06	1 day
13	Cast-In-Place Concrete	Wed 7/20/05	Tue 3/28/06	175 days
14	Masonry	Tue 9/20/05	Fri 2/24/06	110 days
15	Roofing	Wed 10/26/05	Fri 4/28/06	128.56 days
16	Elevators	Fri 2/10/06	Fri 4/14/06	46 days
17	Playing Field	Tue 9/20/05	Fri 4/28/06	155 days
18	Landscaping and Plantings	Wed 3/1/06	Mon 5/1/06	44 days
19	Glass and Glazing	Tue 1/3/06	Fri 4/28/06	84 days
20	Metal Panels	Tue 1/3/06	Fri 3/31/06	64 days
21	General Trades	Mon 9/12/05	Mon 5/1/06	162 days
22	Plumbing	Wed 9/7/05	Mon 5/1/06	165 days
23	HVAC	Mon 9/26/05	Mon 5/1/06	152 days
24	Fire Protection	Tue 11/1/05	Fri 4/28/06	125 days
25	Electrical	Wed 9/7/05	Mon 5/1/06	165 days
26	Scoreboard and Videoboards	Wed 3/1/06	Mon 5/1/06	44 days
27	Sound System and Distributed TV	Wed 3/1/06	Mon 5/1/06	44 days
28	Stadium Seating	Wed 3/1/06	Mon 5/1/06	44 days
29	Aluminum Grandstand System	Thu 12/1/05	Mon 5/1/06	106 days
30	Signage and Graphics	Mon 2/20/06	Mon 5/1/06	50.81 days
31	PUNCHLIST / CLOSE-OUT	Mon 5/1/06	Mon 6/19/06	36 days
32	Certificate of Occupancy	Mon 5/1/06	Mon 5/1/06	1 day
33	First Pitch	Mon 6/19/06	Mon 6/19/06	1 day

1.0 STRUCTURAL STEEL TAPERED COLUMN ANALYSIS

1.0.1 EXECUTIVE SUMMARY

The structural columns that support the light fixtures design includes one (1) W14x132 columns and two (2) W14x90 columns with cross-bracing members connecting the structural bays. Because the structural steel package is on the critical path of the project and costs saving measures are often needed, I will analyze the structural columns which support the field lighting fixtures in terms of:

1. Value engineering methods to determine if an alternative structural member (ex. HSS) can be used to lessen the steel tonnage and decrease the cost while supporting the same loading.
2. Constructability methods to determine if the columns can be altered, but still achieve the aesthetic smooth appeal required by the architect.

There are three main factors that control steel design: trucking weight, steel length, and torsional loads. Trucking weight can be considered the least factor for this analysis, but it is important to note that the legal trucking load on a roadway is twenty (20) tons. The second factor, steel length, is very relative to the steel columns being analyzed. Because the columns are 120.5 feet (on the first base side) proper design considerations should be determined to allow for correct splicing positions. The most import factors to the steel column design are the torsional loads including wind load and lateral-torsional buckling. The shape of the designed columns is similar to what has been observed of past minor league stadium projects; however there are 1" stiffner plates encasing the column on the sides and a 3/8" plate parallel to the flange as shown in the picture above. The plates add a significant amount of weight to the structural column design.

The proposed column aesthetically looks the same as the designed members. Essentially, this method was chosen after studying the plan view of the designed column. It is apparent that the flange of the W14X132 member in the center of the tapered column does not do much structurally as depicted with a red arrow in the figure below.

The alternative column design is a positive value engineering suggestion for the project. It provides an overall cost savings of $45,184.20 in labor, material, and equipment and a schedule savings of 7 days on erection of the columns.

1.0.2 OVERVIEW

The structural system package was released for bid in late May 2005 and bids were received by the middle of June 2005. The structural system package included 600 tons of structural steel which included the structural columns that support the light fixtures as depicted below.

Ballpark rendering with the area highlighted which will be analyzed.

The area highlighted on the first base side is typical for the third base light fixtures as well. The design includes one (1) W14x132 columns and two (2) W14x90 columns with cross-bracing members connecting the structural bays. The overall height of the W14 members varies between the first and third base side because there is a sixteen (16) foot elevation difference; this is due to the fact that there is a basement level on the first base side but not on the third base side. Although the rendering appears to have the same structural support for the scoreboard in left field, this is not true. The structural supports for the scoreboard are being designed in conjunction with the scoreboard manufacturer, Daktronics Inc.

Barton Malow Company, the construction manager for the project, has developed a strong niche in the sports construction market including minor league baseball facilities. Because this project is not a design-build project, Barton Malow can only advise design changes. During the bid review period and post-bid meetings,

Barton Malow suggested that these columns could be altered to support the same structural loading as well as achieve the same aesthetic look for the architect. One of the concerns proposed by Barton Malow and stated earlier was the fact that this area of the project accounted for 15% of the entire structural steel package. Furthermore, from past projects of similar size, Barton Malow has learned that the columns which support the main light fixtures of the stadium can be designed under 100 lbs/ft.

Because the structural steel package is on the critical path of the project and costs saving measures are often needed, I will analyze the structural columns which support the field lighting fixtures in terms of:

1. Value engineering methods to determine if an alternative structural member (ex. HSS) can be used to lessen the steel tonnage and decrease the cost while supporting the same loading.
2. Constructability methods to determine if the columns can be altered, but still achieve the aesthetic smooth appeal required by the architect.

Once my technical analysis has been completed and modeled in AutoCAD, an alternative way to design the field lighting fixture structural supports will be suggested. This will ultimately allow for cost savings in the structural steel package, but might allow for a quicker erection time in this area due to lighter and less steel members.

1.0.3 DESIGN CONDITIONS

There are three main factors that control steel design: trucking weight, steel length, and torsional loads. Trucking weight can be considered the least factor for this analysis, but it is important to note that the legal trucking load on a roadway is twenty (20) tons. The second factor, steel length, is very relative to the steel columns being analyzed. Because the columns are 120.5 feet (on the first base side) proper design considerations should be determined to allow for correct splicing positions. The most import factors to the steel column design are the torsional loads including wind load and lateral-torsional buckling.

The location of the baseball stadium presented a challenge to the design team. With a massive steel structure, Beaver Stadium, to the northwest and a heavy masonry structure, Bryce Jordan Center, to the west, the design team had to find a way to integrate the baseball stadium with its surroundings. How can the design team compete with the shear mass of the Bryce Jordan Center and Beaver Stadium? This question was posed many times throughout the design process.

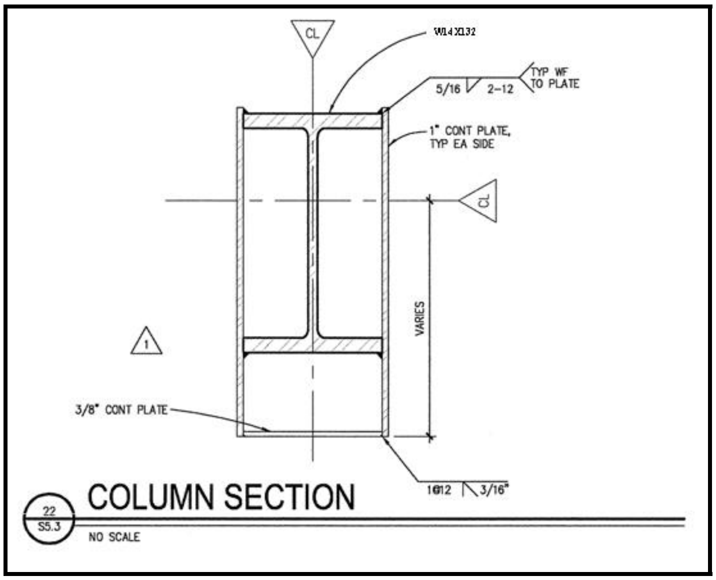
To address this concern the design team took several measures with the steel design. The three (3) pole design for the field lighting columns was chosen to help overcome the mass of Beaver Stadium. The columns are twice as tall as needed for a typical minor league baseball facility. Typically, the lighting columns are approximately sixty (60) feet above field level; however, the columns on the first and third base line are at 120.5 feet above field level. Lastly, an ingenious idea by the design team was to make the field lighting column height at the baseball stadium the similar height to the football field lighting column at Beaver Stadium's Gate C. Furthermore, a smooth "uninterrupted" 120'-6" tall column was the conveyed final product preferred by the architecture team.

1.0.3.A UNDERSTAND DESIGN PROCESS OF STRUCTURAL ENGINEER

A main concern imposed on a structural engineer is to understand how the structural design relates to the architect's design intent. Very often an architect can control the structural design on a project. For the structural supports on the field lighting columns, it is important to look at different options. Wind loading controls this design and more bracing is needed so the structures does not buckle or twist (rolling).

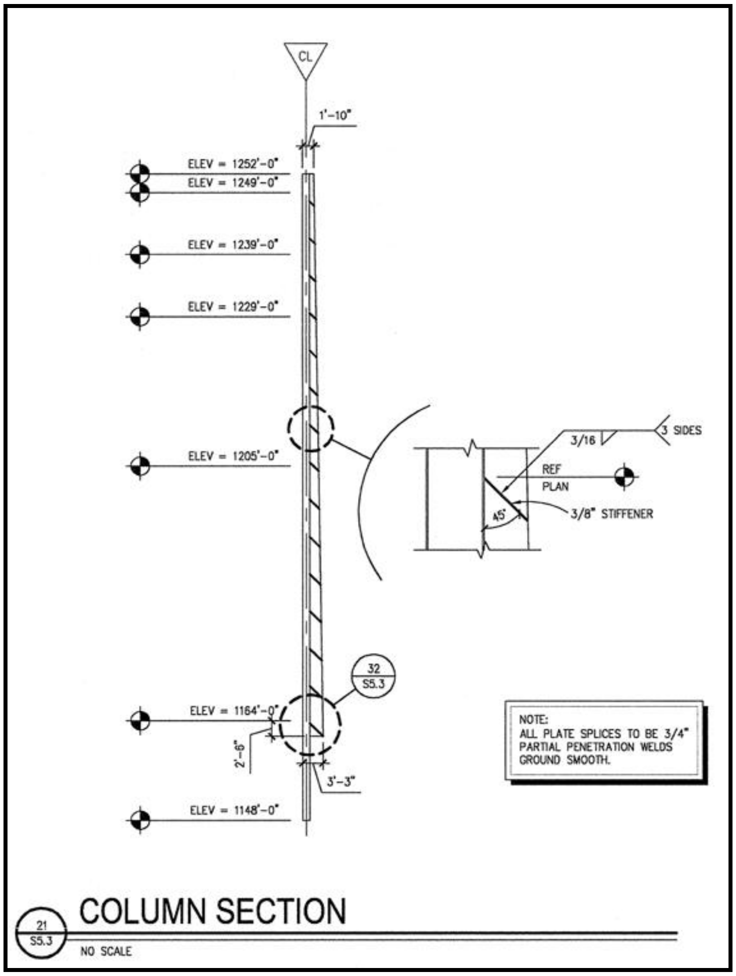
1.0.4 DESIGNED COLUMN

Together, L. Robert Kimball & Associates (lead architect) and DLR Sports (structural engineer) designed the field lighting column as depicted below.



Column Plan Per Original Design

Essentially the columns are a huge cantilever comprised of a W14x132 in the middle with a W14x90 on each side. The span of the entire field lighting structure is 85'-4" horizontally and 120'-6" vertically for the first base side and 105'-10" vertically for the third base side. There are three horizontal rows of HSS 12x8x5/16 tube steel members which provide lateral stability and help resist buckling of the columns. The shape of the columns is similar to what has been observed of past minor league stadium projects; however there are 1" stiffner plates encasing the column on the sides and a 3/8" plate parallel to the flange as shown in the picture above. The plates add a significant amount of weight to the structural column design.



Column Section Per Original Design

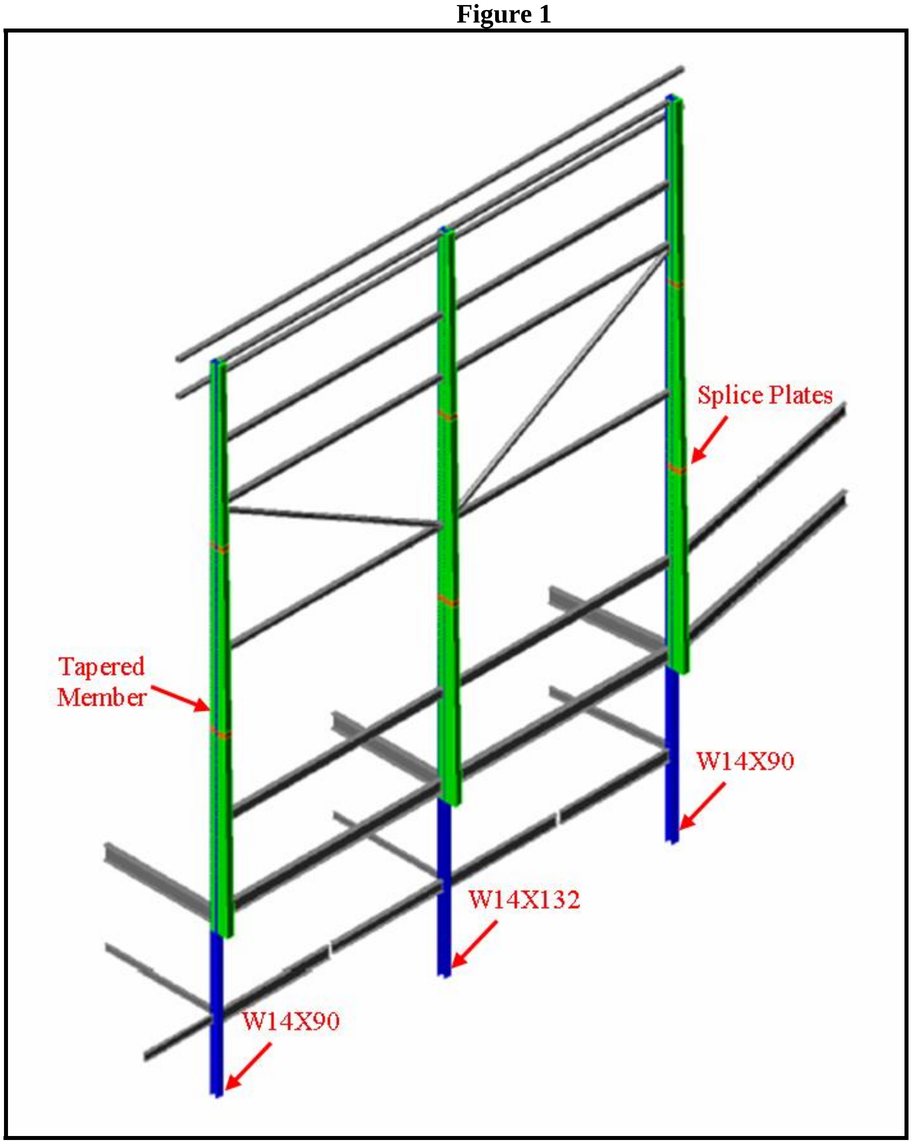
The stiffner plates encase the column vertically 92'-0" with the top having a 1'-10" offset and the bottom having a 3'-3" offset as depicted above. Inside the tapered part of the W14 member and the 3/8" stiffner plates are 3/8" stiffner plates approximately every six feet at a 45 degree angle to help resist twisting. As far as structurally integrity of the column is concerned, the stiffner plates do not add any additional structural integrity to the design. The plates are simply a means to aesthetically apply mass to the columns and present a tapered look to the field lighting structure.

1.0.4.A DESIGNED COLUMN WIND LOADS

The wind loads are in accordance with the 2003 International Building Code with a basic wind speed design equally ninety miles per hour (90 mph). Each column is pinned at its base with a concrete spread footing 4'-0" square by 1'- 4" and reinforced with (4) #5 bars each way at the bottom. A 1" base plate supports the column at the base and (4) ¾" diameter anchor bolts connect the base plate to the concrete spread footing.

Figure 1 illustrates the tapered member beginning approximately 32' above field level and also shows the designed splice connections by the steel fabricator. Please note that there a two splicing locations on each column. Essentially, the designed structure is a 92'-0" cantilever member with lateral bracing at various points throughout that span.

Figure 1



1.0.4.B DESIGNED COLUMN WELDING REQUIREMENTS

The required "smooth" appeal by the architect was accompanied with a hefty labor cost. There are nine column splices on each structure per the subcontractor design. At each of these splices, a 3/16" full penetration weld on three sides is needed since a bolted connection is not preferable. All nine welds per structure took a total of four weeks to be performed and were much more costly to the erection team than anticipated. The added costs were a result of additional crane time to support an ironworker while welding, pre-heating measures since erection is during the winter months, an inspector to check the welds being performed, and grinding measures to smooth the welds. Please consult section *1.0.6.A* for a more detailed breakdown of the cost. Furthermore, an understanding of the full penetration weld only occurred during construction which added to the addition labor costs associated with erection. Additionally, the designed column contains a stitch weld to connect the tapered plates and structural steel members. It is important to note that a stitch weld does not make column weather tight and therefore leakage is a possibility. To help resist corrosion of the welding areas, high performance zinc rich primer/paint is applied to the structural members.

Below are a series of pictures relating to the erection and welding of the column splices for the light tower structure.

Erection of Lighting Structure Columns

Grinded Splice Plate Connection

Detailing/Welding Splice Plate Connections

W-Member Connections

1.0.4.C DESIGNED COLUMN MATERIAL QUANTITY

The material quantity take-off table below proves that the designed columns are quite heavy with each 92'-0" section weighing approximately 14 tons. Encasing the W-member with plates adds a significant amount of weight to each column assembly. All steel weights were found in the *AISC Steel Manual, 3rd Edition*.

Designed Column Material Take-Off					
	Description	Length	lb/ft	Quantity	Lbs.
W14 X 132 COLUMN	W14x132	92	132	1	12144
	PL 1x14	92	47.6	2	8758.4
	PL 1x8	29	27.2	2	1577.6
	PL 1x13	30	44.2	2	2652
	PL 1x19	30	64.6	2	3876
	PL 3/8x14	93.5	17.8	1	1664.3
	PL 3/8x14	1.5	28.7	15	645.75
	Totals for W14x132 column				31318.05
W14 X 90 COLUMN	W14x90	92	90	1	8280
	PL 1x14	92	47.6	2	8758.4
	PL 1x8	29	27.2	2	1577.6
	PL 1x13	30	44.2	2	2652
	PL 1x19	30	64.6	2	3876
	PL 3/8x14	93.5	17.8	1	1664.3
	PL 3/8x14	1.5	28.7	15	645.75
	Totals for W14x90 column				27454.05
W14 X 90 COLUMN	W14x90	92	90	1	8280
	PL 1x14	92	47.6	2	8758.4
	PL 1x8	29	27.2	2	1577.6
	PL 1x13	30	44.2	2	2652
	PL 1x19	30	64.6	2	3876
	PL 3/8x14	93.5	17.8	1	1664.3
	PL 3/8x14	1.5	28.7	15	645.75
	Totals for W14x90 column				27454.05
	Totals for columns (3) per light tower structure				86226.15
	Totals for 6 columns related to light tower str.				172452.3
	Total Tons				**86.22615**

Material Quantity Take-Off for Designed Column

1.0.4.D DESIGNED COLUMN LABOR QUANTITY

The table below shows the labor quantity associated with the designed column. Detailing of the designed column structure is estimated to require approximately 3 days which includes connection design and modeling in detailing software. Fabrication of each column will take one day with a crew of two workers and an additional two days with a crew of four workers is required for detailing. Three ironworkers (two in air and one on ground) are needed to erect each structure which takes one week to erect. An additional four weeks of crane time is needed for the full penetration welding for splice connections per tower structure.

Designed Column Labor Take-Off			
Classification	Quantity	Duration (Days)	Hours
Detailer	1	3	24
Fabrication	4	6	192
Ironworkers	3	5	120
Ironworkers	2	21	336
Crane Operator	1	26	208
		Totals for (1) light tower	880
		Totals for (2) light towers	1712

Labor Take-Off for Designed Column

1.0.4.E DESIGNED COLUMN EQUIPMENT QUANTITY

The table below shows the equipment take-off associated with the designed column. Erection of the designed tower structure takes approximately five days with an additional four weeks needed for welding. All welding must be performed using a crane with an attached bucket. Welding is performed using a 225A welding machine which also requires diesel fuel to operate.

Designed Column Equipment Take-Off			
	Description	Duration (Days)	Hours
Per Light Tower Structure	100 Ton Crawler Crane	5	40
	100 Ton Crawler Crane with Bucket	21	168
	225A / 25V Engine Driven Welding Machine	21	168
	Diesel Fuel for Welding Machine	21	168
		Totals for (1) light tower	544
		Totals for (2) light towers	1088

Equipment Take-Off for Designed Column

1.0.5 PROPOSED ALTERNATIVE DESIGN

An alternative way to design the field lighting fixture structural supports is important to propose cost savings in the structural steel package and also a quicker erection time in this area due to an easier structure assembly. In order to propose an alternative column member, a full understanding of the loads on the original design had to be analyzed. One of the goals of the proposed re-design was to keep the aesthetic appeal desired by the architect.

1.0.5.A ALTERNATIVE COLUMN DESIGN ANALYSIS

The 1" tapered plates on the outside face of the W14x132 column provide zero to no structural integrity to designed system. The important load that had to be analyzed is not the weight of the light fixtures, but the wind load. This is because the weight of the light fixtures at the top of the cantilever are very minimal compared to the wind loads acting on the 92'-0" cantilever span. In order to analyze the wind loads, a copy of *ASCE 7 (Minimum Design Loads for Buildings and Other Structures), Chapter 6 (Wind Loads)* version 2005 was obtained. After carefully reading *Chapter 6*, it was determined that the field lighting structure would be analyzed as a *Design Wind Loads on Other Structures (6.5.15).* Item 6.5.15 was chosen due to the fact that the field lighting structure can be considered an open lattice sign.

The equation to determine the designed wind force is:

$$F = q_z G C_f A_f \quad \text{(lb) (N)} \qquad \text{(Equation 6-28)}$$

The following is a description each variable:

q_z = velocity pressure evaluated at height z of the centroid of the area A_f using exposure defined in Section 6.5.6.3
G = gust-effect factor from Section 6.5.8
C_f = force coefficients from Figs. 6-21 through 6-23
A_f = projected area normal to the wind except where C_f is specified for the actual surface area, ft^2

After performing the various calculations, the designed wind force is 7840.386 lbs acting at the centroid of the column which is approximately 75'-0" above field level. For an in depth analysis of all assumptions, determined factors, and calculations used to determine the designed wind force, F, please consult the *Appendix – Structural Steel Tapered Column Analysis*.

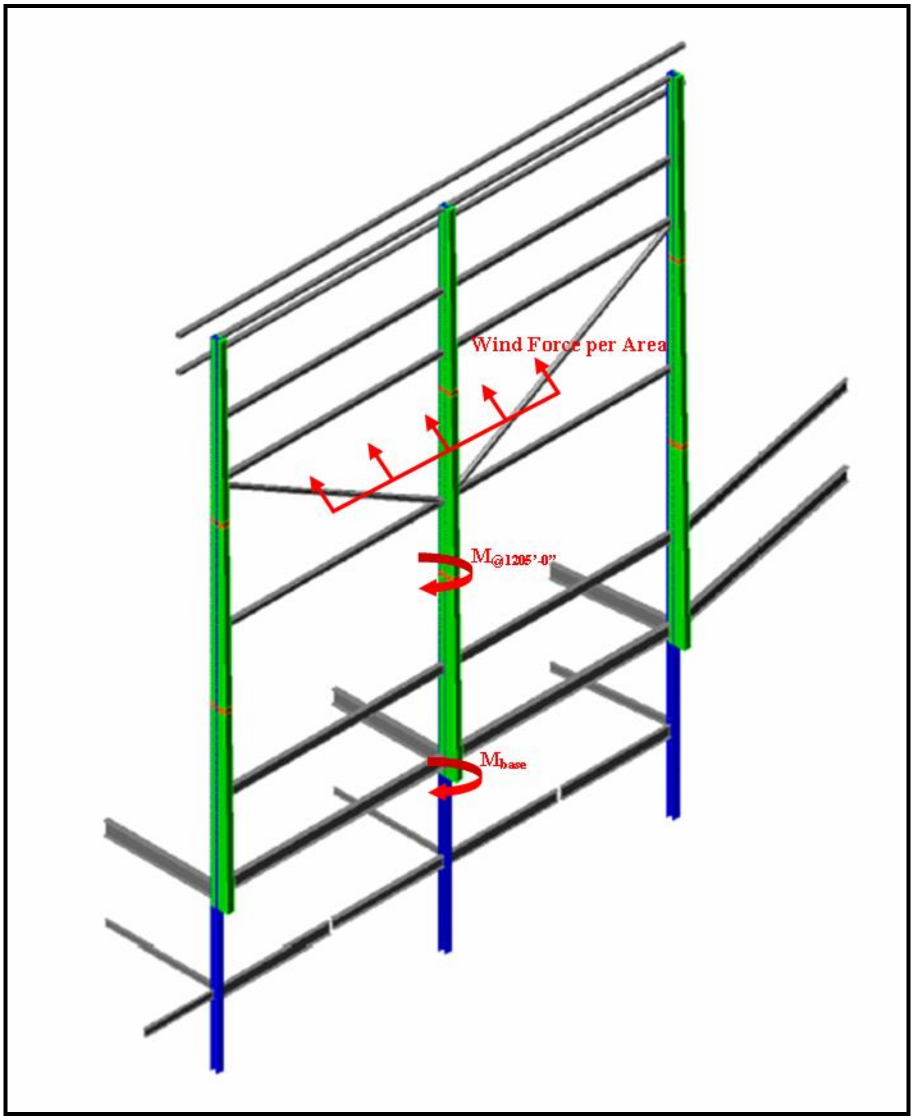
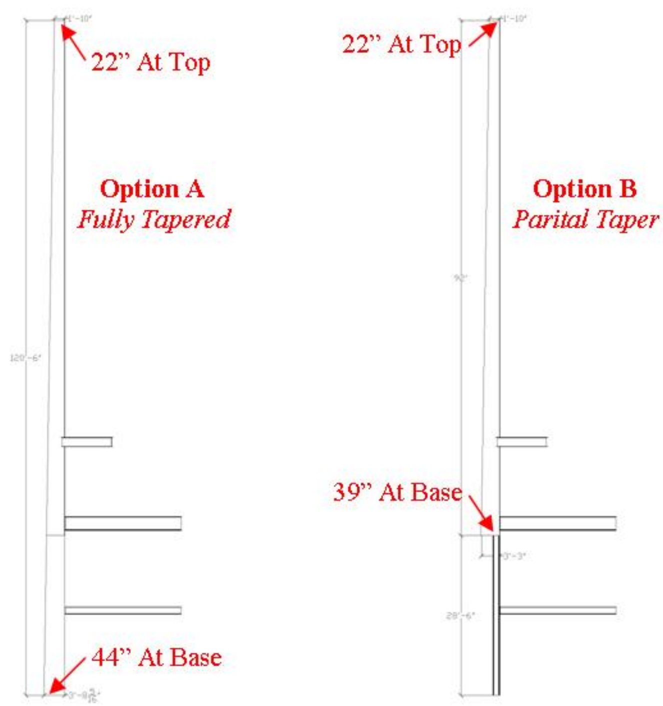


Figure 2: Depiction of Location of Moment Calculations

Upon determining F, the moment at the bottom of the tapered member needed to be calculated. The ultimate moment at that point was calculated to be 497.72 ft-k; consult *Appendix – Structural Steel Tapered Column Analysis* for a detailed calculation. Since the moment was calculated at the base of the tapered member, an alternative member can be evaluated. It is also important to note that the structural consultant, Dr. Walter Schneider, determined from his experience that the moment of 497.72 ft-k seems appropriate and a more detailed structural calculation and deflection calculation is not necessary for this analysis. Please consult *Figure 2* for a depiction of the loads acting on the middle column.

