Design of the New WPI Residence Hall

A Major Qualifying Project Report

Submitted to the faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the degree requirements for the

Degree of Bachelor of Science

by

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Abstract

This Major Qualifying Project consists of the design of the new upperclassman residence hall for Worcester Polytechnic Institute (WPI). The project covers several aspects of the design of the structural system and the management process; such as the design of the members and the design of the foundation from a structural perspective, Time & Schedule, and cost estimation from a project management side. A steel structure was designed and excel spreadsheets were developed to calculate the size of the members needed. Foundation design was also covered, and spread footing foundation was proposed. Primavera was the main computer software used for management and cost estimation purposes. The cost estimation of the building was computed for both steel and reinforced concrete structures even though the structure was designed using steel as the main construction material.

Acknowledgements

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The authors would also like to thank those who contributed their time and expertise to this project, including: Professor Leonard Albano of the WPI Civil and Environmental Engineering department for his help with the steel design and Professor Guillermo F. Salazar of the WPI Civil and Environmental Engineering department for his help with project management and cost estimating.

Capstone Design Experience

Our capstone design investigated the structural design and the project management activities of the WPI New Residence Hall.

In this project according to the cost estimation analysis, steel structure was chosen over the concrete structure because it has lower cost. Based on the cost analysis for a 23' x 18' bay in the first floor, the cost of material, labor and equipment for the specified bay was determined. On the other hand, based on the concrete needs (cubic yard) for the specified bay, the cost for the concrete structure was calculated and it was compared with the cost of steel structure. At the end, the costs of both steel and concrete structures of the specified bay were applied to the whole building then it was found that the steel structure was cheaper than the concrete structure by $650,000. After it was considered that the steel was the logical material to be used, time & scheduling activities were done for only steel structure.

Throughout the design of the steel structure, there were different bays on each floor that were chosen based on the column locations. The number of beams that would support the interior part of each bay was selected based on the size of the bay and the tributary area that each beam should support and in this project it was tried to keep the limit of each beams tributary area less than 10 ft^2.

There are two possible methods to design the girders and columns, tributary area method (based on the tributary area that each girder or column would support regardless of any concentrated loads acting on them) and concentrated load method (based on the concentrated load acting on girders due to the beams or acting columns due to the girders and cantilevers). In this project the concentrated load method was chosen because it is more accurate.

In this project in order to design the floor slab, a composite floor system was chosen. Basically in composite system there is a specified thickness of concrete slab which would be poured on top of the metal decking. Similar to reinforced concrete slab, in composite metal decking, concrete is used because it is strong in compression, and the metal decking is used because it is strong in tension. The advantage of this system over reinforced concrete slab is that it is easier to install and the overall cost is cheaper than reinforced concrete.

In this project the metal decking is chosen to be corrugated because it has more bending capacity than the flat top decking and it would make a better bounding with concrete so it would have a better shear resistance. The metal decking and the concrete slab are connected to each other by shear studs which provide more shear resistance and it would allow the concrete and the metal decking to work together as one stronger system.

In this project green roof system was chosen and there are some advantages of that:

1. Green roof reduces and delays storm water runoffs.
2. Reduces the level of Carbone Dioxide in the air.
3. Provides insulation for the roof. Therefore, the usage of heat and air conditioning decreases.

4. Increases life expectancy of rooftop waterproofing due to protection from ultraviolet rays and mechanical impacts.
5. Assists the owner to achieve a LEED certification.

In this project the elevator shaft is located between two beams and the distance between the beams (tributary area of the beam in that bay) is 7’8”. The width of the elevator cart was chosen to be 6’8” so it would fit in between the beams and it would have one foot of space for mechanical purposes.

For the method of scheduling, fast track method was chosen because it decreases the time from concept to completion notably and it allows developing the investment much quicker than a usual delivery system.

In foundation design, a spread footing foundation was chosen because the total spread footing area was calculated to be less than the area of the foot-print of the building. In that case, the price of spread footing would be cheaper than the Mat or other foundations.

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Executive Summary

Worcester Polytechnic Institute (WPI) has launched a new project which will help to accommodate incoming students for the following academic years.

The WPI New Residence Hall will be located between Boynton and Dean Streets and will be an apartment style for upperclassmen. Apartments will contain 4-person apartments with full kitchen, living room, compartmentalized bathroom and either single or double bedrooms.

The goal of this MQP is designing the structure and managing the project by using Construction Project Management and Structural Engineering skills.

Cost is one of the most important factors that should be considered in every project. By using the cost estimating skills, the cost of the New WPI Residence Hall with a steel structure and also with a concrete structure was calculated and it was found that it would cost more to for a concrete structure. As the result the cost of the steel structure was estimated to be $5,950,568 and concrete structure was estimated to be $6,596,166.

Time is other factor that should be considered in all the projects. The project manager should make sure that the project would finish on time based on a given deadline. Primavera was software that was used to schedule the predicted time for the different steps of the project. It was estimated that it would take 399 work days in order to complete the WPI New Residence Hall project.

In order to start a safe construction project, permits need to be taken from the government. For this project the permits were provided by different departments of the

Commonwealth of Massachusetts and City of Worcester. For example, Massachusetts Uniform Application for Permit to do Plumbing is a permit that is needed for plumbing reasons.

Based on the cost estimation analysis, steel structure was chosen over the concrete structure because it has lower cost. In order to design the steel structure, each floor of the building was divided into bays with different sizes and based on the live and dead loads of different bays, the beams, girders and columns were designed. There were different sizes of beams, girders and columns designed for each bay. As a result, for bay 4, beam F-3.2 to G-3.2 is the biggest member size (33x118) that was designed for this project. For convenience of calculation for the right beam, girder and column sizes, excel spread sheets were used. Also for the slab of each floor, a 4.5" concrete slab with corrugated metal decking was designed.

In order to design the foundation, a soil profile was provided based on the standard penetration test for three boreholes. Based on the soil profile, the foundation of this building was designed to be spread footings. After calculations and using different spread sheets such as the Terzaghi and Vesic spread sheet, three different sizes (6' thick with 14'x14', 3' thick with 11'x11', 2' thick with 10'x10') of foundation for different columns of the building were designed.

Also an elevator shaft and a stair case were designed for this project. The elevator shaft is required to support a load of 13 kips (due to the elevator cart and the counterweight) and load of the elevator mechanical room which is 125 psf. The elevator cart was chosen to have a load capacity of 3000 lbs and an insider car area of 31.7 square feet (6'8" wide x 4'9" deep).

In this project, detail calculations and explanations of structural design and construction project management were indicated in the next chapters.

1.0 Introduction

Worcester Polytechnic Institute (WPI) has launched a new project that consists of a new residence hall between Boynton and Dean St. According to the WPI website, the new residence hall is a 103610 sq. ft and five story building that will house approximately 232 students (WPI NewResHall Facts and Figures, 2007). The building will consist of 4 person apartments with full kitchens, living rooms, bathrooms and either single or double bedrooms. It will also include recreation and fitness spaces. Figure 1 is futuristic image of the finished building.

***Figure 1*. Futuristic image of the WPI New Residence Hall.**

2.0 Background

The new residence hall is specifically designed for upperclassmen students, juniors, and seniors. According to Janet Richardson, the Vice President of Student Affairs and Campus Life at WPI, the building is designed to suit the student's needs and expectations and to provide a friendly environment which will push the upperclassmen students to remain on campus and participate in campus life.

As stated on the WPI website (WPI, NewResHall-Facts and Figures, 2007), this building is considered to be a "green" building; therefore, it was designed under the leadership in Energy and Environmental Design (LEED) program where approximately 95% of the materials used were recyclable.

Moreover, the construction of the parking garage is going to solve some of the parking issues. Some advantages of new parking place are less traffic during morning rush hours, more parking spots for the visitors etc.

2.1 Objective

The main purpose of this project was to come up with the most efficient structural design that can be used to suit the needs of WPI. Therefore, different schemes were evaluated in order to provide the most economical design. This project includes a cost estimation analysis of both steel structure and reinforced concrete structure in order to decide from a management perspective which structure is more cost effective.

This project covered both structural and management aspects. For the structural part, it covered the steel structure design of the building and the foundation design according to the Massachusetts Sate Building Code. The project management aspects took into account the cost estimation and the construction schedule of the building.

2.1.1 The Massachusetts State Building Code

The Massachusetts State Building Code (6th edition) was used as a reference for all aspects of design.

The Massachusetts State Building Code is published by the Commonwealth of Massachusetts (Mass, 2007) and It is considered to be the reference for any design and construction work in the state. It includes all the regulations and laws which apply to construction and it is based on the National Building Code published by the Building Officials and Code Administrators, International (BOCA, 2007).

2.1.2 Leadership in Energy and Environmental design (LEED)

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the U.S. Green Building Council, provides a suite of standards for environmentally sustainable construction. (USGBC, 2007).

LEED was created to accomplish the following issues:

1. Define "green building" by establishing a common standard of measurement
2. Promote integrated, whole-building design practices
3. Recognize environmental leadership in the building industry

4. Stimulate green competition
5. Raise consumer awareness of green building benefits
6. Transform the building market

In recent years, WPI decided to build new structures as a LEED structure by following the LEED Structure guide in order to make environmental friendly building. This approach of using the LEED Standards to construct new buildings identifies WPI as an environmentally friendly campus.

2.1.3 Green Roof System

Green roof systems assist a building owner to achieve a LEED certification. A green roof is a roof of a building that is covered with plants over a waterproofing membrane, root barrier membrane, drainage and irrigation systems.

When implementing a green roof, structural and load bearing capacity, plant selection, as well as, waterproofing and drainage system should be considered. Figure 2 provides a typical green roof layout with a list of the materials that are included when designing a green roof.

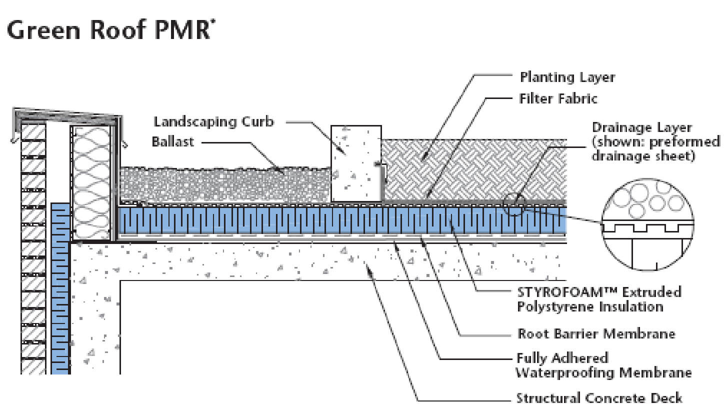


***Figure 2*. Green Roof layout.**

A typical green roof could be built in different ways which are outlined below:

Extensive Green Roofs: lighter than intensive green roofs. *Soil depth* is 1-6 inches and *weight load* 15 – 50 psf. The plants used are usually low to the ground like grass and short flowers.

Intensive Green Roofs: heavier than extensive green roofs. *Soil depth* is typically 6-24 inches (or more) and *weight load* is 80-150 psf. The plants used can be of any kind even trees could also be used.

Green Roofs have lots of advantages, below is a list of some of the advantages provided by green roofs:

6. Green roofs reduce and delay storm water runoffs.
7. Reduce the level of Carbone Dioxide in the air.
8. Provide insulation for the roof. Therefore, less usage of heat and air conditioning.
9. Increase life expectancy of rooftop waterproofing due to protection from ultraviolet rays and mechanical impacts. (Dow, 2005)

2.1.4 Foundation design

Foundation is one of the most important parts of the design of a structure, because it has the responsibility to transfer the structure loads from the columns to the soil. In that case, the designer should make sure to use a right type of foundation. Generally there are two different types of foundations, Shallow Foundations and Deep Foundations.

2.1.5 Shallow Foundation

The Shallow foundation is a type of foundation which transfers the loads from the structure to the top layers of the ground. The most popular types of shallow foundation are Mat-slab foundation and Spread footing.

1. Mat Foundation

Mat foundation is a type of foundation which is used when the soil has poor and irregular conditions, and when the building loads are so extensive. For mat foundations there would be a specific thickness of concrete slab under the whole area of the building, and there would be reinforcements within the concrete slab. (Suite101, 2007).

2. Spread Footings

   A spread footing or pad footing is used to support a single point of contact, such as under a pier, column or a post and it is made with reinforced concrete (3000 - 5000 psi compression). The shape of a spread footing could be square, rectangle or circular and they would have different size and thickness according to the applied column load and the soil conditions that they are located on.

2.1.6 Deep Foundation

Deep foundations are distinguished from shallow foundations by the depth they are embedded into the ground. There are different terms used to describe different types of deep foundations including piles, drilled shafts, caissons, and piers. Deep foundations can be made out of timber, steel, reinforced concrete and pre-tensioned concrete. Deep foundations can be installed by either driving them into the ground or drilling a shaft and filling it with concrete, mass or reinforcements.

2.1.7 Choosing the foundation Type

The type of foundation that should be chosen for a project depends on many variables; use of the structure, size of project, location of project which effects the soil properties of that place. Usually deep foundation is used when the top layers of soil under the structure are not strong enough to hold the structure, in that case they use deep foundation to have supports from the lower layers of soil which are stronger and have higher bearing capacity. If the top soil layers have big enough bearing capacity for the structure, then shallow foundation could be considered for the project.

As it was described before there are different types of shallow foundations. Two of the ones that will be considered in this project are mat foundation and spread footings. In order to select one of these two types, the cost is a big factor that should be considered.

For mat foundation a lot of concrete and reinforcements need to be used because concrete covers the whole base area of the building. On the other hand for spread footing, the concrete and reinforcements only cover where the columns would be located and they transfer the load from the column to the soil. The size of a spread footing is dependent on the magnitude of the load and the bearing capacity of the soil. If the total area of the spread footings covers more than half the building foot-print, then a mat foundation is more economical since the savings in labor cost will offset the increased material cost and it would be more convenient for the labor. And if the area of the spread footings cover less than half of the building foot-print, then the spread footing would be more desirable since mat foundation would be more expensive than the spread footings because of usage of more materials.

Soil Profile

Geotechnical soil reports (soil profiles) are also called Soil reports are determined by civil engineers who have experience in geotechnical engineering. The soil reports help to understand the soil properties of the layers of the earth. The soil reports should be provided before the construction starts and they help to design the foundation of the building. There are many methods to determine the soil profile such as; test pits, drilling core samples and driving steel rods into the soil. In this project, standard penetration test is used to determine the soil conditions.

Standard Penetration Test

Standard Penetration Test (SPT) is mainly used to provide information like strength, stiffness, density and depth of different soil layers. Normally before any construction, the geotechnical engineers would choose different spots (boreholes) on the ground where the foundation of the building will be located and they apply the SPT. At each borehole they would drive a steel tube with specified dimensions vertically in to the ground by hitting the steel tube with a specified force and mean while they would count the number of blows (hits) per foot and they would record it. At a depth that the number of blows per foot is greater, the density of soil is higher and that results in higher bearing capacity for the soil at that depth.

2.2 Project Management Activities

Project management is the application of knowledge, skills, tools and techniques to a broad range of activities in order to meet the requirements of the particular project. A project is a temporary endeavor undertaken to achieve a particular aim. Project management knowledge and practices are best described in terms of their component processes. These processes can be placed into five Process Groups: Initiating, Planning, Executing, Controlling and Closing. (NCSU.EDU, 2007)

Project Management activities are important to control the project and meet the requirements that are specified by the architect and the structural engineer. There are many issues that will be reflected by the project manager but the most important topics include life cycle cost, time, scheduling, and permits.

1. The objectives of any project management program are briefly listed below:
2. Making sure that projects are delivered within certain budget
3. Making sure that projects are delivered within certain schedule
4. Attention on the quality solutions
5. Reduced errors
6. Improve effectiveness
7. Appropriate risk management and internal controls
8. Continuous process improvement via collaboration
9. Implementing project communications and oversight (FIN, 2007)

2.2.1 Life Cycle Cost

The main concern in the construction business is the finance and how adequate money flows in the project. While predicting the project cost, project manager must use some forecast to balance the actual money and the expenses. If the forecast is not accurate enough and doesn't meet the requirements then there will be a big problem for both contractors and owner; furthermore, project may not be completed at all.

Life cycle cost is a mathematical method used to form or support a decision and it is usually employed when deliberating on a selection of options. It is an auditable financial ranking system for mutually exclusive alternatives which can be used to promote the desirable and eliminate the undesirable in a financial environment. (Bull, 1992)

In order to make adequate financial balance, project manager must receive detailed information about the project on time and without any mistakes.

There are three common methods that are used to check the life cycle cost and to determine whether the investment is logical or not:

- Simple payback: defined as the time taken for the return on an investment to repay the investment.
- Net present value: defined as the sum of money that needs to be invested today to meet all future financial requirements as they arise throughout the life of the investment.
- Internal rate of return: defined as the percentage earned on the amount of capital invested in each year of the life of the project after allowing for the repayment of the sum originally invested. (Hundal, 2001)

2.2.2 Time & Scheduling

A project, in general, is defined as a one-time job that has a starting point, ending point, scope and budget. Scheduling is a very important tool to understand the time and cost. The main idea behind the time & schedule concern is fitting the project in order and building it within an agenda. Overall planning of the project is based on cost analysis and the cost analysis is based on time & schedule.

2.2.3 Permits

According to Cape Cod Commission (2002) "Building permit means an official document of certification issued by the building official which authorizes the construction, alteration, enlargement, conversion, reconstruction, remodeling, rehabilitation, erection, demolition, moving or repair of a building or structure. In the case of a change in use or occupancy of an existing building or structure, the term shall specifically include Certificates of Occupancy and Occupancy Permits, as those terms are defined by county bylaw. The terms building permit and certificate of occupancy permit also mean those municipal permits which are equivalent to the county permits, regardless of the names by which they are called within a municipality" (Exhibit 1, Model Impact Fee Bylaw).

In this case, Worcester County permit regulations are applied to the WPI new residence hall project. In order to get permit for specific building, criteria must meet the requirements. Furthermore, there are many design and condition aspects that are usually inspected by the city executive inspectors at the laboratories and in case of any failure, permits will not be approved.

