Dept. of Civil & Env. Engineering
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Major Qualifying Project Proposal

Alternative Gravity Load Resisting System for Clark University's Alumni & Student Engagement Center

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CAPSTONE DESIGN STATEMENT

Clark's Alumni and Student Engagement Center will serve as the university's new campus center after its completion in June of 2016. This Major Qualifying Project (MQP) involved creating alternative floor systems and analyzing column connections based off of the original building structure. To complement the alternative design, a new schedule and cost estimate were generated. To complete the structural analysis, cost estimate and schedule, AutoCAD, RISA, Revit, NavisWorks, and Microsoft Project were used.

Throughout the course of this project, we addressed the following construction and design constraints: economic, environmental, sustainability, constructability, health and safety, and social.

Economic

The economic impact was addressed by creating a new cost estimate and schedule for the project, taking into account the changes in the materials and structural designs.

Environmental

The environmental impact of this project was addressed during the excavation stage of the project where we learned about building on contaminated soils.

Sustainability

The sustainability constraint was met for this project through learning about LEED certified buildings as the Alumni and Student Engagement Center is LEED Platinum certified. We also learned about LEAN construction and its environmental benefits.

Constructability

The constructability constraint was met during this project through the use of design software to create a Building Information Model (BIM).

Health & Safety

Health and Safety constraints were met through applying building and zoning codes to the alternative design.

Social

Social constraints were met through attending Owner's meetings and learning about the challenges of constructing a building on land shared by two owners. This was also met because the building maintains an open concept which promotes connections between students and alumni.

Ethical

Ethical constraints were met through respecting both Clark University's and Consigli Construction's confidentiality. This was met by keeping sensitive information to ourselves and out of our report.

PROFESSIONAL LICENSURE STATEMENT

A Professional License is a document of verification that demonstrates that the engineer has exceptional skills and certification to perform his or her practice. According to the National Council of Examinations for Engineering and Surveying, NCEES, the professional licensure protects the public by enforcing standards that restrict practice to qualified individuals who have met specific qualifications in education, work experience, and exams (NCEES, 2015).

Although requirements vary from state to state, candidates must complete a series of steps to be fully licensed as a Professional Engineer. The first step that the National Society of Professional Engineers recommends is to successfully complete the Fundamentals of Engineering, FE, exam after completing an accredited, undergraduate engineering degree. Upon passing the FE exam, the candidate is certified as an Engineer In Training, EIT, also known as an Engineering Intern, EI (Civil Engineering Careers, 2015). With this certification, the engineer in training can begin working as civil engineer under the supervision of a Professional Engineer. Before an EIT or EI can take the Principles and Practice of Engineering, PE, exam they are required to have completed four years of experience as an engineer. After successfully completing the PE exam, the candidate becomes certified as a Professional Engineer. For the candidates who wish to specialize in structural engineering, some states require them to take the Structural Engineering Exam, SE, to be certified as a structural engineer (Civil Engineering Careers, 2015).

Obtaining professional licensure is viewed as a distinguished achievement and a prestigious title by clients, government, employers, and by the public. Obtaining this license shows responsibility and authority because only Professional Engineers can "offer services to the public, be principal of a firm, perform consulting services, bid for government contracts, and stamp and seal designs," (NCEES, 2015). Those who have achieved licensure will also be able to enjoy the professional benefits that accompany this distinction.

Our work on this project with the design of an alternate flooring system and the project management analysis for Clark University's Alumni and Student Engagement Center has served as a stepping stone to obtain the Professional Licensure. The completion of an MQP is a requirement for earning our engineering degrees at WPI, and this significant design experience has allowed us to gain realistic knowledge and apply concepts learned in class to a real-world project.

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1.0 INTRODUCTION

To promote engagement among students, alumni, and faculty, Clark University is building a new Alumni and Student Engagement Center, ASEC. The ASEC is being constructed by Consigli Construction on Main Street in Worcester, Massachusetts. This building is recognized for its effect building strategies and techniques by receiving a Leadership in Energy and Environmental Design, LEED, Platinum certification. The building will serve as a collaboration center where alumni can communicate with undergraduate students on projects that involve the local community. The ASEC will be a headquarters for Clark University's Liberal Education & Effective Practice, LEEP, program which allows students to create a positive impact on their community using the knowledge gained from classwork.

The goal of this project is to develop an alternative gravity load resisting system while considering the impacts of this alternative structural design on the cost and schedule of the project. The project team will establish the current forces acting on the AESS columns and provide cost effective alternatives to the design. We will analyze the structural integrity of the current floor framing system, design a new alternative floor framing system and analyze its impact on the cost and schedule. We will track submittals and Requests For Information, RFI's, to determine their impact to the ASEC project schedule and cost. The team will create a cost estimate for the alternative floor framing system and the AESS columns and determine their impact on the project schedule. Lastly, we will develop a 5D BIM model to visualize the new design, schedule and cost. This project demonstrates knowledge of structural engineering and construction management. To gain a better understanding of the project, we conducted background research in relevant areas of Civil Engineering.

2.0 BACKGROUND

In this chapter we review the characteristics and methods of construction project management and structural design of buildings. We will explain the concepts of alternate floor framing systems versus slab-on-metal decking flooring systems to grasp a better understanding of our project. To provide a better knowledge of AESS Column Design we explore the types of fabrications, welding and galvanizing techniques, primers, framing, finishing and installation methods. We also explore the effects of using BIM and the method of Lean Construction to gain knowledge on cost estimating and scheduling of a project. For a further understanding of Clark University's ASEC we discuss LEED and building codes for this project.

2.1 Need for Alumni & Student Engagement Center

The Clark Alumni & Student Engagement Center's purpose is to bring current students in to see what Clark University has to offer and to bring alumni back to reconnect with their alma-mater. The ASEC will serve as a place for academic and professional development, welcome to both current and graduated students. Clark University's current layout does not offer a place big enough to house that many people for everything that the university wants to achieve. Clark University has not yet branched out into the Worcester community; every Clark building is consolidated onto only one side of Main Street. The ASEC jumps over that barrier; this prominent building will be located on the other side of Main Street. This enhances the university's image to the rest of the world and to their community.

This building will also serve as a headquarters for Clark University's LEEP efforts. LEEP is the university's way to connect their students' liberal studies with real world problems. Students are able to apply what they learn in liberal education classes to real world problems. LEEP projects are able to be completed by seniors in good academic standing. Projects are completed at off-site non-profits and must respond to the organization's need. The old LEEP center was located in a building that houses multiple other departments. By moving the location of the LEEP center, Clark is building a greater focus on LEEP.

2.2 Existing Building Gravity Load Resisting System

The gravity load resisting system refers to the following structural elements of Clark University's ASEC that we are focusing on are the floor framing systems and AESS columns.

2.2.1 Building Design Loads

When it comes to designing a building for any type of site, two design aspects a project engineer must consider are structural and foundation designs ("The Importance of Structural Enginering," 2015). Building design encompasses the building as a whole, what's keeping the building together, and how the loads get transferred throughout the system. Foundation design deals with what is under the building and where the load is being transferred to. Each design needs to be calculated carefully as one flaw would cause a failure in both designs.

2.2.2 Structural Design Loads

The structural design is one of the major focuses of most construction process. When Odeh Engineers, Inc. designed the initial blueprints for the structure, they followed the provisions of the 2015 *International Building Code*, *IBC*, and Massachusetts-specific amendments to the IBC. Massachusetts amendments are used because the specifications provide design loads for all structures in the Massachusetts area. These design loads include snow, wind, rain, and earthquake loads that the engineer must take into account when designing a building ("9th Edition 780 CMR Base Code Proposed MA Amendments to the IBC 2015," 2015). After loads are placed on the system, steel member sizes are determined based on the load distribution on the entire system. The selection of structural systems is typically directed at achieving the most effective design at the lowest price. Material properties and design criteria for any form of structure can be found with the American Institute of Steel Construction, AISC, and American Concrete Institute's, ACI, *Building Code Requirements for Reinforced Concrete Steel Construction.*

2.2.3 AESS Column Design

With advances in structural designs for buildings and other construction projects, architects are now looking into new designs that incorporate Architecturally Exposed Structural Steel, AESS. AESS columns are used in the architectural design as an art form for Clark's ASEC. These columns remain exposed for viewers to appreciate and they allow for architects to add more appeal to the facility.

AESS can be a very complex material and since the steel is on display, there needs to be minimal imperfections in the steel in order to gain the full architectural appeal. In order to incorporate AESS into a building design, the structural engineer, architect, and project manager must have a full understanding on the AESS fabrication and installation process outlined in ASTM A6/A6M, "*Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Steel Piling"* and section 10 of AISC 303-05, *"Codes of Standard Practice for Steel Buildings and Bridges* (Enclos, 2010). The American Institute for Steel Construction, AISC, also created a matrix that specifies techniques with different appearances the architect may be trying to achieve for the building's AESS. Each resource outlines each step throughout the fabrication and erection processes which is needed in order to understand the AESS matrix.

Fabrication

There are many important decisions to be considered during the fabrication of any AESS element. In order to obtain AESS, the Project Manager must seek help from an AESS certified steel fabricator while construction begins on the foundation, as standard steel fabricators are not sufficient. To begin AESS fabrication, one must first choose between cold formed or hot rolled steel. It is important to note that cold formed steel is considerably more costly than hot rolled, but many architects prefer it because it allows sharper corners (Enclos, 2010). After forming the steel, the Project Manager must provide the fabricator with specifications for the AESS. The general specifications for AESS steel can be found in Appendix A.

Welding & Galvanizing

There are two types of welding that are used with AESS: Tungsten Inherent Gas, TIG, or Metal Inherent Gas, MIG (Enclos, 2010). The differences between the two welds are MIG welds use thin wire as an electrode and are typically the easiest process to learn, while TIG welds are high quality welds with high versatility, but require a significant amount of practice which make it least productive ("Differences in Welds," 2009). Other costs can occur when there are specifications on the smoothness of the weld. For example, Figure 1 below shows a typical fillet weld verses a smooth weld (Enclos, 2010). The weld on the left has excess melt steel protruding out of the corner, whereas a processed, smoothed weld will have no excess melted steel leaving the corner sharp. The added smoothness doesn’t increase or decrease the strength of the weld but rather provides a cleaner look to the steel member.