1.0.5.B ALTERNATIVE COLUMN DESIGN

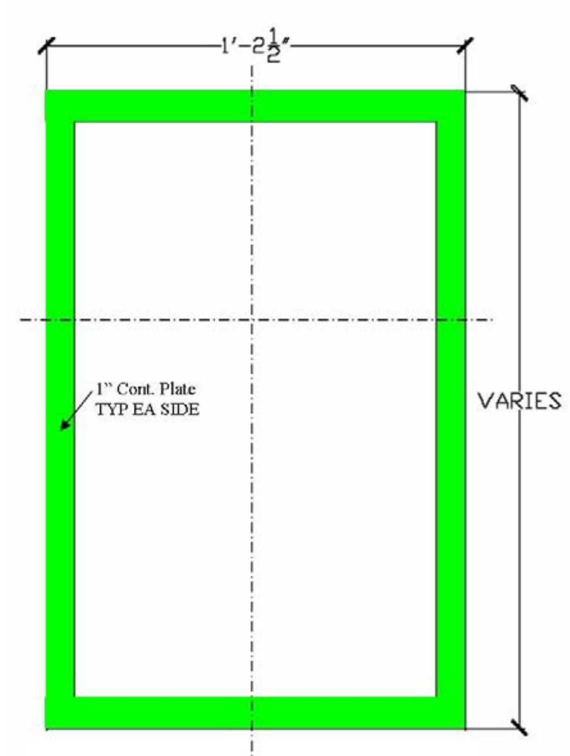
Because the same aesthetic appeal requirement is still trying to be fulfilled with an alternative design, a more slender W member alone would not work. After discussing with structural and construction consultants as well as observing other projects, two alternative tapered columns were documented.



Proposed Alternative Column Design

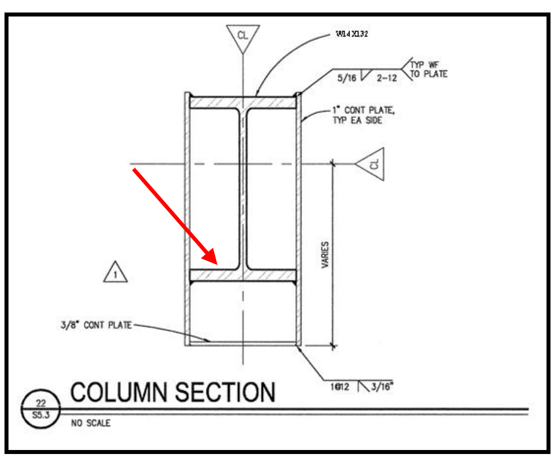
Both of the proposed column alternatives can be said to be “custom” HSS tapered columns. They are composed of 1” plate on all four sides with the one side tapered. The term tapered implies that at the base the column is 39” in depth and at the top is 22” in depth. The only difference between the two alternative columns is the fact that *Option A* is tapered the full height while *Option B* is only tapered a vertical distance of 92’-0”. After fully researching the added affects of *Option A* on the space layout and the rest of the building, this proposed alternative was not viewed further. If the column was tapered its entire length, the footings would have to be moved and room/space layout would have to be modified.

The proposed column aesthetically looks the same as the designed members.



Plan View of Proposed Alternative Column Design

Essentially, this method was chosen after studying the plan view of the designed column. It is apparent that the flange of the W14X132 member in the center of the tapered column does not do much structurally as depicted with a red arrow in the figure below.



Column Plan Per Original Design with Red Arrow Depicting W Flange

Therefore, the alternative column design was based on moving the flange of the W14x132 to the outside of the tapered column. Consequently, the flange thickness of a W14x132 is 1" which is the same thickness of the plates being used on the sides of the column.

1.0.5.C ALTERNATIVE COLUMN DESIGN LOAD ANALYSIS

The connection at the base and at the concourse and suite level can be analyzed with the assumption that these are pin connections. In order to determine if the proposed column would support the structural loads, the moment of the re-design had to be calculated and observed at various points, and also compared to the design moment. This was accomplished using the formula:

$$\varnothing M_n = \varnothing_b F_y Z$$

$$Mu \le \varnothing M_n$$

The following were the values used with the above calculation:

$\varnothing_b = 0.9$

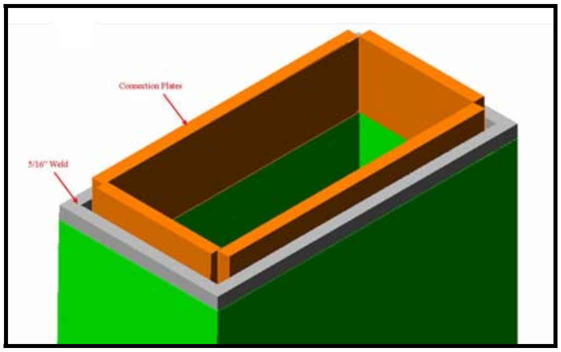
F_y = 36 ksi steel plates

$$Z = \frac{bd^2}{4} - \frac{b_1 d_1^2}{4} \qquad \text{(17-33, Steel Manual)}$$

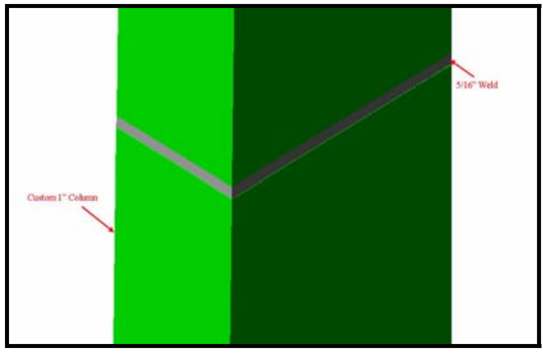
The section modulus was observed at three different heights and a corresponding moment was observed at that height. Even though the column structurally sufficed at the base, a double check of various other points was determined for a more concise understanding of the structural loads. Please consult *Appendix – Structural Steel Tapered Column Analysis* for the plastic section modulus and moment calculations.

1.0.5.D ALTERNATIVE COLUMN DESIGN WELDING REQUIREMENTS

The required "smooth" appeal by the architect presented a hefty labor cost with the original design. There are nine column splices on each structure which were kept with the re-design. At each of these splices, a 5/16" full penetration weld on all four sides is needed since a bolted connection is not preferable. Unlike the original design, splicing plates will not be required. A welding bead as depicted will suffice and add a significant decrease is detailed field labor cost.



Alternative Column Proposed Connection



Alternative Column Proposed Single Weld

1.0.5.E ALTERNATIVE COLUMN DESIGN MATERIAL QUANTITY

The table below shows the material quantity take-off associated with the alternative column design. The material quantity take-off proves that the alternatives columns are still quite heavy with each 92'-0" section weighing approximately 13.5 tons; however, this is less than the designed structure with an average column weight of 14 tons. All steel weights were found in the *AISC Steel Manual, 3rd Edition, section 1-85*.

Alternative Column Material Cost Estimate				
Description	Length	lb/ft	Quantity	Lbs.
PL 1x14.5	92	49.3	1	4535.6
PL 1x14.5	93.5	49.3	1	4609.55
PL 1x17	93.5	57.8	2	10808.6
PL 1x22	92	74.8	1	6881.6
Totals for (1) Alternative Column				26835.35
Totals for columns (3) per light tower structure				80506.05
Totals for 6 columns related to light tower str.				161012.1
Total Tons				**80.50605**

Material Quantity Take-Off for Proposed Alternative Column

1.0.5.F ALTERNATIVE COLUMN DESIGN LABOR QUANTITY

The table below shows the labor quantity associated with the designed column. Detailing of the alternative column structure is estimated to require approximately 2 days which includes connection design and modeling in detailing software. Fabrication and detailing of each column will take one day with a crew of four workers. Three ironworkers (two in air and one on ground) are needed to erect each structure. An additional two weeks of crane time is needed for the full penetration welding for splice connections per tower structure.

Alternative Column Labor Take-Off			
Classification	Quantity	Duration (Days)	Hours
Detailer	1	2	16
Fabrication	4	6	192
Ironworkers	3	5	120
Ironworkers	2	14	224
Crane Operator	1	19	152
		Totals for (1) light tower	704
		Totals for (2) light towers	1376

Labor Take-Off for Proposed Alternative Column

1.0.5.G ALTERNATIVE COLUMN DESIGN EQUIPMENT QUANTITY

The table below shows the equipment take-off associated with the alternative column design. Erection of the designed tower structure takes approximately five days with an additional two weeks needed for welding. All welding must be performed using a crane with an attached bucket. Welding is performed using a 225A welding machine which also requires diesel fuel to operate.

Alternative Column Equipment Take-Off			
	Description	Duration (Days)	Hours
Per Light Tower Structure	100 Ton Crawler Crane	5	40
	100 Ton Crawler Crane with Bucket	14	112
	225A / 25V Engine Driven Welding Machine	14	112
	Diesel Fuel for Welding Machine	14	112
		Totals for (1) light tower	376
		Totals for (2) light towers	752

Equipment Take-Off for Proposed Alternative Column

1.0.6 COST ANALYSIS

Designed Column Cost Estimate Summary	
Description	Total
Labor	$59,525.12
Material	$65,159.20
Equipment	$98,569.44
Total	**$223,253.76**

Designed Column Cost Estimate

Alternative Column Cost Estimate Summary	
Description	Total
Labor	$46,266.88
Material	$60,089.72
Equipment	$71,712.96
Total	**$178,069.56**

Proposed Alternative Column Cost Estimate

The alternative system provides a cost savings of $45,184.20 in labor, material, and equipment. The erection duration of the columns remained the same; however, the savings is noted with less time in field detailing of the columns which affects labor, material, and equipment.

1.0.6.A DETAILED LABOR ANALYSIS

Designed Column Labor Cost Estimate					
Classification	Hourly Rate	Quantity	Duration (Days)	Hours	Cost
Detailer	$45.00	1	3	24	$1,080.00
Fabrication	$26.00	4	6	192	$4,992.00
Ironworkers	$39.36	3	5	120	$4,723.20
Ironworkers	$39.36	2	21	336	$13,224.96
Crane Operator	$32.80	1	26	208	$6,822.40
			Totals for (1) light tower	880	$30,842.56
			Totals for (2) light towers	**1712**	**$59,525.12**

Designed Column Labor Cost

Alternative Column Labor Cost Estimate					
Classification	Hourly Rate	Quantity	Duration (Days)	Hours	Cost
Detailer	$45.00	1	2	16	$720.00
Fabrication	$24.00	4	6	192	$4,608.00
Ironworkers	$39.36	3	5	120	$4,723.20
Ironworkers	$39.36	2	14	224	$8,816.64
Crane Operator	$32.80	1	19	152	$4,985.60
Totals for (1) light tower				704	$23,853.44
Totals for (2) light towers				**1376**	**$46,266.88**

Proposed Alternative Column Labor Cost

Labor Pricing Clarifications:

- Detailer rate of $45.00/hr for shop drawing development. Wage rate received from local steel subcontractor.
- Fabrication rate of $24.00/hr received from local steel subcontractor.
- Ironworker rate of $39.36/hr received from local steel subcontractor. First line item for erection (2 in air, 1 on ground) and second line item for detailing (2 in air).
- Crane rate of $32.80/hr received from local steel subcontractor. Line item includes crane for erection and crane for welding with bucket.
- Labor cost of painting new design offsets cost of painting original design.

The alternative system provides a cost savings of $13,258.24 in labor. The erection duration of the columns remained the same; however, the majority of the savings is noted with less time in field detailing of the columns.

1.0.6.B DETAILED MATERIAL ANALYSIS

Designed Column Material Cost Estimate						
	Description	Length	lb/ft	Quantity	Lbs.	Cost
W14 X 132 COLUMN	W14x132	92	132	1	12144	$4,532.14
	PL 1x14	92	47.6	2	8758.4	$3,268.63
	PL 1x8	29	27.2	2	1577.6	$588.76
	PL 1x13	30	44.2	2	2652	$989.73
	PL 1x19	30	64.6	2	3876	$1,446.52
	PL 3/8x14	93.5	17.8	1	1664.3	$621.12
	PL 3/8x14	1.5	28.7	15	645.75	$240.99
	Totals for W14x132 column				31318.05	$11,687.90
W14 X 90 COLUMN	W14x90	92	90	1	8280	$3,090.10
	PL 1x14	92	47.6	2	8758.4	$3,268.63
	PL 1x8	29	27.2	2	1577.6	$588.76
	PL 1x13	30	44.2	2	2652	$989.73
	PL 1x19	30	64.6	2	3876	$1,446.52
	PL 3/8x14	93.5	17.8	1	1664.3	$621.12
	PL 3/8x14	1.5	28.7	15	645.75	$240.99
	Totals for W14x90 column				27454.05	$10,245.85
W14 X 90 COLUMN	W14x90	92	90	1	8280	$3,090.10
	PL 1x14	92	47.6	2	8758.4	$3,268.63
	PL 1x8	29	27.2	2	1577.6	$588.76
	PL 1x13	30	44.2	2	2652	$989.73
	PL 1x19	30	64.6	2	3876	$1,446.52
	PL 3/8x14	93.5	17.8	1	1664.3	$621.12
	PL 3/8x14	1.5	28.7	15	645.75	$240.99
	Totals for W14x90 column				27454.05	$10,245.85
	Totals for columns (3) per light tower structure				86226.15	$32,579.60
	Totals for 6 columns related to light tower str.				**172452.3**	**$65,159.20**

Designed Column Material Cost

Alternative Column Material Cost Estimate					
Description	Length	lb/ft	Quantity	Lbs.	Cost
PL 1x14.5	92	49.3	1	4535.6	$1,692.69
PL 1x14.5	93.5	49.3	1	4609.55	$1,720.28
PL 1x17	93.5	57.8	2	10808.6	$4,033.77
PL 1x22	92	74.8	1	6881.6	$2,568.21
Totals for (1) Alternative Column				26835.35	$10,014.95
Totals for columns (3) per light tower structure				80506.05	$30,044.86
Totals for 6 columns related to light tower str.				**161012.1**	**$60,089.72**

Proposed Alternative Column Material Cost

Material Pricing Clarifications:

- As of March 29, 2006, the cost per pound of steel is $0.3772/lb.
- Material cost of painting new design offsets cost of painting original design.

The alternative system provides a cost savings of $5,069.48 in material. This is a direct result of less members of steel needed to construct the columns.

1.0.6.C DETAILED EQUIPMENT ANALYSIS

Designed Column Equipment Cost Estimate					
	Description	Hour Rate	Duration (Days)	Hours	Total Cost
Per Light Tower Structure	100 Ton Crawler Crane	$225.00	5	40	$9,000.00
	100 Ton Crawler Crane with Bucket	$225.00	21	168	$37,800.00
	225A / 25V Engine Driven Welding Machine	$12.00	21	168	$2,016.00
	Diesel Fuel for Welding Machine	$2.79	21	168	$468.72
			Totals for (1) light tower	544	$49,284.72
			Totals for (2) light towers	**1088**	**$98,569.44**

Designed Column Equipment Cost

Alternative Column Equipment Cost Estimate					
	Description	Hour Rate	Duration (Days)	Hours	Total Cost
Per Light Tower Structure	100 Ton Crawler Crane	$225.00	5	40	$9,000.00
	100 Ton Crawler Crane with Bucket	$225.00	14	112	$25,200.00
	225A / 25V Engine Driven Welding Machine	$12.00	14	112	$1,344.00
	Diesel Fuel for Welding Machine	$2.79	14	112	$312.48
			Totals for (1) light tower	376	$35,856.48
			Totals for (2) light towers	**752**	**$71,712.96**

Proposed Alternative Column Equipment Cost

Equipment Pricing Clarifications:

- Equipment rates received from local steel subcontractor.
- 80' Boom lift cost not documented because only used during erection and same duration for erection is found for both systems.
- Welding machine tank holds 10 gallons and crew will use 30 gallons/day.
- Equipment cost of painting new design offsets cost of painting original design.

The alternative system provides a cost savings of $26,856.48 in equipment. The erection duration of the columns remained the same; however, the majority of the savings is noted with less crane time associated in field detailing of the columns.

1.0.7 ALTERNATIVE COLUMN DESIGN SPLICING VALUE ENGINEERING

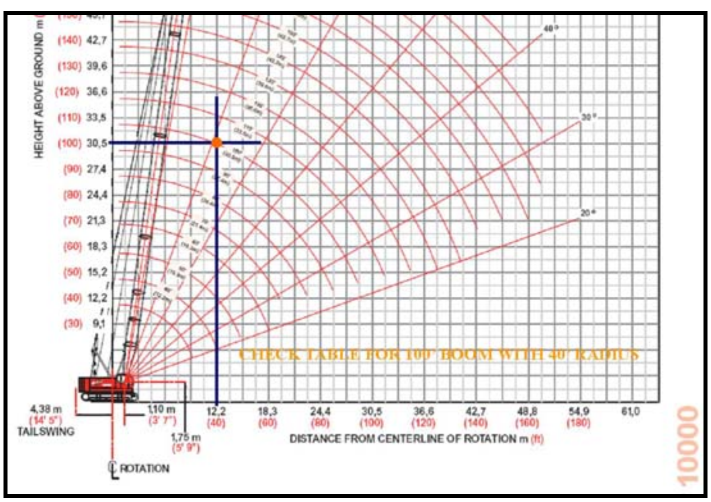
An alternative splicing location can be analyzed in an attempt to receive more labor savings regarding field welding. If only one splicing location is used on each column erection can proceed even faster. A quick cost analysis along with a crane load analysis was prepared to see if one splicing location located at 46’-0” would suffice.

The steel contractor determined two splicing locations would be needed to suffice the original column design with each of the splicing locations located 30’-0” apart. The governing factors for determining the splicing locations are the maximum allowable load for transporting/hauling, length of stock steel available, and also lifting capacity of the crane.

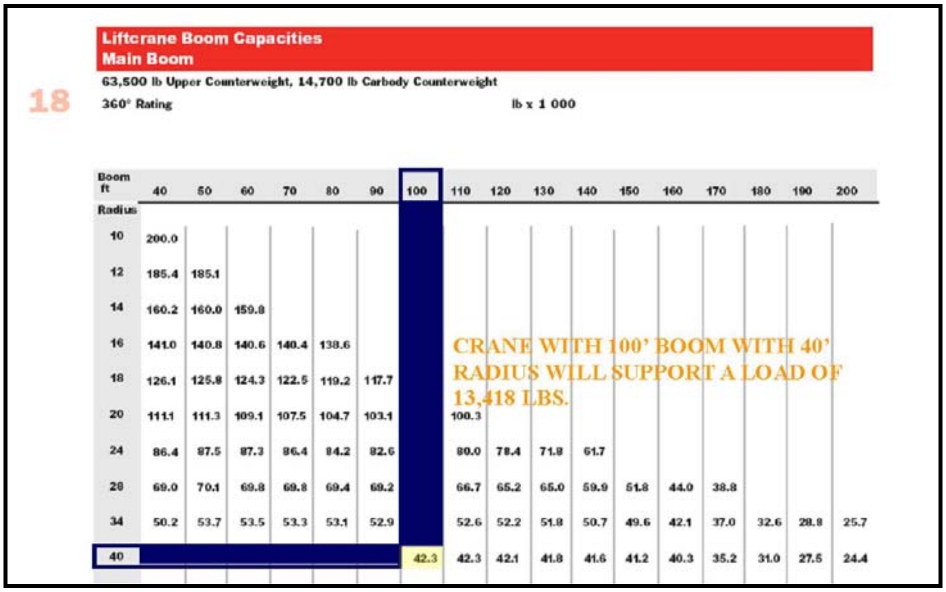
The allowable trucking weight in Pennsylvania is 40 tons (80,000 pounds) for over-road trucking. A typical tractor with a trailer is 15-20 tons which means a load can be 20 tons. An average trailer length is 48’-0” and a 4’-0” overhang is the maximum allowable overhand on a trailer. Any load over a length and load restriction would need to purchase a non-divisible load permit. Typically, the stock length is 41’-0” however a 60’-0” piece can also be obtained for a 20% increase in cost.

1.0.7.A VALUE ENGINEERING CRANE LIFTING CAPACITY

The crane used on this project was a Manitowoc crawler crane, model 10000, which has a 100 ton lifting capacity. The material weight of an alternative column design is 13.5 tons (26,835 pounds).



Loading Chart from Manitowoc Model 10000 Product Brochure



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Liftcrane Boom Capacities
Main Boom
63,500 lb Upper Counterweight, 14,700 lb Carbody Counterweight
360° Rating
lb x 1 000

Radius \ Boom ft	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
10	200.0																
12	185.4	185.1															
14	160.2	160.0	159.8														
16	141.0	140.8	140.6	140.4	138.6												
18	126.1	125.8	124.3	122.5	119.2	117.7											
20	111.1	111.3	109.1	107.5	104.7	103.1		100.3									
24	86.4	87.5	87.3	86.4	84.2	82.6		80.0	78.4	71.8	61.7						
28	69.0	70.1	69.8	69.8	69.4	69.2		66.7	65.2	65.0	59.9	51.8	44.0	38.8			
34	50.2	53.7	53.5	53.3	53.1	52.9		52.6	52.2	51.8	50.7	49.6	42.1	37.0	32.6	28.8	25.7
40							42.3	42.3	42.1	41.8	41.6	41.2	40.3	35.2	31.0	27.5	24.4

Boom Capacities from Manitowoc Model 10000 Product Brochure

1.0.7.B VALUE ENGINEERING COST ANALYSIS

Alternative Column Cost Estimate Summary	
Description	Total
Labor	$46,266.88
Material	$60,089.72
Equipment	$71,712.96
Total	**$178,069.56**

Alternative Column Cost Estimate

Alternative Column Splicing Value Engineering - Cost Estimate Summary	
Description	Total
Labor	$33,776.64
Material	$72,107.66
Equipment	$44,856.48
Total	**$150,740.78**

Alternative Column with Splicing Value Engineering Cost Estimate

The alternative system with only one splicing location provides a cost savings of $27,328.78 in labor, material, and equipment. The cost savings is directly related to a reduce amount of time needed for field detailing of the columns with only one splicing location.

Splicing Value Engineering Pricing Clarifications:

- Labor duration for field detailing the columns reduced to 7 days.

- Material cost per pound increased by 20% for 60'-0" stock steel.
- Equipment duration reduced by 7 days per labor clarification listed above.

1.0.7.C VALUE ENGINEERING CONCLUSION

An alternative splicing location can be analyzed to attempt to receive more labor savings regarding field welding. If only one splicing location is used on each column, erection can proceed even quicker. A cost analysis showed a savings of $27,328.78 by using one splicing location with the alternative design versus the two splicing locations with the designed column. This value engineering suggestion would be implemented by the construction team since it is a means a methods alternative for fabricating and erecting the structural column.

1.0.8 PROJECT IMPACTS

As discussed in the cost analysis section, the alternative column design provides a cost savings of $45,184.20 and could additionally provide a savings of $31,334.76 with only one splicing location on each column. The field light column structure is not on the critical path of project activities, but provides the opportunity for seven (7) days quicker erection of the columns and allows for heavy equipment to be moved off-site quicker. An additional advantage to the implementation of the proposed column is the continuous weld needed to connect the 1" plates. The weld will add an extra waterproofing feature to the column versus the stitch welds with the designed column. Another advantage is pulling the SJO cable to power the light fixtures will be easier since no W member interference will occur while pulling the cable.

Because the same design intent was used with the re-design, it is important to note that column maintenance is still an issue. These maintenance concerns include painting and fixture repair just to name a few.

The only noted disadvantage with the alternative column design is that the additional welding expertise to fabricate a "custom" column could limit the amount of steel fabricator's willing to bid the work.

Proposed Alternative Column Design	
Advantages	Disadvantages
Erection duration savings of 7 days.	Possibly could limit the amount of steel fabricator's bidding on project.
Overall cost savings of $45,184.20.	
Heavy equipment (crane) moved off-site quicker.	
Continuous weld on plates adds extra waterproofing of structural member.	
Easier ability to run SJO cable to power light fixtures.	