There are many types of permits according to the purpose of the building. Required sample permits and their definitions are explained in permit section of this project.

3.0 Project Management activities for the WPI Residence Hall

The background chapter included a brief definition about the management activities that usually occur when a new project is taking place. However, this section consists of a detailed explanation that shows the importance of a good project management profile. In addition, it was necessary to conduct research on some of the project achieved on campus that have similar structure and format, in order to develop management criteria for this new residence hall. It was also important to get a better understanding of the company that is responsible of accomplishing this current project; therefore, a profile about Gilbane Construction Company was also included in this section.

3.1 Project Management

Project Management is the discipline of organizing and managing resources in such a way that the project is completed within defined scope, quality, time and cost constraints (Foxhall W. B., 1996). A project is a temporary and one-time endeavor undertaken to create a unique product or service, which brings about beneficial change or added value. This property of being a temporary and one-time undertaking contrasts with processes, or operations, which are permanent or semi-permanent ongoing functional work to create the same product or service over and over again. The management of these two systems is often very different and requires varying technical skills and philosophy, hence requiring the development of project management (NCSu.EDU, 2007).

In the professional life, the contracting process has three main participants; owner of the project, designer, contractor team CM (Lester, 1991). All participants have unique responsibilities in order to execute the projects. CM or GC (General Contractor) counsels rest of the participant from the beginning of design and project management process till completing the project.

In addition, there are some differences between the development of a building and the construction management. Scheduling, packaging of contracts and life cycle cost, excluding the development of the building itself, are the instruments that are used by the CM. Construction Project Management and General Contractor terms are slightly different. Construction project management is responsible for coordinating and communicating in the entire project process, minimizing the project and cost, maintaining the project quality. On the other hand, General Contractor is an independent contractor. The General Contractor operates sub-project such as electrical, mechanical, in its own behalf (Clough, CPM, 1979). Provided below, Figure 3 show the CM hierarchy and the participants in the project process and Figure 4 show the GC hierarchy and the participants in the project process.

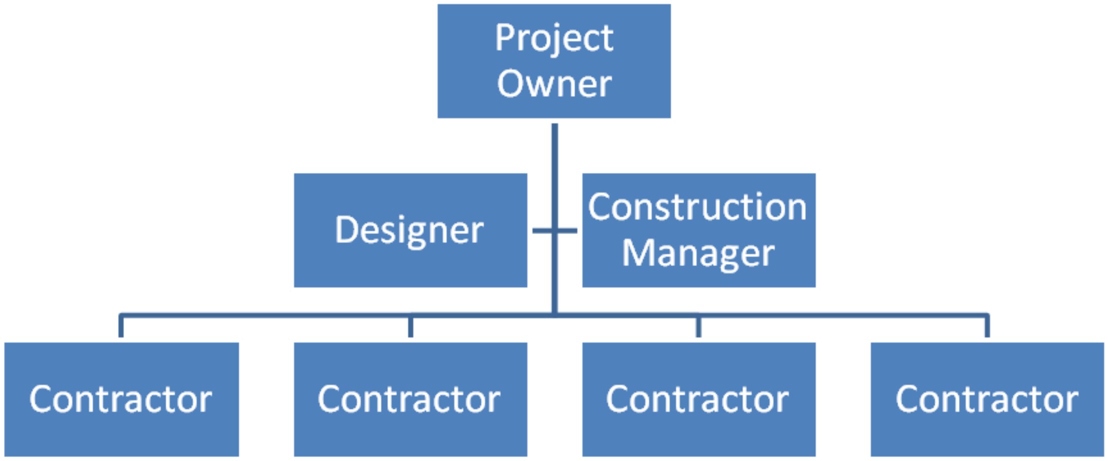


***Figure 3*. Construction management hierarchy and the participants in the project process.**

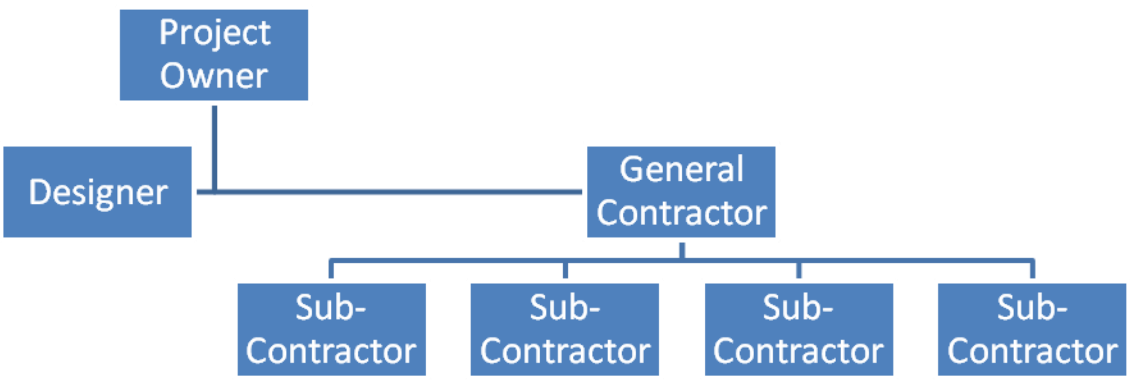


***Figure 4*. General contractor hierarchy and the participants in the project process.**

Additionally, it is important to mention that the CM firms are not responsible for the design but they help in the design period. While the design process is running, CM supplies the designer and project owner with the most efficient economical usage of the material (such as steel, concrete, wood etc.) and method. Moreover, the firm also points out potential accessibility to material, labor force etc.

Furthermore, coordination and communication of the project is responsible for CM. CM firm should organize the relationship between the project owner, designer, construction team, material and equipment vendors, and external parties governmental regulatory agencies. (Clough , 1979). If there is any leak (secret information) in the organization then the construction project might fail and the project may not be completed.

Every construction business contains its own uncertainties. Knowledge, experience and teamwork lead to the professional job in the project management and the completion of every step effectively, reducing uncertainties as well as risks. Some of the uncertainties in the construction business arise due to:

1 Extreme fragmentation of the industry, which comprises over 100,000 general contractors, many of whom are small, undercapitalize, and financially unstable.

2 The prevalence of subcontracting, whereby specialized trades per from as much as 90% of the work.

3 The unsophisticated or poor management skills, and inherent inefficiencies in the industry caused by complex laws and regulations, multi-unions, and the seasonal nature of the industry in places where construction can be affected by weather.

4 The sharp escalation in construction costs, which places a premium on shortening the construction time.

5 The inability of architects and contractors to provide effective schedule and cost control methods and to deliver the project on the time and within the budget, because of their conventional roles. (Stanley Goldhaber, 1977)

Another important concern is the factors that affect the project's success. In today's world technology, economical and financial planning are major concerns for the project success. Moreover, inflation, construction speed and size of the project are important keys that support the major elements needed for the success of the project.

Technology has been involved in the construction projects since the 1970s and modern building ideas lead to the usage of the technological advances. Nowadays, many software and computer models analysis are used more commonly in the design process giving more choices to the designer and the project manager in order to see more detailed analysis of materials subsystems, and methods, etc.

Construction Project Management is an important issue in the construction business and every year, CM becomes more challenging to finalize adequate construction projects (Foxhall W. B., 1996).

2.2 Significant Construction Projects at WPI

In recent years, WPI was expanding significantly according to its needs. It is important to analyze previous construction projects such as WPI Campus Center, WPI New Admission Building: Bartlett Center, Gateway Park, in order to better understand the necessity of the new WPI Residence Hall.

3.2.1 WPI Campus Center

The construction of WPI Campus Center began in the fall of 1999 and was completed in the beginning of 2001. Gilbane Construction Company was the CM firm on behalf of WPI as the owner's representative in the project. Campus Center was built in a site bordered by Olin Hall, Higgins Laboratories, Alumni Gym and Higgins House.

The cost of the project was $17 million where 35 different subcontractors were involved in the construction process. Campus Center Project was successfully completed in the specified time and budget (WPI NEWS, 2007).

3.2.2 WPI New Admission Building: Bartlett Center

Bartlett Center is the first WPI building to be registered with the U.S. Green Building Council (USGB), a national organization that certifies buildings that are green, are sustainable, and protect the environment. The architects, CBT /Childs, Bertman Tseckares Inc., Boston, designed the building using the following USGB guidelines:

1. Using local building materials
2. Using renewable building materials
3. Increasing recycling of construction materials
4. Reducing energy costs over the scores of years it will operate
5. Making better work environments for employees (WPI, 2007)

The Bartlett Center is a two story building, expanded over 16,589-square-foot, and located at east end of the WPI Quadrangle. Gilbane Construction Company was the CM firm of the Bartlett Center. The picture of the new admission building, Bartlett Center is shown in Figure 5.

***Figure 5*. Bartlett Center.**

3.2.3 Gateway Park

Gateway Park is a joint venture of Worcester Polytechnic Institute (WPI) and the Worcester Business Development Corporation (WBDC). Located in Worcester, near the intersection of I-190 and I-290, Gateway Park is designed as an 11 acre, mixed-use destination for life sciences and biotech companies and the people who work for them. The picture of WPI Gateway Park is shown in Figure 6.

***Figure 6*. WPI Gateway Park.**

The project includes: five life sciences buildings totaling 500,000 square feet of flexible, adaptable lab space designed to meet the needs of research organizations, 241,000 sq. ft. of market rate, loft condominiums as well as several planned retail establishments. Project cost is estimated $55 million and Federal and state funding (EPA, EDA, Infrastructure and Research Funds) invested in the projects equal more than $15 million. (WPI, 2007)

2.3 Gilbane Construction Company

Gilbane Construction Company is a family-owned nationwide construction and development company. Gilbane Company was founded in 1873 by William Gilbane and his brothers as a general contractor in Providence, Rhode Island.

In the early 1900s, William H. Gilbane took control of the company and steered it through the lean times of the Great Depression. In the 1930s, his sons Thomas and William joined the company and made Gilbane's reputation as a pioneer in construction management — first with major defense projects during World War II, and then with the Smithsonian's National Air and Space Museum, which opened on time and budget in Washington, D.C. on July 4, 1976.

In 1970 Gilbane expanded its services and formed the development unit now known as Gilbane Development Company (GILBANE CONSTRUCTION INC., 2007). WPI has been accomplished many projects with Gilbane Construction Company since 1990s.

Gilbane Construction Company has a wide-ranging CM service which gives construction management, program management, design-build, general contracting services to its clients.

It has 25 different offices all around the nation and profiting annual $2.5 billion. Over the years, Gilbane Construction Company has been increased its reputation due to the successful projects, furthermore, company ranked 10th largest building constructor in United States according to the ENR (Foxhall W. B., 1996).

In addition, Gilbane Construction Company has considerable experience on higher education buildings, hospitals. Transportation, federal/public buildings, sport facilities and financial institutions.

Finally, the following list shows Gilbane Construction Company's feature projects in New England region:

1. Keene State College Science Building
2. Fidelity Investments, 245 Summer Street
3. Jordan Hospital Pavilion
4. Worcester Trial Court
5. Concord Hospital - East & North Wings
6. Connecticut Convention Center
7. St. Vincent's Medical Center Master Plan Phase I
8. Fenway Park Renovations
9. GTECH Center
10. Providence Schools Master Plan
11. Harvard University Allston Campus - Utility Delivery Systems (GILBANE PROJECTS, 2007).

2.4 Construction Management at Risk

Construction Management at risk (CM at risk) is a project delivery system that refers to production of construction relationship between construction contractor, owner and the designer. Construction Management at risk is usually one of the delivery methods that involve liability of construction manager to complete the project within Guaranteed Maximum Price (GMP) (CSCOS, 2007).

The construction industry has more uncertainty and complex risk formation than other type of business. Additionally, many external factors must be considered in order to reduce risk at the construction. Furthermore, hiring CM as early as possible may increase the strength of the project and has a great influence to understand both sides, owner-CM, during the project.

In order to maintain sufficient CM at risk, investor needs to consider every detail properly. Investments are concerned with:

1. Annual Yield
2. Capital Value
3. Growth in capital values over both the short and the long term
4. Total return
5. Outgoings (Norman, 1993)

Forecasting is another factor that must be considered to reduce risk in the project from investor. Also, forecasting is not mathematical evolution of trends but regression analysis with certain techniques or dynamic programming. It is the key element to understand benefits of the project for investors. In the successful projects, most efficient way is the looking at the past experiences that owner faced up and predict forecast about the future by gained information. At the Figure 7, the forecasting processes is shown (BTF, 2007).

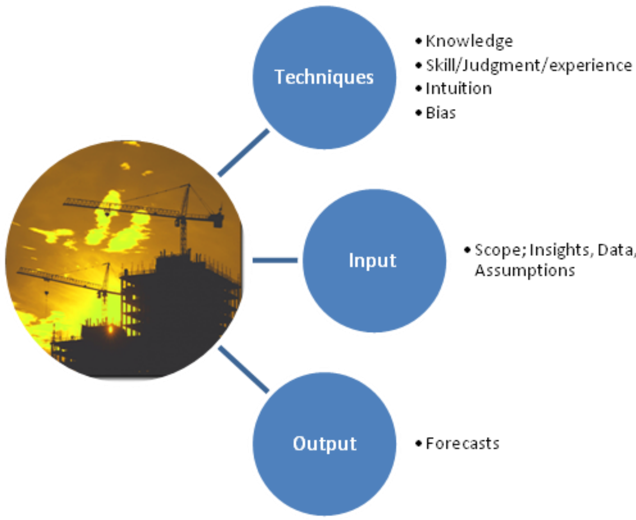


***Figure 7*. The forecasting process.**

In manufacturing and construction industry; risk is defined as widespread to all aspects of the investment decision. The investor needs some knowledge in any emergency cases (such as economical uncertainty, unpredictability financial market, and possibility of downturn in the economic conditions), so risk position can be determined.

Typical risks on a construction project include:

1. Failure to complete within the stipulated design and construction time
2. Failure to obtain the expected outline planning, detailed planning or building code/ regulation approvals within the time allowed in the design program me
3. Unforeseen adverse ground conditions delaying the project

4. Exceptionally inclement weather delaying the project
5. Strike by the labor force
6. Unexpected price rises for labor and materials
7. Failure to let to a tenant upon completion
8. An accident to an operative on site causing physical injury
9. Latent defects occurring in the structure trough poor workmanship
10. A claim from the contractor for loss and expense caused by the late production of design details by the design team
11. Failure to complete the project within the client's budget allowance (Norman, 1993)

WPI New Resident Hall project is well defined and logical choice for WPI's long term development. Every year, unknown incoming freshmen need more accommodation. In this case, WPI hired Gilbane Construction Company which has done many construction projects for WPI before. If there will be no unexpected phenomenon such as unexpected delays or surprises, WPI New Residence Hall will be completed in stated budged and time.

2.5 *Permits*

Permits are the rules that define the minimum acceptable level of safety for construction projects and they allow the enforcement of codes which are provided by the state or country. When someone wants to invest in a building project, the building has to be built according to the building codes and the permits, therefore the building permits should be provided before the construction starts. The purpose of the building permits are safety and protection of public health.

Before any construction or remodeling work begins, the zoning permits have to be provided. The Zoning Enforcement Officer can illuminate codes requirements. The building permits application should be taken for construction work. The typical questions answered for building applications are: “Where the work will be done”, “What work will be done”, and “How the work will be done”. The drawings, sketches and other plans of the building should be submitted for review. If the building is in agreement with the zoning code, building application and other applicable laws, then the application is accepted. If not, the application is denied. When results are refused, the application must be corrected again and submitted for a second review.

The owner of the building must post the permit notice card on the construction site. Any changes should be noticed by the Code Official. Changes are reviewed and approved by the Code Official. Each major part of the construction has to be inspected by the Code Official to make sure the codes are correctly used. Each inspection must be requested by the person who is responsible for the construction. The certificate of occupancy is issued by the inspector when the code compliance is determined. This certificate gives permission to complete the construction with the safety standard of the township. Table 1 provides a list of the permits that are required for residential construction with a brief definition of each one; however Appendix F includes a copy of each of these permits applications.

Table 1
***Permits for residential construction*.**

Permit name	Brief definition
Massachusetts State Building Code	This code was established by governing the construction work in the Commonwealth and Commonwealth of Massachusetts. This code depends on the National Building Code published by Building Officials and Code Administrators (BOCA).
Massachusetts Electrical Code	This code is determined by the Commonwealth in order to all electrical work activities done. Basically these activates are; Installation, addition, replacement, or change in the design of an electrical system
Massachusetts Plumping Code	This code is also considered by the Commonwealth in order all plumping work done in the Commonwealth.
Mechanical permit	for installation, addition, replacement, or change in the design of a heating or air conditioning system
Lexington Zoning By-Law	This code is depended on the unique to each town. Basically, this code by-law is mostly to specify which uses are allowed to use for the town where these uses are allowed and controls are put on the these uses; building heights, parking requirements, setbacks. The each town accept own by-lays which govern uses of property which does not include the method of construction, that being under the scope of the above listed codes
Zoning Permit	Governs conformity to property zoning classification and setback requirements.
Gas piping permit	For installation, addition, replacement, or change in design of a gas piping system. This permit is typically issued to a gas piping contractor who does not also have a heating or plumbing license. Any gas piping done by a heating or plumbing contractor may be included under their mechanical or plumbing permit
Sewer Service Approval	Application for new sewer service or additions to existing sewer systems (new fixtures) should be made directly to the Metropolitan Sewerage District (MSD). The Building Safety Development Services Center can provide assistance
Grading Permit	for disturbing areas of land

Water Service Approval	Applications for new water service should be made directly to the Asheville Buncombe Water Authority. The Building Safety Development Services Center can provide assistance
Driveway Access Permit	for a driveway connection to a city street

2.6 Fast Track

Fast Track is a method of scheduling approach in which the sequencing of construction activities enables some portions of the project to begin before the design is completed on other portions of the project. The process of fast track is shown in Figure 8. The normal process of construction scheduling involves the performance of a series of discrete functions, one after the other, in a predetermined sequential order.