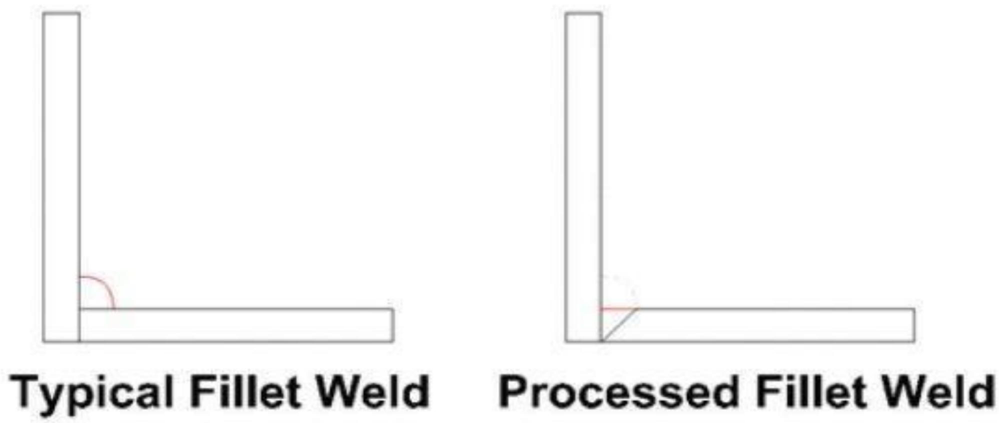

Figure 1 Typical vs. Smooth Welds (Enclos, 2010)

After welding has taken place, the steel must be galvanized to ensure there is a surface protection on the steel. Before the steel can be galvanized, it must be cleaned using power tools and chemical solvents to ensure the entire surface is clean. It is very important that all welding be done before galvanizing the steel as there is a specific procedure to follow in order to weld galvanized steel that is very costly. In order for the steel to be galvanized, it is placed through a hot dip galvanization process. This process involves the steel being placed in a tank where an electrochemical process is used to deposit a layer of zinc on the steel surface (Enclos, 2010). This process will make the steel rough, and often times sandblasting is done to try and smooth the steel out to keep the primer coating.

Primers

After the steel has been galvanized, it must be primed between a selection of inorganic and organic material. Several different types of primer must be chosen for the steel: Alkyd, Acrylic, Epoxy, and Zinc Rush. Each type has many differences, however Alkyd and Acrylic are the lower cost options. Typically, projects will use either Epoxy primers, which are used for corrosion resistance and hiding imperfections in the steel, or Zinc Rich primers, which are used for superior corrosion resistance and protection to the steel galvanically. Each has an organic and inorganic property and each differ in curing times. For example, inorganic primers have a longer curing time than organic primers (Enclos, 2010). The current plan for the AESS columns involves a Fast Dry DTM Alkyd based primer to be applied once the columns are erected.

Fireproofing

When applying primers it is also important to apply fireproofing to AESS elements that are a part of the primary structure which are specified on Consigli Construction Life Safety & Load Compliance Plans, drawing G0.03 found in Appendix B. Since Clark University's ASEC AESS columns support the canopy, they are a part of the primary design. The fireproofing is very simple and is applied during the painting and primer process. In order to provide fireproofing to AESS, the steel must be coated in intumescent paint, a fireproofing paint (Enclos, 2010). It is important to keep in mind that many AESS design will require multiple layers of paint in order to satisfy fireproofing needs.

Finishing and Installation

The finishing touches for the AESS elements are painting and quality control. In order to maintain any AESS it is important to allow proper drying time for paint, as improper drying time will call for later touch ups and increase cost. It is also very important to have a paint representative who makes sure the paint has been inspected consistently and applies more where needed. Any paint applied over the intumescent layers after must be approved by the fireproof manufacturer and must be applied over several layer of SprayFilm Topseal ("Fire Proofing Application - Instumescent," 2014).

The last step with incorporating AESS into a building or structure is installation. It is significant to have a firm understanding of the site and a solid field plan. It is also very important that the proper equipment is used when erecting the AESS. Improper equipment could cause deflection or bowing which would result in improperly connections (Enclos, 2010). Having a backup plan set in place will ensure that any disruptions on the site will occur with minimal delay and get the job completed quicker.

2.2.4 Slab-on-Metal Decking Floor Framing System

The current flooring system in Clark University's ASEC consists of slab-on-metal decking floor framing system, which involves four main elements: metal decking, mesh reinforcement, concrete slab and connectors. The metal decking in Clark University's ASEC is three inches in height and stretches from beam to beam. The metal decking sits on top of the beams, with the corrugated valleys running perpendicular to the beams. The metal decking is then connected to the beam with screws, fasteners or welds. The mesh reinforcement is then laid on top of the metal decking (Porter & Ekberg Jr., 1975). This mesh reinforcement is 6X6 W2.9X2.9, meaning the mesh creates six inch by six inch squares and the rebar's cross section is 0.029 inches squared. The concrete slab on top of the connectors, decking and mesh reinforcement is five inches thick. The concrete has a 28 day compressive strength of 4000 psi and is lightweight. Figure 2 is an example of slab-on-metal decking at Clark University's ASEC.

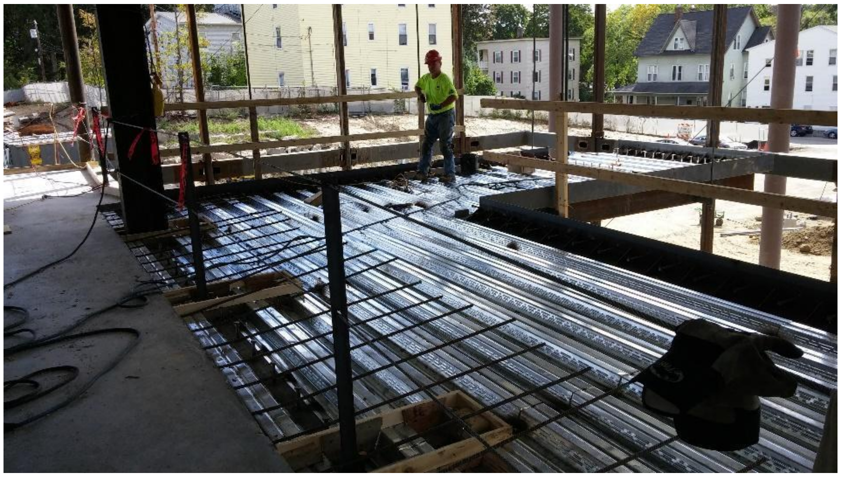

Figure 2 Slab-on-metal decking at Clark University's ASEC

The Clark University ASEC's slab-on-metal decking floor framing system is a very common to see in the construction of low-rise buildings. The current floor framing system at Clark University's ASEC was constructed on-site and integrated with the overall construction process. This is more time-consuming than constructing a more complex floor framing system. However, the current floor framing system poses fewer threats to delaying the construction process than a more sophisticated floor framing systems would. It would be easier to fix issues related to installing the slab-on-metal decking floor framing system than it would be to fix issues with another floor framing system. Any issues that arose with the construction process of either of these systems would also have a negative impact on the project's overall cost and schedule. Although the systems use approximately the same materials, the alternative floor framing systems are much more expensive because of its detailed construction.

2.3 Alternative Design Solution

2.3.1 Slimline Floor Framing System

If Clark University were to use the Slimline floor framing system in the ASEC design, the project would become more costly. The system is relatively new and more difficult to construct than more commonly used systems. However, the Slimline floor framing system takes up significantly less space vertically by allowing space for mechanical, electrical and plumbing, MEP, system components. This system can also incorporate radiant heating and cooling systems into its design. This could potentially bring the overall building height down in the magnitude of feet, which can decrease the overall cost of the building. Less material is used, less labor is needed and less fire protective measures are needed on a shorter building ("Slimline Buildings Construction," 2014).

The Slimline floor framing system was invented in the Netherlands, and it has had a positive impact on buildings within and around that country ("Slimline Buildings Construction," 2014). Slimline floor framing systems, as shown in Figure 3, are composed of steel I-beams embedded into slabs of concrete. The bottom flange of the I-beam is also embedded into the slab; the bottom of that slab serves as the ceiling for the floor below. There is space between the flooring and the ceiling for storage of mechanical, electrical and plumbing (MEP) components ("Slimline Buildings Construction," 2014).

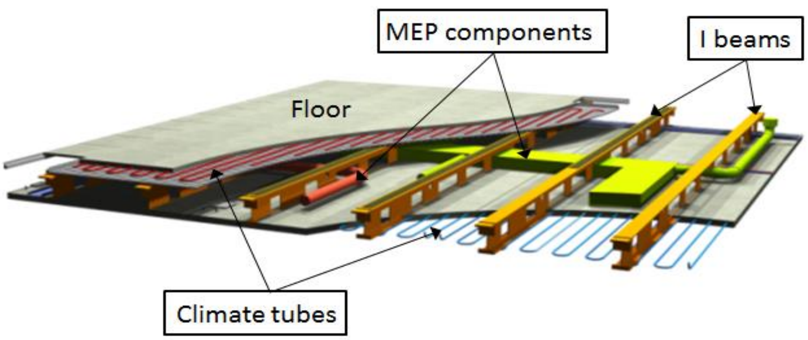

Figure 3 Slimline Floor Framing System Overall Design("Slimline Buildings Construction," 2014)

See Figure 4 below for details on the thickness of the flooring system. The Slimline floor framing system is composed of steel I-beams embedded into three-inch thick slabs of concrete. The bottom flange of the I-beam is embedded approximately one inch into the slab; the bottom of that slab serves as the ceiling for the floor below. On top of the I-beam, there is a layer of rubber granulate approximately one-half inch thick for acoustic purposes. On top of that is approximately two inches of flooring tiles for the floor above. The overall depth of the Slimline floor framing system is around 16 inches depending on the design of the elements incorporated into the floor framing system ("Slimline Buildings Construction," 2014).