1.0.9 CONCLUSION

The alternative column design is a positive value engineering suggestion for the project. It provides an overall cost savings of $45,184.20 in labor, material, and equipment and a schedule savings of 7 days on erection of the columns. Through this analysis several advantages were noted including added waterproofing and easier electrical cable installation to the power the field lighting fixtures. The only noted disadvantage with the alternative column design is that the additional welding expertise to fabricate a "custom" column could limit the amount of steel fabricator's willing to bid the work. By performing this analysis, I was able to successfully provide an alternative design and satisfied the goals of providing:

1. A value engineering method to determine if an alternative structural member (ex. HSS) can be used to lessen the steel tonnage and decrease the cost while supporting the same loading.
2. A review of a constructability method to determine if the columns can be altered but still achieve the aesthetic smooth appeal required by the architect.

This analysis is a valuable tool for a construction manager to be able to discover. An understanding of the cost and benefits to changing a structural column can help identify alterations of future projects.

2.0 ELECTRICAL SUPPLY AT RETAIL BUILDING

2.0.1 EXECUTIVE SUMMARY

The retail store and ticket building is separate from the rest of the structure and will be used during non-operating game times. Within the 2000 square foot structure, there is a ticket booth area, a retail store, an office, a small mechanical room, and a storage area. The spaces contain standard electrical equipment devices including light fixtures, wall receptacles, and data outlets.

The current design includes portions of two (2) panels which are not located within the building. One panel is 300A, 3 phase, 4 wire panel at 208V/120V for panel while the lighting is on a 225A, 3 phase, 4 wire panel at 480V/277V; both are located approximately 275' from the retail building.

The proposed alternative design adds two (2) panels and a transformer. Panel RB-1 is a 480Y/277V panel fed from the main electrical room. Most of the loads associated with this panel are lighting loads; however, there are two (2) types of mechanical equipment and a step-down transformer powered from this panel as well. Panel RB-2 is a 208Y/120V panel fed from the adjacent RB-1 panel and through a 15kVA transformer. Most of the loads associated with this panel are receptacles loads in the retail building.

The alternative system is a positive value engineering suggestion for the project. It provides a cost savings of $8,771.38 in labor and material but most importantly the alternative system will provide the owner better electrical maintenance means during the building lifetime. Furthermore, the ease of expansion within the retail building will be much easier with the alternative system because wires and conduit do not need to be installed 275' away from the source of expansion.

2.0.2 OVERVIEW

As depicted below, the retail store and ticket building is separate from the rest of the structure and will be used during non-operating game times.

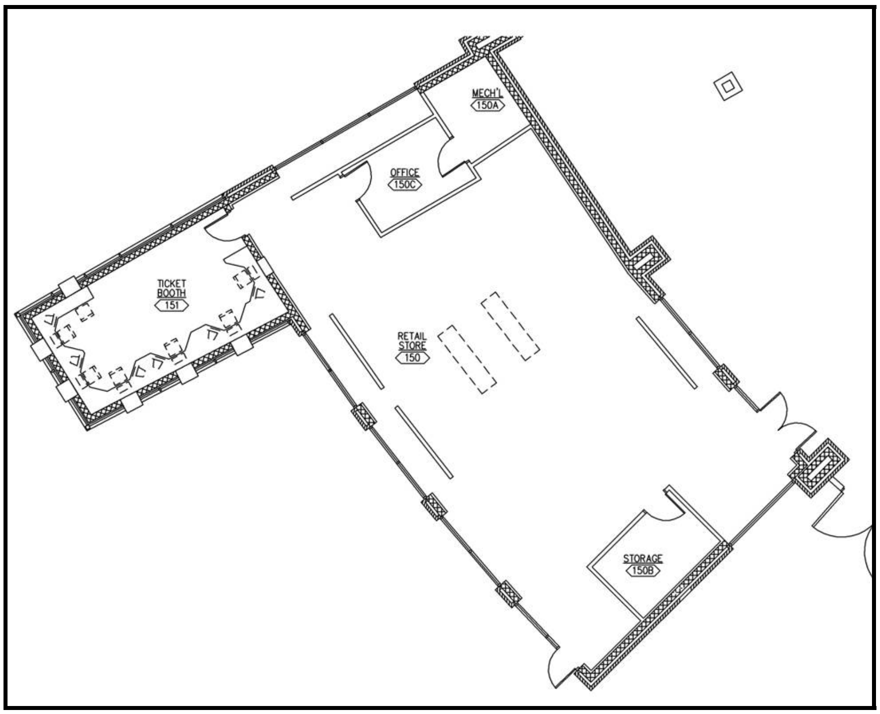
Ballpark rendering with the area highlighted which will be analyzed.

Within the 2000 square foot structure, there is a ticket booth area, a retail store, an office, a small mechanical room, and a storage area. The spaces contain standard electrical equipment devices including light fixtures, wall receptacles, and data outlets. All of the electrical wiring for this area is designed to be run overhead through the canopy structure and into the building. Because there is no underground raceway conduits designed for this area, there is an added labor cost for running all wires through the canopy along with extra material cost for running the wires to the required panel board. Furthermore, by not designing an electrical panel within the building, electrical maintenance could become an issue. If an electrical problem arises, the maintenance crew must find an electrical panel that is not near the retail store and ticket building.

Because of the issues named above, an electrical panel located within the building will be designed. The current panel which is not located within the building is 300A, 3 phase, 4 wire panel at 208V/120V for panel while the lighting is on a 225A, 3 phase, 4 wire panel at 480V/277V. In order to design a new panel, all of the connected loads with the appropriate electrical design factors for lighting, receptacles, and mechanical equipment will be determined. Underground raceways will be provided to the help minimize the wires that travel through the canopy area. Lastly, before beginning the electrical calculations it is understood that two electrical panels will be required and a step- down transformer will be needed for the electrical receptacles in the area. Furthermore, a cost-benefit analysis between the designed system and the proposed re-design to help determine the value of using an alternative system.

2.0.3 DESIGN CONDITIONS

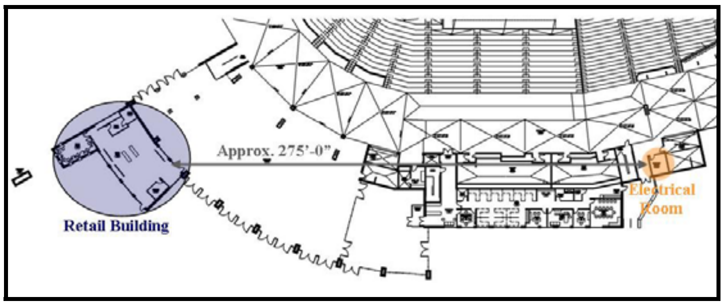
The retail store and ticket building will be operational year round which is much different than the rest of the facility. The main operating times of the stadium will be between March and September which will encompass both the college and minor league baseball seasons. During non-operational times, the stadium will be shutdown except for the retail store / ticket building, the Penn State baseball team offices, and the State College Spikes administration offices which will remain operational year round. Within the retail store and ticket building, there will be standard electrical equipment devices, determined by the client, which will require both 480Y/277V and 208Y/120V power supply.



Plan View of Retail Building (N.T.S.)

2.0.4 DESIGNED SYSTEM

The actual design at the time of the bid had all the electrical devices in the retail building connected to a panel in room 126 approximately 275 feet away. It is important to note that for this analysis fixtures connected to the normal / emergency power were not analyzed during re-design.



Partial Plan View of Concourse Level

In room 126, there is a 480Y/277V panel along with a 208Y/120V panel with the feeders for those panels coming directly from the main electrical room. Per the design, the conduit and wires supplying the retail building would need to be run through the webs of the steel joists in the canopy because underground feeders are not documented for this area on the drawings.

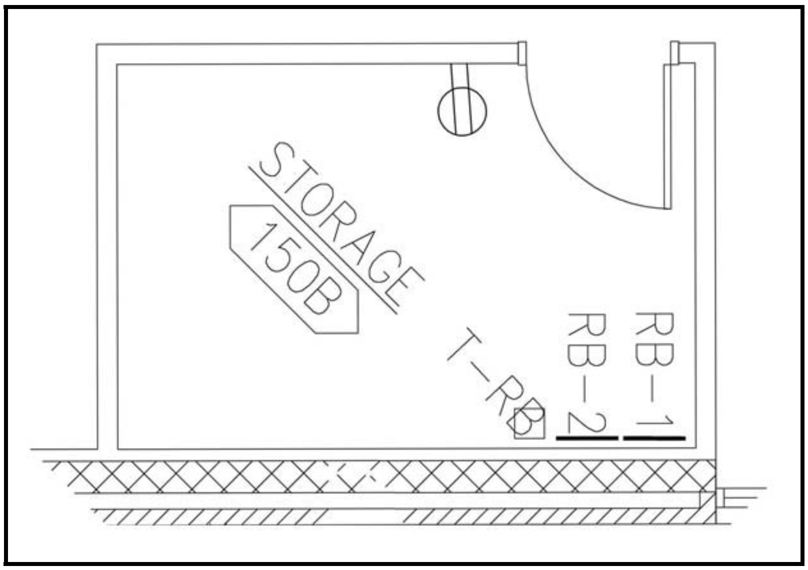
Designed System Components											
	Feeder						Circuit Breaker			
Equipment Type	Name	Size	Rating (A)	Ground	Conduit Size	Length (ft)	Feeding	Size (A)	Phase	Voltage
BRANCH CIRCUITS	RB - Power (8)	(3) #12	25	#12	3/4"	275				
BRANCH CIRCUITS	RB - Lighting (3)	(3) #12	25	#12	3/4"	275				
BRANCH CIRCUITS	RB - AHU-3	(3) #12	25	#12	3/4"	275				
BRANCH CIRCUITS	RB - ACCU-3	(3) #8	50	#8	3/4"	275				
CIRCUIT BREAKER							RC1 - Ckt. 17	20	1	208Y/120
CIRCUIT BREAKER							RC1 - Ckt. 18	20	1	208Y/120
CIRCUIT BREAKER							RC1 - Ckt. 19	20	1	208Y/120
CIRCUIT BREAKER							RC1 - Ckt. 20	20	1	208Y/120
CIRCUIT BREAKER							RC1 - Ckt. 21	20	1	208Y/120
CIRCUIT BREAKER							RC1 - Ckt. 22	20	1	208Y/120
CIRCUIT BREAKER							RC1 - Ckt. 23	20	1	208Y/120
CIRCUIT BREAKER							MP1 - Ckt. 7,9,11	20	3	480Y/277
CIRCUIT BREAKER							MP2 - Ckt. 56,58,60	30	3	480Y/277
CIRCUIT BREAKER							LP2 - Ckt. 10	20	1	480Y/277
CIRCUIT BREAKER							LP2 - Ckt. 12	20	1	480Y/277

Designed System Components

2.0.5 PROPOSED ALTERNATIVE DESIGN

The design of the electrical system with regards to the retail store building is not very accommodating for future maintenance issues the owner may develop. It is important to realize that if there is ever an electrical problem in the retail building that there is not an electrical panel within close proximity to the structure. Furthermore, from an electrical design perspective, the retail building should be viewed as its own structure and should only receive main power from the rest of the facility. Therefore, the proposed re-design adds (2) electrical panels, a 480Y/277 volt and a 208Y/120 volt panel, along with a step-down transformer in the storage room in the retail building (Figure 1). Both of these panels will supply the power necessary to operate the retail building.

Figure 1



Plan View of Storage/Electrical Room 150B with Proposed Electrical Equipment (N.T.S.)

The following tables depict the components associated with the re-designed system. These components included panelboards, feeders, a transformer, and circuit breakers.

Proposed System Components													
	Panelboard							Feeder					
Equipment Type	Name	Load Connected (A)	Rating (A)	# Poles	Spaces	Voltage	Protection (A)	Name	Size	Rating (A)	Ground	Conduit Size	Length (ft)
PANEL	RB-1	50	100	3	24	480Y/120	60						
PANEL	RB-2	19	50	3	24	208Y/120	30						
FEEDER								#3RB1	(4) #4	85	#8	1-1/4"	275
FEEDER								FD - T-RB	(4) #10	35	#8	3/4"	5
FEEDER								FD - RB2	(4) #10	35	#8	3/4"	5

Proposed System Components (Panelboards and Feeders only)

Proposed System Components									
Transformer						Circuit Breaker			
Equipment Type	Name	kVA	Primary Voltage	Secondary Voltage	Type	Feeding	Size (A)	Phase	Voltage
TRANSFORMER	T-RB	15	480Δ	208Y/120	DRY				
CIRCUIT BREAKER						PANEL RB-1	100	3	480Y/277
CIRCUIT BREAKER						T-RB Primary	50	3	480Y/277
CIRCUIT BREAKER						PANEL RB-2	30	3	208Y/120
CIRCUIT BREAKER						RB1 - Ckts. 2,4,6,7,9	20	1	480Y/277
CIRCUIT BREAKER						RB1 - Ckts. 11,13,15	20	3	480Y/277
CIRCUIT BREAKER						RB1- Ckts. 1,3,5,8,10,12	30	3	480Y/277
CIRCUIT BREAKER						RB2 - Ckts. 1,2,3,4,5,6,8,9,12	20	1	208Y/120
CIRCUIT BREAKER						PANEL RC-1	100	3	480Y/277

Proposed System Components (Transformer and Circuit Breakers only)

Below are the designed panels associated with the proposed alternative system. Please consult the *Appendix – Retail Building Electrical Analysis* for larger panel schedules.

Panel RB-1 is a 480Y/277V panel fed from the main electrical room. Most of the loads associated with this panel are lighting loads; however, there are two (2) types of mechanical equipment and a step-down transformer powered from this panel as well.

Panel Schedule																			
Panel: RB-1																			
Voltage: 480Y/277			Mains: MLO		Loads (VA)										Loc: STORAGE 150B (Area C)			AIC: 18K	
Amps: 100A	Wires: 4		Phase: 3												Mounting: SURFACE				
Branch Circuit	Amp	P	Description	Ckt	Ltg		Recept		Motor		Lg Motor		Equip		Ckt	Description	P	Amp	Branch Circuit
----	----	----	----	1		342	720						1910		2	Lighting Canopy (West)	1	20	3/4"C / 3#12+1#12GRD
3/4"C / 3#10+1#8GRD	30	3	Transformer RB-2	3		216	2520								4	Lighting Ticket Booth	1	20	3/4"C / 3#12+1#12GRD
----	-	-	----	5		363	2700		250						6	Lighting Mech., Office, Stor.	1	20	3/4"C / 3#12+1#12GRD
3/4"C / 3#12+1#12GRD	20	1	Lighting Canopy (East)	7	456							6033			8	----	----	----	----
3/4"C / 3#12+1#12GRD	20	1	Ligthing Retail Store	9	810							6033			10	ACCU-3	3	30	3/4"C / 3#8+1#8GRD
----	----	----	----	11					497			6033			12	----	----	----	----
3/4"C / 3#12+1#12GRD	20	3	AHU-3	13					497						14	-	-	-	-
----	----	----	----	15					497						16	-	-	-	-
-	-	-	-	17											18	-	-	-	-
-	-	-	-	19											20	-	-	-	-
-	-	-	-	21											22	-	-	-	-
-	-	-	-	23											24	-	-	-	-
Connected Load Phase A: (A)			36.0			798		720		497		6033.3		1910		Demand Load Phase A: (A)	42.1		
Connected Load Phase B: (A)			36.4			1026		2520		497		6033.3		0		Demand Load Phase B: (A)	42.7		
Connected Load Phase C: (A)			35.5			363		2700		747		6033.3		0		Demand Load Phase C: (A)	41.3		
Total VA:		34950																	
Load: (A)		42.1																	
25% Growth: (A)		52.6																	

Proposed 480Y/277V Panel in Retail Building Storage Room

Panel RB-2 is a 208Y/120V panel fed from the adjacent RB-1 panel and through a 15kVA transformer. Most of the loads associated with this panel are receptacles loads in the retail building.

Panel Schedule																			
Panel: RB-2																			
Voltage: 208Y/120			Mains: MCB		Loads (VA)										Loc: STORAGE 150B (Area C)			AIC:	18K
Amps: 50A	Wires: 4		Phase: 3												Mounting: SURFACE				
Branch Circuit	Amp	P	Description	Cir	Ltg		Recept		Motor		Lg Motor		Equip		Cir	Description	P	Amp	Branch Circuit
3/4"C / 2#12+1#12GRD	20	1	DF-2	1				720					230		2	Rm. 151 Receptacles	1	20	3/4"C / 2#12+1#12GRD
3/4"C / 2#12+1#12GRD	20	1	Rm. 150A/C Receptacles	3			1080	720							4	Rm. 151 Receptacles	1	20	3/4"C / 2#12+1#12GRD
3/4"C / 2#12+1#12GRD	20	1	Pressure Switch & Pump	5				360			250				6	Rm. 150 Televisions	1	20	3/4"C / 2#12+1#12GRD
-	20	1	SPARE	7										1680	8	Ticket Window	1	20	3/4"C / 2#12+1#12GRD
3/4"C / 2#12+1#12GRD	20	1	Rm. 150 Quad Receptacles	9			720								10	SPARE	1	20	-
-	-	-	-	11				1080							12	Rm. 150 Receptacles	1	20	3/4"C / 2#12+1#12GRD
-	-	-	-	13											14	-	-	-	-
-	-	-	-	15											16	-	-	-	-
-	-	-	-	17											18	-	-	-	-
-	-	-	-	19											20	-	-	-	-
-	-	-	-	21											22	-	-	-	-
-	-	-	-	23											24	-	-	-	-
Connected Load Phase A: (A)			21.9			0		720		0		0		1910		Demand Load Phase A: (A)	21.9		
Connected Load Phase B: (A)			21.0			0		2520		0		0		0		Demand Load Phase B: (A)	21.0		
Connected Load Phase C: (A)			14.1			0		1440		0		250		0		Demand Load Phase C: (A)	14.8		
Total VA:		6903																	
Load: (A)		19.2																	
25% Growth: (A)		24.0																	

Proposed 208Y/120V Panel in Retail Building Storage Room

The following demand factors were used when sizing the panel loads:

Lighting: 1.25
Receptacle (<10kVA): 1.0
Receptacle (>10kVA): 0.5
Motor: 1.0
Large Motor: 1.25
Equipment: 1.0

Electrical Design Assumptions:

- Conduit and conductors were sized at a 75°C THHW temperature rating.
- Junction boxes in ticket booth are connected to final equipment with a sizing of 2A per box.

Voltage Drop Calculations							
Feeder	Size	V_{L-N}	Amperage	Length	Factor	V_{drop}	% Vd_{rop}
#3RB1	(4) #4	277	53	275	0.3	4.340	1.57
Branch	#12	120	28	55	1.749	2.722	2.27

Voltage Drop Calculation

Assumptions:

- No voltage drop between 480Y/277V panel and 208Y/120V panel.
- Voltage at in transformer, T-RB, is regulated to 208Y/120V meaning no voltage drop occurs through transformer.
- Original design suffices for ¾" conduit and #12 wire for branch circuits back to panel in P126. Therefore, no voltage drop experienced on designed branch circuits.

Per NEC 2002 Article 215.2.A.4, the wire size of (4) #4 and the branch circuit suffice for a voltage drop required of less than 5% total.

It is important to note that a new main panel is not needed because the overall load on that panel has not changed.

2.0.6 COST ANALYSIS BETWEEN SYSTEMS

Designed System Component Pricing								
Equipment Type	Product Number	Quantity	Material Cost	Total Material Cost	Labor Quantity	Labor Cost ($/hr)	Total Labor Cost	Total Cost
FEEDER (3 #12)	Electrical Supplier	5775	0.30	1732.50	115.5	29.58	3416.49	5148.99
EMT (3/4")	Electrical Supplier	1925	0.90	1732.50	154.0	29.58	4555.32	6287.82
FEEDER (5 #8)	Electrical Supplier	1375	0.20	275.00	16.5	29.58	488.07	763.07
EMT (3/4")	Electrical Supplier	275	0.90	247.50	22.0	29.58	650.76	898.26
FEEDER (5 #12)	Electrical Supplier	1375	0.30	412.50	16.5	29.58	488.07	900.57
EMT (3/4")	Electrical Supplier	275	0.90	247.50	22.0	29.58	650.76	898.26
FEEDER (5 #12)	Electrical Supplier	4125	0.30	1237.50	49.5	29.58	1464.21	2701.71
EMT (3/4")	Electrical Supplier	825	0.90	742.50	66.0	29.58	1952.28	2694.78
CIRCUIT BREAKER (20A - PNL RC1)	QOB120	8	26.50	212.00	1.0	29.58	29.58	241.58
CIRCUIT BREAKER (20A - PNL MP1)	EDB34020	1	754.00	754.00	1.0	29.58	29.58	783.58
CIRCUIT BREAKER (30A - PNL MP2)	EDB34030	1	754.00	754.00	1.0	29.58	29.58	783.58
CIRCUIT BREAKER (20A - PNL LP2)	EDB14020	3	170.00	510.00	1.0	29.58	29.58	539.58
							Total Cost:	$22,641.78

Designed System Component Pricing

Proposed System Component Pricing								
Equipment Type	Product Number	Quantity	Material Cost	Total Material Cost	Labor Quantity	Labor Cost ($/hr)	Total Labor Cost	Total Cost
PANEL RB-1	NQOD424L100CU	1	708.00	708.00	1.0	29.58	29.58	737.58
PANEL RB-1 BOX	MH23	1	75.00	75.00	1.0	29.58	29.58	104.58
PANEL RB-1 COVER	MHC23	1	293.00	293.00	1.0	29.58	29.58	322.58
PANEL RB-1 (60A BREAKER)	FCL34060	1	1206.00	1206.00	1.0	29.58	29.58	1235.58
FEEDER (4 #4)	Electrical Supplier	1200	0.64	768.00	18.0	29.58	532.44	1300.44
FEEDER GROUND (#8)	Electrical Supplier	300	0.20	60.00	0.0	0.0	0.00	60.00
PVC (1 1/4")	Electrical Supplier	300	1.35	405.00	24.0	29.58	709.92	1114.92
CIRCUIT BREAKER (20A - PNL RB1)	EGB14020	5	170.00	850.00	1.0	29.58	29.58	879.58
CIRCUIT BREAKER (30A - PNL RB1)	EGB34030	2	754.00	1508.00	1.0	29.58	29.58	1537.58
CIRCUIT BREAKER (20A - PNL RB1)	EGB34020	1	754.00	754.00	1.0	29.58	29.58	783.58
TRANSFORMER T-RB	15T2F	1	2322.00	2322.00	24.0	29.58	709.92	3031.92
FEEDER (3 #10)	Electrical Supplier	15	0.25	3.75	0.3	29.58	8.87	12.62
FEEDER GROUND (#8)	Electrical Supplier	20	0.20	4.00	0.0	0.0	0.00	4.00
EMT (3/4")	Electrical Supplier	5	0.90	4.50	0.4	29.58	11.83	16.33
PANEL RB-2	NQOD424L50CU	1	708.00	708.00	1.0	29.58	29.58	737.58
PANEL RB-2 BOX	MH23	1	75.00	75.00	1.0	29.58	29.58	104.58
PANEL RB-2 COVER	MHC23	1	293.00	293.00	1.0	29.58	29.58	322.58
PANEL RB-2 (30A BREAKER)	FCL34030	1	1206.00	1206.00	1.0	29.58	29.58	1235.58
FEEDER (4 #10)	Electrical Supplier	20	0.25	5.00	0.3	29.58	8.87	13.87
FEEDER GROUND (#8)	Electrical Supplier	20	0.20	4.00	0.0	0.0	0.00	4.00
EMT (3/4")	Electrical Supplier	5	0.90	4.50	0.4	29.58	11.83	16.33
CIRCUIT BREAKER (20A - PNL RB2)	QOB120	10	26.50	265.00	1.0	29.58	29.58	294.58
							Total Cost:	$13,870.40

Proposed System Component Pricing

Please consult the *Appendix – Retail Building Electrical Analysis* for larger component pricing information.

Pricing Clarifications:

- Material pricing with product numbers were calculated using the SquareD Digest supplied by Schneider Electric.
- Material pricing for wire and conduit was given by a State College area electrical supplier.
- Material quantity for feeders is noted as number of wires and then wire type and multiplied accordingly. Example is FEEDER (4 #4) translates to four, number 4 wires.
- Main feeder is run underground through 1-1/4" PVC conduit. All other braches use EMT conduit.
- Feeder (wire) labor quantity assumes 100 feet of wire will take 2 men, 3 hours to pull and terminate. (data from electrical contractor)

- All wires are pulled at the same time when calculating the labor rate for feeders.
- Conduit labor quantity assumes 100 feet of conduit will take 1 man, 8 hours to install. (data from electrical contractor)
- Labor rate per hour was determined by using the 2006 PA prevailing wage labor rate for an Electrician Class 1 without fringe benefits.
- Conduit labor quantity assumes 100 feet of conduit will take 1 man, 8 hours to install. (data from electrical contractor)
- Transformer labor quantity assumes 2 men, 1 day to lug and set into place, and a second day to make all connections to panels.
- Grounding wire labor quantity include with feeder labor quantity per previous assumption.

The alternative system provides a cost savings of $8,771.38 in labor and material. The material savings is easily noted with the decrease in the amount of wire and conduit used with the proposed system.

2.0.7 PROJECT IMPACTS

As discussed in the cost analysis section, the alternative system provides a cost savings of $8,771.38 and also provides a true worthwhile value engineering suggestion to the owner. Electrical systems often need to be shutdown and it only makes sense to have an electrical panel located in close proximity to the structure. Furthermore, the retail building is one of the few areas in the facility that will be operational year round. If an electrical problem is found in the retail building with the designed system, the maintenance staff would have to enter the stadium and locate the electrical room, P126, a distance of 275’ away. By implementing the alternative system, the owner will have all power and lighting loads fed within the retail building. Most importantly, any electrical maintenance occurring within the retail building will not require entrance into the stadium unless the main feeder needs to be shutdown.

The construction of the retail building is the last sequence on the project to be completed and is not on the critical path for final completion. However, the alternative system requires less labor to run multiple feeders to electrical room, P126. An underground raceway will still be required to feed from the main electrical room to storage, 150B, within the retail building; but, there is a significant labor savings by keeping the branch circuits within the retail building. Additionally, there a decrease in coordination with other trades for electrical branch conduits installed through main concourse per original design.

There are no disadvantages found with implementing the alternative system.