Time is a key element in the WPI New Residence Hall project. The construction method is chosen as Fast Track in the WPI New Residence Hall because this method decreases the time from concept to completion notably and allows developing the investment much quicker than a usual delivery system.

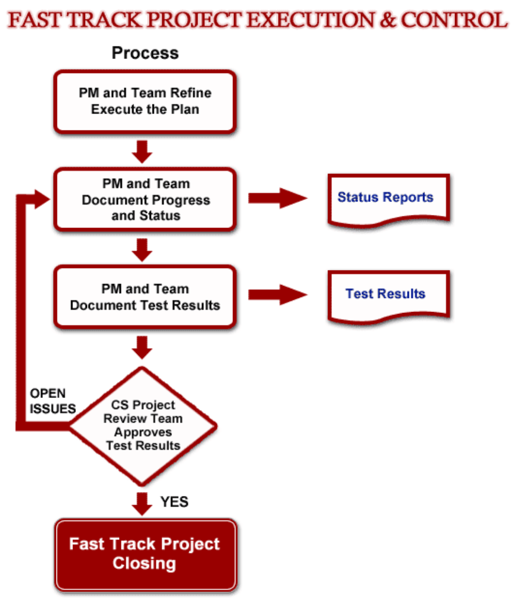


Figure 8. Fast Track process.

This is shown on the first line of the accompanying diagram (Normal Construction Schedule). Each activity is virtually completed before the next may be commenced. To perform all of these functions will take a certain amount of time (DCD, 2006).

3.7 Project Management of WPI New Residence Hall

Today, construction is a project-oriented industry. Most work is carried out as a project, which means that facilities to be constructed or objectives to be achieved are designed and that an effort is then made to achieve these within certain time and cost parameters.

One characteristic of projects is their continuous growth in size and complexity as technology advances. Complexity generates the necessity for specialization and since each specialist has his own jargon, specialization may lead to breakdown of communications. For example, in a project for the construction of a certain plant, many specialist such as; mechanical, electrical, heating and ventilating, system engineers, civil engineers, may be involve to the project (Ahuja, 1994).

Another characteristic of projects is the increasing importance of timely completion. If a company is trying to develop a certain product before a competitor can introduce a similar product into a market, the company must meet its own schedule or it may lose even its present market share. Today engineering design can be completed by modern computers must faster than before. Therefore, more organizations can quickly place more designs on the market, reducing the life of a design and increasing the necessity to plan and schedule.

The cost of capital is another important factor that places a high emphasis on establishing a schedule and working to achieve its targets. No one can afford to lose interest on the investment in a project while it is unproductive. An effort has to make the investment productive as early as possible. Because of increased outlay, technical complexity, price escalation and longer spans, the element of risk in construction projects has increase. Financiers of large projects demand not only technical feasibility reports but also documented schedulers and reliable estimates to substantiate the management's ability to execute and control the operations economically (Van Kempen, 1993).

Time & Scheduling process of the WPI New Residence Hall is estimated and calculated by computer software called "primavera" and all management activities are organized and placed according to the CSI index system in a logical way as shown in Figure 9.

CSI Index >

C2 Chooser	Code	Division
	01000	General Conditions (8)
		General Conditions , Project Meeting , Submittais , Quality Control , Constr. Facilities & Temp Constr , ...
	02000	Sitework (11)
		Subsurface Investigation , Demolition , Site Preparation , Earthwork , Piles and Caissons , ...
	03000	Concrete (8)
		Concrete Formwork , Concrete Reinforcement , Concrete Material & Placing , Concrete Finishing , Pre-Cast Concrete , ...
	04000	Masonry (5)
		Mortar & Masonry Grout , Masonry Accessories , Unit Masonry , Stone , Masonry Restoration and Cleaning
	05000	Steel (8)
		Metal Fastening , Structural Metal Framing , Metal Bar Joists , Metal Decking , Cold Formed Metal Framing , ...
	06000	Wood & Plastics (9)
		Fasteners and Adhesives , Rough Carpentry , Heavy Timber Construction , Wood and Metal System , Prefabricated Structural Wood , ...
	07000	Thermal & Moisture Protection (14)
		Waterproofing , Insulation , Exterior Insulation & Finish System , Fireproofing , Firestopping , ...
	08000	Doors & Windows (11)
		Metal Doors and Frames , Wood and Plastic Doors , Door Opening Assemblies , Special Doors , Entrances and Storefronts , ...
	09000	Finishes (13)
		Metal Support Systems , Lath and Plaster , Gypsum Board , Tile , Terrazzo , ...
	10000	Specialties (24)
		Visual Display Boards , Compartments and Cubicles , Louvers and Vents , Grilles and Screens , Service Wall Systems , ...
	11000	Equipment (25)
		Maintenance Equipment , Security and Vault Equipment , Teller and Service Equipment , Ecclesiastical Equipment , Library Equipment , ...
	12000	Furnishings (8)
		Fabrics , Artwork , Manufactured Casework , Window Treatment , Furniture and Accessories , ...
	13000	Special Construction (17)
		Air Supported Structures , Integrated Assemblies , Special Purpose Rooms , Sound, Vibration, & Seismic Control , Radiation Pritection , ...
	14000	Conveying Systems (8)
		Dumbwaiters , Elevators , Lifts , Material Handling Systems , Hoists and Cranes , ...
	15000	Mechanical (12)
		Mechanical , Mechanical Insulation , Fire Protection , Plumbing , HVAC , ...
	16000	Electrical (10)
		Basic Electrical Materials , Power Generation , Medium Voltage Distribution , Service and Distribution , Lighting , ...

***Figure 9*. CSI index system.**

Life cycle cost of the WPI New Residence Hall is done by the construction estimating process which is widely described in Construction Cost Estimate book (Tumblin, 1990) and all variables are shown in the spread sheets. Furthermore, detail observations and knowledge of process are shown in the next chapters of the project.

3.8 Time & Scheduling Process of WPI New Residence Hall

The purpose of time scheduling progress planning of the WPI New Residence Hall is to build a model that allows predicting which activities and resources are critical to the timely completion of the project.

In order to understand Time & Scheduling process, it is important to identify procedure of Time & Scheduling and how it is organized for specific project.

Time & Scheduling strategies may be implemented to ensure that activities and resources are managed properly, thus ensuring that the project will be delivered both "on time" and "within budget".

WPI New Residence Hall project planning aims to:

- Optimize time
- Evaluate different methods
- Optimize the use of resources
- Provide an early warning of potential problems
- Enable you to take proactive and not reactive action
- Identify risks
- Set priorities (Harris, 2005)
-

Planning helps to avoid the delayed or untimely completion of a project and thus prevent:

- Increased project costs or reduction in scope and/or quality
- Additional change over and/or operation costs

- Extensions of time claims
- Loss of your client's revenue
- Contractual disputes and associated resolution costs
- The loss of reputation of those involved in a project
- Loss of a facility or asset in the event of a total project failure

Specific Project Planning Metrics of the WPI New Residence Hall:

There are three main components (Figure 10) that may be measured and controlled using planning and scheduling software:

- Time
- Cost
- Effort (resources) (Harris, 2005)

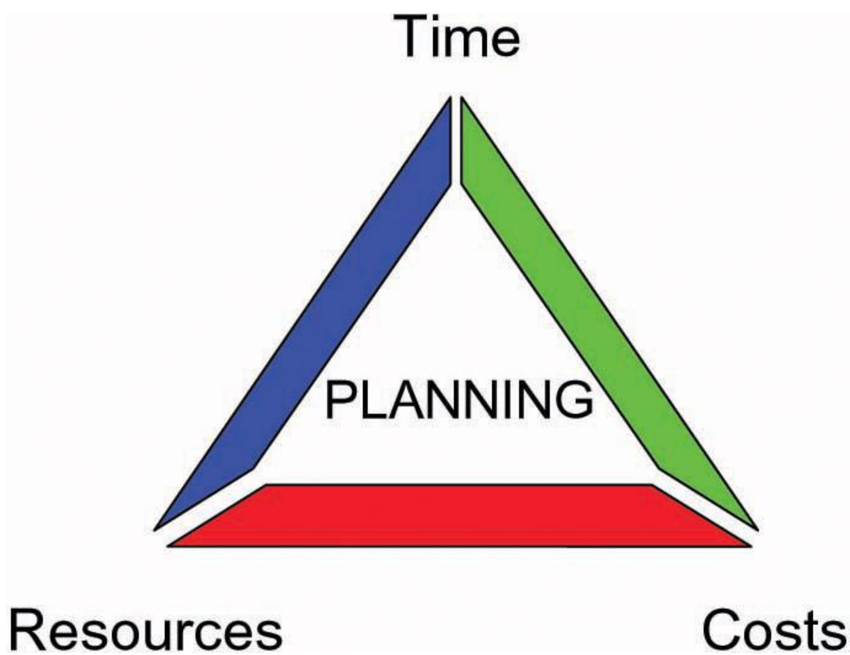


***Figure 10*. Project planning components.**

Other project management functions that are not traditionally managed with planning and scheduling software but may have components reflected in the schedule includes:

- Document management and control,
- Quality Management,
- Contract Management,
- Issue Management,
- Risk Management

Understanding the WPI New Residence Hall Project:

Before the process of creating a project plan starts, it is important to have an understanding of the WPI New Residence Hall project and how it will be executed. On large, complex projects, this information is usually available from the following types of documents:

- Project scope
- Functional specification
- Requirements baseline
- Contract documentation
- Plans and drawings
- Project execution plan
- Contracting and purchasing plan
- Equipment lists
- Installation plan
- Testing plan (PRIMAVERA, 2007)

It is important to gain a good understanding of the project process before starting to plan the WPI New Residence Hall project. You should also understand what level of reporting is required. Providing too little or too much detail will often lead to the schedule being discarded or not being used.

There are three processes required to create or maintain a plan of the project at each of the four levels:

- Collecting the relevant project data.
- Entering and manipulating the data in software.
- Distributing the plan, reviewing and revising it. (PRIMAVERA, 2007)

The ability of the scheduler to collect the data is as important as the ability to enter and manipulate the information using the software. On larger projects like WPI New Residence Hall, it may be necessary to write policies and procedures to ensure accurate collection of data from the various people, departments, stakeholders/companies, and sites (Harris, 2005).

3.9 Cost Estimating Process of WPI New Residence Hall

Estimating of construction work defines the process of calculating the quantities and costs of the various items entering into the work.

As the estimate is made before the work is done, the estimated cost is only the probable cost and is never the actual cost. The agreement of the estimated cost with the actual cost will depend upon the skill and judgment of the estimator. Skill implies the accurate use of good estimating methods, and judgment implies the correct visualization of the work as it will be done (Ostwald, 1992).

3.9.1 Kinds of Estimates

An estimate of the cost of a construction job is the probable cost of that job as computed from the plans and specifications. There are several kinds of estimates as flows;

1. A Detailed Estimate: which includes the quantities and cost of everything that a contractor is required to provide and do for the satisfactory completion of the work
2. Unit –Quality Method: All the costs of a unit quantity of the item considered are found and summarized. Then the total cost for the item is found by multiplying the cost per unit quantity by the number of unit.
3. Total-Quantity Method: The total quantities of each kind or class of material and labor needed are first found, then these quantities are multiplied by their individual costs and the results summed up.
4. Complete Estimate: This is one that includes all costs relating to the work in addition to those included in the main contract and subcontracts.
5. Architect's or Engineer's Estimate: This is made by the architect or engineer usually for the purposes of financing the work and for checking bids made by contractors.
6. Progress Estimates: This estimate is made by the engineer at periodic intervals during the progress of the work determining the amounts of partial payments to be made to the contractor.
7. Final Estimate: This is made by the engineer at the completion of the contract. The purpose of this estimate is to determine the amount of final payment due the contractor and also to determine the exact quantities that have been used (B.I.D&I.S., 2006).

3.9.2 Preliminary Investigations of Cost Estimating

Before preparing an estimate, the estimator should visit the site and make a study of the conditions there.

The work of estimating may usually be divided into five essential subdivisions as follows:

1. Material: The preparation of a list of materials is known as the take-off. The estimator takes off the various materials from the plans and specifications and tabulates on quantity sheets all these different materials as to kind number, size, weight, volume or other units used.
2. Labor: When preparing labor estimates, due allowances must be made for variations in wages, for vacations in the length of time (hours) required to do a certain item of work, for variations in working conditions, and for variations n the classes of labor required for different kinds of work
3. Plant: A complete construction plant or equipment for any construction job will include all temporary building and structures, machinery and tools necessary for the work.
4. Overhead: Overhead costs include such general office and other labor costs as are not considered as direct productive labor on the job overhead cost includes rents, general insurance, workmen's compensation insurance, special security tax, office equipment and stationery, taxes. Legal expenses of plans and specifications etc (Atkinson, 1994).

In brief, the main concerns in project management are keeping each activity on budget, time and satisfy of owners need. In order to apply these objectives to the building process of the WPI New Residence Hall advance methods must be used. These methods such as cost estimation, time & scheduling, steel design and foundation design explained in the next chapter.

4.0 Design

This project covers the design of steel structure for the New WPI Residence Hall which includes design of beams, girders, floor plates, and staircase and elevator shaft. Also foundation was another aspect of the design in this project; as a result of that a spread footing foundation was chosen for the building. Additionally, this project also covers the project management activities of the designed building which includes scheduling, cost estimation and permitting.

As it was mentioned before, this building has five floors. The architectural drawing of the first floor is shown in the Figure 11 and the architectural drawing of the second to the fourth floor is shown in Figure 12. Each floor was divided into small bays according to the distribution of the columns. The bays for one part of the floor are shown in Figure 13. The other parts of the floor are symmetric of shown part. For each bay, beams girders, columns, floor plates and sometimes elevator or staircase were considered. The methodology also covered the foundation design and the cost estimating analysis.