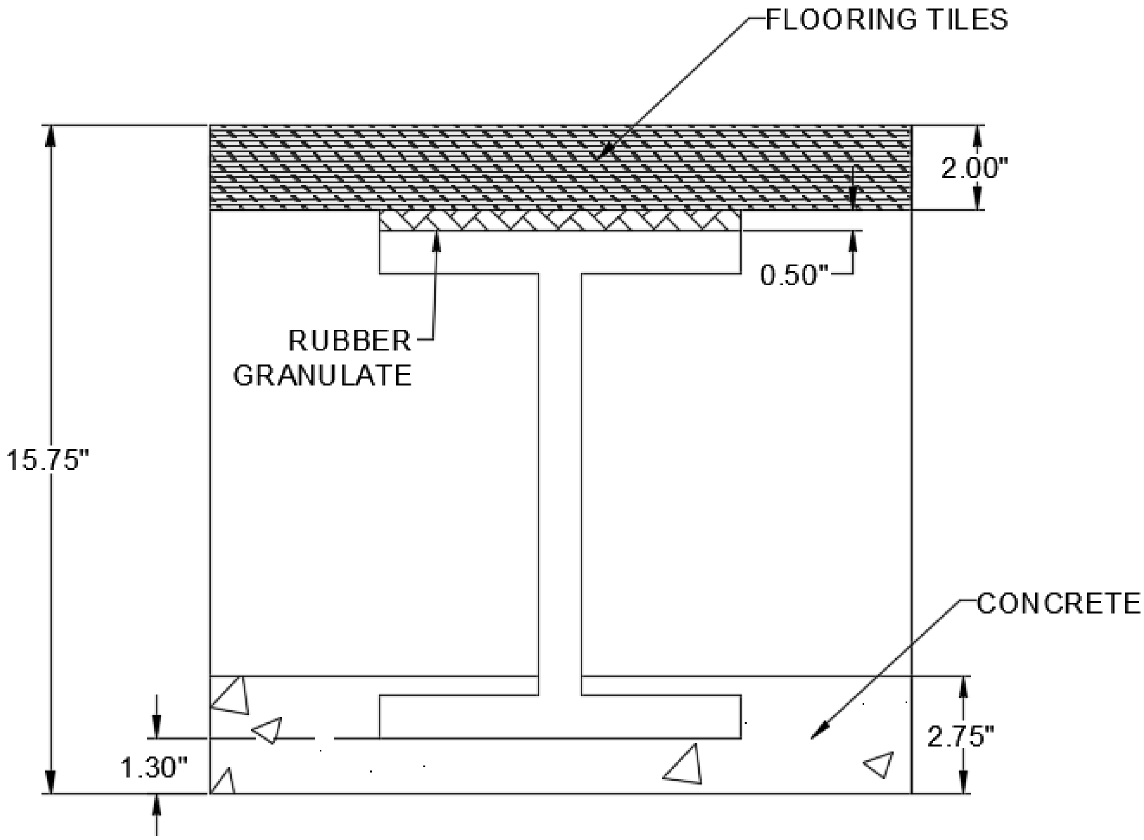

Figure 4 Slimline Floor Cross-Section with No Climate Tubes

Climate tubes can be installed within the concrete slab to better control the heating and cooling of the structure. Climate tubes are copper or polyethylene pipes that are placed under or above the I-beam. Hot or cold water is then pumped through the pipes to cool down or heat up the structure. Water temperature can vary from 90ºF-60ºF ("Radiant cooling and Radiant heating," 2013). The pipes cannot exceed one quarter inch in diameter and must be spaced at least six inches apart.

Climate tubes can be installed above or below the I-beam as seen in Figures 5 and 6 respectively. If climate tubes are installed above the I-beam for heating purposes, a one-inch layer of insulation is required above the climate tubes to protect the elements of the flooring system from the heat. With climate tubes installed above the I-beam for, the total thickness of the floor is around 18 inches. If climate tubes are installed below the I-beam for cooling purposes, a one-inch layer of insulation is required below the climate tubes to protect the elements of the flooring system from the cold temperature. Six inches of concrete is then placed directly onto the climate tubes if they are installed below the I-beam, resulting in a total floor depth of around 21 inches ("Slimline Buildings Construction," 2014).

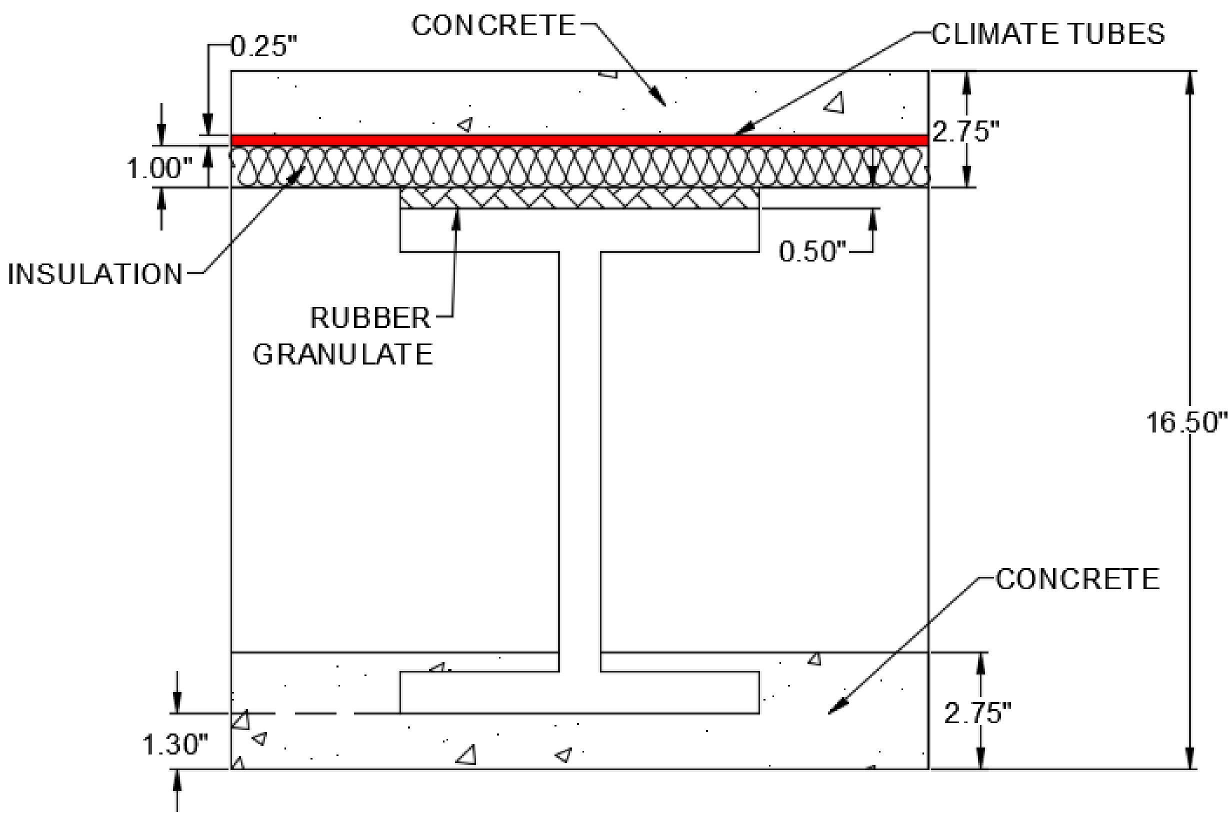

Figure 5 Slimline Floor Framing System Cross-Section with Climate Tubes Above

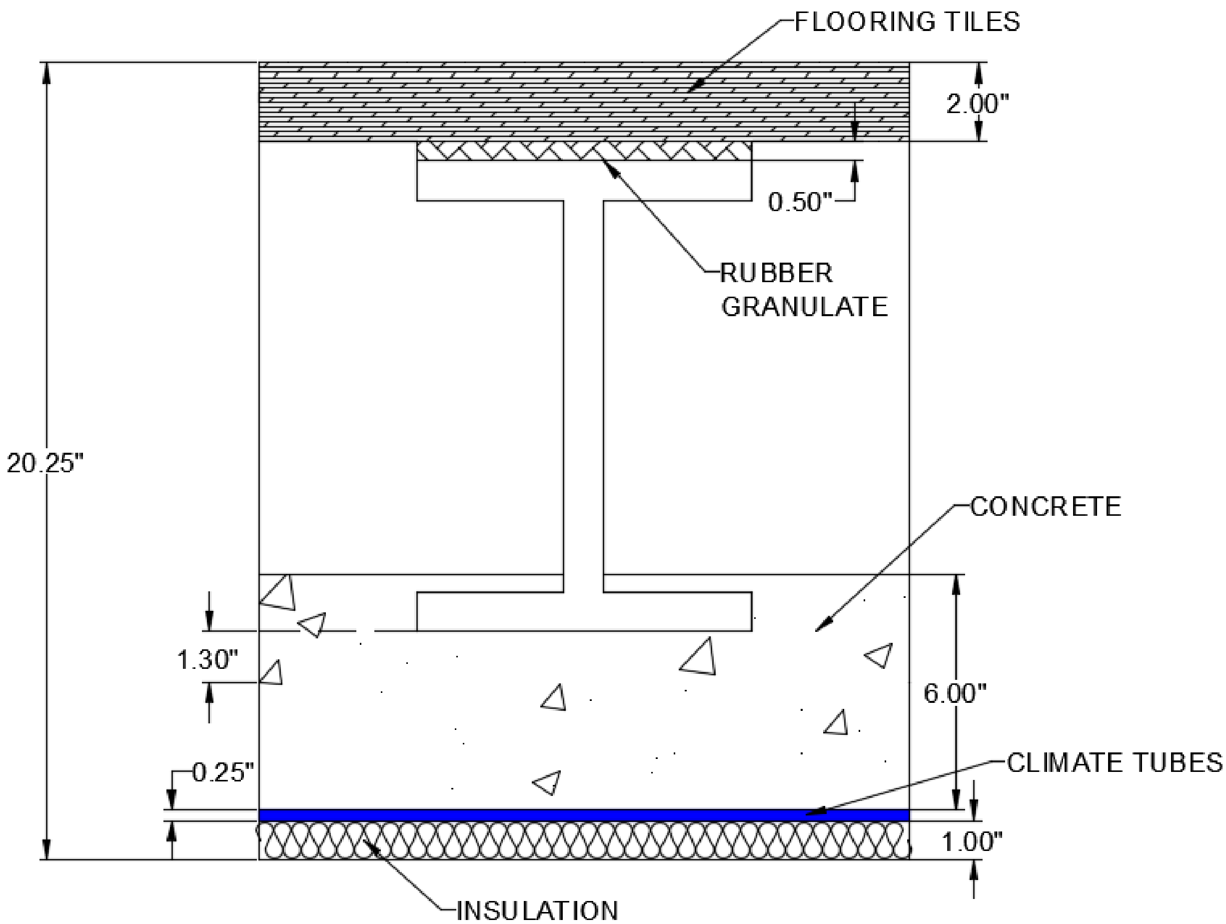

Figure 6 Slimline Floor Framing System Cross-Section with Climate Tubes Below

Depending on the length of the span of the floor system and how much additional MEP components are stored within the space between the concrete slab and rubber granulate, the concrete slab's mesh reinforcement can vary. Mesh reinforcement is required to increase the stability of the concrete slab. Depending on the types of loads acting on the concrete slab, different types of mesh reinforcements are necessary to ensure the strength of the concrete slab. Please see Figure 7 for details on each type of mesh reinforcement ("Slimline Buildings Construction," 2014). Basic reinforcement consists of a mesh of steel rebar one-quarter inch in diameter spaced six inches apart. Break reinforcement is also required between beams to prevent the slab from ripping from the lower flanges. Break reinforcement mesh consists of one-quarter inch diameter steel rebar spaced 18 inches apart from each other. If climate tubes are installed, wing reinforcement is required on the opposite side of the break reinforcement. This mesh has the same dimensions as the break reinforcement but is welded to the steel. If a small amount of equipment is stored within the floor, the span from beam to beam can be as great as four feet ("Slimline Buildings Construction," 2014).