Proposed Alternative System	
Advantages	Disadvantages
Cost savings of $8,771.38.	
Ease of electrical system maintenance during owner operation.	
Decrease in amount of conduit and wire needed (labor savings).	
Decrease in coordination with other trades for electrical branch conduits installed through main concourse per original design.	
Ease of expansion.	
Less voltage drop experienced on branch circuits.	

2.0.8 CONCLUSION

The alternative system is a positive value engineering suggestion for the project. It provides a cost savings of $8,771.38 in labor and material but most importantly the alternative system will provide the owner better electrical maintenance means during the building lifetime. Furthermore, the ease of expansion within the retail building will be much easier with the alternative system because wires and conduit do not need to be installed 275’ away from the source of expansion.

This analysis is a valuable tool for a construction manager to be able to utilize when providing value engineering suggestion to an owner. An understanding of the cost and benefits to modifying an electrical system can help identify alterations of future projects.

Overall, the alternative system is a very positive electrical value engineering suggestion for the owner and will provide positive effects during the building operation.

3.0 STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

3.0.1 EXECUTIVE SUMMARY

A familiar problem in the construction industry is that a building is often designed on paper during the design phase; and then re-designed to determine “ability for construction” during the construction phase. The idea of re-design is very apparent with the steel, mechanical, electrical, and plumbing trades with the requirement of shop drawing completion on many projects for those trades.

The following discussion focuses on streamlining the structural steel design to construction through the implementation of computer modeling, along with how to take advantage of current technology to help a project team is also addressed.

In order to propose a more streamline process for the steel phase of a project through computer modeling, a current understanding of steel design and construction practice must be analyzed. The research methods included journal and industry article reviews, telephone interviews with steel industry professionals, and the development of a steel BIM for *Penn State Ballpark*.

Interviewing industry professionals proved to be a very valuable method to fully understanding the steel design to construction process. Each industry professional was very helpful and insightful with responding and adding to the proposed interview questions.

A case study with the *Penn State Ballpark* project examined the effects a BIM could have on a better delivery on the design and expediting the steel shop drawing duration with a building information model supplied by the structural engineer. The implementation of such a model benefits each project team member from design to construction.

Construction industry trends will show more and more projects implementing this technology over the next few years. The CIS/2 modeling standards will help software developers implement the proper exporting capabilities to make different software packages interoperable with each other.

By analyzing existing practices during the steel phase of a project, a more streamline process for the steel phase of a project through computer modeling has been addressed. The above research discussion has benefited structural designers, construction managers, and steel fabrication because each entity can more effectively perform his/her job with the implementation.

3.0.2 CHAPTER 1
Problem Statement

A familiar problem in the construction industry is that a building is often designed on paper during the design phase; and then re-designed to determine “ability for construction” during the construction phase. The idea of re-design is very apparent with the steel, mechanical, electrical, and plumbing trades with the requirement of shop drawing completion on many projects for those trades.

Duplication of design during the steel phase of a project often presents challenges to the project team. “[The] development and approval of drawings is a tedious but important component of the fabrication process that enables the project to be properly fabricated and assembled smoothly during the erection process” (Danso-Amoako et.al). The structural engineer designs the steel structure for the building and then the structural steel contractor, upon award, re-designs the building through steel shop drawings. Because of the need to produce these shop drawings, steel cannot begin fabrication until six to eight weeks after an award is made to the steel contractor and shop drawings are approved. Consequently, duplication of structural design delays fabrication of structural members and is a problem that affects each project in the construction industry. Furthermore, if created correctly, 3D models are more accurate than 2D drawings because they rely on exact dimensions and geometries. (Post)

The following discussion will focus on streamlining the structural steel design to construction through the implementation of computer modeling. A discussion of how to take advantage of current technology to help a project team will also be addressed.

3.0.2.A Significance

In July 2005, the General Services Administration (GSA) announced that all new projects requiring their funding will need to include a building information model (BIM) as part of the project proposal. The term BIM is a relatively new term in the industry, but in the past has been noted as a project model or multi-dimensional (MD) modeling. Essentially a building information model is an intelligent 3D CAD model with information attached to all items drawn in the 3D space. No longer are items just colored blocks, but with BIM these items are objects with data association. This is apparent with a 3D structural steel BIM with the fact that the 3D objects are modeled as scalable W members, steel type, connection type, along with many other inputted properties. Furthermore, risk is reduced by developing 3D models of structures at the very beginning of projects. These models reflect the entire geometry and connectivity of the structure. [Hamburg, et.al]

The GSA's requirement with a BIM needed for all of their future projects is a new approach to project design and delivery. In the past, many projects have been designed in three dimensions, but have not included the object properties which would make it a BIM. Computer aided project development has been in the industry for quite some time, however implementing it has been a hardship. Many owners, architects, and construction managers have not seen the value that these models can bring to a project mostly due to initial costs and time to develop the models.

Furthermore, NIST recently completed a study on the costs of inadequate interoperability in U.S. Capital Facilities Industry with a stunning figure of $6.8 billion dollars lost due to poor interoperability during construction. The added expenses are partly due to manual reentry of data and request for information management which can be directly associated with the steel construction phase. (Jun et.al)

The steel construction industry is a technological savvy industry and a very important part of the United States economy. Structural steel fabrication and erection contributed 8.5 billion dollars of production and half of million workers from a 1999 and 2001 survey. (Eastman, et.al) For many years, steel detailers and fabricators have used computer software to generate documents that could be used in fabrication with computer numerically controlled (CNC) equipment. Many projects contain 3D steel structures modeled by the steel contractor which take time to develop.

3.0.2.B Objectives

This research will focus on streamlining the structural steel design to construction through the implementation of computer modeling. A better understanding of BIM will be found through the development of a steel building information model for the steel structure of the *Penn State Ballpark*.

The goals and objectives of this research are to answer the following questions:

1. Can the construction industry reduce the waste in the steel shop drawing process through implementing building information modeling?
2. What are the challenges to implementing this technology on a project?
3. How can a project team implement building information modeling on a project, specifically the steel phase?

By analyzing existing practices during the steel phase of a project, this paper will propose a more streamline process for the steel phase of a project through computer modeling.

3.0.3 CHAPTER 2
Research Approach

In order to propose a more streamline process for the steel phase of a project through computer modeling, a current understanding of steel design and construction practice must be analyzed. The research methods included journal and industry article reviews, telephone interviews with steel industry professionals, and the development of a steel BIM for *Penn State Ballpark*. Additional information regarding BIM was collected through class and industry presentations during the spring semester (2006).

3.0.3.A Research Means and Methods

The initial research included journal and industry article reviews. Most of the literature was accessed through the *American Institute of Steel Construction* or from the *National Institute of Standards and Technology's Building Fire and Research Laboratory*. Additional articles were found through *Engineering News Record* and steel construction industry standards books (CIS/2). A more detailed understand of literature can be found in the literature review, 3.0.4.

The majority of my research information came from phone interviews with steel industry professionals. A method was needed to collect to data to understand the current practice related to design and construction in the steel industry. An interview method was chosen because more value would be achieved through direct discussions than a survey method. Furthermore, the interview technique allowed for more in depth discussions to be addressed depending on the response to interview questions. From discussions with professors, contacts from printed articles, and past interaction with industry members, industry organizations, structural engineers, steel fabricators, and construction managers were contacted about participating in an interview. The initial contact was generated through electronic mail with an attached cover letter which described the research objective. The only group that was strategically chosen for participation was the fabricators. The goal with the fabricator interview set-up was to interview a smaller, medium size, and large steel fabricator. The following table states the industry members that agreed to participate in an interview to help foster a better understand regarding steel design to construction process.

Contact Name	Group	Company
Ron Sinopoli	Construction Manager	Barton Malow Company
Ryan Maibach	Construction Manager	Barton Malow Company
Erleen Hatfield	Design Firm	Thorton-Tomasetti
Kevin Fast	Design Firm	HOK Sports
Nathan Appleman	Design Firm	HOK Sport
Babette Freund	Fabricator	Ritner Steel
Mark Holland	Fabricator	Paxton & Vierling Steel Co.
Glenn Sherrill	Fabricator	Steelfab of Alabama, Inc.
Charlie Carter	Industry Organization	AISC
Robert Lipman	Industry Organization	NIST

After an initial response from the listed industry professionals, a date and time for a telephone interview was established along with forwarding a series of question to be addressed in the interview. As found in the *Appendix – Streamlining Structural Steel Design & Construction through Computer Modeling*, a standard set of interview questions was generated for each important role in the steel design and construction phase. Each interview contained approximately ten (10) questions and the interview discussion was limited to thirty (30) minutes. It is important to note that the same questions were not asked during each interview; some questions did not pertain to each steel phase entity. For example, a designer was not asked about steel fabrication techniques because he/she does not perform fabrication tasks.

During each interview, data was collected by importing the discussion and responses into a Microsoft word document. Interview data was not collected via tape recording nor was any confidentiality statement supplied for interviews. Upon completion of all phone interviews, each interview discussion was printed to be analyzed. From analyzing the data, seven (7) similar questions were asked of each group. The seven questions and responses were analyzed through an "information web;" the webs can be found in the *Appendix – Streamlining Structural Steel Design & Construction through Computer Modeling.* Results from the interviews were found and can be viewed in section, 3.0.5.

3.0.3.B Case Study: Penn State Ballpark

Penn State Ballpark is a current construction project at The Pennsylvania State University. The project cost is $30.9 million with construction duration of twelve (12) months. The structure for the *Ballpark* is structural steel (550 tons) with masonry load bearing walls. In order to better understand building information modeling, a structural BIM was created of *Penn State Ballpark* using Revit Structure 2. Revit Structure 2 was chosen because of past familiarity with Revit Building and ease of interoperability between AutoCAD programs. Revit Structure 2 also has already preloaded all of the structural members found in the current *AISC Manual of Steel Construction*. All of the 2D structural drawings from AutoCAD were obtained from the architectural firm and imported into Revit Structure 2 to ease in the modeling process.

3.0.4 CHAPTER 3
Literature Review

Currently, there has been a lot of research devoted to computer aided design/construction research. Most of this research is based on project case studies and not how to effectively implement computer aided models on a construction project. Many projects are documented with a 3D model which is made during the preconstruction phase of a project. These models are used to develop a rendering of the project which is mainly used for marketing purposes. Unfortunately, these models are 3D models and not building information models. Furthermore, these models are very rarely taken from the design phase of a project and implemented in the construction phase.

However, several projects are beginning to implement steel building information models and reaping the benefits as a result of the implementation. On a recent three school design-build project, RAMSteel was used to create a design model and transferred to the steel detailer to import into SDS/2 for connection design. (Gavin and Pollak) As anticipated, the project was very successful and the use of software “gave the engineers more confidence that the design was carried through.” Unlike many case studies and discussions with engineers, a model can be an advantage to an engineer and not necessarily fee related and unwillingness to cooperate by developing a design model.

An underlying belief is that more risk is associated with implementing and transferring data with a building information model on a project. However, Fowler recently completed a hospital project in which BIM implementation proved to be very successful. He found through the process “as long as the proper checks are in place and each party understands what is expected from the other, any potential added risk can be eliminated.” (Fowler)

The “poster” project for implementing a steel building information model and then transferring the data to the steel contractor is the 13,000 ton steel renovation project at Soldier Field in Chicago, IL. Thornton-Tomaseti Engineers took the lead to create a 3D design data model and share with the steel fabricator which allowed them to detail connections more easily. “The steel detailer simply enhances the engineer’s design model by adding all the elements such as bolt holes, bolts, angles and plates required for fabrication and erection.” (Post) Furthermore, model reviews on the project were implemented to lessen the paper trail associated with the shop drawing process.

Carrato et.al lists significant cost and schedule benefits for the use of 3D model data; however, this requires redefining business practices. Hatch has turned to a paperless project delivery system which reduces the project schedule by 4-8 weeks. There time was spent on perfecting the model and checking accuracy and makes the steel design process faster and error-free. (Coleman) The paperless process eliminates a lot of waste. There are fewer mistakes, less waste of steel, and less time and money wasted. (Pollak) By allowing fabricators to use the design model as the foundation for faster, more accurate shop drawing creation and manufacturing, you significantly reduce errors, provide better communication between engineers and fabricators, receive fewer RFI's, and a happier client. (Karp et.al) Until the entire project team can see direct benefits in the creation of a project model, there will not be acceptance of this new way of doing business. Another obstacle with universal acceptance is that a lot of the project team members are still living in a 2D world, and are not prepared to spend the extra money or train their people in 3D design techniques. (Engler)

3.0.5 CHAPTER 4
Research Findings

The following sections describe the results from interviews with steel construction industry professionals as well as documents the effects of a building information model with the *Penn State Ballpark* project.

3.0.5.A Interview Results

Interviewing industry professionals proved to be a very valuable method to fully understanding the steel design to construction process. Each industry professional was very helpful and insightful with responding and adding to the proposed interview questions. After analyzing the responses from the four interview groups, seven (7) similar questions answered by all four groups were found. The seven similar questions found are as follows:

- Have the development of steel design/shop drawings changed over the past five (5) years? (3D modeling, etc.)
- Has 3D modeling/BIM changed the steel shop drawing development and review process?
- Describe some common problems during the development of shop drawings.
- Describe the communication techniques between the designer and detailer during the shop drawing development process.
- What are the barriers to implementing building information modeling (BIM) on a project? (cost, time, legal, etc.)
- Describe the ideal steel shop drawing review process.
- Do you think the design to construction process will change in the next few years? If so, how?

The other questions that were asked added value to understanding the steel design and construction process and did not directly affect each interviewed group. Common responses for the seven similar questions are listed below:

- Have the development of steel design/shop drawings changed over the past five (5) years? (3D modeling, etc.)
    - Hand drawing to Automation
    - 3D Shop Drawing Models linked to CNC Equipment
    - 3D Design Model Given to Contractors for Bidding

- Has 3D modeling/BIM changed the steel shop drawing development and review process?

  - Defined Scope with BIM During Design
  - Model Reviews Instead of Drawing Reviews are Becoming More Common
  - Models Exported Directly to CNC Equipment

- Describe some common problems during the development of shop drawings.
  - Model Maintenance and Discipline
  - Architectural Changes During Approval Process
  - Incomplete Design Documents
  - Coordination with Architectural Documents

- Describe the communication techniques between the designer and detailer during the shop drawing development process.
  - Rarely Direct Contact between Designer and Detailer
  - Attach Screen Shot of Model to Requests for Information (RFI)

- What are the barriers to implementing building information modeling (BIM) on a project? (cost, time, legal, etc.)
  - Different Way Of Thinking
  - Fee Issues with More Design Services
  - Accuracy of Model
  - Interoperability
  - Understanding How BIM Benefits Project Team

- Describe the ideal steel shop drawing review process.
  - Coordinated Team
    - Decisions Made Instead of Delay Decision Making
    - Software Easily Exchange Information
  - Model Review Instead of Paper Drawings
  - Information Exchanged Electronically

- Do you think the design to construction process will change in the next few years? If so, how?
  - Software Companies Forming More Strategic Alliances
  - 3D Steel Shop Drawing Model Review Meetings
  - Interoperability Will Determine the Change to Construction Process.

Please consult *Appendix – Streamlining Structural Steel Design & Construction through Computer Modeling* for a detailed depiction of each questions response.

While performing the research interviews, it became apparent that the overwhelming feeling is very positive with implementing such technology during the steel phase. The question then becomes, how do we use the technology to have a successful project? The following table outlines the most common challenges associated with BIM on the steel phase of a project and gives a control method to overcoming challenges.

BIM for Steel Phase on a Project	
Challenges	**Control Method**
Contract Language	AISC Code of Standard Practice (Chapter 16) assists with correct verbage.
Design Management	Design decisions made sooner. Better design coordination through a design model.
Technology	Choose up-to-date software with most effective date exchanging capabilities. CIS/2 continues to help with exchanging data between software will become less of a problem. Create an FTP site to post all documents to be exchange electronically.
Communication	Promotes constant communication and project understanding by project team.
Paper Drawings	3D Model reviewed and approved. Erection Drawings Only.

These challenges include contract language, design development and management, technology, communication with project team members, and the issuing of hard copy (paper) drawings. The control methods listed on the right describe ways to overcome the challenges and allow a project to benefit from the use of building information modeling.

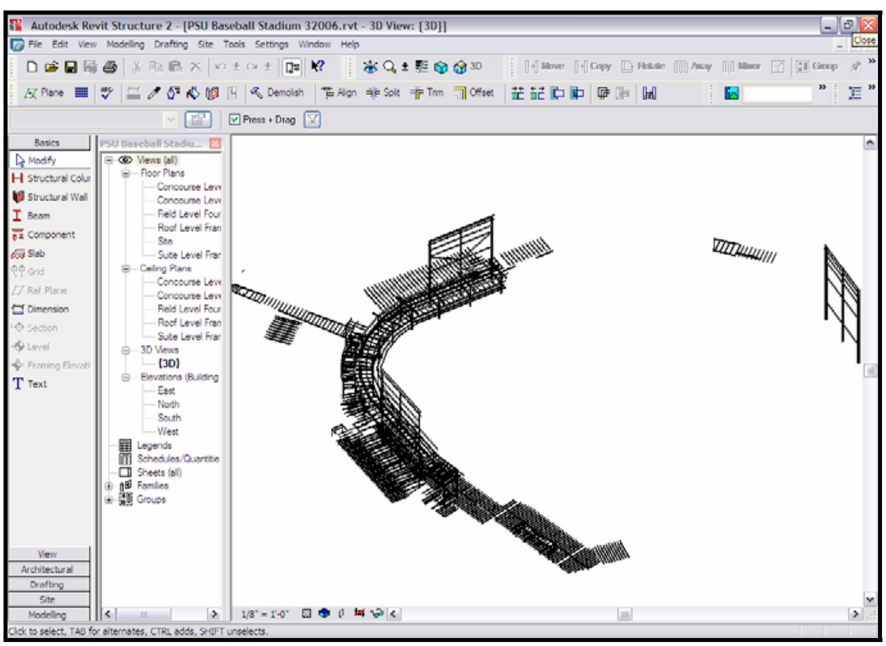
Ideas to overcoming the challenges of technology have already been implemented on school projects where several of the projects shop drawings were reviewed using a projects intranet server. (Garvin and Pollak) The concern with technology is the directly related to interoperability which is integrating design and construction processes by eliminating the need for manual re-entry of data. (Ruby) Manual re-entry is becoming less of a hassle with data exchange methods between software programs through the CIMsteel Integration Standards (CIS/2). The CIS/2 standards are a set of formal computing specifications that allow software vendors to make their engineering applications compatible. (Danso-Amoako et. Al)

3.0.5.B Case Study Results: Penn State Ballpark

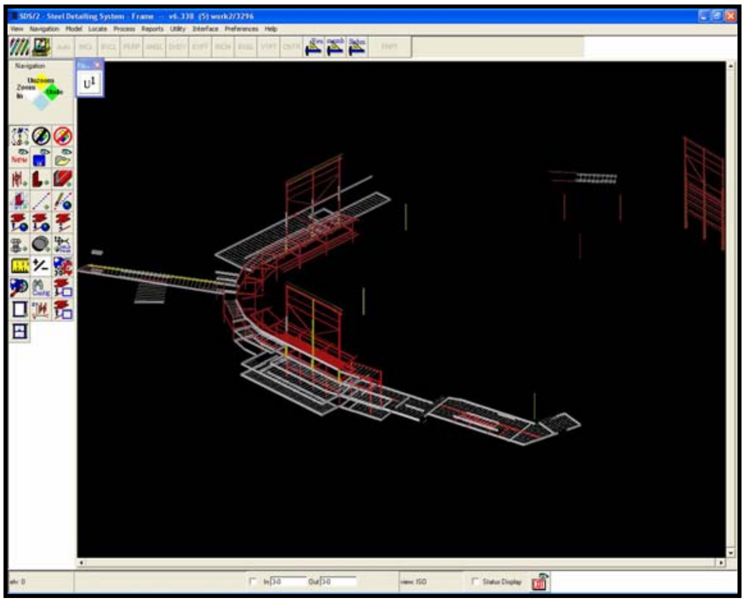
Using the *Penn State Ballpark* as a case study project, a BIM was generated for the steel phase of the project using Revit Structure 2. There were several reasons in choosing to generate a BIM. One, it is important to understand how such a model is created and how to use the software in which a model is created. Another reason was to find if there are any direct problems with the current software used for structural building information modeling. A better understanding of the structural design and seeing if there was any direct design conflicts wanted to be observed. If the information on the contract drawings is incomplete or inaccurate, then the building cannot be built either in the computer or in the field. (Trinchero) Lastly, a better understanding of BIM wanted to be created to construction industry members through an actual project. The table below documents information pertaining to the BIM created for *Penn State Ballpark*.

Case Study BIM Model
Revit Structure 2
65 Hours to create BIM.
Some areas could not be modeled.
Known steel quantities with schedules.

The baseball stadium geometry is fairly simple; however it was difficult to model some areas of the structure. For example, not all of the angled roof beams could be created due to the angle of the members. Most of the modeling went smoothly minus those few heartaches that took some time to try and solve. All in all, the model took sixty-five (65) hours to develop which is about 8 working days. This number is also somewhat skewed because of being a new user with the modeling software. Below is a screen shot of the model created in Revit Structure 2.



This can be compared to the SDS/2 fabrication model depicted below. At the fabrication, more detail is needed regarding connections and fabrication length but a "similar" model is generated.



Model Courtesy of Ritner Steel, Inc.

The geometry alone with a fabrication model can take a week or two to create before detailing begins. The *Penn State Ballpark* project is a fast-track, design-bid-build delivery system with construction duration at 12 months. As with most stadium projects, the steel structure is very vital to finishing the project on time and therefore is on the critical path. Any time that can be saved during "non-construction" activities will add time value savings to the construction activities. Consequently, developing a structural design BIM and giving the model to the awarded steel contractor would allow the detailing process to begin sooner. This is due to the fact that the contractor does not have to take the time to regenerate the column lines along with each steel member; more value can be associated with connection design.

As stated earlier, the steel shop drawing approval process is often time consuming typically taking several weeks with this project being no exception. In order to begin steel erection on November 1, 2005, the first three steel sequences needed to be approved by August 1, 2005. This gave the steel contractor four (4) weeks from award to develop and submit for approval the first three sequences of shop drawings. With the statements made earlier, it often takes a week or so to get the detailing software set-up with the initial structural information before detailing can begin. If a BIM was given to the steel contractor, detailing of the structure could have begun immediately instead of time “wasted” during the creation of the building geometry and designed structural members.

A design to construction BIM will also help manage the request for information process. As of March 31, 2006 there were 650 RFI’s on the project with 115 of the RFI’s related to the steel construction phase. Through the CIS/2 standards, fewer requests for information will result or the requests will be coordinated and managed at one time rather than trickling in over a long period of time. (Carato et.al) This would allow the construction engineer to spend more time with other phases of a project and not be tied down with an extravagant amount of steel RFI’s.

Furthermore, a BIM will give each project team member a better understanding of the structure and supply valuable information to the construction team. One example of this is the ability to create quantity schedules with the creation of a BIM. Because data is linked with each item drawn with BIM software, creating column, beam, and joist schedules is very easy. Unfortunately, the construction team was not supplied with a column schedule for the project. This presented a problem during the bidding period and also during construction. On the design documents, base plate elevations were mislabel 100’-0” and caused many questions regarding column lengths for bidding purposes. Furthermore, a column schedule is important to the construction team to be able to verify building height and determining scheduling activities. By using BIM, a column schedule is created instantaneously when drawing the structure. Below are three schedules created from the building information model in Revit Structure 2.

Sample Quantity Schedules Created in Revit Structure 2

Penn State Ballpark *Structural Column Schedule*						
Column Description	Quantity	Length	Base Level	Base Offset	Top Level	Top Offset
W14X90	1	118' - 6"	Concourse Level Framing Plan	-14' - 6"	Roof Level Framing Plan	75' - 0"
W14X43	1	15' - 9 1/2"	Field Level Foundation Plan	-1' - 6"	Concourse Level Framing Plan	-0' - 8 1/2"
W14X132	1	120' - 6"	Field Level Foundation Plan	-1' - 6"	Roof Level Framing Plan	75' - 0"
W14X43	1	15' - 8"	Field Level Foundation Plan	-1' - 6"	Concourse Level Framing Plan	-0' - 10"
W14X90	1	120' - 6"	Field Level Foundation Plan	-1' - 6"	Roof Level Framing Plan	75' - 0"

Penn State Ballpark *Structural Beam Schedule*			
Beam Description	Quantity	Length	Reference Level
HSS-Hollow Structural Section: HSS5X5X.1875	1	7' - 6 1/2"	Concourse Level Framing Plan
W-Wide Flange: W10X12	1	18' - 1 7/32"	Concourse Level Framing Plan
W-Wide Flange: W10X12	1	18' - 7 1/32"	Concourse Level Framing Plan
W-Wide Flange: W12X14	1	24' - 7 5/16"	Concourse Level Framing Plan
W-Wide Flange: W12X19	1	11' - 5 27/32"	Concourse Level Framing Plan

Penn State Ballpark *Structural Joist Schedule*			
Joist Description	Quantity	Length	Reference Level
LH-Series Bar Joist: 18LH02	1	16' - 10"	Concourse Level Framing Plan
LH-Series Bar Joist: 18LH02	1	16' - 10"	Concourse Level Framing Plan
LH-Series Bar Joist: 18LH02	1	16' - 10"	Concourse Level Framing Plan
LH-Series Bar Joist: 18LH02	1	16' - 8 3/32"	Concourse Level Framing Plan
LH-Series Bar Joist: 18LH02	1	16' - 8 3/32"	Concourse Level Framing Plan

A case study with the *Penn State Ballpark* project examined the effects a BIM could have on a better delivery on the design and expediting the steel shop drawing duration with a building information model supplied by the structural engineer. The implementation of such a model benefits each project team member from design to construction.

3.0.6 CHAPTER 5
Conclusion

By implementing building information modeling during the design phase, the time invested during the shop drawing phase can be decreased. On a recent casino project, using CIS/2 translators, a [design model] was imported into SDS/2 detialing software package and was able to detail and finish the first sequence of fabrication in just 19 days. Without this exchange capability, this project would have taken an additional four weeks to complete. (Melnick) From interview discussions with steel construction industry professionals, there are several challenges to implementing this technology. These challenges include contract language, design development and management, technology, communication with project team members, and the issuing of hard copy (paper) drawings. With the stated challenges, a proposed method to addressing the challenge is expressed.