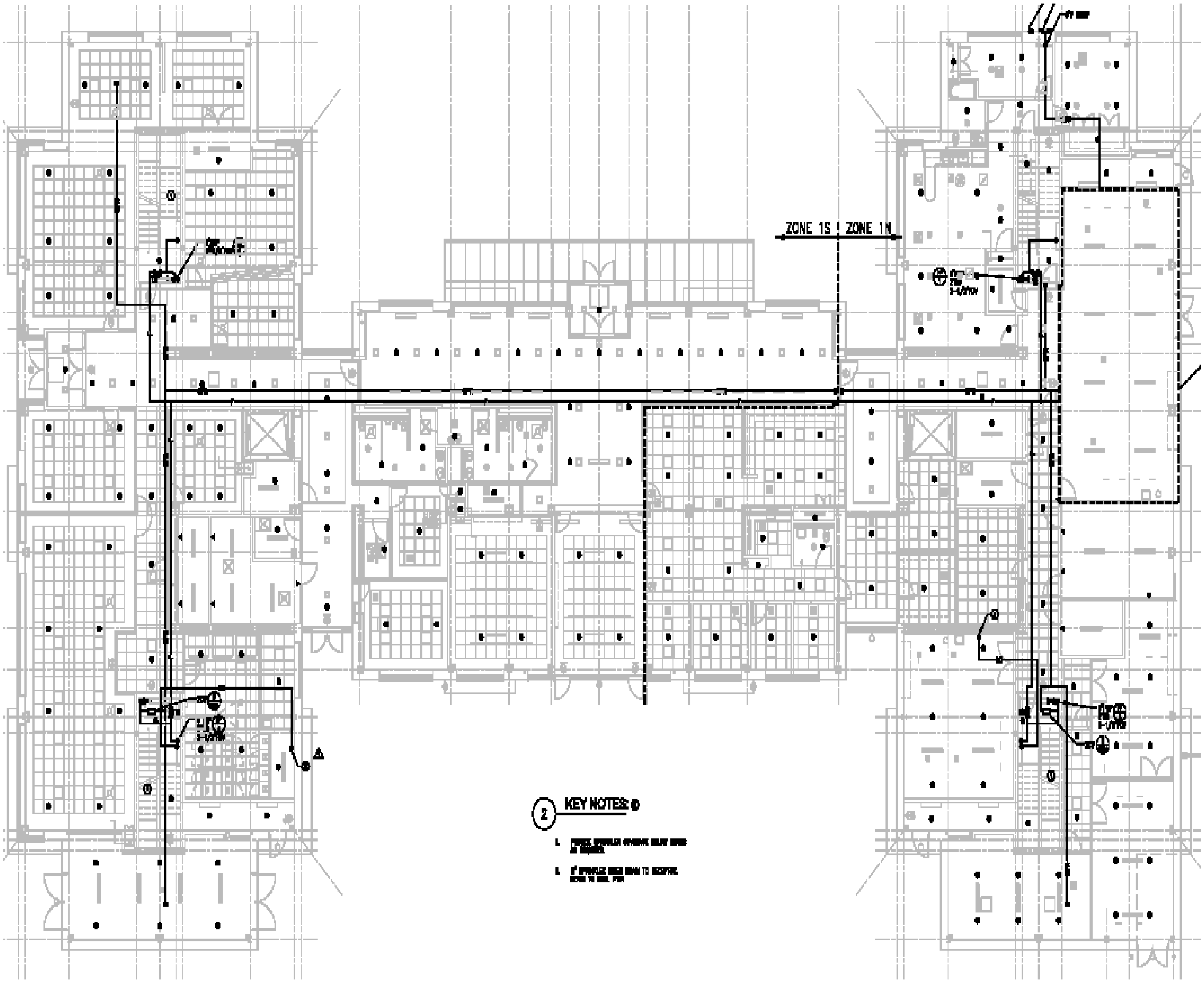


Figure 11. **First floor Plan.**

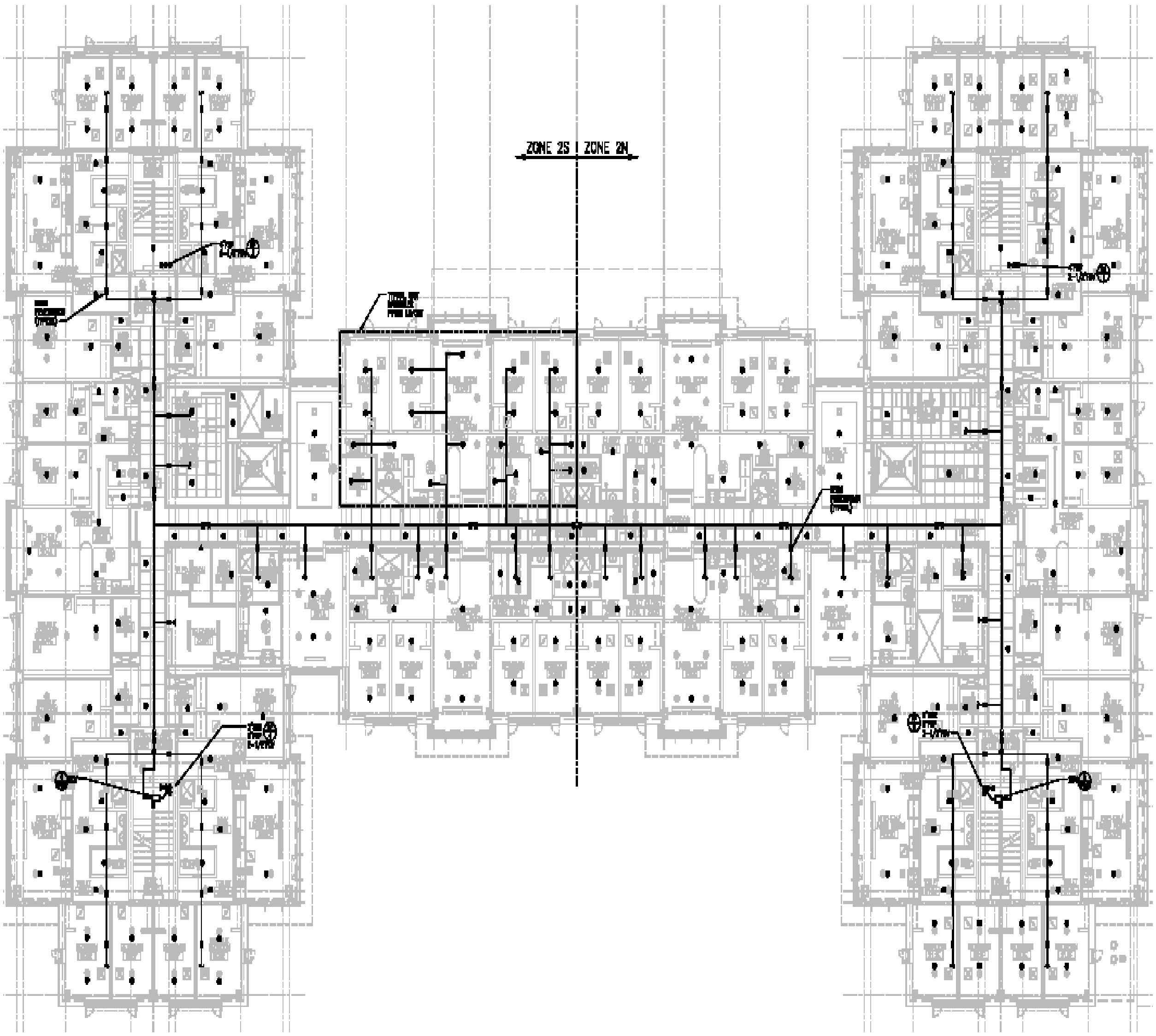


***Figure 12*. Second to fourth floor plan.**

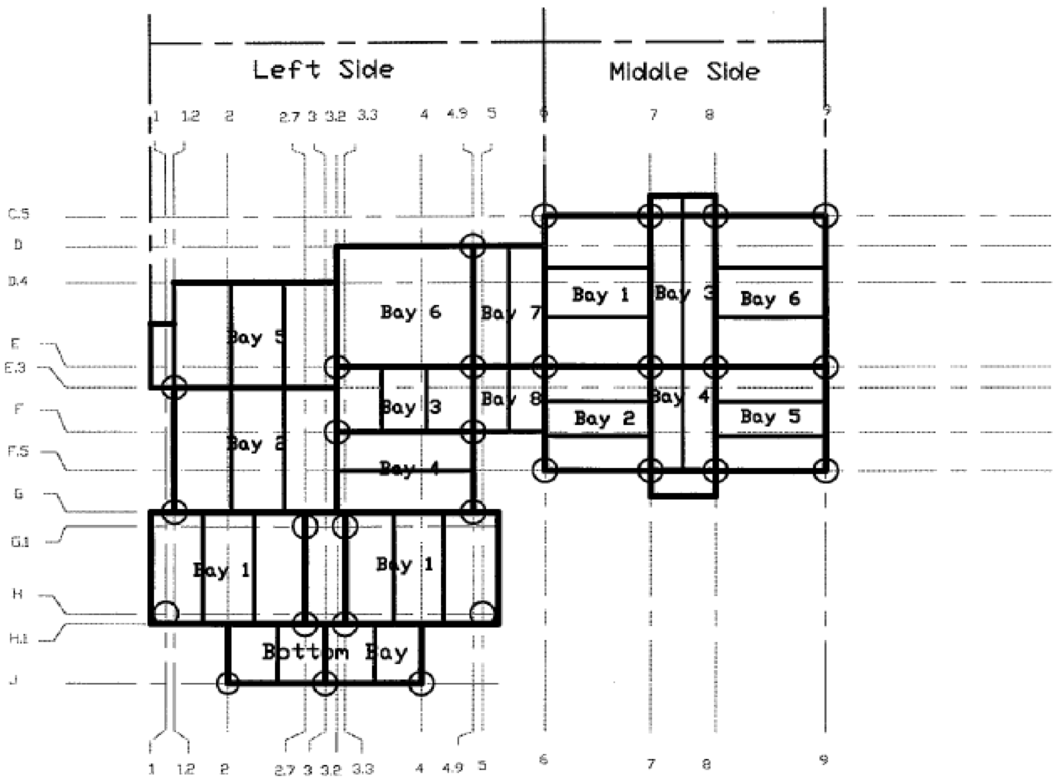


Figure 13. **Bays location in Left side and Middle side.**

4.1 Steel Design

As indicated above the steel structure included the design of beams, girders, columns, floor plates and sometimes elevator or staircase. For sample calculation bay 1 which is 20.5'x23' was chosen to be designed. Figure 14 is a sketch of bay 1 and the location of this bay is shown in Figure 13**.** As it is shown in Figure 12, this bay covers a kitchen so there would not be any elevator or staircase. All the variables, equations are taken from Structural steel design book, 2006.

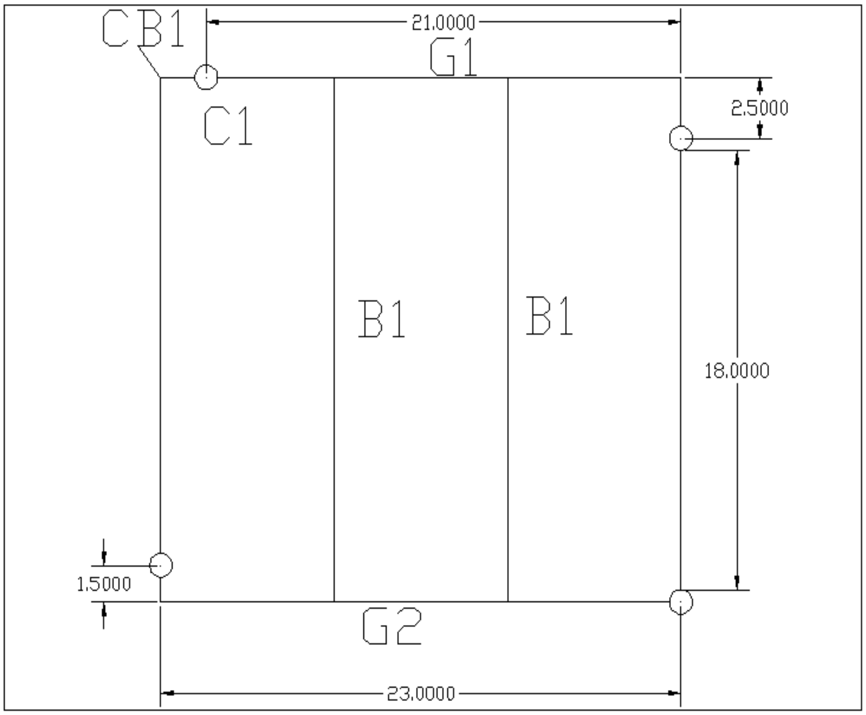


***Figure 14*. Sketch of bay 1.**

4.1.1 Beam Design

Floor Beam Design

Dead load and live load were obtained and calculated according to the Massachusetts Building Code (MSBC 6th edition, 2007), using Appendix G of MSBC for dead load and chapter 16 of MSBC for structural live loads and Snow loads. Table 10 and Table 13 in Appendix A show the dead, live and the snow loads for each floor.

The computed dead load included the weight of the concrete slab, floor finish, MEP, cement tiles, interior and exterior walls. However the live load included the load provided for a hotel building since no load specifications were given for residence halls. The values of the live load changed according to the designed bay. For instance, the assigned live load for bedrooms is 40 psf , however it is 100 psf for living rooms. Appendix A includes a list of the loads used. The weight of the beam was ignored in the beginning and then added to the total weight after the beam size was selected.

Different schemes were considered in order to come up with the most economical design. The method provided below was used to analyze each of the trial schemes. A sample calculation of two different schemes is provided in Appendix B.

The factored design load of each of the schemes was calculated using the following equation

$$W = 1.2\ DL + 1.6\ LL$$

The calculated weight was used to calculate the maximum design moment –using the following equation

$$M_u = 1/8\ WL^2$$

In order to use table 3-19 of the *AISC Manual, 2006* to find an appropriate beam size, Y2 was calculated assuming that the concrete stress block “a” is equal to 1.0 and the moment provided in the table was compared with the value of M_u obtained to select the beam size

The values obtained for each of the schemes were used to satisfy the $\varphi\ M_n \geq M_u$ inequality for both full and partial composite.

$$M_n = (A_s)\ (F_Y)\ (d/2 + t + a/2)$$

$$\Phi = 0.90$$

Noting that the M_n Value is given in the *AISC Manual* section 3-19

Once the beam size was determined the actual value for Y2 and the actual depth of the concrete compression zone “a” were calculated

$a = \frac{\sum Qn}{0.85\, f_c b_E}$

Where F'_c is equal to 3.0 ksi and E equal to 29000 ksi for steel.

For each option the number of ¾ in diameter studs, the $\sum Q_n$ required along the beam span was calculated using the tabulated horizontal shear force given in table 3-19 of the steel manual.

The number of shear studs for each alternative was calculated using the following equation

$$N = V_n / Q_n$$

Where Q_n is equal to $0.5\, Asc\sqrt{(f'_c * E_c)}$

The deflection of the composite section during service was calculated for each alternative using the following equation

Dead load deflection: $D_d = \frac{5W_d \times L^4}{384\, EI}$

Live load deflection: $DL = \frac{5\, W_l \times L^4 \times 0.5}{384\, EI}$

Where $I = \frac{AsYs \times AcsYc}{As + Acs}$ Also, I value is provided in the steel manual section 3-20.

And the live load deflection was limited to L/360 or 1in max.

The strength, and deflection of the structural steel beam used in unshored construction were calculated for each alternative using the following equation:

$$D_c = \underline{5\, W_c\, L^4}$$

$$384\ EI_x$$

Where W_c is the factored live load, and I_x is obtained from table 1-1 of the steel manual

And the unshored deflection was limited to 1.5in max.

Partial composite:

Table 3-19 of the steel manual was used to choose a M_n value that is bigger than the Mu value calculated, in order to select the TFL value.

Once the TFL was chosen the same calculation used for the full composite action were repeated and a reduced amount of studs was calculated. And in order to finalize our decision the spacing of the studs, as well as the deflection of the composite section during service and in unshored construction were checked.

Table 3-20 of the steel manual was used to obtain the Lower Bound Moment of Inertia needed to calculate the deflection of the composite section during service for each alternative.

Roof Beam Design

The design of the roof beams differed from the floor beam design only by the selection of the loads acting on the roof. The dead loads acting on the roof consisted of roof decking, MEP, suspended ceiling, cement tiles and exterior walls when applicable. The main live loads acting on the roof are the snow load and roof live load. According to the *Massachusetts State Building Code*, the roof live load is equal to 20 psf, and the snow load is equal to 35 psf.

The following load combinations were used in order to determine the most critical axial force P_u

$$1.2\ DL + 0.5(L_r \text{ or } S)$$

$$1.2\ DL + 1.6\ (L_r \text{ or } S)$$

Where L_r is the abbreviation for roof live load and S for snow load. In this project the snow load was used because the snow load is bigger than the roof live load in the Worcester zone.

The middle part of the building consists of a green roof. Therefore, the dead load of the roof for this section should also include the loads applied on the building because of the green roof. This load is determined according to the type of green roof installed. The type of green roof installed is usually selected by the customer (owner of the building). However, in this case, Extensive green roofs were used for this building with an assumed weight load of 30 psf.

4.1.2 Girder Design

Girders could be designed using two different techniques. These two techniques mainly differ by the method applied to calculate the max Moment.

1. Girders could be treated as beams therefore the beam design process would also be applied to design girders. However the span and length of the girders are different and usually bigger than the beams therefore the tributary area and width would be different.
2. The superposition law will be used to compute the max moment. The distributed loads on the beams will be converted into concentrated load on them and since girders support the beams, the reactions on the girder due to the beams will be calculated. Sometimes other than the concentrated loads due to the beams, there are distributed loads that the girder would have to support. The girders are supported by the columns and based on the loads that were acting on the girders; the support reaction provided by the columns will be calculated. After calculating the support reactions which support the girders and the loads

on the girders, by using the superposition law and the moment diagram, the maximum moment will be calculated.

The first technique was used to compute the girders in the same direction as the beams. However, the second method will be considered to calculate the rest of the girders since finding the reactions at the girder's supports will facilitate further calculation.

Girders are taken as simply supported beams with concentrated loads. The applied concentrated loads include loads from both bays that the girder is supporting. The shear and moment diagram were drawn in order to find the maximum moment. The steel manual was used to select the appropriate girder size.

The moment caused by the weight of the girder was calculated using the following formula

$$M_u = 1/8\ WL^2$$

Since the weight of the girder was treated as a distributed load. Both moments were added together, using the superposition law, in order to find the maximum moment.

As done in the beam design, both full and partial composite were considered in order to come up with the most sufficient structure.

Deflection was checked using the following formula

$$\frac{ML^2}{CIx} + \frac{5WL^4}{384EI} < \frac{L(in)}{360} \text{ or max } 1"$$

Deflection is calculated using unfactored loads. And the value C1 is a constant that depends on the loading condition. In this case, C1 is equal to 158 at center.

4.1.3 Cantilever Beam Design

Cantilever beams were also considered in our design since the columns were neither in perfect shape nor at the corners.

As well as the girder design, the superposition law was also considered in designing the cantilever beams. However, in this case the cantilever beam has to also support some tributary area. Therefore the computed max moment included the moment from the tributary area that the beam is suppose to cover as well as the moment caused by the weight of the beam and the load from the girder.

To select the appropriate cantilever beam size the steel manual was used. Then the deflection was checked using the following formula.

$$\frac{PL^3}{3EI} + \frac{WL^4}{8\ EI} < \frac{L(in)}{360}\ or\ a \max of\ 1".$$

W includes the weight of the beam and the weight from the tributary area. Unfactored weight is used in both cases. The value of I is obtained from the steel manual table 1, and E is equal to 29000 KSI.

4.1.4 Column Design

The column design for the first two floors is based on the column size needed for the first floor to resist the load from the above four floors and the roof. The column design for the third, forth, and fifth floor is based on the column size needed for the third floor to resist the loads from the fourth and the fifth floor, as well as, the load from the roof. Columns support the loads coming from the girders and cantilever beams. The loads acting on the columns were added together, and the sum of all these loads was used to select trial size columns from AISC manual of steel construction.

When selecting the appropriate size, the width of the flange of the girder as well as the thickness of the web and the width of the flange of the column selected were taken into consideration in order to choose a size that fits with the size of the girder selected. In general, W12 and W14 are the most preferred steel column sizes.

Finally the capacity of each of the trials was evaluated using the interaction equation. The interaction equation was simplified to the following since no bending effect was considered.

$$\frac{Pu}{\phi Pn} \leq 1$$

Where Pu is equal to the sum of the loads acting on the column and Pn was calculated using the following formula.

$$P_n = \Phi \text{ fcr Ay}$$

To apply the appropriate formula to calculate Fcr, it was necessary to identify if the columns used were short and intermediate or long. To do so, the column action was calculated in both X and Y direction, using the following formula.

(K(x, y)*L(x, y))/R(x, y)

For each column, the highest value obtained governed. And this value was used to identify if the column is short or long using the following formula.

$$\Lambda n = 4.71\sqrt{\frac{E}{Fy}}$$

If value obtained $\leq 4.71\sqrt{\frac{E}{Fy}}$ then the column should be treated as a short or intermediate column.

If value obtained $\geq 4.71\sqrt{\frac{E}{Fy}}$ then the column should be treated as a long column.

For short and intermediate frame,

$$Fcr = (0.658\ Fy/Fe) * Fy$$

$$Fe = \frac{\pi^2 * E}{\left(\frac{Ky * Ly}{Ry}\right)^2}$$

For long frame,

$$Fcr = 0.877\ Fe$$

Columns in the staircases and elevators were designed using the same technique as the rest of the columns in the building. However columns in the stair cases and elevator have to support different loads than the rest of the columns. Loads acting on a stair case and elevator were obtained from the Massachusetts State Building Code, chapter 16.