Figure 7 Slimline Floor Framing System Mesh Reinforcement Details ("Slimline Buildings Construction," 2014)

However, Slimline floor framing systems are very uncommon in the United States. The system is relatively new, so most buildings that have Slimline floor framing systems are in the Netherlands and surrounding countries. For the projects that have incorporated Slimline floor framing systems in their design, construction has been positively impacted in terms of schedule and cost. Slimline floor framing systems can be prefabricated off-site and delivered with steel I-beams already embedded into the concrete slabs. Although this makes the construction process easier, it leaves more room for error. Delayed deliveries, faulty materials and installation of the system could hinder the overall construction process ("Slimline Buildings Construction," 2014).

2.3.2 Girder-Slab Floor Framing System

The Girder-Slab System is used in construction as a floor framing systems. Materials used in the system are prefabricated off-site which makes for efficient construction. The main components of the Girder-Slab System are structural steel and precast hollow-core slabs (Stein, 2008). During the fabrication process, slabs are connected to the structural steel with cementitious grout to maintain the shape and hold the slabs. A unique component to this flooring system is the open-web dissymmetric beam, often referred as a "D-beam" (Stein, 2008). A D-beam is structural steel that supports precast, prestressed hollow core slabs on the lower flange. Often times beams are cut in half and then corrugated to allow for grout to flow through the opening in the web. Figure 8 below shows typical D-beam section cuts.

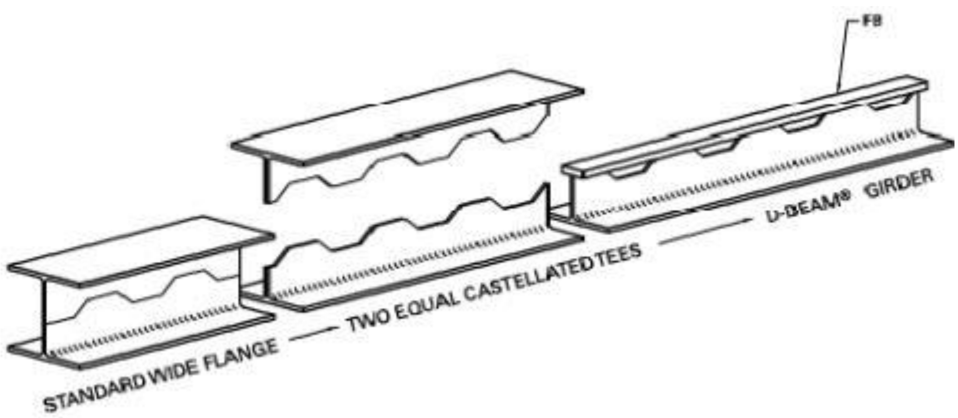

Figure 8 D-Beam Web Sections (Stein, 2008)

From the figure above, you'll notice that the cuts in the web may separate to allow for more or less grout flow. The distance between the cut ends of the beam will not only affect the strength of the D-beam, but also the thickness of the floor. It's very important that the D-beams cut is balanced for both thickness regulations and structural integrity.

Girder-Slab floor framing systems are similar to Slimline floor framing systems in many ways. They serve the same purpose, to make the floors shallower and conserve space. Both Slimline floor framing systems and Girder-Slab floor framing systems can contain climate tubes within the precast-concrete slab. Girder-Slab floor framing systems do not have any space for MEP components, while Slimline floor framing systems do. The Girder-Slab floor framing systems are significantly thinner than Slimline floor framing systems. This means that the Girder-Slab floor framing system uses less material than the Slimline floor framing system.

2.4 Project Design Visualization & Evaluation

2.4.1 Building Information Modeling (BIM)

Building Information Modeling is a series of software packages that the construction industry uses a 5D representation of a future structure. With the increasing pressure of bid competition, production deadlines and continually increasing quality expectations, BIM is a commonly used tool in the construction industry (Popov, Juocevicius, Migilinskas, Ustinovichius, & Mikalauskas, 2010). Some identify BIM as dealing with only 3D modeling and visualization. Using the process of BIM, one would have the capability of creating a three dimensional, 3D, four dimensional, 4D, and/or five dimensional, 5D, representation of a future structure. A 4D model is a visual representation of the future structure incorporating the construction schedule. A 5D model is a visual representation of the future structure incorporating the construction schedule and the cost estimate of the entire project.

BIM software tools cover virtually all phases of the construction process such as the planning, cost, design, estimating, scheduling, construction, fabrication, maintenance and facility management. BIM is used to improve business function so that both the owner and the project management firm benefit from a faster and more cost effective completion date. *Autodesk Revit 2015* and *Navisworks* are one set of BIM software tools. This 5D model is a 3D representation of a building structure that includes two other dimensions, a construction schedule and the cost of the structure (Popov et al., 2010).

Autodesk Revit 2015

Autodesk Revit 2015, also known as Revit, is a software for structural engineers, architects, designers and MEP engineers that is used for BIM models. This software allows users to model with 2D elements, such as a floor plan, to create and design 3D buildings, structures, and components. Revit users can create a 4D model by using tools to plan and track various stages in a building's lifecycle. Revit consists of three main templates that allows the user to create the architectural plan, structural plan, and the MEP plans of a building to convert into a 3D model. Revit allows the user to use pre-made building component families as well as loadable families which can be made from scratch to construct the desired design. These families can range from furniture and light fixtures to structural columns and beam types. Revit also allows the user to create renderings of their design to show a more realistic representation. Revit also allows the user to create walkthroughs and fly-around animations (Revit, 2015).

Autodesk Navisworks

Navisworks is a BIM software tool that integrates the architect, project manager, and owner to view the project schedule and cost through animation. Navisworks allows the user to import Revit files and Microsoft Project files to develop 5D models. Navisworks allows the user to create a video of the building that shows the phases of the construction and the cost of each phase throughout the project (Navisworks, 2015). With the combination of these building information modeling software tool, a 5D model is created.

2.5 Project Implementation

2.5.1 Construction Cost Estimating

Cost estimating is used to predict the total cost of a project. Construction companies use cost estimating to bid construction projects. The more accurate the cost estimate, the more likely the construction company will stay on budget and make a profit. Inaccuracies within the cost estimate can cause projects to go over budget and companies to lose money on projects. Going over budget can cause a company to go out of business (Halpin, 2010).

Types

There are four main types of cost estimates used during the design and construction process of a building. They are conceptual estimate, preliminary estimate, engineer's estimate, and bid estimate. The conceptual estimate and preliminary estimate take place during the design phase and are both reviewed by the owner. Once the final design of the project is completed, the engineer drafts an engineer's estimate with the projected project cost and estimated unit quantities for all of the bid items. This estimate is used in the bidding process for all construction firms bidding the project. The bid estimate is produced by the construction firm bidding the project, and includes a unit price for each item in the bid list, which factors in the cost of materials, labor, equipment, and man hours. This estimate also includes a mark-up, which is additional money allocated for overhead, non-project related costs associated with running a business, and profit, money the construction company makes on the job (Halpin, 2010).

Methods

The most common way of generating these preliminary cost values is through a unit cost estimate. A unit cost estimate is generated by multiplying the unit quantity of an item with an estimated price per unit of the item. A common source for unit pricing values is the R. S. Means Company's *Building Construction Cost Data* (Halpin, 2010).

2.5.2 Scheduling/Project Control

Project planning encompasses a wide variety of tasks including scheduling, organizing, controlling, and coordinating. Each of these functions play a large role in the project planning process, and these tasks are usually carried out by a project manager. Table 1 below shows each of these functions and why they are important to the project process ("Planning, Scheduling and Construction Management," 2014).

Table 1 Functions of Scheduling ("Planning, Scheduling and Construction Management," 2014)

Function	**Importance**
Planning	Determines what needs to be accomplished and how it will be accomplished.
Scheduling	Outlines project duration and establishes task completion dates.
Organizing	Compiles project tasks and assigns them to their respective departments.
Controlling	Tracks project progress and makes adjustments to stay on track.
Coordinating	Forms collaboration between all involved departments to ensure synergy.

Importance of Scheduling

The objective of scheduling is to link the project plan to a time-line. Project scheduling shows the duration and order of various tasks to be carried out during the project. In creating this schedule, the projected start and finish dates for the overall project are determined. There are many advantages to creating a schedule such as determining the best method of executing the project. It allows for the quantity of workers, material and equipment to be determined at different stages of the project. Additionally, scheduling enables progress to be tracked which determines if the project is staying on target. The purpose of the schedule is to create a visual representation of the project time-frame to allow for coordination between all parties involved on the project. This shows the order the project tasks will be completed in and exposes any constraints that may affect the schedule, such as weather. An important part of the schedule is the critical path. This is the connection of tasks that make up the longest pathway in the schedule and determines the initial start and end dates of the project. The critical path is very significant because any delay to the tasks along the critical path will result in a delay to the overall project schedule (Sheba).

Microsoft Project

Microsoft Project is a scheduling software package that allows project managers to analyze budgets, timelines and resources. Using Microsoft Project, project managers can also measure the construction progress and anticipate project needs through monitoring the schedule. Project executives are able to measure strategic impacts and view project status. Microsoft Project improves collaboration between contractors and subcontractors because it allows easy access to change and sends these changes to the team (Microsoft Office Project, 2015). This program also allows the user to sync the schedule and cost estimate together so that the user can eventually develop a 5D model in Navisworks with Revit.

2.5.3 Project Communication

Owner's meetings, also commonly referred to as Owner/Architect/Contractor, OAC, meetings, usually occur on-site on a weekly basis as a source of project communication. These meetings allow the Owner/Owner's representative, Architect, and Construction Manager, CM, to discuss the project progress. The agenda is created by the CM, who also runs the meeting. The following table summarizes topics most commonly addressed during these meetings (Radosavljevic, Bennett, & Ebrary Academic, 2012).

Table 2 Common Topics of Discussion (Radosavljevic et al., 2012)

Common Topics of Discussion
Submittal, RFI, and Change Order Status
Payment Requisition Status
Budget
Schedule
Resolve Drawing Discrepancies
Safety Report

Discussing all of these topics while the Owner, Architect, and CM are all in same room allows for efficient conflict resolution and decision making (Radosavljevic et al., 2012). When there is a lack of information in the drawings or specifications, the CM will submit a RFI to the Designer, usually the Architect or Engineer, for clarification.