A case study with the *Penn State Ballpark* project examined the effects a BIM could have on a better delivery on the design and expediting the steel shop drawing duration with a building information model supplied by the structural engineer.

More research should be examined with implementing full-scale building information models on projects. The literature review analyzed several projects that have implemented a BIM, but more attention should be addressed to how these projects were successful. Further research can also be analyzed with coordination between various fabricators involved with the structural package. There is often improper coordination between metal deck, metal joists, and structural steel which leads to fabrication and construction delays. It is possible with BIM that the improper document coordination methods can be eliminated. The steel phase is very dependent on exact dimensions for fabrication purposes and building information can only help this area of a project. Furthermore, BIM is estimated to reduce detailing costs by 50%, 10%-20% reduction in shop production costs, and 50% to 80% reduction in estimating costs. (Hamburg)

Construction industry trends will show more and more projects implementing this technology over the next few years. The CIS/2 modeling standards will help software developers implement the proper exporting capabilities to make different software packages interoperable with each other.

By analyzing existing practices during the steel phase of a project, a more streamline process for the steel phase of a project through computer modeling has been addressed. The above research discussion has benefited structural designers, construction managers, and steel fabrication because each entity can more effectively perform his/her job with the implementation.

SUMMARY AND CONCLUSIONS

The structural analysis proved that an alternative column design could be used and is a positive value engineering suggestion for the project. It provides an overall cost savings of $45,184.20 in labor, material, and equipment and a schedule savings of 7 days on erection of the columns. Through this analysis several advantages were noted including added waterproofing and easier electrical cable installation to the power the field lighting fixtures. The only noted disadvantage with the alternative column design is that the additional welding expertise to fabricate a “custom” column could limit the amount of steel fabricator’s willing to bid the work. By performing this analysis, I was able to successfully provide an alternative design and satisfied the goals associated with the analysis. This analysis is a valuable tool for a construction manager to be able to discover. An understanding of the cost and benefits to changing a structural column can help identify alterations of future projects.

The electrical analysis proved that an alternative system is a positive value engineering suggestion for the project. It provides a cost savings of $8,771.38 in labor and material but most importantly the alternative system will provide the owner better electrical maintenance means during the building lifetime. Furthermore, the ease of expansion within the retail building will be much easier with the alternative system because wires and conduit do not need to be installed 275’ away from the source of expansion. This analysis is a valuable tool for a construction manager to be able to utilize when providing value engineering suggestion to an owner. An understanding of the cost and benefits to modifying an electrical system can help identify alterations of future projects. Overall, the alternative system is a very positive electrical value engineering suggestion for the owner and will provide positive effects during the building operation.

The construction industry research topic regarding streamlining the steel design and construction through computer modeling proved to be very information and worthwhile. From interview discussions with steel construction industry professionals, there are several challenges to implementing this technology. These challenges include contract language, design development and management, technology, communication with project team members, and the issuing of hard copy (paper) drawings. With the stated challenges, a proposed method to addressing the challenge is expressed. A case study with the *Penn State Ballpark* project examined the effects a BIM could have on a better delivery on the design and expediting the steel shop drawing duration with a building information model supplied by the structural engineer. By analyzing existing practices during the steel phase of a project, a more streamline process for the steel phase of a project through computer modeling has been addressed. The research discussion has benefited structural designers, construction managers, and steel fabrication because each entity can more effectively perform his/her job with the implementation.

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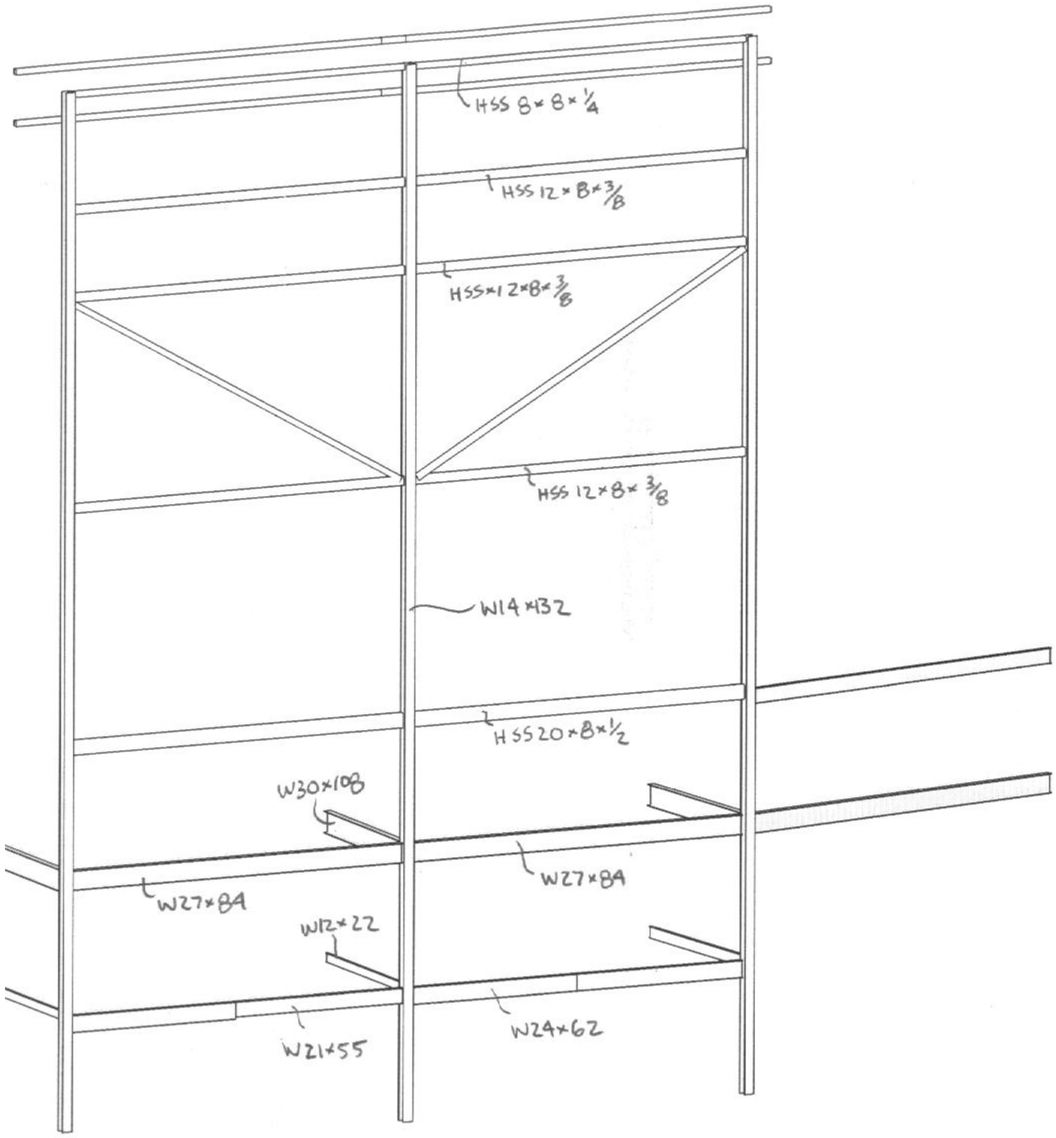
APPENDIX

STRUCTURAL STEEL TAPERED COLUMN ANALYSIS


HSS 8×8×1/4
HSS 12×8×3/8
HSS×12×8×3/8
HSS 12×8×3/8
W14×132
HSS20×8×1/2
W30×108
W27×84
W27×84
W12×22
W24×62
W21×55

ASCE 7-05 pg. 29

· Design Wind Loads on Other Structures

* $F = q_z \, G \, C_f \, A_f$ (lb) (N) (Eq. 6-28)

→ q_z [section 6.5.6.3] pg. 27
· Surface Roughness C
→ open terrain
· Velocity Pressure

$q_z = 9.9826992$ lb/ft.²

→ G [section 6.5.8] pg. 26
· Flexible Structure
· Dust-Effect Factor

$G = 0.8715058736$

→ C_f [figures 6-21 through 6-23] pg. 29/75
· Force Coefficients

$C_f = 2.0$

→ A_f · Projected Area Normal to Wind

$A_f = 450.59834$ ft.²

$F_{14\times132 \text{ column}} = 7840.386$ lbs.

$\rightarrow q_z = 0.00256 K_z K_{zt} K_d V^2 I$ (lb/ft^2) [Eq. 6-15]

$\underline{K_z}$ → velocity pressure exposure coefficient [TABLE 6-3, pg. 79]

- Exposure C (CASE 2)
  - z @ centroid (60'-3") = 1.13
- for 15' ≤ z ≤ z_g

$$K_z = 2.01\left(\frac{z}{z_g}\right)^{2/\alpha} = 2.01\left(\frac{1.13}{900}\right)^{2/9.5} = 0.4925$$

TABLE 6-2, pg. 76

$z_g = 900$ ft.

$\alpha = 9.5$

$\underline{K_{zt}}$ → topographic factor [Sect. 6.5.7.2, 2D escarpment]

- treat building as a hill
- Figure 6-4 for K_1, K_2, & K_3 pg. 45

$$K_{zt} = (1 + K_1 K_2 K_3)^2 = (1 + 0.26(0.5)(0))^2 = 1.0$$

- H = 15' elevation change
- L_H = 50'-0"
- x = 100' escarpment along Porter Road
- z = 60'-3"

$\underline{K_1}$

$$\frac{H}{L_H} = \frac{15'}{50'} = 0.3$$

$\therefore K_1 = 0.26$

$\underline{K_2}$

$$\frac{x}{L_H} = \frac{100'}{50'} = 2.0$$

$\therefore K_2 = 0.5$

$\underline{K_3}$

$$\frac{z}{L_H} = \frac{60'-3"}{15'} = 4.017$$

$\therefore K_3 = 0.0$

→ $\underline{K_d}$ - wind directionally factor [Sect. 6.5.4.4]
· TABLE 6-4 pg. 80
· Open Sign & Lattice Framework

$K_d = 0.85$

→ $\underline{V}$
· Figure 6-1C, pg. 36

$V = 90$ mph

→ $\underline{I}$
· TABLE 6-1, pg. 77
· Category III
· Non-hurricane prone region

$I = 1.15$

$$\therefore q_z = 0.00256(0.4925)(1.0)(0.85)(90)^2(1.15) = 9.9826992 \text{ ft.}^2$$

→ $\underline{G_f}$ - flexible or dynamically sensitive structures

$$G_f = 0.925\left(\frac{1 + 1.7 I_{\bar{z}} \sqrt{g_Q^2 Q^2 + g_R^2 R^2}}{1 + 1.7 g_v I_{\bar{z}}}\right)$$

→ g_Q and g_v shall be taken as 3.4

→ $$g_R = \sqrt{2 \ln(3600 n_1)} + \frac{0.577}{\sqrt{2 \ln(3600 n_1)}} = 4.1894756$$
· $n_1 = 1$ Hz

→ $$R = \sqrt{\frac{1}{\beta} R_n R_h R_B (0.53 + 0.47 R_L)}$$

· $\beta = 1.0$

· $$R_n = \frac{7.47 N_1}{(1 + 10.3 N_1)^{5/3}} = \frac{7.47(6.186471)}{[1 + 10.3(6.186471)]^{5/3}} = 0.04466$$

· $$N_1 = \frac{n_1 L_{\bar{z}}}{\bar{V}_{\bar{z}}} = \frac{1(612.4568)}{100.291} = 6.1068$$
· $n_1 = 1$ Hz

Equation 6-7 pg. 26 · $$L_{\bar{z}} = l\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 500\left(\frac{92}{33}\right)^{1/5.0} = 612.4568$$

$\bar{z} = 92'$
$l = 500'$
$\bar{\epsilon} = 1/5.0$
] TABLE 6-2, pg. 78

$$\rightarrow \bar{V}_z = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}} V\left(\frac{88}{60}\right) = 100.291$$

- $\bar{b} = 0.65$ pg. 78
- $\bar{z} = 92'$
- $\bar{\alpha} = 1/6.5$ pg. 78
- $V = 90$ mph

$$R_{h,B,L} = \frac{1}{\eta} - \frac{1}{2\eta^2}\left(1 - e^{-2\eta}\right) \quad \text{for } \eta > 0$$

- for R_h, $\eta = 4.6\frac{n_1 h}{\bar{V}_z} = 4.6\left(\frac{1(92)}{100.291}\right) = 4.173$

$R_h = 0.21089$

- for R_B, $\eta = 4.6\frac{n_1 EB}{\bar{V}_z} = 4.6\left(\frac{72.6667(1)(1)}{100.291}\right) = 3.333$ (↙ ℄ of building)

$R_B = 0.2551$

- for R_L, $\eta = 15.4\frac{n_1 L}{\bar{V}_z} = 15.4\left(\frac{1(42.6667)}{100.291}\right) = 6.5516$ (↙ tributary area)

$R_L = 0.146672419$

$\therefore R = 0.0346314$

$$\rightarrow I_z = c\left(\frac{33}{z}\right)^{1/6} = 0.16889$$

- $z = 92'$
- $c = 0.2$ TABLE 6-2, pg. 78

$$\rightarrow Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_z}\right)^{0.63}}} = 0.8856$$

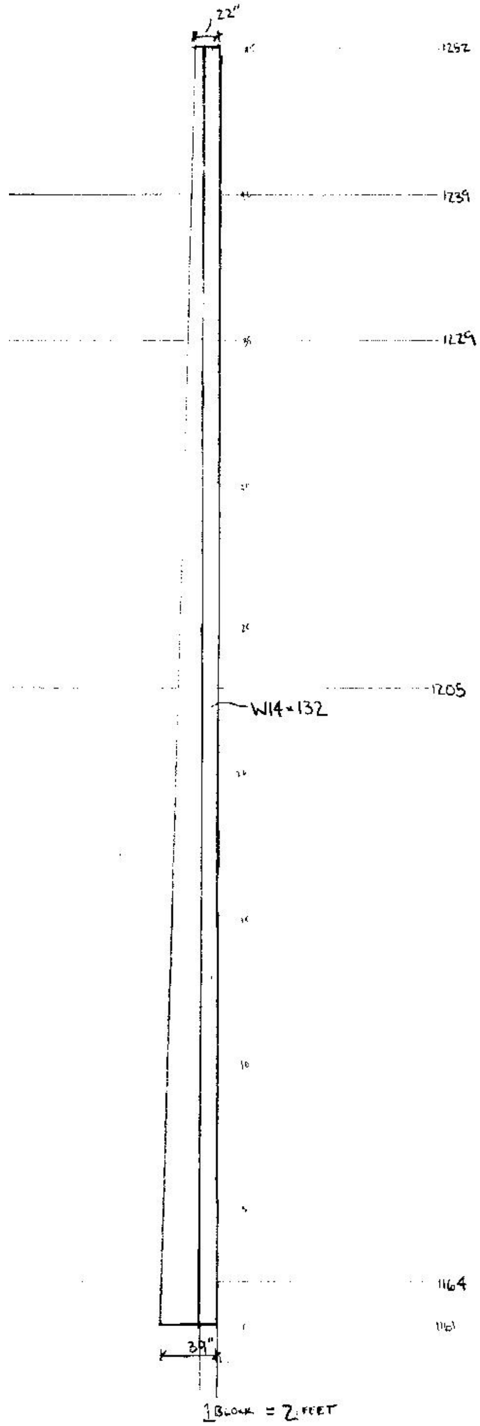
- $B = 72.66667'$
- $h = 92'$
- $L_z = 612.4568$

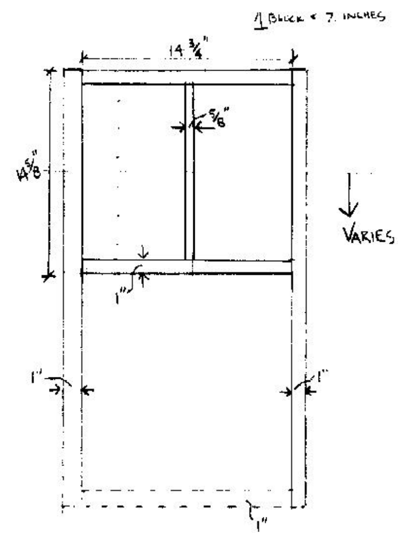
$\therefore G_f = 0.871505873$

$\rightarrow C_f = 2.0$ TABLE pg. 75

A_f Calculation				
Member	d or bf (in.)	d or bf (ft.)	Length (ft.)	Area (ft.^{2})
W14 x 132	14.7	1.225	92	112.7
HSS 12x8x5/16	12	1	42.666667	42.666667
HSS 12x8x5/16	12	1	42.666667	42.666667
HSS 12x8x5/16	12	1	42.666667	42.666667
HSS 8x8x1/4	8	0.66666667	42.666667	28.44444467
HSS 8x8x1/4	8	0.66666667	42.666667	28.44444467
HSS 8x8x1/4	8	0.66666667	42.666667	28.44444467
C12 x 20.7	2.94	0.245	3	0.735
C12 x 20.7	2.94	0.245	3	0.735
C12 x 20.7	2.94	0.245	3	0.735
C12 x 20.7	2.94	0.245	3	0.735
1" stiffner plate	14.7	1.225	92	112.7
1" stiffner plate	1	0.08333333	92	7.666666667
1" stiffner plate	1	0.08333333	92	7.666666667
			TOTAL A_f	**457.0066683**

ACTUAL DESIGN

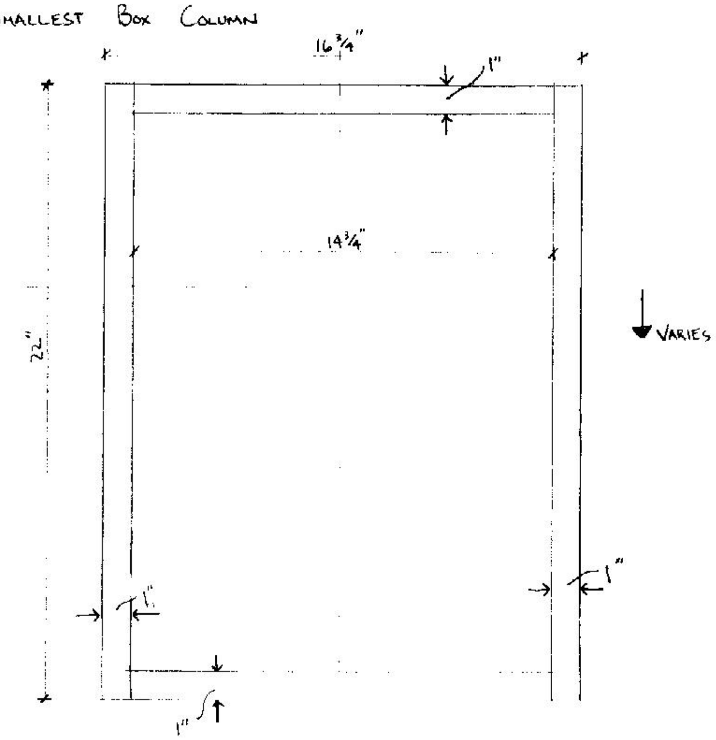




RE - DESIGN

1 BLOCK = 1 INCH

SMALLEST BOX COLUMN



PLASTIC SECTION MODULUS

$$Z = \frac{bd^2}{4} - \frac{b_1 d_1^2}{4}$$

@ 1161'-0"

$$Z = \frac{16.75(39)^2}{4} - \frac{14.75(37)^2}{4} = 1321 \text{ in}^3$$

$$\phi M_n = \phi_b F_y Z$$
$$= 0.9(36 \text{ k/in}^2)(1321 \text{ in}^3)(1 \text{ ft}/12 \text{ in})$$
$$= 3566.7 \text{ ft k}$$

$$M_u = 1.1^k(91') + 1.7^k(78') + 1.7^k(68') + 1.7^k(44') + 1.64^k(45.5')$$
$$= 497.72 \text{ ft-k}$$

$$M_u \le \phi M_n$$
$$497.72 \le 3566.7 \quad \underline{OK}$$

@ 1164'-0"

$$\frac{x}{205.767} = \frac{39}{208.767} \Rightarrow x = 38.44''$$

$$Z = \frac{16.75(38.44)^2}{4} - \frac{14.75(36.44)^2}{4} = 1291.057 \text{ in}^3$$

$$\phi M_n = \phi_b F_y Z$$
$$= 0.9(36 \text{ k/in}^2)(1291.057)(1/12)$$
$$= 3485.9 \text{ ft-k}$$

$$M_u = 1.1^k(88') + 1.7^k(75') + 1.7^k(65') + 1.7^k(41') + 1.64^k(44')$$
$$= 476.66 \text{ ft-k}$$

$$M_u \le \phi M_n \quad \underline{OK}$$

@ 1205'-0"

$$\frac{x}{164.767} = \frac{39}{208.767} \Rightarrow x = 30.78''$$

$$Z = \frac{16.75(30.78)^2}{4} - \frac{14.75(28.78)^2}{4} = 912.96 \text{ in}^3$$

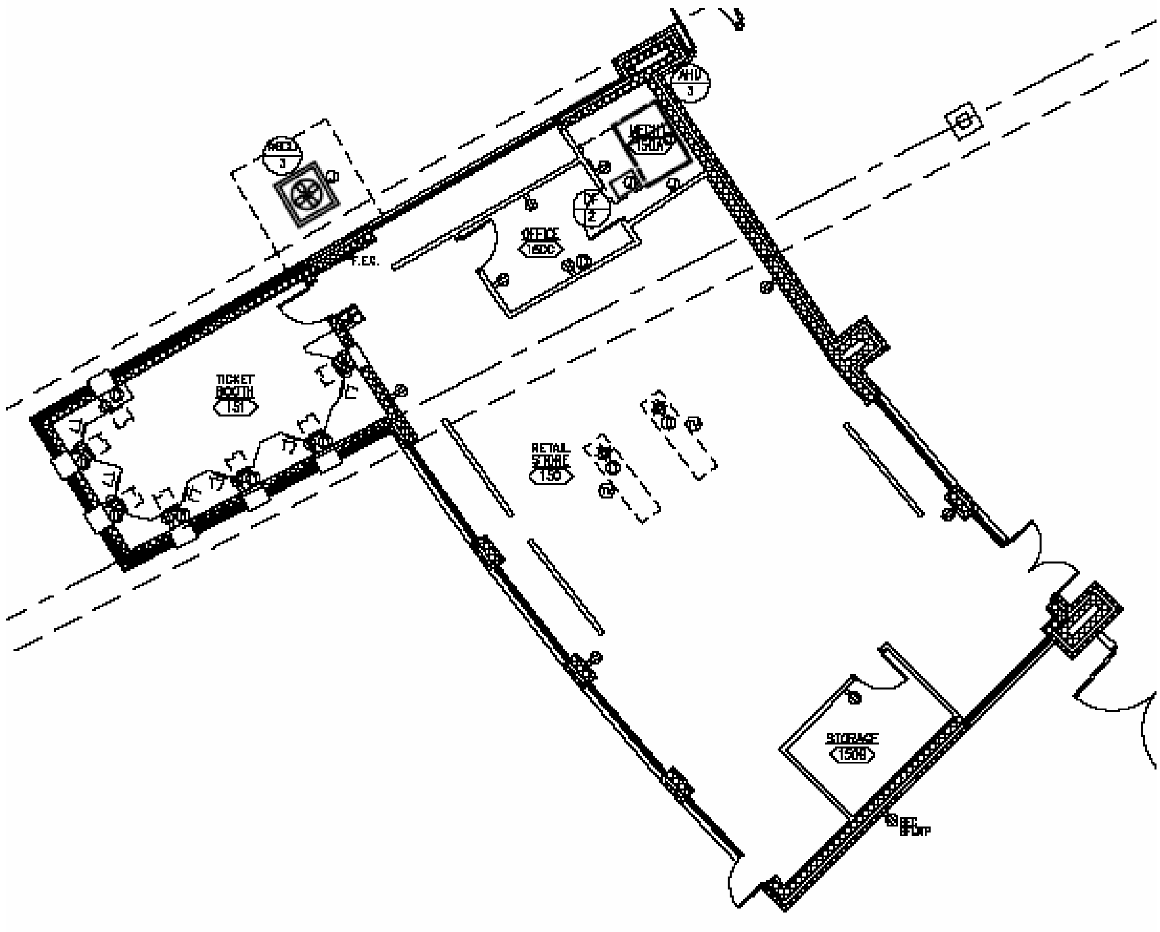
$$\phi M_n = \phi_b F_y Z$$
$$= 0.9(36 \text{ k/in}^2)(912.96)$$
$$= 2464.98 \text{ ft-k}$$

$$M_u = 1.1^k(47') + 1.7^k(34') + 1.7^k(24') + 1.64^k(23.5')$$
$$= 188 \text{ ft-k}$$

$$M_u \le \phi M_n \quad \underline{OK}$$

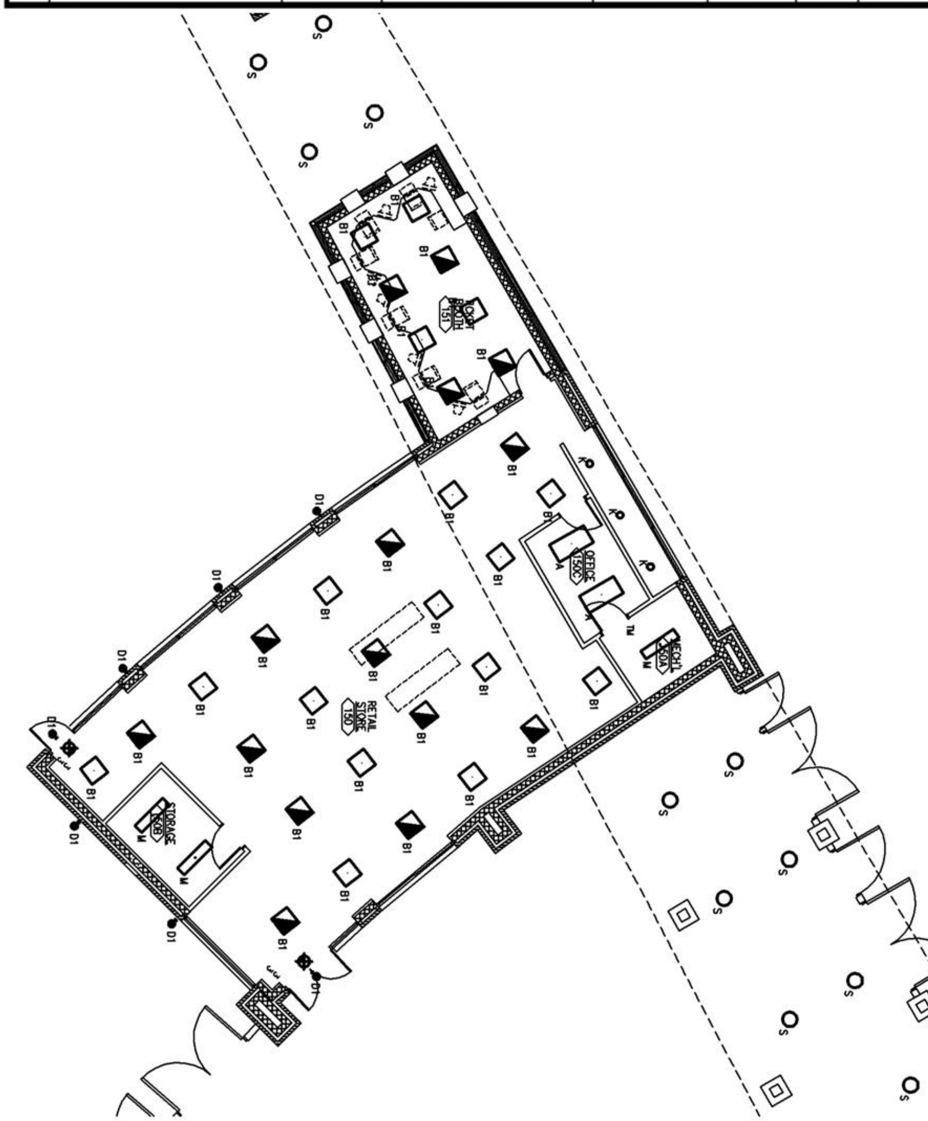
APPENDIX

ELECTRCIAL SUPPLY AT RETAIL BUILDING



Power Plan for Retail Building (Area C)