4.1.5 Floor Plate Design

Since steel decking was considered in our design, the shear studs used in the composite system provides the reinforcement needed. Shear studs are designed to convert the concrete pored and the steel decking into one stronger system that work together to carry the floor load. Figure 15, Figure 16 and Figure 17 provide a list of typical composite floor deck profile and properties. This information is obtained from the Steel Deck Institute website (SDI, 2005)

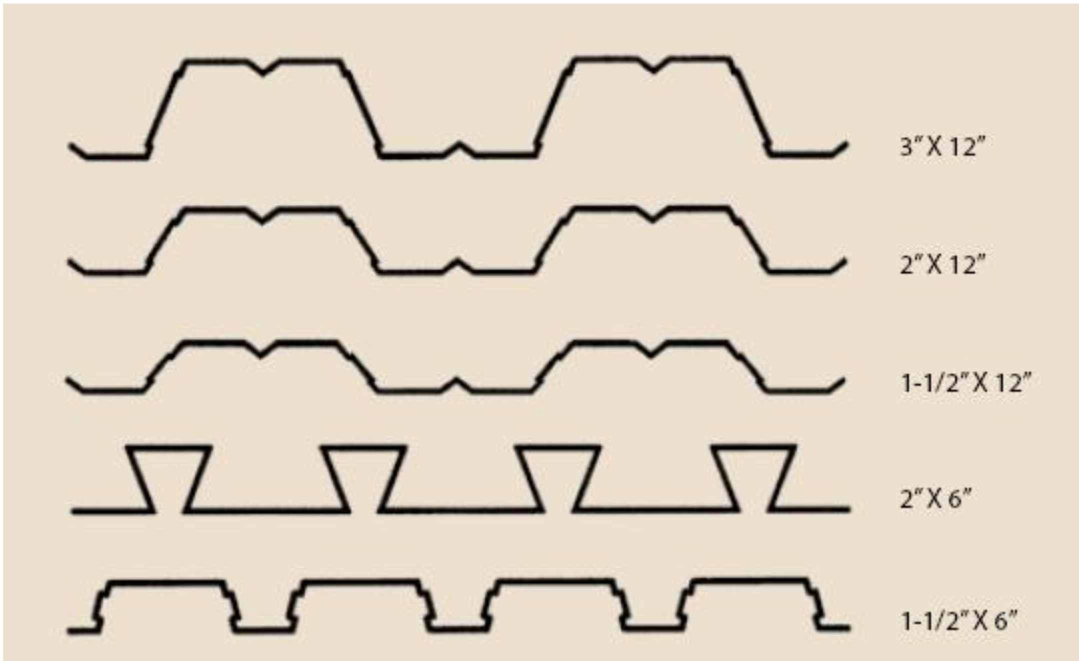


***Figure 15*. Typical composite floor deck profile.**

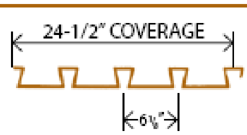
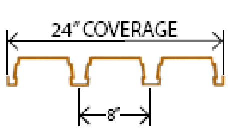
Composite Floor Deck Profiles	Name	Nominal Thickness Range	Weight Range	Comments
	1 ½"X 12" 2"X 12" 3"X 12" Composite	.03" to .06"	2 psf to 4 psf	Embossment patterns will vary from manufacturer to manufacturer. Side laps are flat adjustable or button punchable.
	2"X 6" Composite	.03" to .06"	2 psf to 4 psf	
	1 ½"X 6" Composite	.03" to .06"	2 psf to 4 psf	Embossment patterns will vary from manufacturer to manufacturer. Side laps are flat adjustable or button punchable.
	3"X 8" Composite	.03" to .06"	2 psf to 4 psf	Embossment patterns will vary from manufacturer to manufacturer. Side laps are flat adjustable or button punchable. This profile is not generally suitable for use with shear studs.

***Figure 16*. Properties of composite floor decks.**

In order to decide which steel decking to use it was necessary to refer to the tables provided by the United Steel Deck (INC) website. (USD, 2007).

To select the appropriate steel decking, the highest Live Load applied on the building (125 psf) was needed as well as the depth of the slab (4.5in).

To support the load of 125 psf and to satisfy the thickness requirements (4.5 in), the B-Lock composite decking was used. This type of decking includes shear studs and it is made of 1.5 inches corrugated decking, 6”o.c.

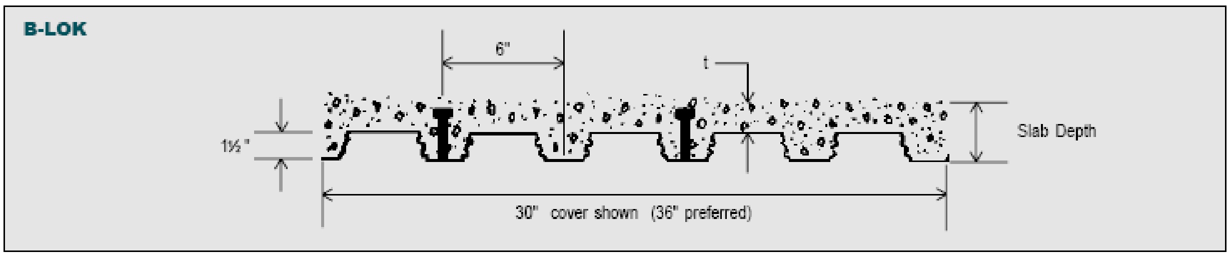


***Figure 17*. Sketch of a B-LOK composite deck.**

Table 2, provided by the United Steel Deck website, includes different kind of composite steel decks that could be used for the design, according to the requirements of the structure being built. As stated on the website: “The Uniform Live Loads provided in the table are based on the LRFD equation φM_n = ((l.6L + 1.2D)*L^2)/ 8.Although there are other load combinations that may require investigation, this will control most of the time. The equation assumes there is no negative bending reinforcement over the beams and therefore each composite slab is a single span.” (USDI, 2007).

Table 2

Composite steel deck capacities based on slab thickness and length.

			L, Uniform Live Loads, psf *												
	Slab Depth	ϕMn in.k	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00
22 gage	4.00	38.19	400	400	400	350	295	255	220	190	165	145	130	115	105
	4.50	44.78	400	400	400	400	345	300	260	225	195	175	155	135	120
	5.00	51.37	400	400	400	400	400	345	295	260	225	200	175	155	140
	5.50	57.96	400	400	400	400	400	385	335	290	255	225	200	175	155
	6.00	64.55	400	400	400	400	400	400	375	325	285	250	220	195	175
	6.50	71.15	400	400	400	400	400	400	400	360	315	275	245	215	195
	6.75	74.44	400	400	400	400	400	400	400	375	330	290	255	225	200
	7.00	77.74	400	400	400	400	400	400	400	390	345	305	270	240	210
20 gage	4.00	45.45	400	400	400	400	355	305	265	235	205	180	160	145	125
	4.50	53.44	400	400	400	400	400	360	315	275	240	215	190	170	150
	5.00	61.44	400	400	400	400	400	400	360	315	280	245	220	195	175
	5.50	69.43	400	400	400	400	400	400	400	360	315	280	245	220	195
	6.00	77.43	400	400	400	400	400	400	400	400	350	310	275	245	220
	6.50	85.42	400	400	400	400	400	400	400	400	390	345	305	270	240
	6.75	89.42	400	400	400	400	400	400	400	400	400	360	320	285	255
	7.00	93.42	400	400	400	400	400	400	400	400	400	375	335	295	265
19 gage	4.00	52.41	400	400	400	400	400	360	310	275	240	215	190	170	150
	4.50	61.81	400	400	400	400	400	400	370	320	285	250	225	200	180
	5.00	71.20	400	400	400	400	400	400	400	370	330	290	260	230	205
	5.50	80.60	400	400	400	400	400	400	400	400	370	330	295	260	235
	6.00	90.00	400	400	400	400	400	400	400	400	400	370	325	295	260
	6.50	99.39	400	400	400	400	400	400	400	400	400	400	360	325	290
	6.75	104.09	400	400	400	400	400	400	400	400	400	400	380	340	305
	7.00	108.79	400	400	400	400	400	400	400	400	400	400	395	355	320
18 gage	4.00	58.42	400	400	400	400	400	400	350	305	270	240	215	185	160
	4.50	69.07	400	400	400	400	400	400	400	365	320	285	255	225	205
	5.00	79.73	400	400	400	400	400	400	400	400	370	330	295	265	235
	5.50	90.39	400	400	400	400	400	400	400	400	400	375	335	300	270
	6.00	101.05	400	400	400	400	400	400	400	400	400	400	375	335	300
	6.50	111.71	400	400	400	400	400	400	400	400	400	400	400	370	330
	6.75	117.04	400	400	400	400	400	400	400	400	400	400	400	390	350
	7.00	122.37	400	400	400	400	400	400	400	400	400	400	400	400	365
16 gage	4.00	58.42	400	400	400	400	400	400	350	305	270	240	215	185	160
	4.50	69.07	400	400	400	400	400	400	400	365	320	285	255	225	205
	5.00	79.73	400	400	400	400	400	400	400	400	370	330	295	265	235
	5.50	90.39	400	400	400	400	400	400	400	400	400	375	335	300	270
	6.00	101.05	400	400	400	400	400	400	400	400	400	400	375	335	300
	6.50	111.71	400	400	400	400	400	400	400	400	400	400	400	370	330
	6.75	117.04	400	400	400	400	400	400	400	400	400	400	400	390	350
	7.00	122.37	400	400	400	400	400	400	400	400	400	400	400	400	365

4.1.6 Stair Case Design

The design of the stair case includes the design of two different landings and the design of the columns. There are two different types of landings (in terms of beams and girders being used) in this design; Type I which includes the entrance to the floors and Type II which is located in between the two floors. Drawings of the stair case and all the beams with their name for reference are provided in Figures 18 and Figure 19.

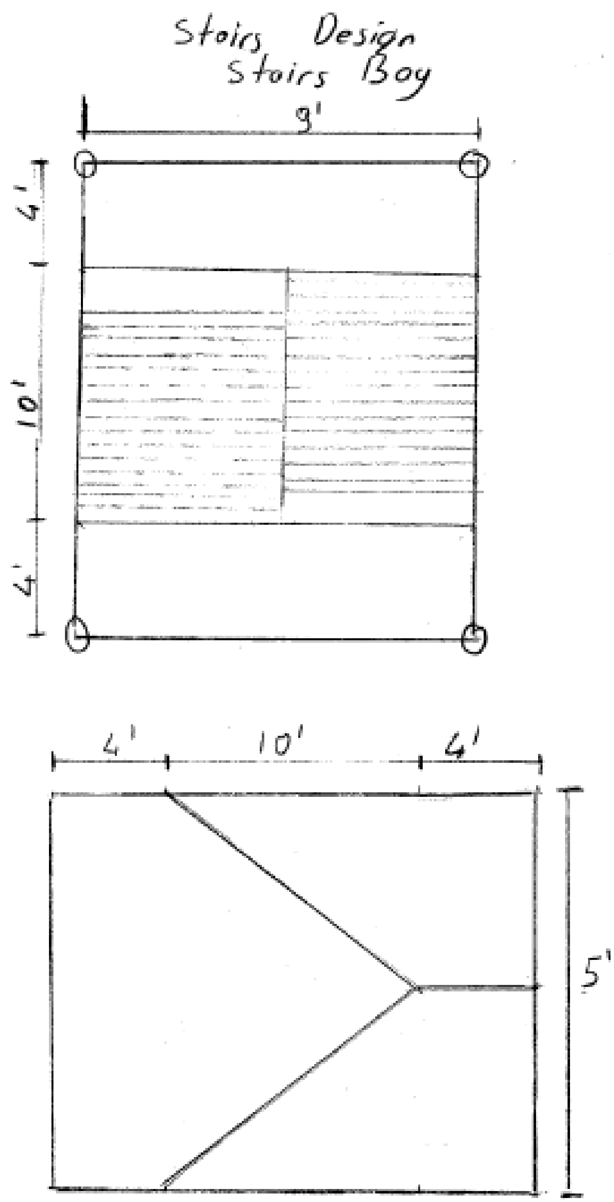


Figure 18. **Top and section view of the stair case.**

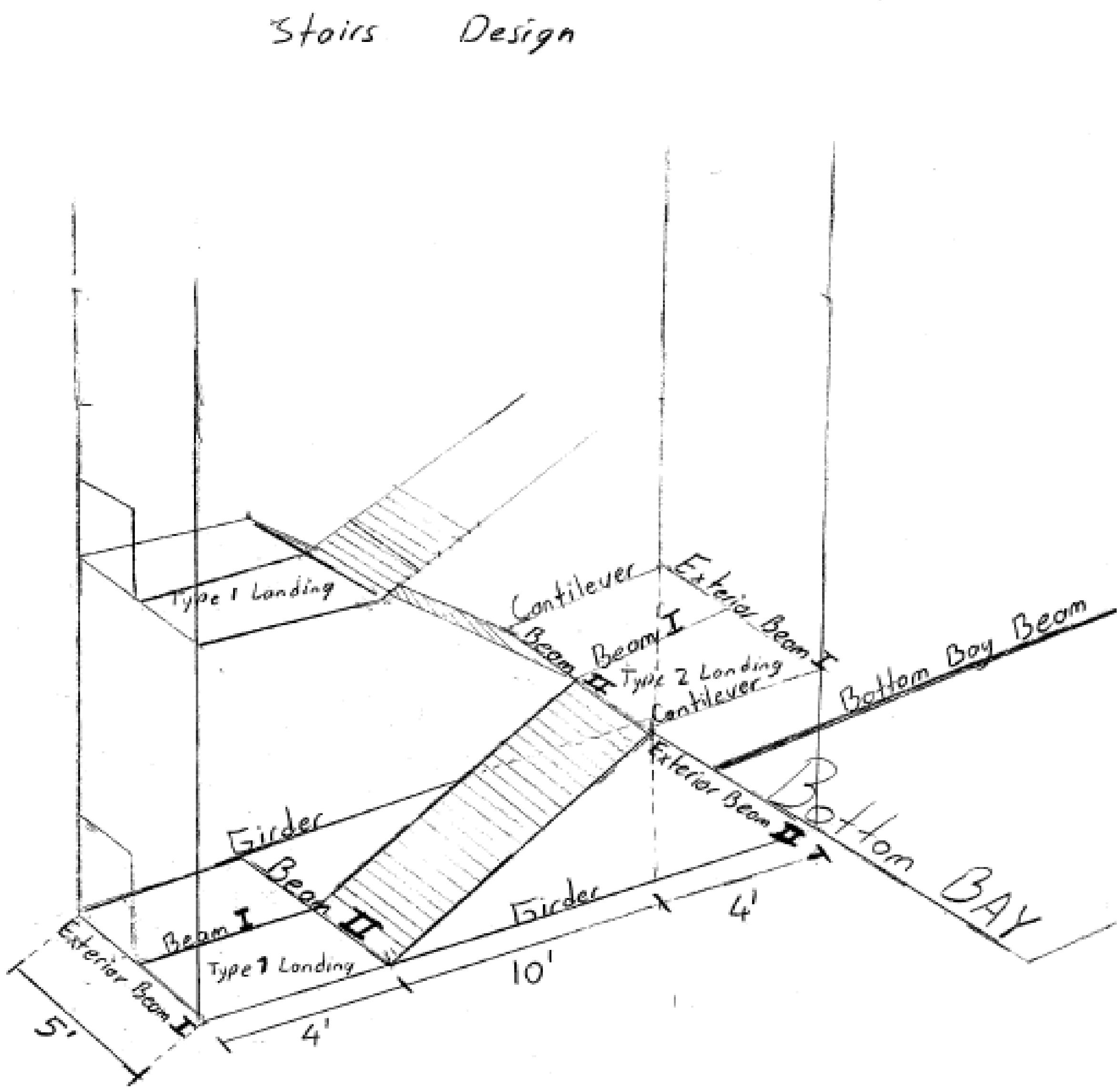


Figure 19. **3D view of the stair case.**

1. Type I landing:

-Beam I: 4 feet long with a tributary width of 4.5 feet. It is located in the middle of the landing and it supports the live and dead load of the landing. This beam is supported by two other beams: Exterior beam and Beam II.

-Beam II: 9 feet long and it supports the Stair way as well as the Beam I. This beam is supported by two long girders at the side of the stair case bay.

-Exterior Beam I: 9 feet long and it supports the Beam I. This beam is supported by two columns.

-Exterior Beam II: 9 feet long and it supports the Beam in Bottom bay. This beam is supported by the columns.

-Girders: 18 feet long with a tributary width of (4.5/2 + 7.6667/2) which is 6.08 feet. This girder supports some load of the floor and the landing as well as Beam II. This girder is supported by the columns of the stair case bay.

2. Type II landing:

This landing includes five small beams and the only difference with Type I is that, instead of two girders it has two cantilever beams.

-Beam I which has the same application, location and size of the one in Type I landing.

-Beam II which also has the same application of the one in Type II landing, but this beam is not supported by two girders and instead it is supported by two cantilever beams.

-Cantilever beams: 4 feet long and supports a tributary width of (4.5/2) which is 2.25 due to the live and dead load of the landing. These cantilevers are supported by the columns of the stair case bay.

-Exterior beam: It has the same application as the one in Type I landing.

4.1.7 Elevator Design

The concept of the elevator consists of a rectangular empty space from the highest floor (roof) to the lowest floor (Basement).This rectangular area provides space for the elevator room (elevator car) to move up and down. Drawings of the elevator and all the beams with their name for reference are shown in Figure 20.

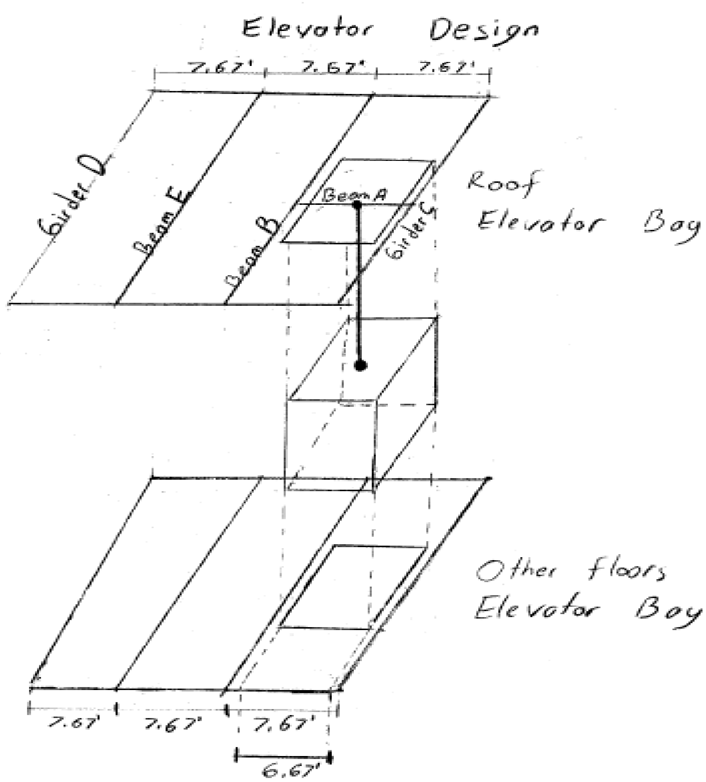


***Figure 20*. Layout of the elevator case.**

In this project the elevator space is located in a bay called the elevator bay. This bay is 23'x23' and it has 2 beams in the middle to support the loads on it. The tributary width of the beams is 7.67' (7' 8") so the rectangular open space for the elevator is designed in a way so it would fit in between the beams.