2.5.4 Lean Construction

Lean construction is a process used to reduce "cost, materials, time and effort:" (Mackie, 2014). Lean originated from the idea of lean production, which was developed by Toyota led by Engineer, Taiichi Ohno. The idea of lean production was developed to eliminate waste in mass production and create more efficiency in the production line.

The goal of lean construction is to maintain maximum production while having minimal waste and time delay. Project managers now use lean construction techniques to efficiently plan and control construction sites. Using Lean construction helps prevent future problems by identifying possible communication issues. Increasing communication between disciplines reduces the overflow of construction waste (Mackie, 2014).

Lean methods increase schedule reliability, predictability, and productivity. These increases are due to a higher rate of planning, increased profits and turnovers, customer satisfaction, worker accountability and job satisfaction. Lean construction also improves the overall project results due to improved communication (Mackie, 2014).

Consigli Construction uses Lean methods throughout all of their projects. “Lean efforts focus on identifying opportunities to reduce inefficient use of resources, and to create more value through our work. It is about encouraging continuous improvement on a daily basis while maintaining respect for people,” ("Lean Project Delivery," 2015). The increase in communication leads to a decrease of stress between workers and management by decreasing the number of workers on site. Fewer workers lead to less clutter on the site which increases worker focus and understanding resulting in few accidents. The industry uses lean construction because it greatly reduces construction time due to increased planning and a stronger focus.

2.6 Constraints on Developing the Alternative Designs

2.6.1 LEED

LEED stands for Leadership in Energy and Environmental Design. LEED is a sustainable building assessment tool created by the United States Green Building Council (USGBC) in 1998 (Richards). It was created with the purpose of achieving the USGBC’s mission: “To transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves quality of life” ("About USGBC," 2015). LEED certifications are becoming more popular throughout the construction industry because of the drive to create a more sustainable infrastructure.

Certification

The LEED rating tool is a credit system. For a building to become LEED certified, it must satisfy a certain number of credits from the 9 different credit categories. The nine categories are: Integrative Process, Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation and Design, and Regional Priority ("LEED credits," 2015). The four different levels of LEED certification are Certified, Silver, Gold and Platinum. A building must achieve 40-49 points to be Certified, 50-59 points to be Silver, 60-79 points to be Gold, and 80 or more points to be Platinum ("LEED certification," 2015). Clark University's Alumni and Student Engagement Center has received the highest LEED certification, Platinum.

2.6.2 Building Codes

In order to build a structure in the United States, three different types of codes must be followed: codes specific to both the city and state and all aspects of the International Building Code, IBC. Typically, building codes for specific cities are found in Ordinances, which is true for the city of Worcester, Massachusetts. Building codes specific to the state are found in the form of state-specific amendments to the IBC, which is true for Massachusetts. A project must comply with all aspects of the IBC except those amendments outlined by the state. A project also must comply with the American Society of Civil Engineers, ASCE, code dealing with structural design and ethics.

Worcester

The ordinances that Consigli Construction had to abide by are outlined in the table below.

Table 3 Worcester Building Codes (Revised Ordinances of 2008, 2015)

Ordinance	Chapter	Action
21	5	Garbage & toxic construction waste cannot be drained in to public sewers.
8	7	Consigli Construction must submit application to the City of Worcester for the building to use city drinking water.
5	34	Consigli must obtain a permit to excavate and verify that all construction waste was correctly disposed of.
12	12	Consigli Construction must state in their construction application to the City of Worcester that the sidewalk will be blocked for duration of project.

Massachusetts

Clark University's ASEC also had to comply with Massachusetts Amendments to the 2015 International Building Code.

Table 4 Massachusetts Amendments to the 2015 IBC

("9th Edition 780 CMR Base Code Proposed MA Amendments to the IBC 2015," 2015)

Section	Action
901.21	Consigli must submit shop drawings of fire protective systems to the fire & building official.
901.5.1	A design professional must certify that fire protection systems have been installed and tested properly.
909.18.8.3.1	Consigli must create a report that states all smoke control systems in the building, who they were tested by, when they were tested and how each device performed during the test. A copy of this report must be submitted to the fire code official and building code official. An identical copy must be kept in the building at all times.
1001.3.1	All exterior stairways and fire escapes must be kept free of snow and ice. These features must be attached to the building with weather resistant fasteners and connection ties.
1001.3.2	All exterior features that carry human load must be tested every five years for structural adequacy by a design professional.
1209.4	All doors, trap doors and openings separating conditioned air from unconditioned air must be fitted with weather strips
1810.3.3.1.1	The factor of safety could not be less than 3.5 if the final driving criteria was determined from the pile driving formula specified in the IBC. The factor of safety could not be less than 2.75 if the final driving criteria was obtained from a wave equation analysis specified in the IBC.
1810.3.14	This section contains various specifications regarding spacing and shape of different types of piles.

The project also had to comply with an addition to section 1604 (1604.11). Section 1604 deals with structural design values specific to each region. This addition is a table that contains various structural design values specific to the city of Worcester. The value p_g represents the ground snow load in psf, pounds per square foot. The value V represents wind speed in a three second gust specific to the region in miles per hour. The value Ss represents the mapped spectral acceleration for short periods in g (meters per second squared). The value S_1 represents the mapped spectral acceleration for a one second period in g, meters per second squared. A spectral response acceleration parameter relates to how violent an earthquake would be in that region for a given amount of time ("9th Edition 780 CMR Base Code Proposed MA Amendments to the IBC 2015," 2015).

Table 5 Structural Design Values for the City of Worcester

("9th Edition 780 CMR Base Code Proposed MA Amendments to the IBC 2015," 2015)

City/Town	p_g	V	Ss	S_1
Worcester	55	100	0.24	0.067

The project had to comply with an addition to section 1605.3.1 (1605.3.1 Equation 16-13). The following equation replaced the original in the IBC, where D represents dead load, W represents wind load, E represents earthquake load, L represents live load, Lr represents roof live load, S represents snow load, R represents rain load and H represents load due to lateral earth pressures. The value f_1 is 1 for places of public assembly, such as parking garages where live loads exceed 100 pounds per square foot; it is 0.5 for other live loads ("9th Edition 780 CMR Base Code Proposed MA Amendments to the IBC 2015," 2015).

Equation 1 Loading Combination Equation

("9th Edition 780 CMR Base Code Proposed MA Amendments to the IBC 2015," 2015)

$$\frac{2}{3}[1.2D + (1.6W \text{ or } 1.0E) + f_1L + 0.5(L_r \text{ or } S \text{ or } R) + 1.6H]$$

The project had to comply with an amendment to section 1610 (1610.2) that deals with seismic loads on foundations and retaining walls. Exterior foundations and retaining walls must be designed to resist an earthquake force of F_w . The value F_a is the site coefficient obtained from Table 1613.3.3(1) dealing with site classes and mapped spectral response acceleration for a short period. The value γt is the total unit weight of the soil. The value H is the height of the wall measured as the difference in elevation of finished ground surface or floor in front of and behind the wall:

Equation 2 Required Earthquake Resisting Force for Exterior Foundation & Retaining Walls ("9th Edition 780 CMR Base Code Proposed MA Amendments to the IBC 2015," 2015)

$$F_w = 0.100(S_S)(F_a)(\gamma_t)(H)^2$$

To implement an alternative flooring into our alternate floor framing design, the manufacturing aspect of the alternate flooring system must comply with an added section to the IBC (780 CMR 110.R3).The project also had to comply with Massachusetts amendments to the appendix of the IBC ("9th Edition 780 CMR Base Code Proposed MA Amendments to the IBC 2015," 2015). The project must contain occupancy sensors, time clock controls & automatic daylighting controls. The project had to comply with all ASCE codes dealing with structural design. The project also had to comply with all IBC aspects besides amendments specified by the State of Massachusetts.

3.0 METHODOLOGY

The goal of this project is to develop an alternative gravity load resisting system while considering the impacts of this alternative structural design on the cost and schedule of the project.

Our objectives are:

1. Analyze exterior AESS columns and their pinned connections and explore the structural impacts on the canopy design.
2. Design an alternative floor framing system and compare with the current floor framing system in terms of structural integrity.
3. Determine the impact of submittals and RFI's on the project schedule.
4. Determine the cost of an alternative floor framing system along with the AESS columns and their impact to the project schedule.
5. Create a 5D BIM model incorporating the new design, schedule and cost.

3.1 Objective 1: Analyze Exterior AESS Columns and Their Pinned Connections and Explore the Structural Impacts on the Canopy Design.

In order to gain a full understanding of the need for the exposed pinned column connections, we will explore the structure as a whole and the effect of each member makes on the integrity of the building. This section will touch upon how we will determine the exterior loadings on the structure and how the AESS columns play a role in keeping the structure intact. Once a full understanding of the structural system is achieved, we will develop alternative steel columns for the exposed structure. The new steel columns will be analyzed through a simulation test using *RISA* software package to see their effects on the entire system. All structural design calculations will be done by hand and checked with the computer software packages above. The group will design an alternate column and test different steel member types to find a more cost effective alternative.

3.1.1 Task 1: Current column loading design

The group will look at the current exterior forces and column designs to have a base point to compare to the alternate column design strength test. To accomplish this, we will look at the building exterior and design specifications while comparing them to the *Massachusetts State Building Codes* and *Worcester Zoning Ordinance* to see which regulations were applied to this building. For more information about the *Worcester Zoning Ordinance* please refer to the Background Chapter.

Exterior Building

The group will analyze the current structural system while providing column design alternatives in accordance with the provisions of the *Massachusetts State Building Codes*. While analyzing the current structural system we will investigate the effects of external loads on the member forces, member connections, and footing designs. The flowchart below illustrates constraints needed to complete a structural analysis on the columns and their effect on the entire system.