Lighting Fixture Schedule (Concourse Level - Area C)							
Type	Description	Manufacturer	Catalog Number	Mounting	Lamps	Voltage	Input Watts
A	2' x 4' Recessed Parabolic	Lithonia	2PM3NGB33218LD277GEB	Recessed Grid	3-FO32-T8	277	90
B1	2' x 2' Lensed Troffer	Lithonia	2SP8G217A12125277GEB	Recessed Grid	2-FO17-T8	277	54
D1	Medium Wall Sconce	Visa	CB6082 DBZ 277 1F50W	Surface Wall	1-50W TT	277	50
K	6" Open Downlight with Dimming	Gotham	AFW-1-32TRT-6-AR-277-DIM	Recessed Grid	1-32W CFL	277	36
M	4" Industrial 10% Uplight	Lithonia	AF10232277GEB	Chain Hung	2-FO32-T8	277	61
S	11" Round Wet Location	Kirlin	FRR-11040-43--13	Recessed	2-42W CFL	277	57



Lighting Plan for Retail Building (Area C)

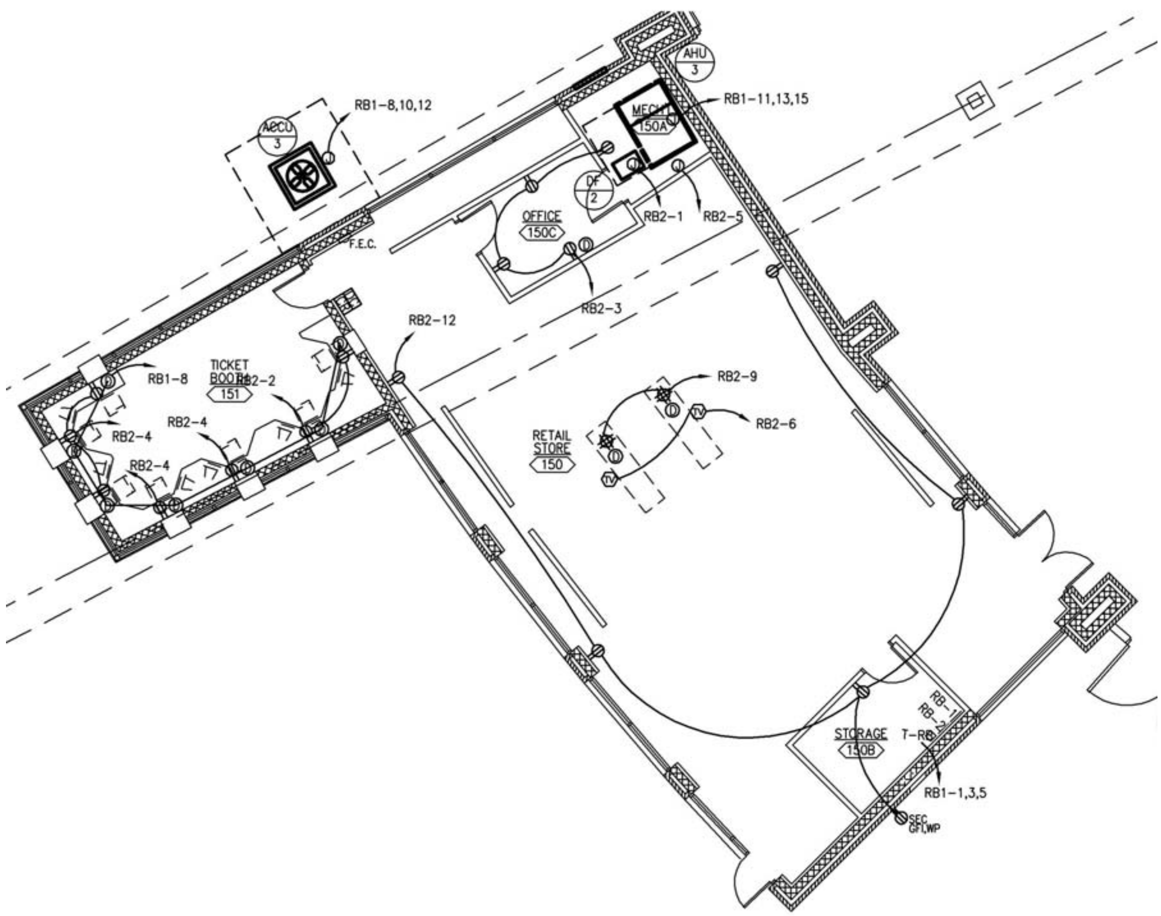
Panel Schedule

Panel: RB-1																			
Voltage: 480Y/277			Mains: MLO		Loads (VA)										Loc: STORAGE 150B (Area C)			AIC: 18K	
Amps: 100A	Wires: 4		Phase: 3												Mounting: SURFACE				
Branch Circuit	Amp	P	Description	Cir	Ltg		Recept		Motor		Lg Motor		Equip		Cir	Description	P	Amp	Branch Circuit
----	----	---	---	1		342	720						1910		2	Lighting Canopy (West)	1	20	3/4"C / 3#12+1#12GRD
3/4"C / 3#10+1#8GRD	30	3	Transformer RB-2	3		216	2520								4	Lighting Ticket Booth	1	20	3/4"C / 3#12+1#12GRD
----	-	-	---	5		363	2700		250						6	Lighting Mech., Office, Stor.	1	20	3/4"C / 3#12+1#12GRD
3/4"C / 3#12+1#12GRD	20	1	Lighting Canopy (East)	7	456							6033			8	---	---	----	----
3/4"C / 3#12+1#12GRD	20	1	Ligthing Retail Store	9	810							6033			10	ACCU-3	3	30	3/4"C / 3#8+1#8GRD
----	----	---	----	11					497			6033			12	---	---	----	----
3/4"C / 3#12+1#12GRD	20	3	AHU-3	13					497						14	-	-	-	-
----	----	---	----	15					497						16	-	-	-	-
-	-	-	-	17											18	-	-	-	-
-	-	-	-	19											20	-	-	-	-
-	-	-	-	21											22	-	-	-	-
-	-	-	-	23											24	-	-	-	-
Connected Load Phase A: (A)			36.0			798		720		497		6033.3		1910		Demand Load Phase A: (A)	42.1		
Connected Load Phase B: (A)			36.4			1026		2520		497		6033.3		0		Demand Load Phase B: (A)	42.7		
Connected Load Phase C: (A)			35.5			363		2700		747		6033.3		0		Demand Load Phase C: (A)	41.3		
Total VA:		34950																	
Load: (A)		42.1																	
25% Growth: (A)		52.6																	

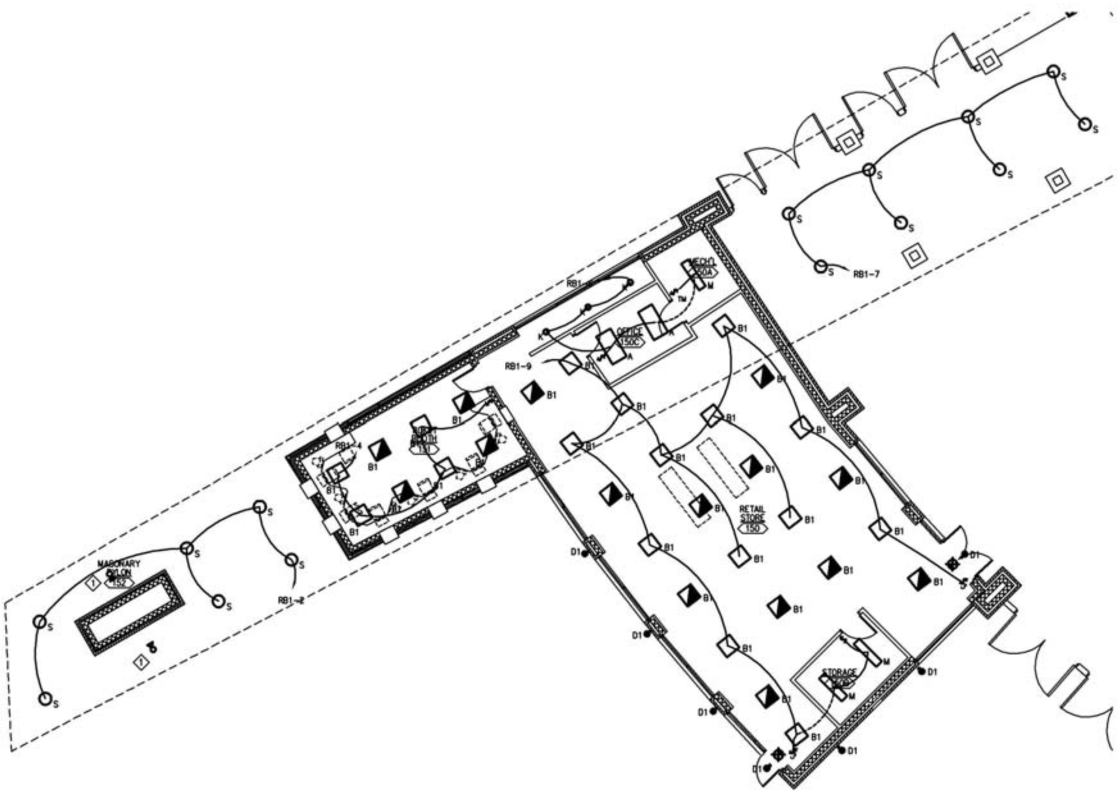
Proposed 480Y/277V Panel in Retail Building Storage Room

Panel Schedule																			
Panel: RB-2																			
Voltage: 208Y/120			Mains: MCB		Loads (VA)										Loc: STORAGE 150B (Area C)			AIC:	18K
Amps: 50A	Wires: 4		Phase: 3												Mounting: SURFACE				
Branch Circuit	Amp	P	Description	Cir	Ltg		Recept		Motor		Lg Motor		Equip		Cir	Description	P	Amp	Branch Circuit
3/4"C / 2#12+1#12GRD	20	1	DF-2	1				720					230		2	Rm. 151 Receptacles	1	20	3/4"C / 2#12+1#12GRD
3/4"C / 2#12+1#12GRD	20	1	Rm. 150A/C Receptacles	3			1080	720							4	Rm. 151 Receptacles	1	20	3/4"C / 2#12+1#12GRD
3/4"C / 2#12+1#12GRD	20	1	Pressure Switch & Pump	5				360			250				6	Rm. 150 Televisions	1	20	3/4"C / 2#12+1#12GRD
-	20	1	SPARE	7										1680	8	Ticket Window	1	20	3/4"C / 2#12+1#12GRD
3/4"C / 2#12+1#12GRD	20	1	Rm. 150 Quad Receptacles	9			720								10	SPARE	1	20	-
-	-	-	-	11				1080							12	Rm. 150 Receptacles	1	20	3/4"C / 2#12+1#12GRD
-	-	-	-	13											14	-	-	-	-
-	-	-	-	15											16	-	-	-	-
-	-	-	-	17											18	-	-	-	-
-	-	-	-	19											20	-	-	-	-
-	-	-	-	21											22	-	-	-	-
-	-	-	-	23											24	-	-	-	-
Connected Load Phase A: (A)			21.9			0		720		0		0		1910		Demand Load Phase A: (A)	21.9		
Connected Load Phase B: (A)			21.0			0		2520		0		0		0		Demand Load Phase B: (A)	21.0		
Connected Load Phase C: (A)			14.1			0		1440		0		250		0		Demand Load Phase C: (A)	14.6		
Total VA:		6903																	
Load: (A)		19.2																	
25% Growth: (A)		24.0																	

Proposed 208Y/120V Panel in Retail Building Storage Room



Proposed Power Circuiting Plan for Retail Building (Area C)



Proposed Lighting Circuiting Plan for Retail Building (Area C)

Designed System Component Pricing								
Equipment Type	Product Number	Quantity	Material Cost	Total Material Cost	Labor Quantity	Labor Cost ($/hr)	Total Labor Cost	Total Cost
FEEDER (3 #12)	Electrical Supplier	5775	0.30	1732.50	115.5	29.58	3416.49	5148.99
EMT (3/4")	Electrical Supplier	1925	0.90	1732.50	154.0	29.58	4555.32	6287.82
FEEDER (5 #8)	Electrical Supplier	1375	0.20	275.00	16.5	29.58	488.07	763.07
EMT (3/4")	Electrical Supplier	275	0.90	247.50	22.0	29.58	650.76	898.26
FEEDER (5 #12)	Electrical Supplier	1375	0.30	412.50	16.5	29.58	488.07	900.57
EMT (3/4")	Electrical Supplier	275	0.90	247.50	22.0	29.58	650.76	898.26
FEEDER (5 #12)	Electrical Supplier	4125	0.30	1237.50	49.5	29.58	1464.21	2701.71
EMT (3/4")	Electrical Supplier	825	0.90	742.50	66.0	29.58	1952.28	2694.78
CIRCUIT BREAKER (20A - PNL RC1)	QOB120	8	26.50	212.00	1.0	29.58	29.58	241.58
CIRCUIT BREAKER (20A - PNL MP1)	EDB34020	1	754.00	754.00	1.0	29.58	29.58	783.58
CIRCUIT BREAKER (30A - PNL MP2)	EDB34030	1	754.00	754.00	1.0	29.58	29.58	783.58
CIRCUIT BREAKER (20A - PNL LP2)	EDB14020	3	170.00	510.00	1.0	29.58	29.58	539.58
							Total Cost:	**$22,641.78**

Designed System Component Pricing

Proposed System Component Pricing								
Equipment Type	Product Number	Quantity	Material Cost	Total Material Cost	Labor Quantity	Labor Cost ($/hr)	Total Labor Cost	Total Cost
PANEL RB-1	NQOD424L100CU	1	708.00	708.00	1.0	29.58	29.58	737.58
PANEL RB-1 BOX	MH23	1	75.00	75.00	1.0	29.58	29.58	104.58
PANEL RB-1 COVER	MHC23	1	293.00	293.00	1.0	29.58	29.58	322.58
PANEL RB-1 (60A BREAKER)	FCL34060	1	1206.00	1206.00	1.0	29.58	29.58	1235.58
FEEDER (4 #4)	Electrical Supplier	1200	0.64	768.00	18.0	29.58	532.44	1300.44
FEEDER GROUND (#8)	Electrical Supplier	300	0.20	60.00	0.0	0.0	0.00	60.00
PVC (1 1/4")	Electrical Supplier	300	1.35	405.00	24.0	29.58	709.92	1114.92
CIRCUIT BREAKER (20A - PNL RB1)	EGB14020	5	170.00	850.00	1.0	29.58	29.58	879.58
CIRCUIT BREAKER (30A - PNL RB1)	EGB34030	2	754.00	1508.00	1.0	29.58	29.58	1537.58
CIRCUIT BREAKER (20A - PNL RB1)	EGB34020	1	754.00	754.00	1.0	29.58	29.58	783.58
TRANSFORMER T-RB	15T2F	1	2322.00	2322.00	24.0	29.58	709.92	3031.92
FEEDER (3 #10)	Electrical Supplier	15	0.25	3.75	0.3	29.58	8.87	12.62
FEEDER GROUND (#8)	Electrical Supplier	20	0.20	4.00	0.0	0.0	0.00	4.00
EMT (3/4")	Electrical Supplier	5	0.90	4.50	0.4	29.58	11.83	16.33
PANEL RB-2	NQOD424L50CU	1	708.00	708.00	1.0	29.58	29.58	737.58
PANEL RB-2 BOX	MH23	1	75.00	75.00	1.0	29.58	29.58	104.58
PANEL RB-2 COVER	MHC23	1	293.00	293.00	1.0	29.58	29.58	322.58
PANEL RB-2 (30A BREAKER)	FCL34030	1	1206.00	1206.00	1.0	29.58	29.58	1235.58
FEEDER (4 #10)	Electrical Supplier	20	0.25	5.00	0.3	29.58	8.87	13.87
FEEDER GROUND (#8)	Electrical Supplier	20	0.20	4.00	0.0	0.0	0.00	4.00
EMT (3/4")	Electrical Supplier	5	0.90	4.50	0.4	29.58	11.83	16.33
CIRCUIT BREAKER (20A - PNL RB2)	QOB120	10	26.50	265.00	1.0	29.58	29.58	294.58
							Total Cost:	**$13,870.40**

Proposed System Component Pricing

APPENDIX

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

RESEARCH COVER LETTER

My name is Jason McFadden and I am currently a senior architectural engineering student pursuing an integrated bachelor and master degree in the construction management option. I am performing a senior capstone project which is related to a current construction project in the industry. Part of my project is a research study related to “Streamlining the Superstructure Design and Construction through Computer Modeling.”

The goal of this research project is to address the following questions:

1. Can the construction industry reduce the waste in the steel procurement process through implementing building information modeling (BIM)?
2. Can BIM help with fabrication coordination (supply-chain management) between the structural steel, decking, and joist suppliers?

By analyzing existing practices (design, shop drawings, and coordination) during the steel phase of a project, I will propose a more streamline process for the steel phase of a project.

By evaluating the efforts to streamlining the superstructure design & construction through computer modeling, I aim to address better techniques in going from the structural design to the fabrication stage and erection of steel in this project. Because the steel phase of a project is often on the critical path, any time that might be able to be saved could result in a quicker delivery of the entire project. Upon completion, this research will benefit structural designers, construction managers, and steel fabricators as well as leave ideas for continued research in streamlining the design to construction of the structural sequence. Furthermore, I will be able to address better coordination techniques between steel suppliers.

By responding, I would like to schedule a thirty-minute phone conversation to discuss this study. Please let me know your availability. Thank you in advance for taking the time to participate in this study. Your insight will allow for a better understanding of the current problems associated with this topic. Please feel free to contact me should you have any other questions.

Respectfully,

Jason McFadden
The Pennsylvania State University
Integrated Bachelor and Master of Architectural Engineering candidate
Phone: (610) 914-8346
Email: jem358@psu.edu
http://www.arche.psu.edu/thesis/eportfolio/current/portfolios/jem358/

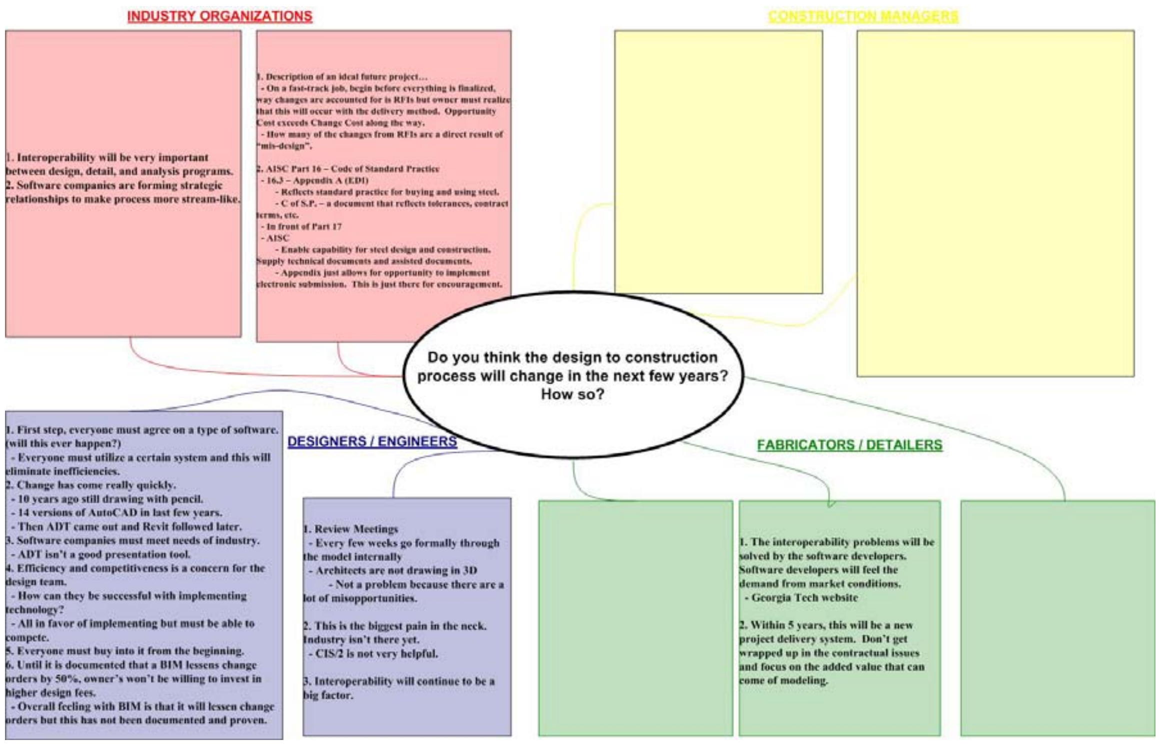
STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

CONFERENCE CALL INTERVIEW SCHEDULE

Contact Name	Group	Company	Conference Date and Time	Phone	Email
Ron Sinopoli	Construction Manager	Barton Malow Company	3/10/06 - - 11:00am (EST)	(434) 455-2447	ron.sinopoli@bartonmalow.com
Ryan Maibach	Construction Manager	Barton Malow Company	2/9/06 - - 10:30am (EST)	(734) 732-0934	ryan.maibach@bartonmalow.com
Erleen Hatfield	Design Firm	Thorton-Tomasetti	2/8/06 - - 2:00pm (EST)	(917) 570-6700	ehatfield@ttengineers.com
Kevin Fast	Design Firm	HOK Sports	2/22/06 - - 3:00pm (EST)	(816) 221-1500	kevin.fast@hok.com
Nathan Appleman	Design Firm	HOK Sport	2/22/06 - - 3:00pm (EST)	(816) 221-1500	nathan.appleman@hok.com
Babette Freund	Fabricator	Ritner Steel	3/7/06 - - 12:30pm (EST)	(717) 249-1449	bfreund@ritnersteel.com
Mark Holland	Fabricator	Paxton & Vierling Steel Co.	2/24/06 - - 3:30pm (EST)	(712) 347-4260	mvholland@compuserve.com
Glenn Sherrill	Fabricator	Steelfab of Alabama, Inc.	2/15/06 - - 12:30pm (EST)	(770) 248-0075	gsherrill@steelfab-inc.com
Charlie Carter	Industry Organization	AISC	3/7/06 - - 10:00am (EST)	(312) 670-5414	carter@aisc.org
Robert Lipman	Industry Organization	NIST	2/23/06 - - 10:00am (EST)	(301) 975-3829	robert.lipman@nist.gov