Based on a table from an elevator design book (Straksoch, 1998) as shown in Figure 21, recommended elevator room properties for the dormitories and residence halls are listed as:

Maximum Load capacity: 2500-3000 lbs.

Door Type and Size: 3' 6" center opening.

Table 11.1. Residential buildings

Type of Building	Population Criteria	Recommended 5-Min Capacity	Maximum Interval
Hotel	1.5–1.9 persons/room	10–15 per cent	40–60 sec
Motel	1.5–1.9 persons/room	10–12 per cent	40–60 sec
Apartments			
Downtown	1.5–1.75 persons/bedroom	5–7 per cent	50–70 sec
Development	1.75–2 persons/bedroom	6–7 per cent	50–90 sec
Dormitories			
Cafeteria feeding	200 ft² net/person	10 per cent	50–70 sec
Dining room feeding	200 ft² net/person	15 per cent	50–70 sec
Residence Halls	Same as dormitories		
Senior Citizen Housing, Housing for Elderly	1.25–1.5 persons/bedroom	6 per cent	50–90 sec

Recommended Elevator Size

Type of Building	Passenger Elevators: Size; Door Type and Size	Service Elevators: Size; Door Type and Size
Hotel	3000–3500 lb 3'6" center-opening	3500–4000 lb 4'0" center-opening
Motel	2500–3000 lb 3'6" center-opening	3500 lb 4'0" center-opening
Apartments	2000–2500 lb 3'0" single slide	2500 lb 3'6" 2 speed
Dormitories, Residence halls	2500–3000 lb 3'6" center-opening	Use passenger elevators at off peak times.
Senior Citizen Housing, Housing for Elderly	2000 lb 3'0" single slide	Arrange 1 passenger car 2500 lb 3'6" 2 speed doors.

Recommended Elevator Speed (in fpm)

Building Height	Hotels-Motels	Apartments and Housing for Elderly	Dormitories and Residence Halls	
2–6 floors	200	100	200	
6–12 floors	250	200	250	
12–20 floors	350–500	250–350	250–500	
20–25 floors	500	350–500	350–500	For buildings of this height, local and express elevators should be considered.
25–30 floors	700	500	500–700	
30–40 floors	800–1000	500–700	700–1000	
40–50 floors	1000–1200	1000–1200	1000–1200	

***Figure 21*. Recommended elevator room properties for residential buildings.**

According to one of the tables of the same elevator design book (Straksoch, 1998), as it is shown in Figure 22, for the Capacity of 3000 the following information was given:

Inside car Area: 31.7 sq. ft

Inside car Size: 6’ 8” wide x 4’9” deep

Number of persons could fit: 16

Table 2.1

Capacity (pounds)	Inside Car Area (square feet)	Inside Car Size	Average Loading Persons
2000	23.2	6′0″ wide × 3′8″ deep	10
2500	28.3	6′8″ wide × 4′3″ deep	12
3000	31.7	6′8″ wide × 4′9″ deep	16
3500	37.5	7′2″ wide × 4′9″ deep	19

now make access to the door difficult and generally require someone to step out of the car to let others out. These complications add a time delay to each elevator stop, which accumulates during the total trip and seriously reduces efficiency. The deep, narrow arrangement also leads to loss in passenger capacity—15 passengers versus the 16 passengers shown in Figure 2.1. Part of this loss is from the extra space required for doors, but most is from platform shape.

Study of the two illustrations suggests the conclusion that the most efficient elevator car is only one person deep! This is true but not practical because efficient door arrangement must also be considered.

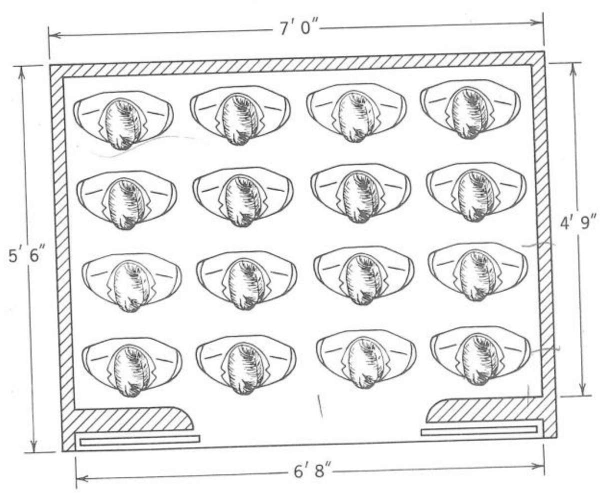


Figure 2.1

***Figure 22*. Interior elevator size for different load capacities.**

Based on one of the figures of Straksoch elevator design book, Figure 22 in this MQP, the actual size of the elevator room is 7' x 5'6". As it was mentioned before the beams tributary width is 7' 8" so there would be enough space to use the elevator with given information.

The maximum capacity of the elevator room is 3000 lbs. Typically in an elevator system there is a counter weight, the counterweight adds accelerating force when the elevator car is ascending and provides a retarding effort when the car is descending so that less motor horsepower is required. The weight of a counter weight is usually about 40%-50% of the Maximum capacity of the elevator cart plus the weight of the elevator cart itself.

Based on an article about elevator renovation which was published by HKA Elevator Consulting, 2007, it is shown that the elevator car weighs around 4000 lbs. Also it is shown that the elevator system is designed based on the weight of the cab interior finishes at the time of the original installation. The elevator code permits cab renovations to exceed this initial weight by no more than 5% of the Total Load.

The Total load on the elevator is summarized here:

-Maximum Capacity of the elevator car = 3,000 lbs.

-Weight of the elevator cart itself = 4,000 lbs.

-Weight of the counterweight = 4,000 + 0.5(3,000) = 5,500 lbs.

- 5% Allowable Weight = 0.05(12,500) = 625 lbs.

Total Weight = 13,125 lbs = 13.125 K.

Load Support:

1. **Elevator Bay on Roof Floor:**

Basically there is a cable to transfer the load 13.125 K to the pulley which is on top of the rectangular space (roof). The pulley is supported by beam A in the middle of the rectangular opening on top. The length of the beam is 7.67' and is supported by beam B and girder C in the Elevator Bay as it is shown in Figure 20.

The two beams (B and F) and two girders (C and D) in the Elevator Bay support the load of the elevator mechanical room (live 125 psf and regular dead load for the roof) located on the roof, as well as the roof itself as shown in Figure 20.

2. **Elevator Bay on other Floors:**

The Beams and Girders in the Elevator Bay located on the other floors, as shown in Figure 20, support a live load of 125 psf (due to the Trash/Recycle Room and Support Area) and a dead load of 124.3 psf (regular floor dead load).

4.1.8 Excel Spreadsheet Explanation

The excel spreadsheets were provided to assist in calculation and selection of the appropriate members. The spreadsheets conducted for the design of bay 1 are provided in Appendix C.

The information highlighted in yellow and sometimes in green are the inputs needed to be inserted into the program and the other information are the output automatically calculated according to the programmed equations.

As it is shown in the excel spread sheets in Appendix C, the information highlighted in yellow consist of the loads acting on the member, the size of the member and its properties such as area, depth, moment of inertia and moment capacity were obtained from the AISC steel manual.

In order to decide whether a member is adequate or not, it was very critical to check for deflections: dead load, live load, and construction live load deflection in case of beam and girder design. To arrive to this final decision, equations were entered to first calculate the factored weight acting on the designed members and the moment needed. Once the member size was chosen accordingly, the appropriate moment was found using the interpolation method and then deflection was checked. This method was used for both full and partial composite. The spreadsheet also included the calculation of the number of shear studs needed for both full and partial composite.

4.2 Foundation Design

In this project the top soil layers properties which are summarized in the soil profile are strong and they have a high enough bearing capacity to support the structure, so shallow foundation could be considered for this project.

4.2.1 Standard Penetration Test (SPT) for WPI Residence Hall

In this project there were three places chosen to do the boreholes for SPT. The whole building was divided into three blocks and each SPT was taken place at middle of each block as it is shown in the Figure 23.

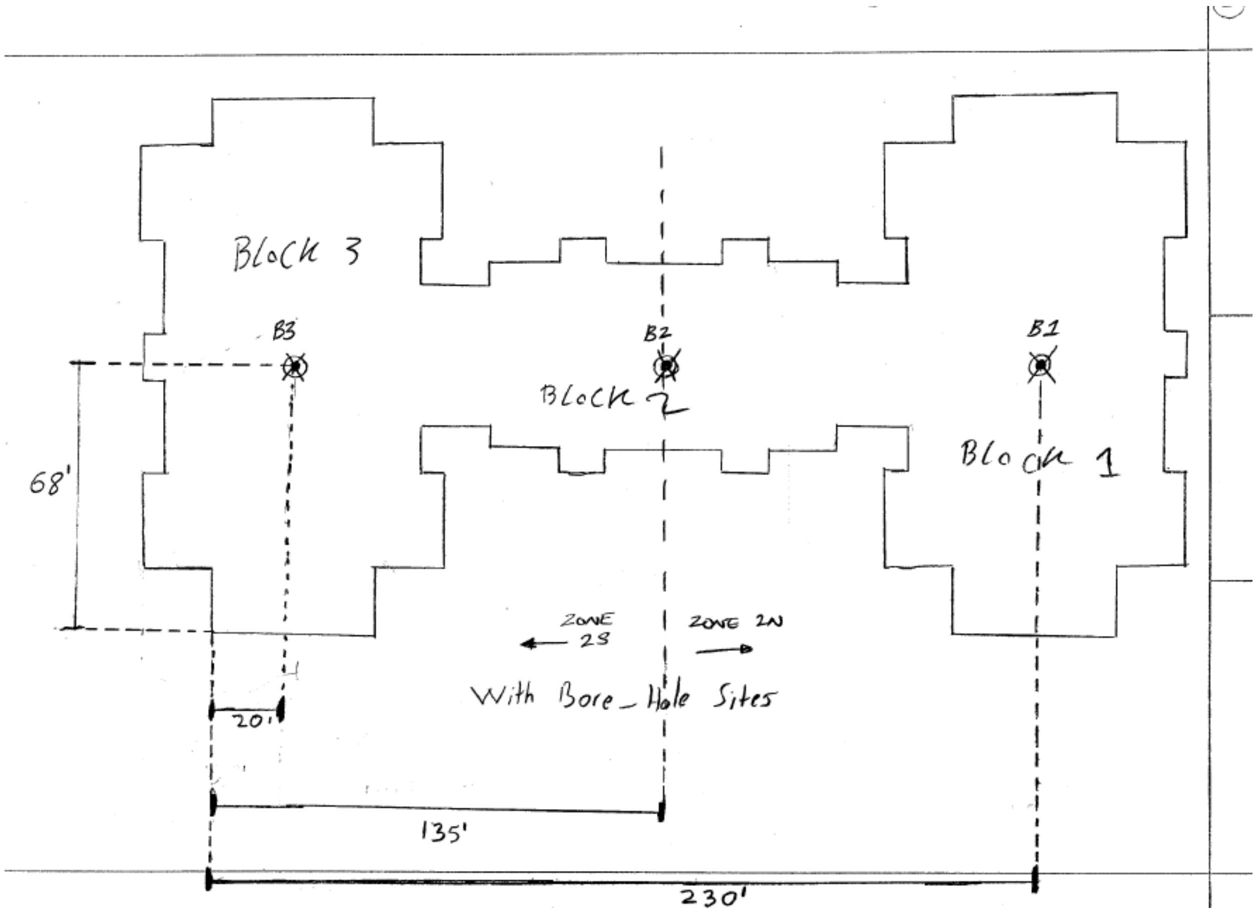


***Figure 23*. Borehole locations.**

The data (assumed) and the graphs for each of these three tests are shown in Figures 24, Figure 25 and Figure 26.

As it is shown, the total number of blows to get to a stable enough soil for borehole #1 is higher than the other two and for borehole #2 is higher than borehole #3.

At the point that the difference of #of blows per foot of two different depth is high, it is known that the rod have entered a new and stronger layer of soil. For example in borehole #3 at the depth of 20 feet under the ground elevation the layer of soil changed. At this point the # of blows to go down one foot (21 foot under the ground) was 22 blows, comparing that to the previous blows per foot, there is a greater difference. This point is shown with “Top of Bedrock” in the diagram.

Bore # 3		
Ground Elevation		502.6
Depth	Blows/Ft	
1	14	
2	11	
3	9	
4	7	
5	5	
6	5	
7	4	
8	5	
9	4	
10	4	
11	4	
12	4	
13	4	
14	4	
15	3	
16	4	
17	5	
18	6	
19	11	
20	13	
21	22	Top of Bedrock
22	33	

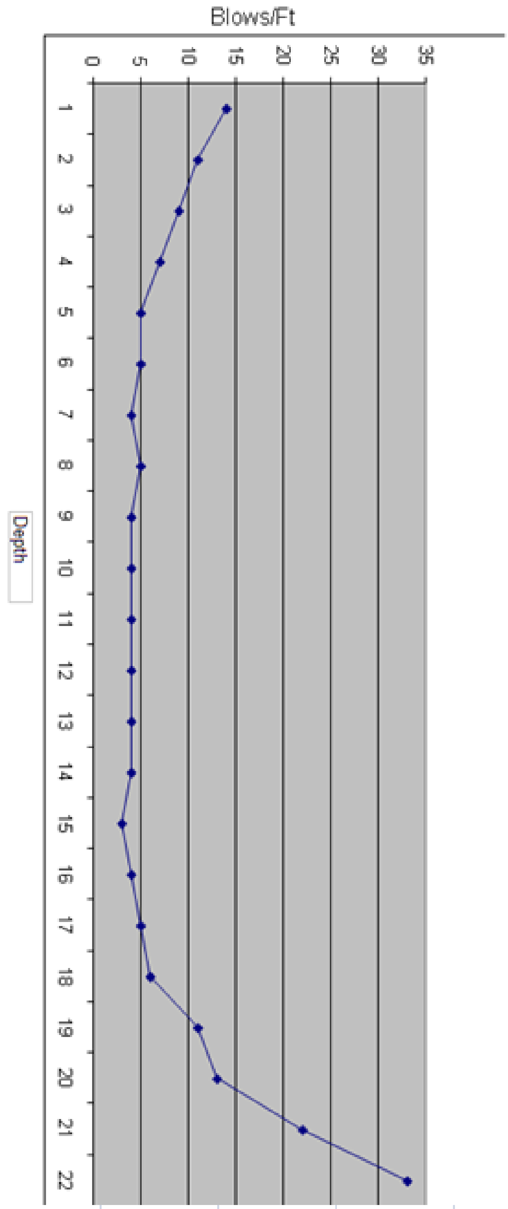


***Figure 24*. Borehole # 3 data and graph.**

Bore # 2		
Ground Elevation		502.6
Depth	Blows/Ft	
1	3	
2	3	
3	2	
4	2	
5	3	
6	4	
7	4	
8	6	
9	8	
10	12	
11	10	
12	7	
13	8	
14	6	
15	5	
16	5	
17	4	
18	2	
19	4	
20	4	
21	5	
22	4	
23	5	
24	6	
25	10	
26	15	
27	24	Top of Bedrock
28	25	

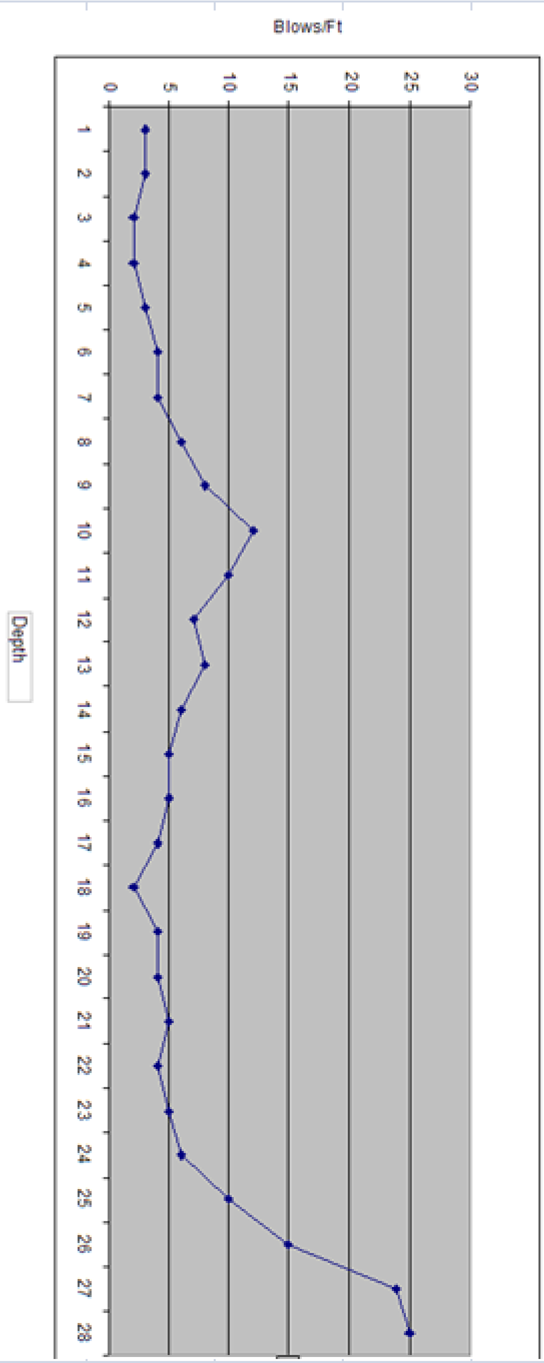


***Figure 25*. Borehole #2 data and graph.**

Bore # 1		
Ground Elevation		502.6
Depth	Blows/Ft	
1	21	
2	11	
3	12	
4	6	
5	5	
6	4	
7	5	
8	5	
9	7	
10	7	
11	9	
12	14	
13	12	
14	11	
15	11	
16	9	
17	8	
18	5	
19	5	
20	4	
21	5	
22	4	
23	3	
24	4	
25	4	
26	4	
27	4	
28	3	
29	4	
30	5	
31	6	
32	11	
33	13	
34	22	Top of Bedrock
35	33	