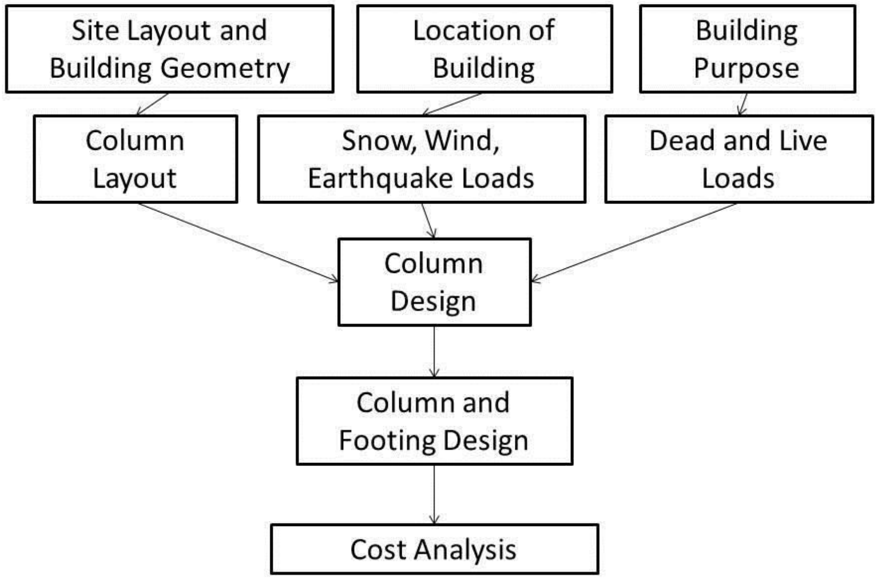

Figure 9 Flowchart of Process

Column Layouts

The group will determine the importance of the current column design and their effect on the building canopy. To do this, we will study the effects on the building if a column were removed or offset in the column layout design. Multiple canopy stability effects due to column removal and alterations will also be analyzed using RISA.

3.1.2 Task 2: Alternative material and design

In order to create an alternative column design, the group will identify and test multiple steel alternatives that will satisfy the design regulations within *Massachusetts State Building Codes*. Below is a flowchart of the process for creating an alternate design for the exposed columns.

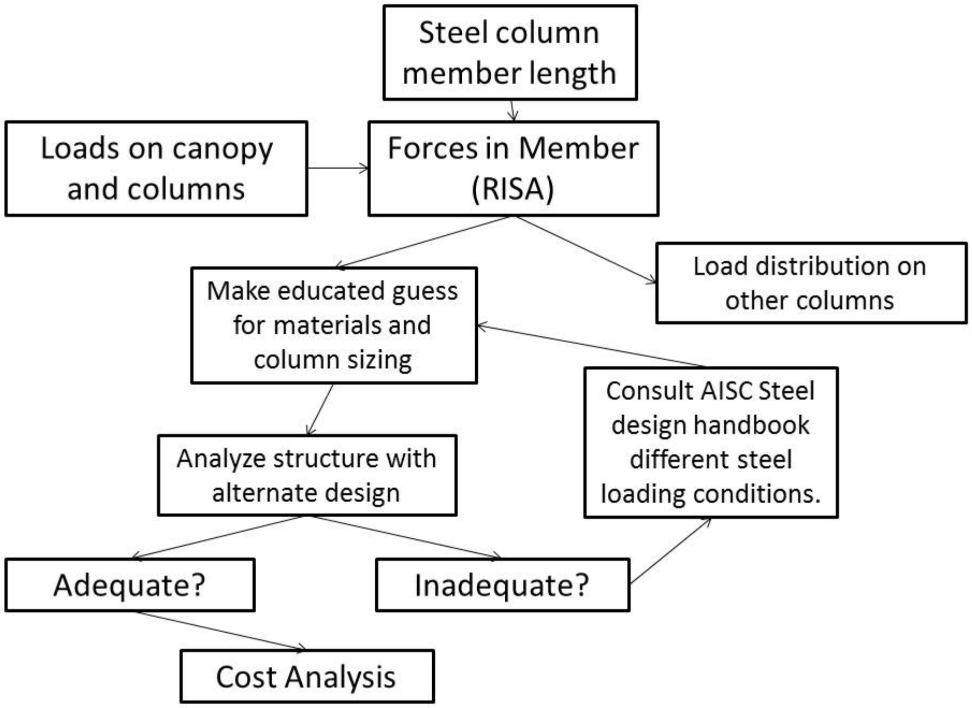

Figure 10 Alternative Flowchart

Sizing and Type of Material

There are several types of materials used for exterior structural columns within a campus building that can be considered. The current design uses AESS coating and surface finishes for structural steel which is a rather costly material. We will be choosing a different steel column size and steel type that will satisfy building loading requirements and pose as a cost effective alternative to the current design. The current steel type is A992 50 ksi and the size is High Speed Steel, HSS,12.750X0.500. This steel shape is a hollow cylinder with a diameter of 12.750 inches and 0.500 inches thick. Other steel types, shapes and sizes will be considered based on loading conditions and their performance with the AESS coating and finishing process. We will ensure the alternative columns remain in compliance with building and zoning codes. From here the group will decide the appropriate material and dimensions of the column.

Loads acting on an exposed columns

Due to the column receiving forces in the x and y directions (Statics and Strength of Structures) the group will make hand calculations to determine countering member forces. All calculations will be confirmed using RISA to analyze the forces within each column member.

Force distribution into other exposed columns

The group will calculate the forces from the canopy to the newly designed column through RISA analysis of the canopy. After the forces are calculated in one column, the remaining columns will be tested with new loads and designs using the RISA analysis software. Once a design alternative has been established, the group will conduct a structural analysis on the entire building with the alternative design for the columns. This will ensure that the building will remain structurally stable and adhere to building code regulations.

3.2 Objective 2: Design an Alternative Floor Framing System and Compare with the Current Floor Framing System in Terms of Structural Integrity.

To begin our structural analysis and design, we need to analyze current loadings on areas of focus within the building. We will determine the live and dead loads on the four AESS columns, canopy and three floor systems. We will use this information to design an alternative floor framing system for the second, third and fourth floor of the building.

3.2.1. Task 1: Calculate current loading on columns and three floor designs

Using the loading plan in the structural drawings, we will determine the live and dead loads on the canopy, columns and the three floor designs. With the accurate loading, we will use knowledge from structural design classes to perform a structural analysis on each individual beam on the canopy. We will compare the actual beam and column size with the appropriate sizes we will determine through our analysis. The structural analysis will determine the allowed loading on each beam. We will compare that value with the actual loading to see if it is sufficiently sized. If the beam is oversized, we will determine a new beam size using knowledge from structural design classes. We will repeat this same process with each floor framing system. We will also consider deflection on the beams as part of our structural analysis. We will be performing calculations by hand and checking them using RISA, a structural analysis software.

3.2.2 Task 2: Develop an alternative floor framing design for floors 2, 3 and 4.

We will calculate the dimensions and weight of the new concrete slab to be placed for the alternative floor framing system. We will then compare the loading factors of the slab on metal decking with our alternative flooring loads. We will factor in the weight of all other components of the alternative flooring systems such as mesh reinforcement, MEP or climate tubes. We will also take into account new column sizes, if there are any, and the impact they have on the alternative floor framing systems. We will then determine the total new dead load on the flooring system. With that new dead load, we will determine if beam section sizes can be changed using knowledge from structural design classes. We will re-evaluate the stability of the concrete slab with the embedded I-beams. Based on the strength of the slab, we will determine the size of the mesh reinforcement, if any, that is required for acceptable performance. We will then determine the size and quantities of all the materials needed for our alternative floor framing system.

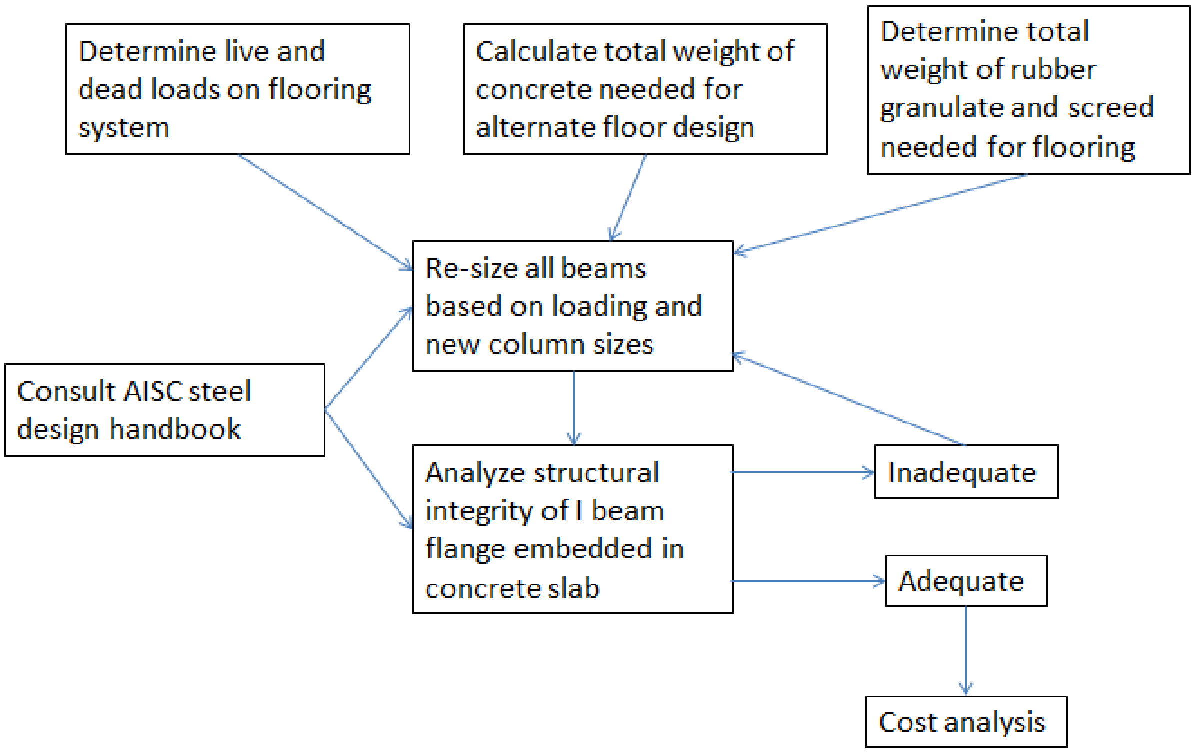

Figure 11 Alternative Floor Framing System Flowchart

3.3 Objective 3: Determine Impact of Submittals and RFI's on the Project Schedule.

To determine the effect of submittals and RFIs on the project schedule, we will attend Owner's meetings.

3.3.1 Task 1: Owner's Meetings

We will attend Owner's meetings on the ASEC site to learn about project progress, obtain meeting minutes, and ask Richard Scopellitti, Consigli Construction's Project Manager, questions about the project. The meeting minutes contain information about start to end dates for submittals and RFIs on the original schedule. We will record the submittals and RFIs information in Microsoft Excel. Appendices C and D respectively show the format of the excel file we will using to collect submittal and RFI data. We will track lag and lead times to determine if they impact the schedule positively (speed up the schedule) or negatively (delay the schedule). Specifically for RFIs, we will track and record the types of information being requested. We will use statistical analysis to determine delays that occur due to late submittals and responses to RFIs. We will create histograms, pie charts, and bar graphs to display this data.