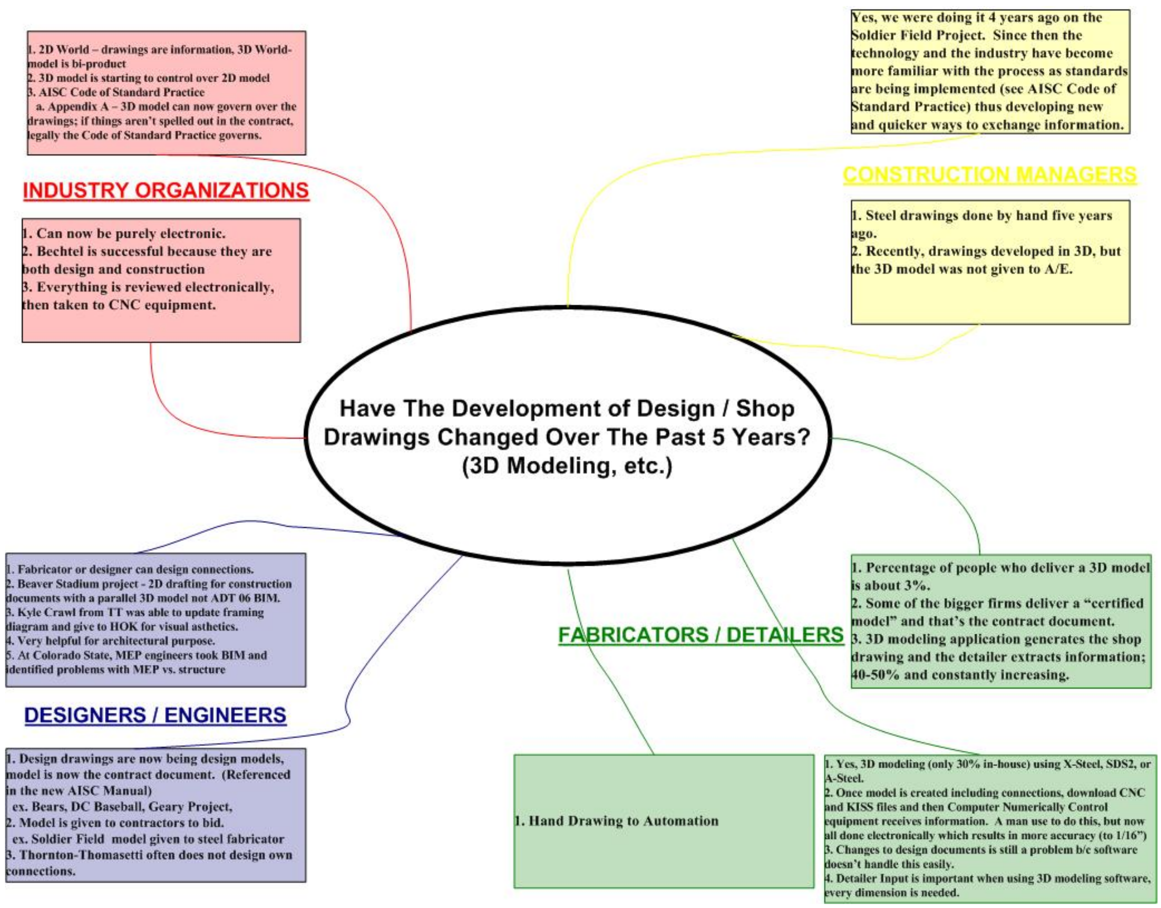
STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

COMPILED INTERVIEW RESPONSES



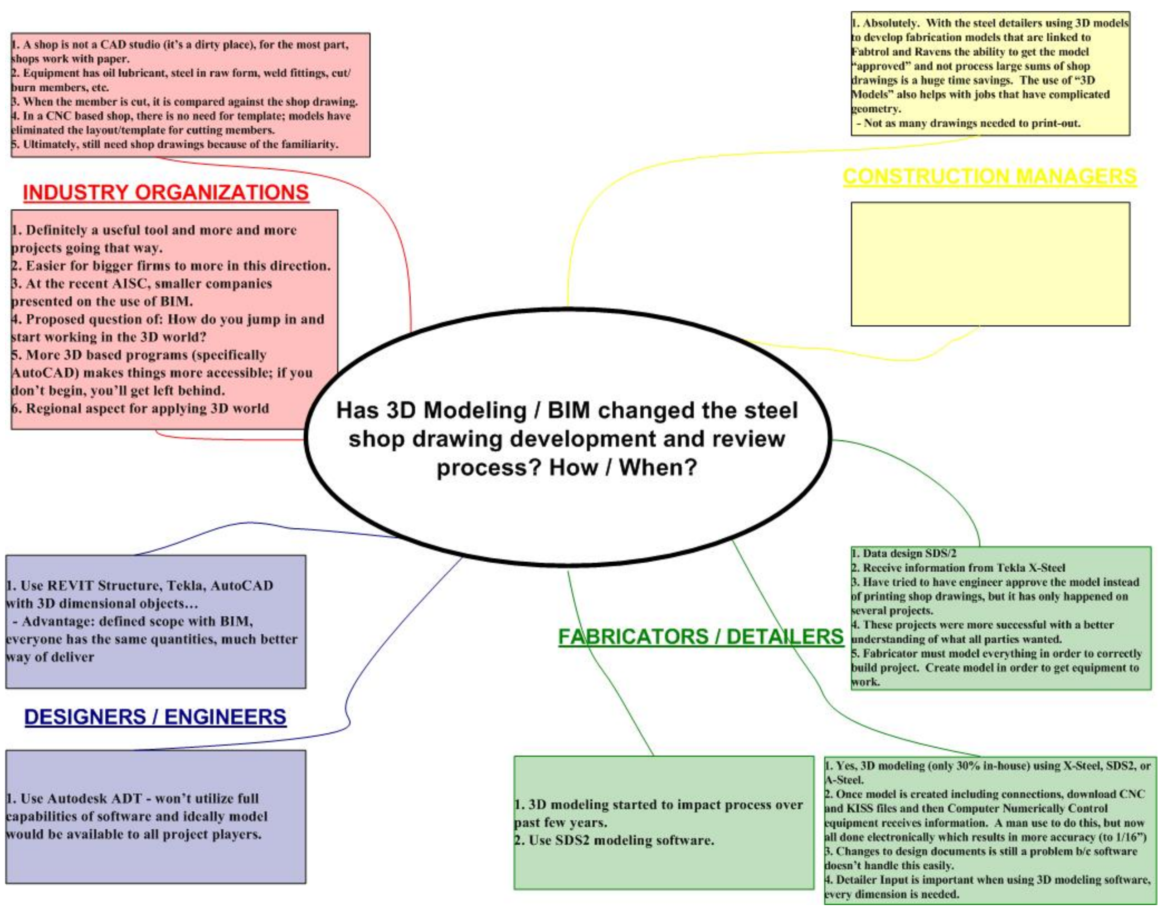
STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

COMPILED INTERVIEW RESPONSES



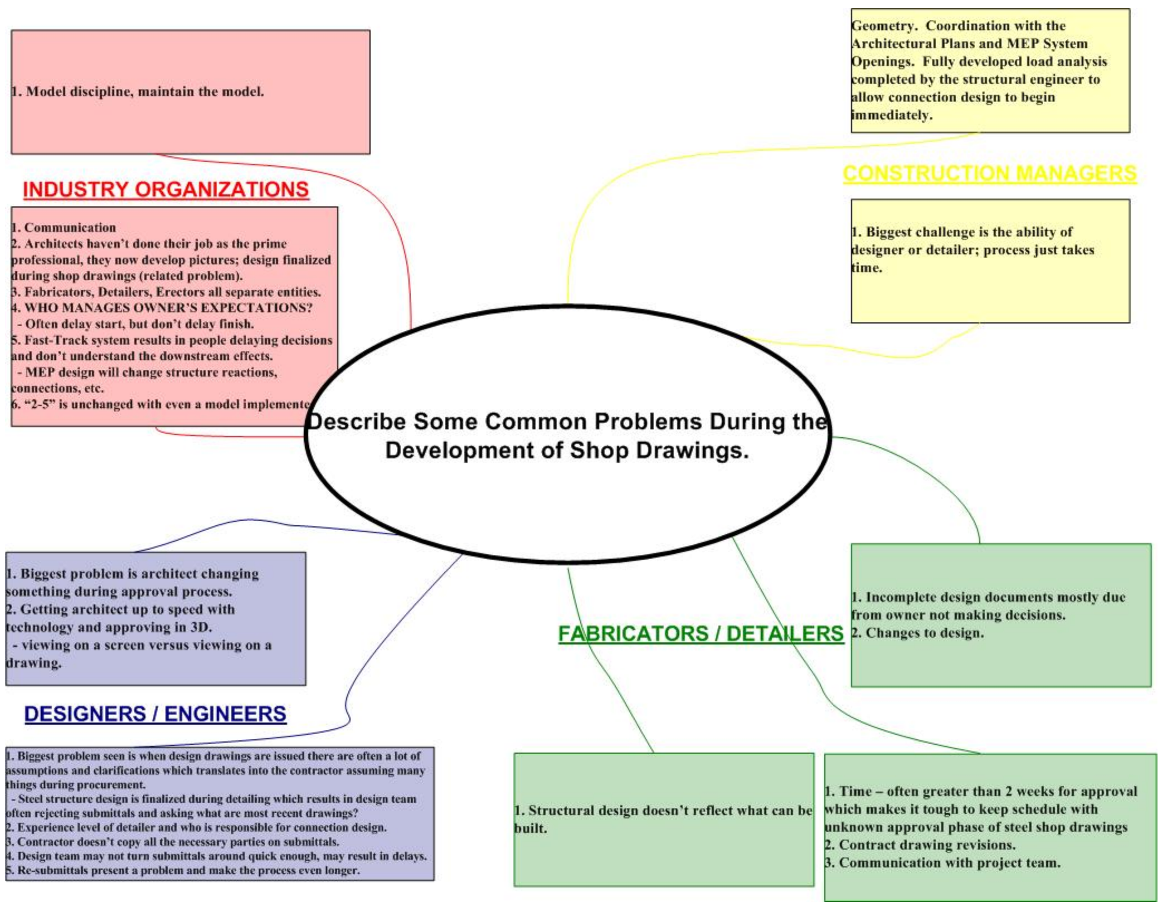
STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

COMPILED INTERVIEW RESPONSES



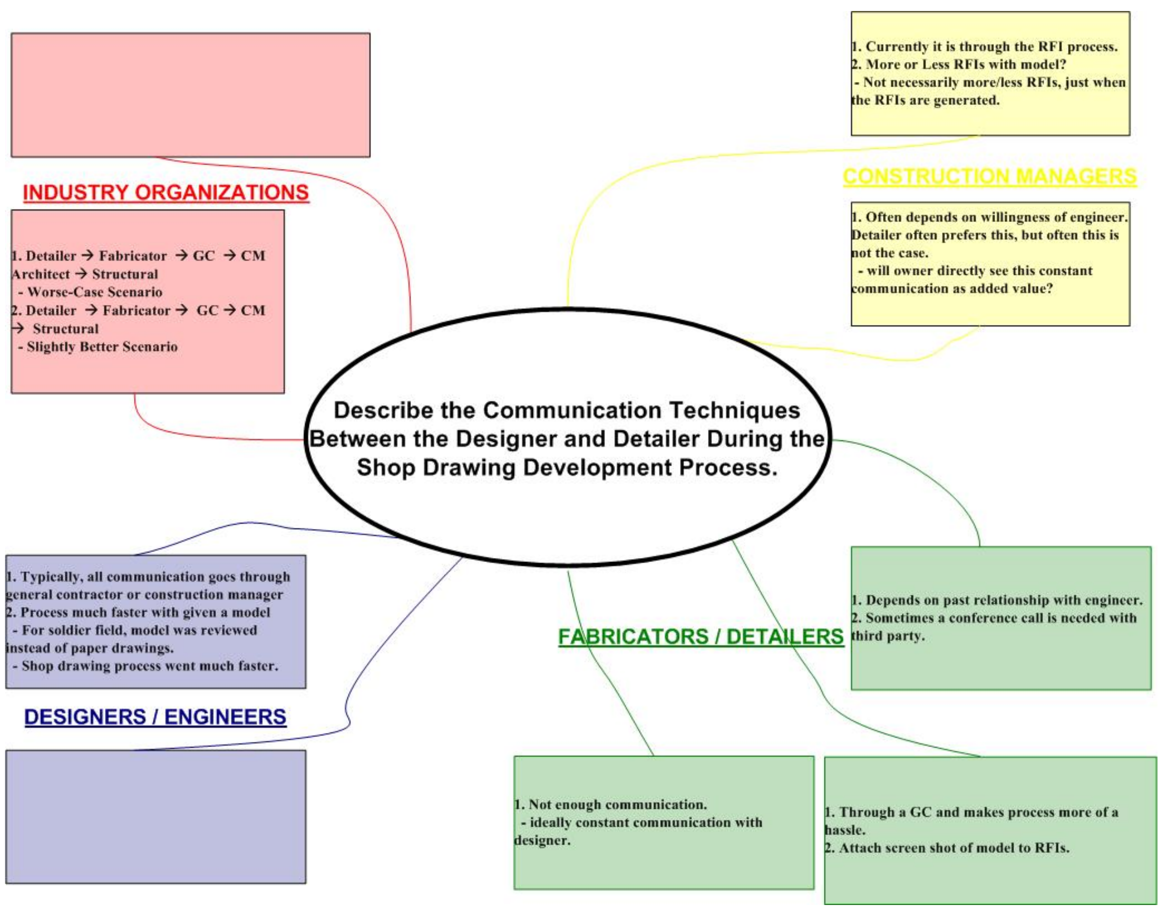
STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

COMPILED INTERVIEW RESPONSES



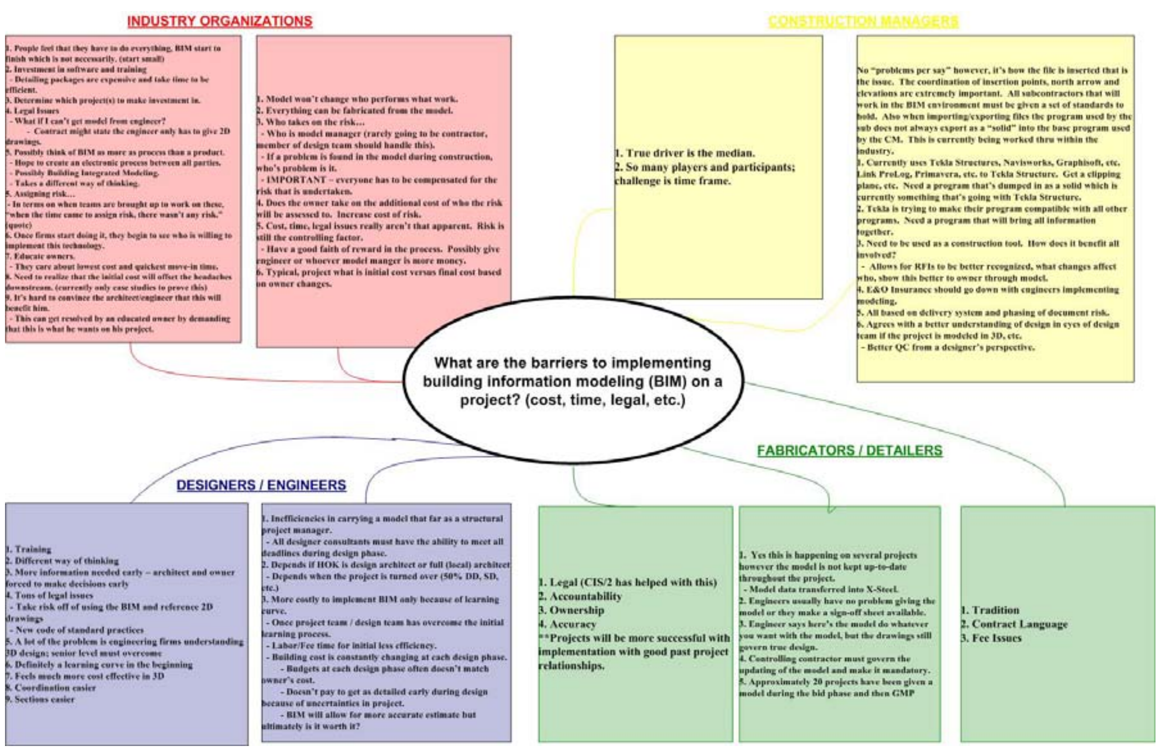
STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

COMPILED INTERVIEW RESPONSES



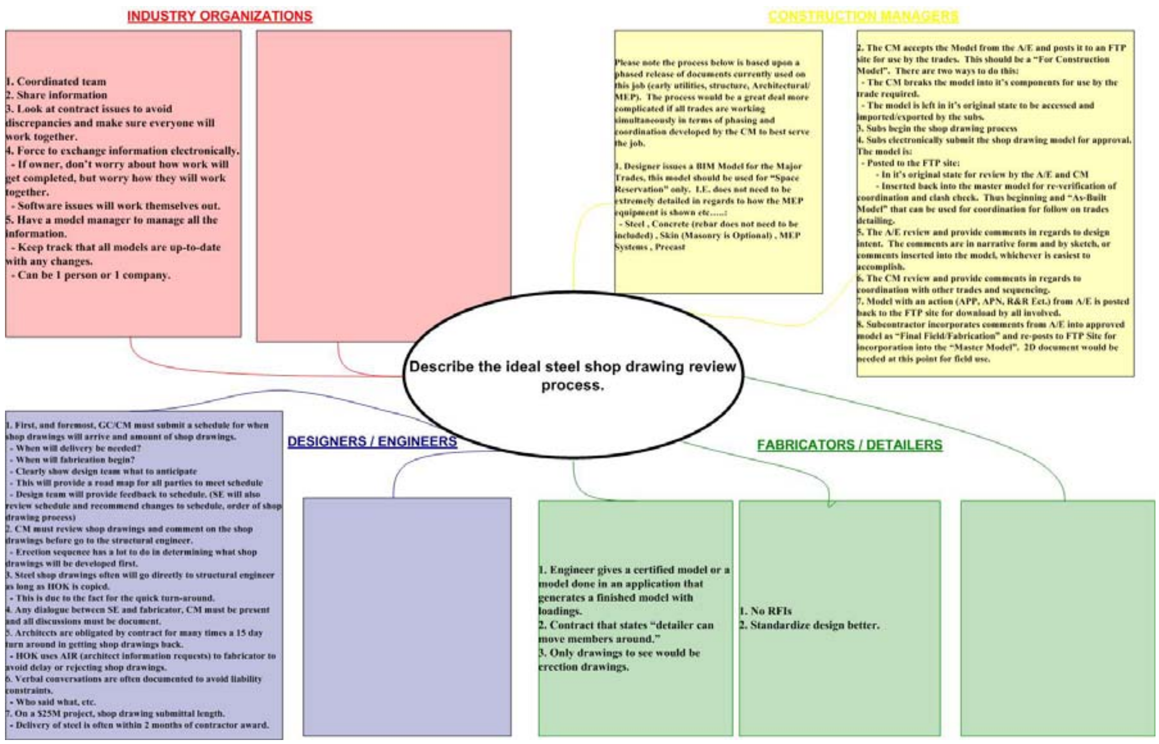
STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

COMPILED INTERVIEW RESPONSES



STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

COMPILED INTERVIEW RESPONSES



SAMPLE INTERVIEW QUESTIONS

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING
STEEL INDUSTRY/RESEARCH ORGANIZATION

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)

2. When did 3D modeling start to impact the process (if at all)?

3. How has digital fabrication changed the steel shop drawing development process?

4. What phase of a project does the steel detailer become involved? Does this ever occur during the structural design phase?

5. Describe the communication techniques between the designer and detailer during the shop drawing development process.

6. Describe some common problems during the development of shop drawings.

7. If a structural engineer develops the steel design in 3D will this benefit the detailer at all? If so, how? Also, are there any problems with an engineer developing the design in 3D?

8. What are the barriers to implementing building information modeling (BIM) on a project? (cost, time, legal, etc.)

9. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with BIM?

10. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

11. Describe the ideal steel shop drawing review process.

Robert Lipman (NIST) February 23, 2006
(301) 975-3829 10 A.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING
STEEL INDUSTRY/RESEARCH ORGANIZATION

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)
    a. Never been in construction industry, research has been involved with this area over the past few years.
    b. 2D World – drawings are information
    c. 3D World- model is bi-product
    d. 3D model is starting to control over 2D model
    e. AISC Code of Standard Practice
        i. Appendix A – 3D model can now govern over the drawings.
        ii. If things aren't spelled out in the contract, legally the Code of Standard Practice governs.

2. When did 3D modeling start to impact the process (if at all)?
    a. Definitely a useful tool and more and more projects going that way.
    b. Easier for bigger firms to more in this direction.
    c. At the recent AISC, smaller companies presented on the use of BIM.
        i. How do you jump in and start working in the 3D world?
    d. More 3D based programs (specifically AutoCAD)
        i. Makes things more accessible.
        ii. If you don't begin, you'll get left behind.
    e. Regional aspect for applying 3D world

3. How has digital fabrication changed the steel shop drawing development process?
    a. Shouldn't matter as long as your generate a CNC file.
    b. GM Plant Project
        i. Douglass Steel (detailing, fabricating, erection)
        Contact: Larry Kruth (lkruth@douglasssteel.com, 517-322-2050x54)
            1. received RAM model from engineer
            2. SDS/2 for detailing
            3. conscientious about keeping model updated in detailing (model detailing)
            4. fabrication process as out dated equipment
                a. no automated equipment (equipment from 1940)
                b. templates made from cardboard

c. equipment costs a lot of money and requires more shop room.
d. This process is successful for them since 1995.

4. What phase of a project does the steel detailer become involved? Does this ever occur during the structural design phase?

5. Describe the communication techniques between the designer and detailer during the shop drawing development process.

6. Describe some common problems during the development of shop drawings.
    a. Model discipline, maintain the model.

7. If a structural engineer develops the steel design in 3D will this benefit the detailer at all? If so, how? Also, are there any problems with an engineer developing the design in 3D?

8. What are the barriers to implementing building information modeling (BIM) on a project? (cost, time, legal, etc.)
    a. People feel that they have to do everything, BIM start to finish which is not necessarily.
        i. Start small.
    b. Investment in software and training
        i. Detailing packages are expensive and take time to be efficient.
    c. Determine which project(s) to make investment in.
    d. Legal Issues
        i. What if I can't get model from engineer?
            1. Contract might state the engineer only has to give 2D drawings.
    e. Possibly think of BIM as more as process than a product.
        i. Hope to create an electronic process between all parties.
        ii. Possibly Building Integrated Modeling.
        iii. Takes a different way of thinking.
    f. Assigning risk…
        i. In terms on when teams are brought up to work on these, "when the time came to assign risk, there wasn't any risk." (quote)
    g. Once firms start doing it, they begin to see who is willing to implement this technology.
    h. Educate owners.
        i. They care about lowest cost and quickest move-in time.
        ii. Need to realize that the initial cost will offset the headaches downstream.
            1. currently only case studies to prove this.

2. Contact: Puma Steel
    a. Team Puma – technology, BIM, group
    b. They talked about smaller.

i. It's hard to convince the architect/engineer that this will benefit him.
    i. This can get resolved by an educated owner by demanding that this is what he wants on his project.

9. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with BIM?

10. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how? Interoperability….
    a. Autodesk Revit Structure with their definition of BIM (fairly good definition)
    b. CIS/2 – standard for steel
        i. Been very successful between moving files around in detailing, design, analysis, etc.
        ii. RAM doesn't import a CIS/2 for analysis.
            3. RAM doesn't have any plans to change this.
        iii. More software companies are starting to support CIS/2.
    c. IFC – standard for building industry
        i. Life cycle of building is very important but not very detailed in terms of steel.
        ii. Packages like ArchiCAD, ADT…
        iii. Information for the building world.
    d. Bentley Structure (bought RAM and STAAD) supports many files natively.
        i. Design model in Bentley and now have ability to bring into RAM for analysis.
            4. can do everything with one program similar to Tekla.
        ii. Companies are forming strategic relationships to make process more streamlike.
        iii. Still prioritize relationship.
    e. More software choices now available.
    f. Team for the project is vital.
        i. Between owner, designer, contractor, etc.
    g. Navisworks – ability to bring many file formats in but not import anything out.
    h. Still many older types of software as well.
        i. SDS/2, Fabtrol, etc.

11. Describe the ideal steel shop drawing review process.

a. Coordinated team
b. Share information
c. Look at contract issues to avoid discrepancies and make sure everyone will work together.
d. Force to exchange information electronically.
    i. If owner, don't worry about how work will get completed, but worry how they will work together.
    ii. Software issues will work themselves out.
e. Have a model manager to manage all the information.
    i. Keep track that all models are up-to-date with any changes.
    ii. Can be 1 person or 1 company.

12. Words of Wisdom
f. BIM is not drawing, drawings are just a bi-product… looking to create information not drawings.
    i. Previously, a wall only contained dimensions, now an information model contains other properties.

Charlie Carter (AISC) March 7, 2006
(312) 670-5414 10 A.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

STEEL INDUSTRY/RESEARCH ORGANIZATION

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)
    a. Can now be purely electronic.
    b. Bechtel is successful because they are both design and construction.
        i. Everything is reviewed electronically.
        ii. Then taken to CNC equipment.
        iii. Pete Carrato (engineer)
            5. P: 301-228-7611
            6. E: pcarrato@bechtel.com
    c. Rex Lewis
        i. Phone: 307-637-7177
        ii. Email: rex.lewis@pumasteel.com

2. When did 3D modeling start to impact the process (if at all)?
    a. A shop is not a CAD studio (it's a dirty place).
        i. For the most part, shops work with paper.
    b. Equipment has oil lubricant, steel in raw form, weld fittings, cut/burn members, etc.
    c. When the member is cut, it is compared against the shop drawing.
    d. In a CNC based shop, there is no need for template.
        i. Models have eliminated the layout/template for cutting members.
    e. Ultimately, still need shop drawings because of the familiarity.

3. How has digital fabrication changed the steel shop drawing development process?
    a. See above.

4. What phase of a project does the steel detailer become involved? Does this ever occur during the structural design phase?
    a. Model tends to force everyone to be involved earlier.
        i. Detailer often forced to talk directly with engineer.
        ii. Forces faster communication.
    b. Paper tends to eliminate the detailer to become involved earlier.
        i. Detailer often prevented to talk directly with engineer.

5. Describe the communication techniques between the designer and detailer during the shop drawing development process.

   a. Detailer → Fabricator → GC → CM → Architect → Structural
      i. Worse-Case Scenario
   b. Detailer → Fabricator → GC → CM → Structural
      i. Slightly Better Scenario

6. Describe some common problems during the development of shop drawings.
   a. Communication
   b. Architects haven't done their job as the prime professional.
      i. They now develop pictures
      ii. Design finalized during shop drawings (related problem).
   c. Fabricators, Detailers, Erectors all separate entities.
   d. **WHO MANAGES OWNER'S EXPECTATIONS???**
      i. Often delay start, but don't delay finish.
   e. Fast-Track system results in people delaying decisions and don't understand the downstream effects.
      i. MEP design will change structure reactions, connections, etc.
   f. "B-E" is unchanged with even a model implemented.

7. If a structural engineer develops the steel design in 3D will this benefit the detailer at all? If so, how? Also, are there any problems with an engineer developing the design in 3D?
   a. See above.