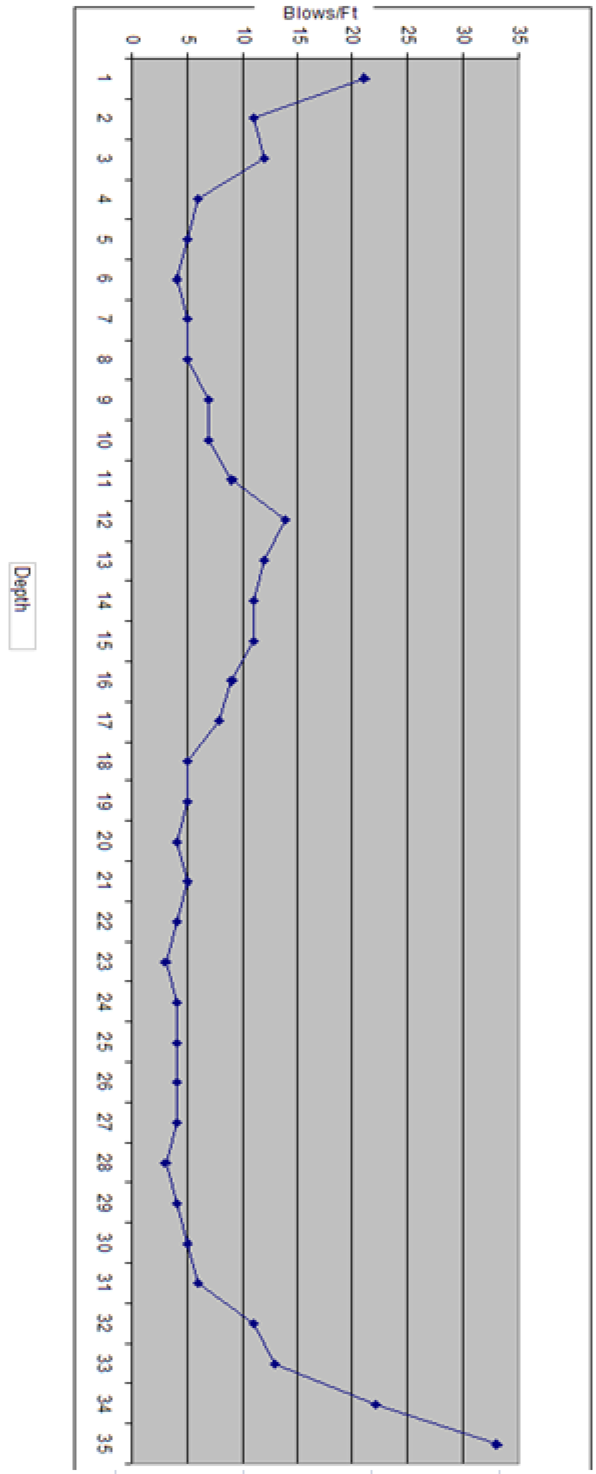


Figure 26. **Borehole #1 data and graph.**

Based on the Diagrams and considering the different depth of bedrock for each borehole a cross sectional sketch of the boreholes and the soil under the structure is shown in figure 27.

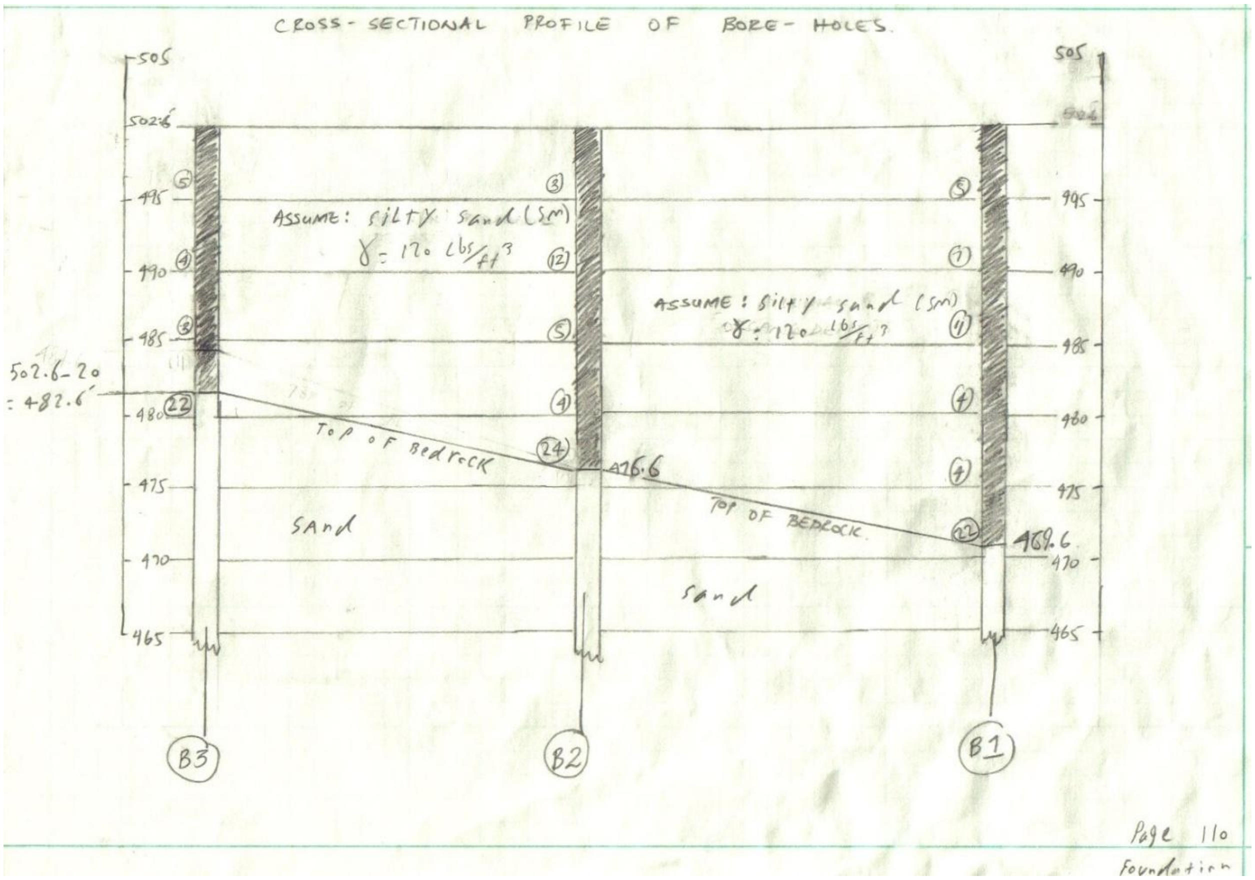


Figure 27. **Cross sectional profile of boreholes.**

The N_{60} value (SPT N value corrected for field procedures) for the standard penetration test that was done in this project is calculated as:

$$N_{60} = (E_m*C_B*C_S*C_R*N) / (0.6)$$

Where E_m is the hammer efficiency which is assumed to be in US, donut hammer with 2 turns on cathead and it is equal to 0.45 (Table 3).

C_B is the borehole diameter correction factor which is assumed to be 65-115 mm (2.5-4.5 in) and it is equal to 1.00 (Table 4).

C_S is the sampler correction factor which is assumed to be standard sampler and it is equal to 1.00 (Table 4).

C_R is the rod length correction factor which is assumed to be 3-4 m (10-13 ft) and it is equal to 0.75 (Table 4)

N is the SPT blow count recorded in field and for borehole #1 (Figure 26) and #3 (Figure 24) it is 22 blows/foot and for borehole #2 (Figure 25) it is 24 blows/foot. The 22 blows/foot is going to be used for the N value in the calculations.

The N_{60} value is

$N_{60} = (0.45*1.00*1.00*0.75*22)/ (0.60)$

N_{60} = 12.38 blows/foot

Table 3
***SPT hammer efficiencies*.**

TABLE 4.3 SPT HAMMER EFFICIENCIES (Adapted from Clayton, 1990).

Country	Hammer Type (per Figure 4.10)	Hammer Release Mechanism	Hammer Efficiency E_m
Argentina	Donut	Cathead	0.45
Brazil	Pin weight	Hand dropped	0.72
China	Automatic	Trip	0.60
	Donut	Hand dropped	0.55
	Donut	Cathead	0.50
Colombia	Donut	Cathead	0.50
Japan	Donut	Tombi trigger	0.78–0.85
	Donut	Cathead 2 turns + special release	0.65–0.67
UK	Automatic	Trip	0.73
US	Safety	2 turns on cathead	0.55–0.60
	Donut	2 turns on cathead	0.45
Venezuela	Donut	Cathead	0.43

Table 4
***Correction factors for borehole, sampler and rod*.**

TABLE 4.4 BOREHOLE, SAMPLER, AND ROD CORRECTION FACTORS (Adapted from Skempton, 1986).

Factor	Equipment Variables	Value
Borehole diameter factor, C_B	65–115 mm (2.5–4.5 in)	1.00
	150 mm (6 in)	1.05
	200 mm (8 in)	1.15
Sampling method factor, C_S	Standard sampler	1.00
	Sampler without liner (not recommended)	1.20
Rod length factor, C_R	3–4 m (10–13 ft)	0.75
	4–6 m (13–20 ft)	0.85
	6–10 m (20–30 ft)	0.95
	>10 m (>30 ft)	1.00

Based on the SPT sample in Figure 28 which was taken from Foundation Design book by Donald P. Coduto, 2006 it is shown that for blow counts for N_{60} values between 0 – 21 (blows/foot), the soil is classified as Silty Sand. In this MQP the N_{60} was calculated to be 12.38 which it lays within the N_{60} range for Silty Sand soil (0-21 blows/foot).

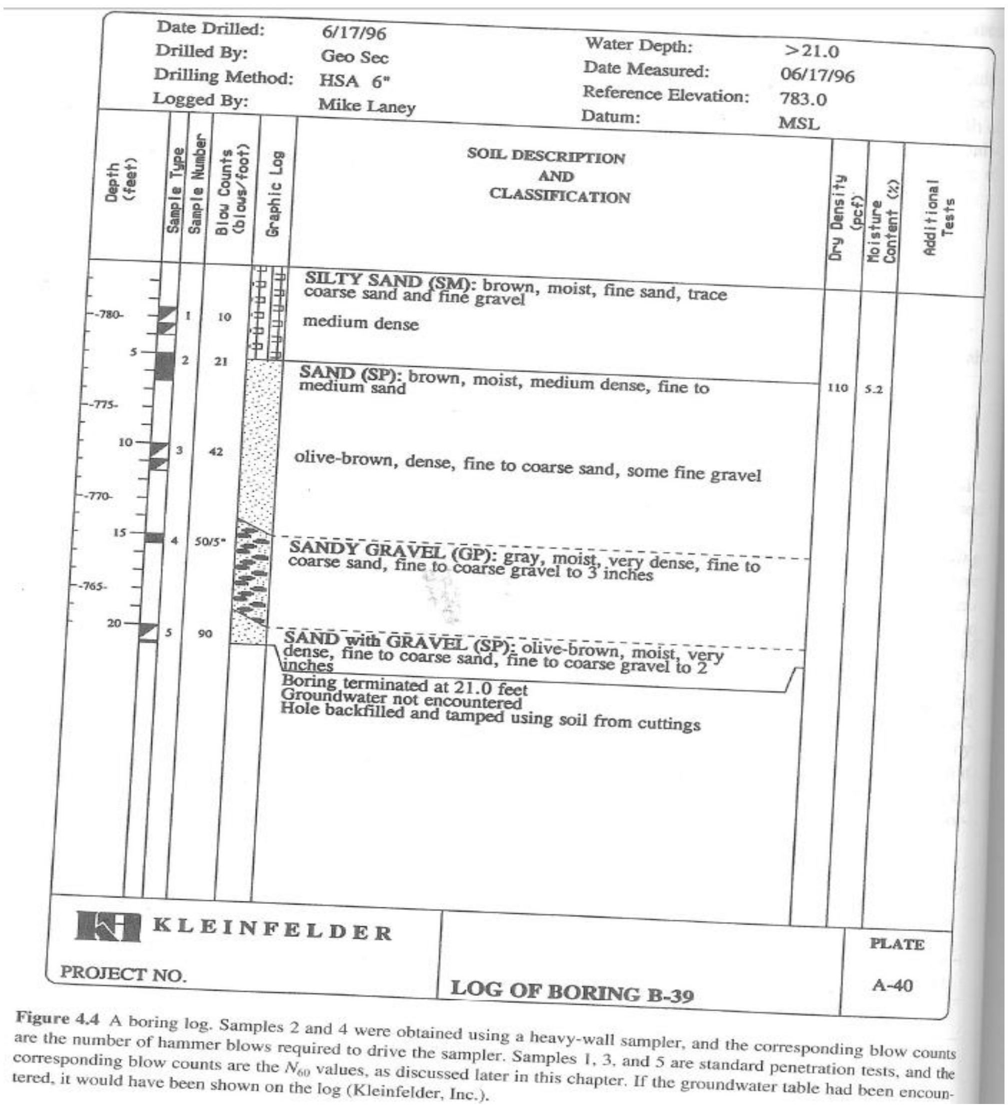


Figure 28. **SPT sample from KLEINFELDER, Inc.**

Based on Table 5, it is shown that the range of soil density (unit weight) for the Silty Sand soil is 80-135 lbs/ft^3. In this project the soil density is assumed to be 120 lbs/ft^3.

Table 5
Typical unit weights.

TABLE 3.2 TYPICAL UNIT WEIGHTS

Soil Type and Unified Soil Classification (See Figure 3.3)	Typical Unit Weight, γ			
	Above Groundwater Table		Below Groundwater Table	
	(lb/ft^3)	(kN/m^3)	(lb/ft^3)	(kN/m^3)
GP—Poorly-graded gravel	110–130	17.5–20.5	125–140	19.5–22.0
GW—Well-graded gravel	110–140	17.5–22.0	125–150	19.5–23.5
GM—Silty gravel	100–130	16.0–20.5	125–140	19.5–22.0
GC—Clayey gravel	100–130	16.0–20.5	125–140	19.5–22.0
SP—Poorly-graded sand	95–125	15.0–19.5	120–135	19.0–21.0
SW—Well-graded sand	95–135	15.0–21.0	120–145	19.0–23.0
SM—Silty sand	80–135	12.5–21.0	110–140	17.5–22.0
SC—Clayey sand	85–130	13.5–20.5	110–135	17.5–21.0
ML—Low plasticity silt	75–110	11.5–17.5	80–130	12.5–20.5
MH—High plasticity silt	75–110	11.5–17.5	75–130	11.5–20.5
CL—Low plasticity clay	80–110	12.5–17.5	75–130	11.5–20.5
CH—High plasticity clay	80–110	12.5–17.5	70–125	11.0–19.5

Based on Figure 29, the friction angle of the soil can be determined by using the vertical effective stress value σ'_z, and SPT N_{60} value. In this project the vertical effective stress is calculated as:

$\sigma'_z = \sigma_z - u$, where σ_z is the vertical total stress and u is the pore water pressure.

$\Sigma_z = \Sigma\gamma H$, where γ is the unit weight of soil stratum and H is the thickness of soil stratum.

In this project, γ is equal to 120 lbs/ft^3 and H for borehole #3 is 21 ft (Figure 24), for borehole #2 is 27 ft (Figure 25) and for borehole # 1 is 34 ft (Figure 26). So the vertical total stress σ_z for these boreholes would be:

Borehole #3

$\sigma_z = 120\ (lbs/ft^3)*\ 21\ (ft)$

= **2520 lbs**.

Borehole #2

$\sigma_z = 120\ (lbs/ft^3)*\ 27\ (ft)$

= **3240 lbs**.

Borehole #1

$\sigma_z = 120\ (lbs/ft^3)*\ 34\ (ft)$

= **4080 lbs**.

Since in σ'$_z$ = σ_z – u the water level is assumed to be low (35 feet below the ground level), the pore water pressure is zero, therefore: σ'$_z$ = σ_z

Based on Figure 29, the friction angle of the soil for all the boreholes is determined to be 30º because the calculated vertical effective stresses of the boreholes and the calculated SPT N_{60} value (12.38 blows/foot) lay in the 30º curve.

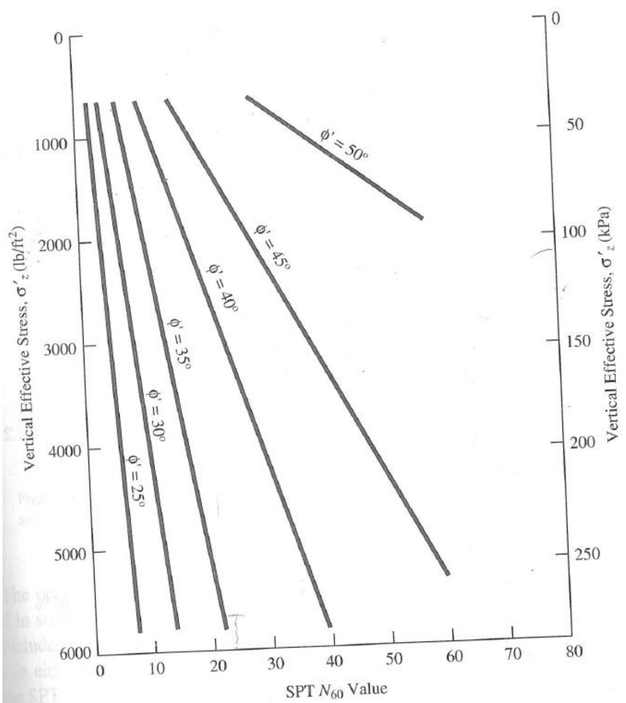


Figure 4.11 Empirical correlation between N_{60} and φ' for uncemented sands (Adapted from DeMello, 1971).