3.4 Objective 4: Determine the Cost of an Alternative Flooring System Along With the AESS Columns and their Impacts to the Project Schedule.

To determine the cost of the alternate floor framing system and its effect on the project schedule, we will create a cost estimate and new schedule for the new flooring system. We will only be addressing the areas impacted by the new design of the gravity load resisting system.

3.4.1 Task 1: Cost Estimate

Using *RS Means* cost data, we will compile a new unit cost estimate for the new alternative floor framing system incorporating material, equipment, and labor costs. The form we will be using to create the cost estimate is shown below in Figure 12. The new design may affect the total labor costs for installing the new floor framing system as different construction methods need to be used. We will do the same for the AESS columns. We will create the cost estimate in *Microsoft Excel*. We will then compare the structural steel cost and pre-cast concrete planks cost determined as part of the cost estimate of the new alternative floor to Consigli Construction's structural steel bid package cost and slab-on deck cost. We will do the same for the AESS columns.

Girder Floor System Cost Estimate

Girder Slab Structural Steel				
Floors 2-4				
size	**weight (lbs)**	**weight (tons)**		
D-Beam				
			Price per ton:	
			Total Cost:	

Girder Labor & Equipment per Ton			
Tons	**cost ($/ton)**		
		Cost:	

Girder-Slab Material Costs:						
Floor Area	Area (SF)	**Metal Deck** $/SF	**Pre-Cast Planks** $/SF	**Cementious Grout** $/SF	**Fireproofing** $/SF	
Floors 2-4						
	Total					

Figure 12 Cost Estimate Sample Template

3.4.2 Task 2: Schedule

We will create a construction schedule for the new floor framing system design and AESS column design. We will research lead-times for obtaining materials for the alternative floor framing system design. We will do the same for the AESS columns. We will be incorporating the delay data for submittals and material deliveries from the current ASEC project into our project schedule. For example, if there was a delay in fabrication process of the AESS columns which resulted in a 2-week delay of getting the columns on site, then we will include this into our schedule. We will create the schedule using the lead-time information for materials and labor productivity rates for construction tasks. This schedule will be created in *Microsoft Project.*

3.5 Objective 5: Create a 5D Model Incorporating the New Design, Schedule, and Cost

To create a 5D Model of the ASEC, we will use Building Information Modeling software such as *Autodesk Revit 2015* and *Autodesk Navisworks*.

3.5.1 Tasks

With the knowledge of Building Information Modeling (BIM) we will develop a 5D model to provide a visual representation of the structural plan of the Alumni and Student Engagement Center. This process will begin on Tuesday, October 27th to analyze the structural plans and create a model for our new gravity load resisting system. Consigli Construction has provided access to the ASEC building's *Autodesk Navisworks* Drawings which will be used as a guide to help create a new alternative structural plan. To do this, we will use the *Autodesk Revit 2015* software to create a 3D model of the structural design of the building using steel beams, steel columns, foundations, flooring systems and roofing system. Using the schedule that we will create in *Microsoft Project*, we will import the *Autodesk Revit 2015* file and the schedule into a program called *Autodesk Navisworks*. This will create a 4D model which will be able to visually align the schedule and construction process. We will also import the cost estimate into the *Navisworks* file to show the cost of installing the new gravity load resisting system. By doing this, we will create a 5D model of the structural design of the Alumni and Student Engagement Center. This model will show the gradual construction process that we have observed on site by showing the phases of which the original has been built with the adjustments to the gravity load system. This model will include the buildings site layout and the steel structure. The *Navisworks* model will be updated when new alterations are developed.

The methods described above will be used to fulfill our goal: develop an alternative gravity load resisting system while considering the impacts of this alternative structural design on the cost and schedule of the project. Our final project deliverables will consist of a new alternative floor framing system design and AESS column layout design for the Alumni and Student Engagement Center, a new cost estimate, a new construction schedule and the 5D *Navisworks* model to show the new building. Our projected progress can be found in Appendices E and F, which show our list of tasks from our gantt chart and compressed gantt chart respectively.

APPENDICES

Appendix A

AESS Columns vs Structural Steel	
Specification	**Description**
Special Care in Processing AESS **Basic**	Upgraded care in process of fabricating, trucking, handling, storing, and erecting the material is required to obtain minimally acceptable AESS
Tolerances: One Half Standard **Basic**	The tolerances for structural steel frames are set by AISC Code of Standard Practice. If AESS is specified, these tolerances are required to be one-half of those of a standard structural steel.
Coping and Blocking Tolerances Minimized **Basic**	Requires that all copes, miters, and cuts in AESS material are to be made with a uniform gap of 1/8”
Joint Gap Tolerance Minimized **Basic**	A clear distance between abutting members of 1/8” is required.
Piece Marks Hidden **Basic**	AESS pieces are marked in inconspicuous places whenever possible, but there are many cases where these marks are seen. If removal of these marks is required for aesthetic reasons, this classification should be specified.
Surface Defects Minimized **Basic**	In the process of handling the materials, the flanges of the beams and columns will inevitably be deformed and scarred. If this classification is specified, these deformities and scars will be removed
Rolled Members **Category 3**	Minimize Distortion – When rolling members into various shapes, the member will be distorted. Distortion must be minimized.
Bolt Head Orientation Dictated **Category 3**	Special attention is required in the shop and the field for the bolt heads to be orientated in a particular direction
Welds Ground Smooth **Category 2**	In standard structural steel, welds are left in as is welded condition with slag and weld spatter removed. This is the same for AESS, however, if it is specified, welds must be ground smooth
Welds Contoured and Blended **Category 2**	If transitions of smoothly grounded welds are required to be contoured and blended, this process will be done by hand and will leave blemishes around the weld area. Samples should be submitted for review
Weld Show Through Minimized **Category 2**	Weld show through is seen on the opposite side of where the piece was welded. If required, weld show through is ground by hand, and may leave a

	blemish.
Field Welding Aids Removed **Category 2**	Sometimes field welding aids are not removed due to structural integrity issues. If specified, special attention is required in the shop and field.
Close Weld Access Holes at Full Pen Welds **Category 2**	Weld access holes are holes in the web of beams and columns to allow the welder to weld in areas of the member's web. If they are required to be closed for aesthetic reasons, special attention is required in the shop and field.
Continuous Welds **Category 1**	Intermittent welds required for strength, may be required to be continuous for aesthetic reasons. Special attention is required to avoid distortion of the member
Mill Marks Removed **Category 1**	Steel mill marks with their heat numbers and producer information identifying the material chemistry and strength, must be removed
Grinding of Sheared Edges **Category 1**	Materials with sheared edges during the fabrication process may demand that rough surfaces be deburred and ground smooth
Seal Welds to Close Open Gaps **Category 1**	Frames may require welds to seal gaps from environmental implications or aesthetic reasons. Note that this may cause distortion.

Appendix B

Please see myWPI for the Life & Safety Load Compliance Drawing G0.03 under the Final Proposal Folder.

Appendix C

Clark University's Alumni & Student Engagement Center Submittal Log																					
Spec Section	#	Title	Rev.	Created At	Updated At	Received Date	Issue Date	Required On Site Date	Lead Time	Planned Return Date	Design Team Review Time	Planned Internal Review Completed Date	Internal Review Time	Planned Submit By Date	Submit By	Sent Date	Returned Date	Final Due Date	Status	Distributed Date

Appendix D

Clark University's Alumni & Student Engagement Center RFI Log												
#	Initiated At	Due Date	Subject	Cost Impact	Cost Impact Value	Schedule Impact	Schedule Impact Value	Drawing #	Reference	Closed Date	Closed?	Latest Assignee Response Date

Appendix E

MQP gannt chart revised 3

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**Develop Project Proposal**	**18.88 days**	**Mon 9/28/15**	**Wed 10/14/15**		
2	**Complete Methodology**	**12 days**	**Mon 9/28/15**	**Thu 10/8/15**		
3	Revise Methodology	12 days	Mon 9/28/15	Thu 10/8/15		*
4	**Complete Background**	**15.38 days**	**Mon 9/28/15**	**Sun 10/11/15**		
5	Submit 1st draft of Background	12 days	Mon 9/28/15	Thu 10/8/15		*
6	Revise Background	3 days	Fri 10/9/15	Sun 10/11/15	5	*
7	**Complete Intro/Conclusion**	**6.75 days**	**Tue 10/6/15**	**Sun 10/11/15**		
8	Write Intro/conclusion	3.38 days	Tue 10/6/15	Thu 10/8/15		*
9	Revise Intro/conclusion	3.38 days	Fri 10/9/15	Sun 10/11/15	8	*
10	**Complete Licensure Statement**	**12.38 days**	**Mon 9/28/15**	**Thu 10/8/15**		
11	Revise Licensure Statement	12.38 days	Mon 9/28/15	Thu 10/8/15		*
12	Compile proposal	1 day	Mon 10/12/15	Mon 10/12/15	3,6,9,11	*
13	finalize proposal	2 days	Tue 10/13/15	Wed 10/14/15	12	*
14	**Develop Project Presentation**	**5.5 days**	**Thu 10/8/15**	**Mon 10/12/15**		
15	**draft presentation**	**4.5 days**	**Thu 10/8/15**	**Sun 10/11/15**		
16	create PPT presentation	4.5 days	Thu 10/8/15	Sun 10/11/15		*
17	**finalize presentation**	**1 day**	**Mon 10/12/15**	**Mon 10/12/15**		
18	revise PPT presentation	1 day	Mon 10/12/15	Mon 10/12/15	15	*
19	early output schedule?	4.5 days	Sat 10/3/15	Tue 10/6/15		J
20	**Objective 1**	**41 days**	**Tue 10/27/15**	**Wed 12/2/15**		
21	**Task 1: analyze current column loading design**	**9 days**	**Tue 10/27/15**	**Tue 11/3/15**		
22	calculate loads on columns	2 days	Tue 10/27/15	Wed 10/28/15		N,R
23	moment shear diagrams	2 days	Wed 10/28/15	Fri 10/30/15	22	N,R
24	detemine AESS properties	5 days	Fri 10/30/15	Tue 11/3/15	23	N,R
25	**Task 2: Suggest Alernative Material and Design**	**32 days**	**Wed 11/4/15**	**Wed 12/2/15**		
26	analyze different column layouts	8 days	Wed 11/4/15	Wed 11/11/15	24	N,R
27	stress anaylsis in RISA	5 days	Thu 11/12/15	Tue 11/17/15	26	N,R
28	test different AESS properties/SS	12 days	Tue 11/17/15	Fri 11/27/15	27	N,R
29	suggest alternative column design	5 days	Sat 11/28/15	Wed 12/2/15	28	N,R