8. What are the barriers to implementing building information modeling (BIM) on a project? (cost, time, legal, etc.)
   a. Model won't change who performs what work.
   b. Everything can be fabricated from the model.
   c. Who takes on the risk…
      i. Who is model manager (rarely going to be contractor, member of design team should handle this).
      ii. If a problem is found in the model during construction, who's problem is it.
      iii. IMPORTANT – everyone has to be compensated for the risk that is undertaken.
   d. Does the owner take on the additional cost of who the risk will be assessed to. Increase cost of risk.
   e. Cost, time, legal issues really aren't that apparent. Risk is still the controlling factor.
      i. Have a good faith of reward in the process. Possibly give engineer or whoever model manger is more money.
   f. Typical, project what is initial cost versus final cost based on owner changes.

9. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with BIM?

10. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

11. Describe the ideal steel shop drawing review process.

12. Description of project…
    a. On a fast-track job, begin before everything is finalized, way changes are accounted for is RFIs but owner must realize that this will occur with the delivery method. Opportunity Cost exceeds Change Cost along the way.
    b. How many of the changes from RFIs are a direct result of "mis-design".

13. New software…
    a. How to use technology.
        i. Marketplace will drive technology.
        ii. Will it increase process?
        iii. How does it benefit daily tasks.
    b. Autodesk Revit example (structure, building, MEP)
    c. Someone will get into this enough and learn the lessons and others will follow.
    d. Look at it as "Isn't the way we use technology great."

14. AISC Part 16 – Code of Standard Practice
    a. 16.3 – Appendix A (EDI)
        i. Reflects standard practice for buying and using steel.
        ii. C of S.P. – a document that reflects tolerances, contract terms, etc.
    b. In front of Part 17
    c. AISC
        i. Enable capability for steel design and construction. Supply technical documents and assisted documents.
        ii. Appendix just allows for opportunity to implement electronic submission. This is just there for encouragement.

SAMPLE INTERVIEW QUESTIONS

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

ARCHITECTS & STRUCTURAL ENGINEERS

1. How has your development of design drawings changed over the past five years? (3D modeling, etc.)

2. Do you currently develop a 3D model for your projects? If so what modeling software do you use? Is this model available to the contractor?

3. As a designer, what are the barriers to implementing 3D modeling/BIM on a project? (cost, time, value, legal, etc.)

4. What phase of a project does the steel detailer become involved? Does this ever occur during preconstruction?

5. Describe the communication techniques between the designer and detailer during the shop drawing development process.

6. Describe some common problems during the development of shop drawings.

7. Describe the ideal steel shop drawing review process.

8. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

Erleen Hatfield (Thornton-Tomasetti Group) February 8, 2006
(917) 570-6700 2 P.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING
ARCHITECTS & STRUCTURAL ENGINEERS

1. How has your development of design drawings changed over the past five years? (3D modeling, etc.)
    a. Design drawings are now being design models, model is now the contract document. (Referenced in the new AISC Manual)
        i. Bears, DC Baseball, Geary Project,
    b. Model is given to contractors to bid.
        i. Ex. Soldier Field → model given to steel fabricator
    c. Thornton-Tomasetti often does not design own connections.

2. Do you currently develop a 3D model for your projects? If so what modeling software do you use? Is this model available to the contractor?
    a. Revit Structure, Tekla, AutoCAD with 3D dimensional objects…
        i. Advantage: defined scope with BIM, everyone has the same quantities, much better way of deliver

3. As a designer, what are the barriers to implementing 3D modeling/BIM on a project? (cost, time, value, legal, etc.)
    a. Training
    b. Different way of thinking
    c. More information needed early – architect and owner forced to make decisions early
    d. Tons of legal issues
        i. Take risk off of using the BIM and reference 2D drawings
        ii. New code of standard practices
    e. A lot of the problem is engineering firms understanding 3D design; senior level must overcome
    f. Definitely a learning curve in the beginning
        i. Feels much more cost effective in 3D
    g. Coordination easier
    h. Sections easier

4. What phase of a project does the steel detailer become involved? Does this ever occur during preconstruction?
    i. TT has acquired a lot of detailers to work in the office to assist with assisting with design for details and connections.
        ii. Engineers with a fabrication background

        iii. This is a great resource for TT

5. Review Meetings
    a. Every few weeks go formally through the model internally
    b. Architects are not drawing in 3D
        i. Not a problem because there are a lot of misopportunities

6. Describe the communication techniques between the designer and detailer during the shop drawing development process.
    a. Typically, all communication goes through general contractor or construction manager
    b. Process much faster with given a model
        i. For soldier field, model was reviewed instead of paper drawings.
        ii. Shop drawing process went much faster.

7. Describe some common problems during the development of shop drawings.
    a. Biggest problem is architect changing something during approval process.
    b. Getting architect up to speed with technology and approving in 3D.
        i. Viewing on a screen versus viewing on a drawing.
            1. 21” desktop monitors

8. Describe the ideal steel shop drawing review process.
    a. Not applicable

9. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?
    a. This is the biggest pain in the neck. Industry isn’t there yet.
        i. CIS/2 is not very helpful.
    b. Interoperability
        i. TT writes a lot of the application data interchange in-house
        ii. Navisworks

10. Feels this is a very timely topic and relevant to the industry. TT is on the cutting edge with this information.

Nathan Appleman (HOK Sport) — February 22, 2006
Kevin Fast (HOK Sport)
(816) 221-1500 — 3 P.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING
ARCHITECTS & STRUCTURAL ENGINEERS

1. How has your development of design drawings changed over the past five years? (3D modeling, etc.)
    a. Fabricator or designer can design connections.
    b. Superstructure in a stadium becomes visual and architectural aspect of facility.
    c. Beaver Stadium project
        i. 2D drafting for construction documents with a parallel 3D model not ADT 06 BIM.
        ii. 3D systems weren't integrated
        iii. Kyle Crawl from TT was able to update framing diagram and give to HOK for visual aesthetics.
            1. Very helpful for architectural purpose.
    d. Struggle with BIM
        i. Consultants don't utilize software
            1. Interoperability
        ii. If they do have ability to use software…
            1. at Colorado State, MEP engineers took BIM and identified problems with MEP vs. structure
    e. Currently,
        i. Larger projects will often use BIM more so than smaller projects because often contain larger players.
        ii. Architects learning how to draw in 3D is often a hassle. (shifting with times)

2. Do you currently develop a 3D model for your projects? If so what modeling software do you use? Is this model available to the contractor?
    a. Autodesk ADT
        i. Won't utilize full capabilities of software
    b. Ideally, model would be available to all project players
        i. Have not been involved in a project that has done that.

3. As a designer, what are the barriers to implementing 3D modeling/BIM on a project? (cost, time, value, legal, etc.)
    a. Inefficiencies in carrying a model that far as a structural project manager.

        i. All designer consultants must have the ability to meet all deadlines during design phase.
    b. Depends if HOK is design architect or full (local) architect
        i. Depends when the project is turned over (50% DD, SD, etc.)
    c. More costly to implement BIM only because of learning curve.
        i. Once project team / design team has overcome the initial learning process.
        ii. Labor/Fee time for initial less efficiency.
        iii. Building cost is constantly changing at each design phase.
            1. Budgets at each design phase often don't match owner's cost.
            2. Doesn't pay to get as detailed early during design because of uncertainties in project.
            3. BIM will allow for more accurate estimate but ultimately is it worth it?

4. What phase of a project does the steel detailer become involved? Does this ever occur during preconstruction?
    a. Depends on size of project size/scope
    b. Qualifications of structural engineer
        i. Sometimes SE does not provide detailing services
        ii. Sometimes SE provides as "add" services
    c. Depends on delivery method of project
        i. D/B relationship between design team/construction team
    d. Detailer will add value for less headaches down the road
        i. Owner will have to determine if this extra cost is worth it.
        ii. Makes SD, fabrication, and CO process easier.
            1. Not perfect for small projects.
        iii. Important to understand what services a structural engineer provides.
            1. often just loads, forces, and some detailing.
            2. connection details and specifics by fabricator.
            3. ideally an engineer would provide everything
            (3 tiers)

5. Describe the communication techniques between the designer and detailer during the shop drawing development process.
    a. See Question #7

6. Describe some common problems during the development of shop drawings.
    a. Biggest problem seen is when design drawings are issued there are often a lot of assumptions and clarifications.

    i. This is meant that contractor has a lot of assumptions and clarifications and this is how steel is procured.
    ii. Steel structure design is finalized during detailing.
    iii. This results in design team often rejecting submittals.
        1. what are most recent drawings?

  b. Experience level of detailer and who is responsible for connection design.
  c. If contractor doesn't copy all the necessary parties on submittals.
  d. Design team may not turn submittals around quick enough, may result in delays.
  e. Re-submittals present a problem and make the process even longer.

7. Describe the ideal steel shop drawing review process.
    a. First, and foremost, GC/CM must submit a schedule for when shop drawings will arrive and amount of shop drawings.
        i. When will delivery be needed
        ii. When will fabrication begin
        iii. **Clearly show design team what to anticipate
        iv. *****This will provide a road map for all parties to meet schedule
        v. Design team will provide feedback to schedule. (SE will also review schedule and recommend changes to schedule, order of shop drawing process)
    b. CM must review shop drawings and comment on the shop drawings before go to the structural engineer.
        i. Erection sequence has a lot to do in determining what shop drawings will be developed first.
    c. Steel shop drawings often will go directly to structural engineer as long as HOK is copied.
        i. This is due to the fact for the quick turn-around.
    d. Any dialogue between SE and fabricator, CM must be present and all discussions must be document.
    e. Architects are obligated by contract for many times a 15 day turn around in getting shop drawings back.
        i. HOK uses AIR (architect information requests) to fabricator to avoid delay or rejecting shop drawings.
    f. Verbal conversations are often documented to avoid liability constraints.
        i. Who said what, etc.
    g. On a $25M project, shop drawing submittal length
        i. Delivery of steel is often within 2 months of contractor award.

8. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

a. First step, everyone must agree on a type of software. (will this ever happen?)
    i. Everyone must utilize a certain system and this will eliminate inefficiencies.
b. Change has come really quickly.
    i. 10 years ago still drawing with pencil.
    ii. 14 versions of AutoCAD in last few years.
    iii. Then ADT came out and Revit followed later.
c. Software companies must meet needs of industry.
    i. ADT isn’t a good presentation tool.
d. Efficiency and competitiveness is a concern for the design team.
    i. How can they be successful with implementing technology?
    ii. All in favor of implementing but must be able to compete.
e. Everyone must buy into it from the beginning.
f. Until it is documented that a BIM lessens change orders by 50%, owner’s won’t be willing to invest in higher design fees.
    i. Overall feeling with BIM is that it will lessen change orders but this has not been documented and proven.

SAMPLE INTERVIEW QUESTIONS

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

STEEL FABRICATORS & STEEL DETAILERS

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)

2. When did 3D modeling start to impact the process (if at all)?

3. Do you currently develop a 3D model for your projects? If so what modeling software do you use?

4. Is detailing of steel shop drawings performed in-house or is the contracted to a third party?

5. What phase of a project does the steel detailer become involved? Does this ever occur during the design phase?

6. Describe the communication techniques between the designer and detailer during the shop drawing development process.

7. Describe some common problems during the development of shop drawings.

8. If a structural engineer develops the steel design in 3D will this benefit the detailer? If so, how? Also, are there any problems with an engineer developing the design in 3D?

9. What are the barriers to implementing building information modeling (BIM) on a project? (cost, time, legal, etc.)

10. How has your fabrication process changed over the past five years? (digital fabrication, etc.)

11. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with BIM?

12. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

13. Describe the ideal steel shop drawing review process.

Glenn Sherrill (Steelfab of Alabama) February 15, 2006
(704) 394-5376 12:30 P.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

STEEL FABRICATORS & STEEL DETAILERS

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)
    a. Yes, 3D modeling (only 30% in-house)
        i. X-Steel
        ii. SDS/2
        iii. A-Steel
    b. Once model is created including connections, download CNC and KISS files and then Computer Numerically Control equipment receives information
        i. A man use to do this, but now all done electronically
        ii. More accuracy (to 1/16")
    c. Changes to design documents is still a problem
        i. Software doesn't handle this easily
    d. Detailer Input
        i. When using 3D modeling software, every dimension is needed.
        ii. Design needs to be fully finished for the 3D steel model to be developed.

2. When did 3D modeling start to impact the process (if at all)?

3. Do you currently develop a 3D model for your projects? If so what modeling software do you use?
    a. Yes, see question #1.

4. Is detailing of steel shop drawings performed in-house or is the contracted to a third party?
    a. 70% of detailing subbed contractor

5. What phase of a project does the steel detailer become involved? Does this ever occur during the design phase?
    a. No, wait until job is awarded.

6. Describe the communication techniques between the designer and detailer during the shop drawing development process.
    a. Depends on past relationship with engineer.
    b. Sometimes a conference call is needed with third party.

7. Describe some common problems during the development of shop drawings.
    a. Time – often greater than 2 weeks for approval
        i. Makes it tough to keep schedule with unknown approval phase of steel shop drawings
    b. Contract drawing revisions
    c. Communication

8. If a structural engineer develops the steel design in 3D will this benefit the detailer? If so, how? Also, are there any problems with an engineer developing the design in 3D?
    a. Yes this is happening on several projects however the model is not kept up-to-date throughout the project.
        i. Model data transferred into X-Steel.
    b. Engineers usually have no problem giving the model or they make a sign-off sheet available.
    c. Engineer says…
        i. Here's the model do whatever you want with the model.
        ii. The drawings still govern true design.

9. What are the barriers to implementing building information modeling (BIM) on a project? (cost, time, legal, etc.)
    a. See above - question #8
    b. Controlling contractor must govern the updating of the model and make it mandatory.
    c. Approximately 20 projects have been given a model during the bid phase and then GMP

10. How has your fabrication process changed over the past five years? (digital fabrication, etc.)
    a. CNC controlled has been used in the late 80s.

11. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with BIM?

12. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

13. Describe the ideal steel shop drawing review process.

14. Words of Wisdom
    a. Glad to see this is being studied and this is very useful.

Mark Holland (Paxton & Vierling Steel Co.)
(712) 347-4260

February 24, 2006
3:30 P.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

STEEL FABRICATORS & STEEL DETAILERS

1. How has your development of design drawings changed over the past five years? (3D modeling, etc.)
    a. Percentage of people who deliver a 3D model is about 3%.
        i. Some of the bigger firms deliver a "certified model" and that's the contract document.
    b. 3D modeling application generates the shop drawing and the detailer extracts information.
        i. 40-50% and constantly increasing.
    c. The constraints for expanding the use of technology is contract and liability based.
        i. Engineer will "lose" control of design if he gives up his model.
        ii. Fee based and contract based issues, not modeling.

2. Do you currently develop a 3D model for your projects? If so what modeling software do you use? Is this model available to the contractor?
    a. Data design SDS/2
    b. Receive information from Tekla X-Steel
    c. Have tried to have engineer approve the model instead of printing shop drawings, but it has only happened on several projects.
        i. These projects were more successful with a better understanding of what all parties wanted.
    d. Fabricator must model everything in order to correctly build project. Create model in order to get equipment to work.

3. If a structural engineer develops the steel design in 3D will this benefit the detailer? If so, how? Also, are there any problems with an engineer developing the design in 3D?
    a. Yes this has occurred.
    b. Depends how accurately the engineer models the project.
    c. Information must be received in CIS/2 file standard. This is a technical problem.
        i. This is a market problem that will be solved as demand gets higher.
    d. Mark is convinced that the interoperability problems will be solved by the software developers. Software developers will feel the demand from market conditions.

      i. Georgia Tech website

4. How has your fabrication process changed over the past five years? (digital fabrication, etc.)
   a. 4 story office structure (400 tons)
      i. Structural steel detailer: start to finish 5 weeks for model.
      ii. Raw mill order is 8 weeks.
   b. Save time by simplifying review process.
   c. SIM Steel 2 data exchange cd rom by Mark Moser (first of 2 cd's).

5. As a designer, what are the barriers to implementing 3D modeling/BIM on a project? (cost, time, value, legal, etc.)
   a. Tradition
   b. Contract language
   c. Fee issues

6. What phase of a project does the steel detailer become involved? Does this ever occur during preconstruction?

7. Describe the communication techniques between the designer and detailer during the shop drawing development process.
   a. Through a GC and makes process more of a hassle.
   b. Attach screen shot of model to questions.

8. Describe some common problems during the development of shop drawings.
   a. Incomplete design documents mostly due from owner not making decisions.
   b. Changes to design.

9. Describe the ideal steel shop drawing review process.
   a. Engineer gives a certified model or a model done in an application that generates a finished model.
      i. With loads
   b. Contract that states "Mark you can move members around."
   c. Only drawings to see would be erection drawings.

10. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

11. Words of Wisdom
   a. Review AISC Code of Standards Appendix A

b. Within 5 years, this will be a new project delivery system. Don't get wrapped up in the contractual issues and focus on the added value that can come of modeling.

Babette Freund (Ritner Steel) — March 7, 2006
(717) 249-1449 — 12:30 P.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING

STEEL FABRICATORS & STEEL DETAILERS

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)
    a. Yes - from hand drawing to computer automation.

2. When did 3D modeling start to impact the process (if at all)?
    a. Past couple of years.

3. Do you currently develop a 3D model for your projects? If so what modeling software do you use?
    a. Yes – SDS/2

4. Is detailing of steel shop drawings performed in-house or is the contracted to a third party?
    a. Yes – depends on size, complexity, work load, schedule.

5. What phase of a project does the steel detailer become involved? Does this ever occur during the design phase?
    a. Yes - rarely occurs during design; mostly after award.

6. Describe the communication techniques between the designer and detailer during the shop drawing development process.
    a. Not enough – constant communication with designer is needed.

7. Describe some common problems during the development of shop drawings.
    a. Better design meaning design what can be built.

8. If a structural engineer develops the steel design in 3D will this benefit the detailer? If so, how? Also, are there any problems with an engineer developing the design in 3D?
    a. Not if it isn't accurate.

9. What are the barriers to implementing building information modeling (BIM) on a project? (cost, time, legal, etc.)
    a. Legal – CIS/2 has helped with this issue.
    b. Accountability
    c. Ownership

   d. Accuracy
   e. It is important to develop a good working relationship with the engineering firm in order to implement this technology.

10. How has your fabrication process changed over the past five years? (digital fabrication, etc.)
    a. Software.

11. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with BIM?

12. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

13. Describe the ideal steel shop drawing review process.
    a. No RFI's.
    b. Better standardize the design.

SAMPLE INTERVIEW QUESTIONS

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING
CONSTRUCTION MANAGERS

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)

2. Has 3D modeling / building information modeling (BIM) changed the steel shop drawing development and review process? If so, how?

3. If you receive a BIM from a designer, how is the model used? (conflict resolution, estimating, tracking fabrication, digital fabrication, construction visualization, coordination, etc.)

4. What phase of a project does the steel detailer become involved? Does this ever occur during the design phase?

5. Describe the communication techniques between the designer and detailer during the shop drawing development process.

6. Describe some common problems during the development of shop drawings.

7. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with building information modeling?

8. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?

9. Describe the ideal steel shop drawing review process.

Ryan Maibach (Barton Malow Company) February 9, 2006
(734) 732-0934 8:30 A.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING
CONSTRUCTION MANAGERS

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)
    a. Try and contact Tim Webster…
    b. Definitely has changed, but also depends on size of project.
        i. Steel drawings done by hand five years ago.
        ii. Recently, drawings developed in 3D, but the 3D model was not given to A/E.

2. Has 3D modeling / building information modeling (BIM) changed the steel shop drawing development and review process? If so, how?

3. If you receive a BIM from a designer, how is the model used? (conflict resolution, estimating, tracking fabrication, digital fabrication, construction visualization, coordination, etc.)
    a. Not really sure, need to understand intent from engineer. Will the model be used for other systems (MEP)? What exactly can the model be used for?

4. What phase of a project does the steel detailer become involved? Does this ever occur during the design phase?
    a. Fabricator detailer has not been involved during design. Ryan has been mostly involved with laboratory / healthcare work.

5. Describe the communication techniques between the designer and detailer during the shop drawing development process.
    a. Often depends on willingness of designer. Detailer often prefers this, but often this is not the case.
    b. Will the owner see this as value added.

6. Describe some common problems during the development of shop drawings.
    a. Biggest challenge is the ability of designer or detailer; process just takes time.

7. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with building information modeling?

   a. Awarded to one company and then their job to subcontract to necessary companies.

8. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?
   a. True driver is the median. So many players and participants. Challenge is time frame.

9. Describe the ideal steel shop drawing review process.

10. Words of Wisdom
   a. Find a median engineer and get their take. Try and understand where that type of company is headed.
   b. Few other people to try and talk to…
      iii. Tim Webster – Barton Malow
      iv. Neil Lennon?? – Barton Malow (GM Projects)
   c. Don’t necessarily limit the model to steel
      v. BIM will be a huge tool for the MEP process.

Ron Sinopoli (Barton Malow Company) March 10, 2006
(434) 455-2447 11:00 A.M. EST

STREAMLINING THE STRUCTURAL STEEL DESIGN & CONSTRUCTION THROUGH COMPUTER MODELING
CONSTRUCTION MANAGERS

1. Have the development of shop drawings changed over the past five years? (3D modeling, etc.)
    a. Yes, we were doing it 4 years ago on the Soldier Field Project. Since then the technology and the industry have become more familiar with the process as standards are being implemented (see AISC Code of Standard Practice) thus developing new and quicker ways to exchange information.
    b. Is it really quicker?
        i. Typically have to stamp and mark-up 6 sets of shop drawings. On soldier field, model exchange through TT. Only certain number of drawings printed for stamped approval. CM saving 8-16 MH.

2. Has 3D modeling / building information modeling (BIM) changed the steel shop drawing development and review process? If so, how?
    a. Absolutely. With the steel detailers using 3D models to develop fabrication models that are linked to Fabtrol and Ravens the ability to get the model “approved” and not process large sums of shop drawings is a huge time savings. The use of “3D Models” also helps with jobs that have complicated geometry.
        i. Not as many drawings needed to print-out.

3. If you receive a BIM from a designer, how is the model used? (conflict resolution, estimating, tracking fabrication, digital fabrication, construction visualization, coordination, etc.)
    a. Unfortunately I have not had the opportunity to get a full “BIM” model from a designer. At Soldier Field we got a “3D Steel Model” developed in Tekla’s Program “X Steel” for use in developing shop drawings and connection design. A full BIM Model will help with all of the above mentioned, however estimating would be the lowest on the list in my opinion.
        i. If estimating is in quantity take-off, then yes BIM modeling would help.
        ii. Helps with scope reviews.

4. What phase of a project does the steel detailer become involved? Does this ever occur during the design phase?

a. Usually after the Steel Fabricators Contract is awarded, unless the project is a design build or includes a design assist.

5. Describe the communication techniques between the designer and detailer during the shop drawing development process.
    a. Currently it is through the RFI process.
        i. More or Less RFIs with model?
            1. Not necessarily more/less RFIs, just when the RFIs are generated.

6. Describe some common problems during the development of shop drawings.
    a. Geometry.
    b. Coordination with the Architectural Plans and MEP System Openings.
    c. Fully developed load analysis completed by the structural engineer to allow connection design to begin immediately.

7. Who typically manages the supply-chain between all the different entities associated with the steel phase of a project? Does their role change with building information modeling?
    a. The Construction Manager.
    b. The role should not change if a BIM Model is used, it only gets easier and allows better coordination.

8. If you experience problems exchanging data between applications, do they use CIS/2 files? Do you think the design to construction process will change in the few years? If so, how?
    a. No “problems per say” however, it’s how the file is inserted that is the issue. The coordination of insertion points, north arrow and elevations are extremely important. All subcontractors that will work in the BIM environment must be given a set of standards to hold.
    b. Also when importing/exporting files the program used by the sub does not always export as a “solid” into the base program used by the CM. This is currently being worked thru within the industry.
        i. Ron currently uses Tekla Structures. BM also uses Navisworks, Graphisoft, etc. Link ProLog, Primavera, etc. to Tekla Structure. Get a clipping plane, etc. Need a program that’s dumped in as a solid which is currently something that’s going with Tekla Structure.
        ii. Tekla is trying to make their program compatible with all other programs. Need a program that will bring all information together.
        iii. Need to be used as a construction tool. How does it benefit all involved?

        1. Allows for RFIs to be better recognized, what changes affect who, show this better to owner through model.

9. Describe the ideal steel shop drawing review process.
   Please note the process below is based upon a phased release of documents currently used on this job (early utilities, structure, Architectural/MEP). The process would be a great deal more complicated if all trades are working simultaneously in terms of phasing and coordination developed by the CM to best serve the job.
   a. Designer issues a BIM Model for the Major Trades, this model should be used for "Space Reservation" only. I.E. does not need to be extremely detailed in regards to how the MEP equipment is shown ect…..:
      i. Steel
      ii. Concrete (rebar does not need to be included)
      iii. Skin (Masonry is Optional)
      iv. MEP Systems
      v. Precast
   b. The CM accepts the Model from the A/E and posts it to an FTP site for use by the trades. This should be a "For Construction Model". There are two ways to do this:
      i. The CM breaks the model into it's components for use by the trade required.
      ii. The model is left in it's original state to be accessed and imported/exported by the subs.
   c. Subs begin the shop drawing process
   d. Subs electronically submit the shop drawing model for approval. The model is:
      i. Posted to the FTP site:
         1. In it's original state for review by the A/E and CM
         2. Inserted back into the master model for re-verification of coordination and clash check. Thus beginning and "As-Built Model" that can be used for coordination for follow on trades detailing.
   e. The A/E review and provide comments in regards to design intent. The comments are in narrative form and by sketch, or comments inserted into the model, whichever is easiest to accomplish.
   f. The CM review and provide comments in regards to coordination with other trades and sequencing.
   g. Model with an action (APP, APN, R&R Ect.) from A/E is posted back to the FTP site for download by all involved.
   h. Subcontractor incorporates comments from A/E into approved model as "Final Field/Fabrication" and re-posts to FTP Site for incorporation into

the "Master Model". 2D document would be needed at this point for field use.

10. Other Relevant Information
    a. E&O Insurance should go down with engineers implementing modeling.
    b. All based on delivery system and phasing of document risk.
        i. At VA, did not receive 3D file from architect.
    c. Agrees with a better understanding of design in eyes of design team if the project is modeled in 3D, etc.
        i. Better QC from a designer's perspective.