Page 1

MQP gannt chart revised 3

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
30	**Objective 2**	**68.88 days**	**Wed 12/2/15**	**Mon 2/1/16**		
31	**Task 1: analyze current column to flooring load t**	**51.88 days**	**Wed 12/2/15**	**Sun 1/17/16**		
32	based on new column design determine live ar	2 days	Wed 12/2/15	Fri 12/4/15	29	N,R
33	perform structural analysis on individual canop	5 days	Fri 12/4/15	Tue 12/8/15	32	N,R
34	determine new beam sizes for canopy	10 days	Tue 12/8/15	Thu 12/17/15	33	N,R
35	compare loading of original beams to new des	2 days	Thu 1/14/16	Fri 1/15/16		N,R
36	double check hand calculations with RISA	2 days	Fri 1/15/16	Sun 1/17/16	35	N,R
37	**Task 2: develop slimline floor framing design**	**17 days**	**Sun 1/17/16**	**Mon 2/1/16**		
38	calculate dimensions and weight of new concr	1 day	Sun 1/17/16	Mon 1/18/16	36	N,R
39	compare loading of slab w/ metal decking to n	2 days	Mon 1/18/16	Wed 1/20/16	38	N,R
40	consider weight of other slimline components	2 days	Wed 1/20/16	Thu 1/21/16	39	N,R
41	determine dead load on flooring system	3 days	Fri 1/22/16	Sun 1/24/16	40	N,R
42	re-evaluate stability of concrete slabs w/ embe	5 days	Sun 1/24/16	Fri 1/29/16	41	N,R
43	determine required mesh reinforcement size	3 days	Fri 1/29/16	Sun 1/31/16	42	N,R
44	determine size and quantities of materials for	1 day	Sun 1/31/16	Mon 2/1/16	43	N,R
45	**Objective 3**	**148.75 days**	**Tue 10/13/15**	**Mon 2/22/16**		
46	**Task 1: Attend Owner's Meetings**	**142.75 days**	**Tue 10/13/15**	**Tue 2/16/16**		
55	**Record submittal & RFI data in Excel**	**147.75 days**	**Tue 10/13/15**	**Mon 2/22/16**		
64	statistical analysis - lag/lead times	5 days	Wed 2/17/16	Mon 2/22/16	63	J,H
65	record observed program, document (photos)	5 days	Tue 2/16/16	Sun 2/21/16	46	J,H
66	**Objective 4**	**114.88 days**	**Tue 10/27/15**	**Sat 2/6/16**		
67	**Task 1: create cost estimate**	**114.88 days**	**Tue 10/27/15**	**Sat 2/6/16**		
68	Research RS Means cost data for slimline	5 days	Tue 10/27/15	Sat 10/31/15		J,H
69	Research RS Means cost data for AESS	5 days	Sun 11/1/15	Thu 11/5/15	68	J,H
70	Complile Cost Estimate	5 days	Mon 2/1/16	Sat 2/6/16	44,68,69	J,H
71	**Task 2: create schedule**	**103.63 days**	**Fri 11/6/15**	**Sat 2/6/16**		
72	research lead-times	5 days	Fri 11/6/15	Tue 11/10/15	69	J,H
73	compile schedule	5 days	Mon 2/1/16	Sat 2/6/16	44,72	J,H
74	**Objective 5**	**93.25 days**	**Tue 11/17/15**	**Sun 2/7/16**		

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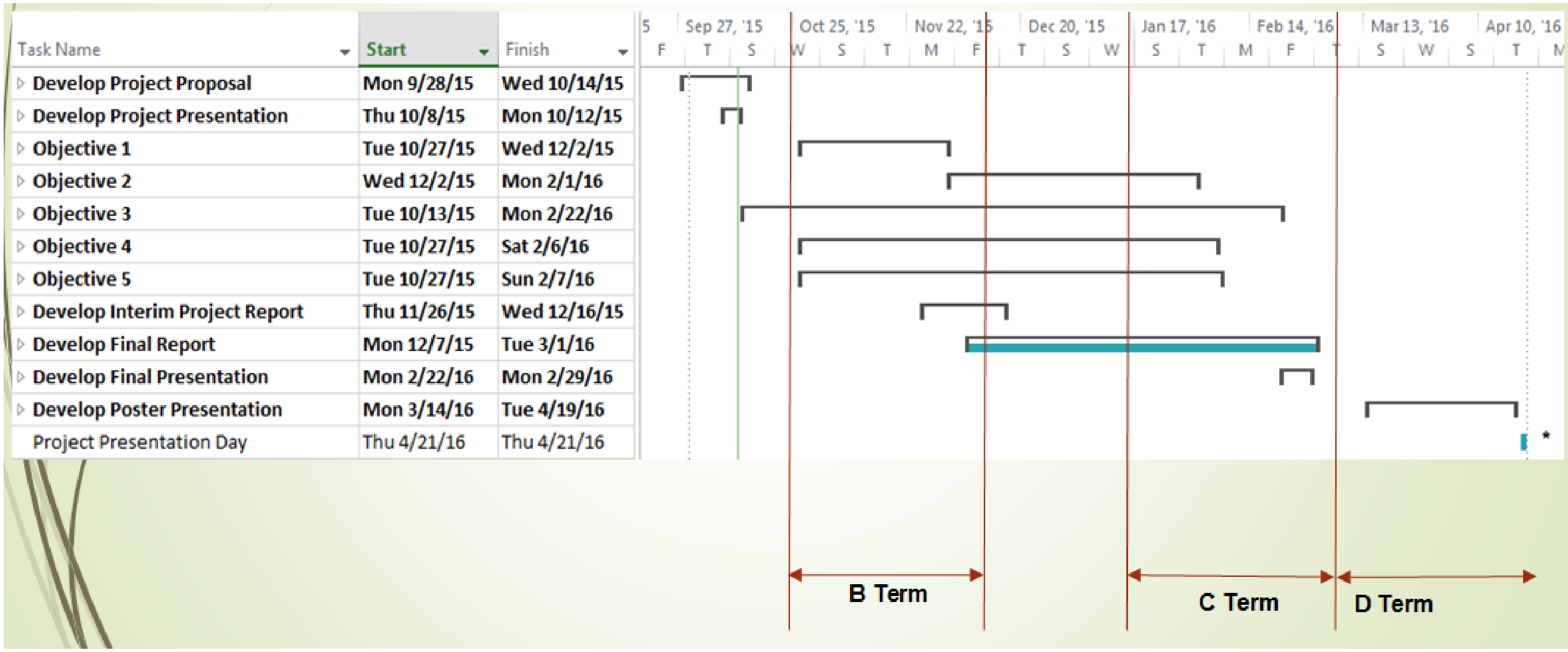
MQP gannt chart revised 3

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
75	**Task 1: create 5D BIM model**	**93.25 days**	**Tue 11/17/15**	**Sun 2/7/16**		
76	create new 3D Revit model (start mid B term)	30 days	Tue 11/17/15	Sun 12/13/15		J,H
77	import schedule into Navisworks (C term)	2 days	Sat 2/6/16	Sun 2/7/16	73	J,H
78	import cost estimate into Navisworks (C term)	2 days	Sat 2/6/16	Sun 2/7/16	70	J,H
79	**Develop Interim Project Report**	**22.88 days**	**Thu 11/26/15**	**Wed 12/16/15**		*
80	Develop Interim Report	20 days	Thu 11/26/15	Sun 12/13/15		*
81	Develop Interim Presentation	2 days	Mon 12/14/15	Wed 12/16/15	80	*
82	**Develop Final Report**	**96.75 days**	**Mon 12/7/15**	**Tue 3/1/16**		*
83	Revise Abstract	5 days	Mon 2/22/16	Fri 2/26/16		*
84	Finalize Abstract	5 days	Fri 2/26/16	Tue 3/1/16	83	*
85	Revise Licensure Statement	5 days	Tue 2/2/16	Sat 2/6/16		*
86	Finalize Licensure Statement	5 days	Sat 2/6/16	Wed 2/10/16	85	*
87	Revise Intro	5 days	Tue 2/9/16	Sat 2/13/16		*
88	Finalize Intro	5 days	Sat 2/13/16	Wed 2/17/16	87	*
89	Revise Background	5 days	Mon 12/7/15	Fri 12/11/15		*
90	Finalize background	5 days	Fri 12/11/15	Tue 12/15/15	89	*
91	Revise Methodology	5 days	Mon 12/7/15	Fri 12/11/15		*
92	Finalize Methodology	5 days	Fri 12/11/15	Tue 12/15/15	91	*
93	Develop Results/Analysis 1st Draft	5 days	Tue 12/15/15	Sat 12/19/15		*
94	Develop Results/Analysis final Draft	5 days	Sat 12/19/15	Wed 12/23/15	93	*
95	Develop Conclusions 1st Draft	5 days	Wed 12/23/15	Mon 12/28/15	94	*
96	Develop Conclusions Final Draft	5 days	Mon 12/28/15	Fri 1/1/16	95	*
97	**Develop Final Presentation**	**8 days**	**Mon 2/22/16**	**Mon 2/29/16**		
98	Draft Power Point Presentation	5 days	Mon 2/22/16	Fri 2/26/16		*
99	Finalize Power Point Presentation	3 days	Fri 2/26/16	Mon 2/29/16	98	*
100	**Develop Poster Presentation**	**40.88 days**	**Mon 3/14/16**	**Tue 4/19/16**		
101	Prepare Poster	34.88 days	Mon 3/14/16	Wed 4/13/16		*
102	Finalize Poster	6 days	Thu 4/14/16	Tue 4/19/16	101	*
103	Project Presentation Day	1 day	Thu 4/21/16	Thu 4/21/16		*

Appendix F



Task Name	Start	Finish
Develop Project Proposal	Mon 9/28/15	Wed 10/14/15
Develop Project Presentation	Thu 10/8/15	Mon 10/12/15
Objective 1	Tue 10/27/15	Wed 12/2/15
Objective 2	Wed 12/2/15	Mon 2/1/16
Objective 3	Tue 10/13/15	Mon 2/22/16
Objective 4	Tue 10/27/15	Sat 2/6/16
Objective 5	Tue 10/27/15	Sun 2/7/16
Develop Interim Project Report	Thu 11/26/15	Wed 12/16/15
Develop Final Report	Mon 12/7/15	Tue 3/1/16
Develop Final Presentation	Mon 2/22/16	Mon 2/29/16
Develop Poster Presentation	Mon 3/14/16	Tue 4/19/16
Project Presentation Day	Thu 4/21/16	Thu 4/21/16

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