Figure 29. **The friction angle of the soil determined by using the vertical effective stress value σ'$_z$, and SPT N_{60} value.**

4.2.2 Choosing the Shallow foundation

As it was mentioned before, choosing the type of foundation for a structure depends on different variables. Since the deep foundation was not necessary and the top layers of the soil have exeptable bearing capacity and other soil conditions, a shallow foundation was chosen to be used for this project.

In order to choose the type of the shallow foundation, if the total area of the spread footings covers more than half of the building foot-print, then a mat foundation is more suitable. And if the area of the spread footings cover less than half of the building foot-print, then the spread footing would be more desirable.

In this project, in order to determine the required area for the Spread Footings, Terzaghi and Vesic excel file (Donald P. Coduto, 2006) was used. In this excel file the unit of measurement (English or metric), the factor of safety, size (B for base, D for thickness or depth, L for length) and shape (square or rectangular or circular) of the footing and some of the properties of the soil such as soil density γ (gamma), water table U_d (Dw), the angle of friction Φ (phi) and effective cohesion © were entered.

As a result the excel file would calculate the allowable load, allowable bearing capacity and the ultimate bearing capacity. It was necessary to check that the applied load of each column is smaller than the calculated allowable load.

In this building there are 81 columns that carry the loads of the building to the foundation. The average load of these columns was calculated and by using the Terzaghi and

Vesic excel file one spread footing size was determined. The calculation of the average column load is shown in Figure 30.

Average Loads						
left side			middle side			
46.14			220.72		216.58	
110.49			464.26		517.1	
381.16			245.66		627.1	
214.62			446.71			
470.67			135.53		total =	1360.78
202.01			182.05			
438.96			239.13			
1058.14			434.37			
217.86			260.58			
28.72			Total =	2629.01		
46.14						
214.62						
381.16			total load of middle = (2629*2)+ 1360.78=	6618.8		
28.72						
217.86						
			columns in the middle			
total =	4057.27		(9*2=18 columns) + 3 columns =21 columns in the middle			
15 columns in the left side						
4 Parts			Total Columns			
15x4=60			60+21=81			
total columns=60						
			Total Load = 16229.08 + 6618.8 =	22847.88		
total Load 1= 4057.21x4=	16229.08					
			Average Column Load			
			22847.88/81	282.0726		

***Figure 30.* Average column load calculation spread sheet.**

As it is shown, the average column load is calculated to be 282.07 kips. Then by using the Terzaghi and Vesic Excel file, a size for a footing is determined that could support an allowable Load which is not less than 282.07 kips. This procedure is shown in Figure 31.

BEARING CAPACITY OF SHALLOW FOUNDATIONS
Terzaghi and Vesic Methods

Date	December 23, 2007					
Identification	Example 6.4					
Input			**Results**			
Units of Measurement					Terzaghi	Vesic
	E	SI or E	Bearing Capacity			
				q ult =	14,079 lb/ft^2	14,671 lb/ft^2
Foundation Information				q a =	4,693 lb/ft^2	4,890 lb/ft^2
Shape	SQ	SQ, CI, CO, or RE				
B =	9	ft	Allowable Column Load			
L =		ft		P =	380 k	396 k
D =	2	ft				
Soil Information						
c =	0	lb/ft^2				
phi =	30	deg				
gamma =	120	lb/ft^3				
Dw =	35	ft				
Factor of Safety						
F =	3					

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Unit conve	1000
Gamma w	62.4
phi (radiar	0.5236
Terzaghi Computations	
a theta =	3.3508
Nc =	37.16
Nq =	22.46
N gamma	20.12
gamma' =	120
coefficient	1.3
coefficient	0.4
sigma zD'	240
Vesic Computation	
Nc =	30.14
sc =	1.61
dc =	1.09
Nq =	18.40
sq =	1.58
dq =	1.06
N gamma	22.40
s gamma	0.60
d gamma	1.00
B/L =	1
k =	0.22222
W sub f	0

***Figure 31*. Terzaghi and Vesic excel file to determine a footing size for applied average load**.

As it is shown in Figure 31, by Using the Terzaghi and Vesic excel file, for a footing base of 9’ and depth of 2’, Both methods provide an allowable column load capacity greater than the applied load of 282.07 k (380 k for Terzaghi and 396 k for Vesic).

Assuming that all the columns are going to have a same size square shape footings which are 9’ x 9’ with a thickness of 2’. The area of each footing would be 81 ft ^{2}.

There are 81 columns so, 81 columns x 81 ft ^{2} = 6,561 ft ^{2}.

The area of the base of the building is 22,620 ft ^{2} and half of this area would be 11,310 ft^^{2}.

$$11,310 \text{ ft}^{2} > 6,561 \text{ ft}^{2}.$$

So using a mat foundation is and Spread footing design would be considered for this project.

4.2.3 Spread Footing Design

The loads of all the columns are shown in the average forces excel file provided above. As it can be seen, the loads varies from 28.72 kips to 1058.14 kips. In order to avoid having many different sizes of footings and also in order to be economical, only three range of column loads were chosen to be used in the design;

0 kips – 381.16 kips

381.16 kips – 627.1 kips

627.1 kips – 1058.14 kips.

These loads are shown with a green highlight in the average forces excel file provided above. The sample calculation for the load 1058.14 kips is shown because it is the greatest load and also the column which support this load also supports moments coming from a cantilever beam. For the other two ranges of loads the calculation is summarized in excel spread sheets.

Calculation of Loads and Moments

The load that is applied to the footing is sum of all the loads of columns on top of the footing. There are five floors (five columns on top of the footing) which four of them have the same loading on their columns and the fifth floor has different loading because it supports the roof. So the load of one of the first floors is multiplied by four and then the load of fifth floor is added to it. This concept also applies to the applied moment.

As it is shown in our sample calculation the Factored load is 1058.14 kips and the un-factored load is 777.94 kips. Based on the Excel spread sheet for Bay 4 column F-3.2, the moment coming from the cantilever beam for one floor is 1556.86 kft and it would be multiplied by 4 and added to the moment due to the cantilever for the roof which would give 7000.24 ft.kips.

In brief, these calculations are described with a picture of all the floors in the Figure 32.

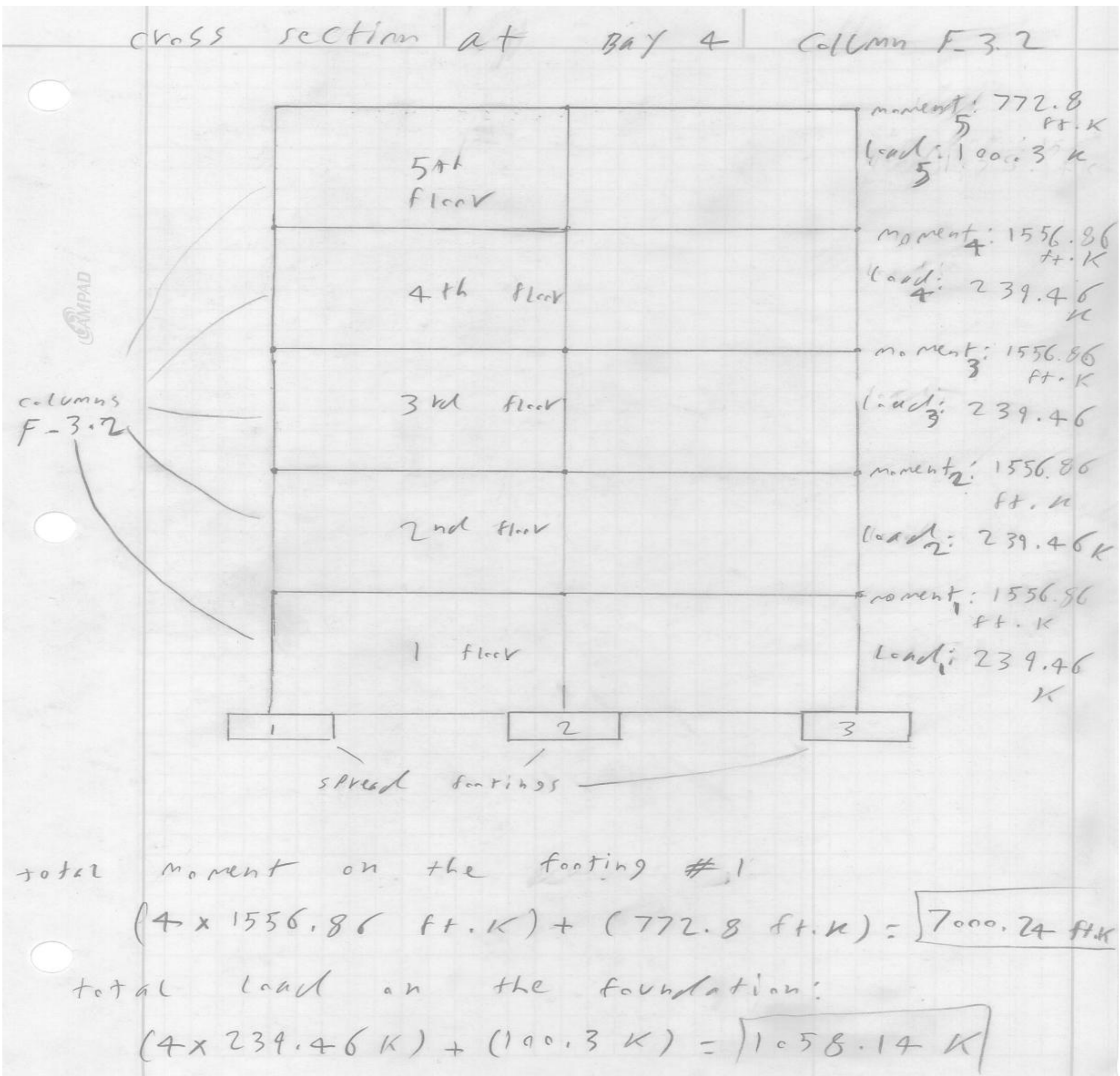

Figure 32. **Calculation of total floor loads and moments on the spread footing.**

Estimating the size of the footing:

qn = qa – (weight of the footing, soil and the floor) – pressure of the moment.

Where, qn is the allowable net soil pressure which would let us know how much pressure is allowed to be exerted other than the pressure of weight of the footing, soil and the floor and pressure of the moment.

Qa is the allowable bearing capacity.

As it is shown in the calculation the allowable net soil pressure for the load is 4.3 ksf so that means that only 4.3 ksf is allowed to be applied by the vertical column load which is 1058.14 kips factored and 777.94 kips.

In this case we could estimate the width of the footing by dividing the load by the allowable net soil pressure. The estimated width was 14' x 14'. The thickness of the footing was assumed to be 6'.

Checking the size for 2-way shear:

In this part the shear on the critical part of the footing is under consideration and it should be smaller than the allowable shear for 2-way shear.

The critical parameter is calculated by d = T – 3 in – db, where T is the thickness of the footing and there is 3 in of cover and db is the diameter of the reinforcement bar which in this case is assumed to be 1 in.

The shear on the critical part is:

Vuc = ((Pu/4) + (Mu/(c +d))) (B^2 – (c + d) ^2)/B^2

Where Pu is the load applied, Mu is the Moment applied, B is the width of the footing and c is the width of the base plate.

This shear should be checked with the nominal two-way shear capacity which is:

Vnc = 4 (b0) d (f'c^ (1/2))

Where b0 = c + d, where c is the width of the base plate which is 14" in this case.

At the end it should be satisfied that:

Φ Vnc > Vuc, where Φ is 0.85.

<u>Check for one-way shear:</u>

Vuc = ((B – c – 2d)/(B)) (((Pu + 6Mu/B)^2) + Vu^2)^(1/2)

Where Vu = 0, because there is no shear force exerted to the footing.

Nominal one-way shear capacity:

Vnc = 2 bw d (f'c) ^ (1/2)

Where bw = 2B.

The following should be satisfied:

Φ Vnc > Vuc, where Φ is 0.85.

<u>Design of Flexural reinforcement:</u>

Muc = (Pu L^2)/(2B) + (2Mu L/B), where L for steel column is: L = (2B – (c + cp))/4 where cp in here is the base plate width and c is the column width. C = 12".

Required Area:

As = (f'c b/ (1.176fy)) (d – ((d^2) – (2.353Muc/ Φf'c b)) ^ (1/2))

Where Φ is 0.9 and f'c is 3000 psi and fy is 60000 psi.

Min Area Required:

As = pBT, where p is the steel ratio and because of using Grade 60 bars (# 8 bars) it is 0.0018.

Between these two As, the greater one is chosen.

Then the bar type should be chosen (in this project all the bars were chosen to be #8 bars with cross sectional area of 0.79 in^2 and diameter of 1.00 in).

# of bars needed = As/Cross sectional area of bar

Clear spacing between bars:

Based on ACI section 7.6.5, the max spacing is 18".

Spacing = (B / (# of bars +1)) – 1.

Check for development length:

(Ld) supplied = L – 3 in

(C + Ktr)/db, where Ktr is 0 for spread footings and C is the smaller of the spacing or cover dimension.

Ld/db = (3/40) (fy/ (f'c) ^ (1/2)) (α β γ λ/ ((c + Ktr)/db))

Where α is the reinforcement location factor, β is the coating factor, γ is the reinforcement factor and λ is the lightweight concrete factor. (Coduto., pp. 319, 320)

All of these factors are 1 in this case.

The following should be satisfied:

(Ld) supplied > Ld.

Bearing Pressure:

e = Mu/ (Pu + Wf), where e is the eccentricity of bearing pressure and the Wf is the weight of the foundation. If $e \leq B/6$ then the bearing pressure distribution is trapezoidal. So there would be minimum and maximum bearing pressure acting under the footing. Then:

$q_{min} = (((P_u + W_f)/A) – U_d) (1 – 6e/B)$

$q_{max} = (((P_u + W_f)/A) – U_d) (1 + 6e/B)$

Where A is the base area of the footing and Ud = 0 because the water table is very low (35').

Qa > qmax should be satisfied.

Checking for the Settlement (δ):

For the settlement it is necessary to check that $\delta \leq \delta a$.

In order to calculate the settlement it is necessary to calculate different variables;

Induced stress:

Δσz = (1 – (1/ (1+ (B/2Zf) ^2)) ^ (1.76)) (q – σ'zd), where σ'zd is the vertical effective stress at a depth D below the ground surface. And Zf is the considering depth for settlement purposes, in this case it was taken to be 2'.

Σ'zd = γD – Ud, where γ is the soil density which in this project is 120 lbs/cf.

Effective Stress:

$\sigma'zf = \sigma'z0 + \Delta\sigma z$, where $\sigma'z0$ is the initial vertical effective stress at midpoint of soil layer. $\Sigma'z0 = \gamma H - Ud$, where H is the Thickness of the soil layer, so in this project based on the boreholes and the cross sectional profile, the depth of the layer (silty sand) changes in each borehole. So it is necessary to calculate the settlement for each of the 3 ranges of load 3 times because of different value of H.

Settlement:

$\delta c = \delta = (r\ Cc/(1+e0))\ H\ Log(\sigma'zf/\ \sigma'z0)$, where r is the rigidity factor which is taken from the table 7.1, (Coduto., 2006). In this case r = 0.85.

Cc is the compression index; e0 is the initial void ratio.

The values of Cc/ (1+e0) could be determined based on the table 3.5 and table 3.7 (Coduto., 2006)

In this project it is taken to be 0.006 for Fine sand with little fine to coarse silt (SM) with relative density of Dr = 80%.

At the end it should be satisfied that:

$\delta \leq \delta a$, where δa in this project is taken to be 1 in.

Based on the calculation there were 3 different footings considered for 3 different loading ranges of columns in this project;

0 kips – 381.16 kips. 10’ x 10’ and a thickness of 2’.

381.16 kips – 627.1 kips. 11’ x 11’ and a thickness of 3’.

627.1 kips – 1058.14 kips. 14’ x 14’ and a thickness of 6’.

These footings are shown in the sample calculation in Appendix B.

The calculation and the spread sheets are provided in Appendices B and C.

As shown in Appendix B, each footing has different settlement based on which borehole area it is located. For example Footing 3, has a settlement of 0.501 in when it is located on the area of Block #3 (borehole #3). It has a settlement of 0.547 in, when it is located on the area of the Block #2 (borehole #2). It has a settlement of 0.586 in, when it is located on the area of the Block #1 (borehole #1). Refer to Figure 23 to check where each area is located.

As it was mentioned before the reason for these different settlements is that for each block the Value of H (Depth of the layer of soil) is different.

Terzaghi and Vesic Method

The designed size for the spread footing should be checked by the Terzaghi and Vesic method which is provided in an excel file. The results are shown in Figure 33, Figure 34 and Figure 35:

BEARING CAPACITY OF SHALLOW FOUNDATIONS
Terzaghi and Vesic Methods

Date December 24, 2007
Identification Example 6.4

Input

Units of Measurement
E SI or E

Foundation Information

Shape	SQ	SQ, CI, CO, or RE
B =	14	ft
L =		ft
D =	6	ft

Soil Information

c =	0	lb/ft^2
phi =	30	deg
gamma =	120	lb/ft^3
Dw =	35	ft

Factor of Safety
F = 3

Results

	Terzaghi	Vesic
Bearing Capacity		
q ult =	29,686 lb/ft^2	34,774 lb/ft^2
q a =	9,895 lb/ft^2	11,591 lb/ft^2
Allowable Column Load		
P =	1,939 k	2,272 k

Unit conve	1000
Gamma w	62.4
phi (radiar	0.5236
Terzaghi Computations	
a theta =	3.3508
Nc =	37.16
Nq =	22.46
N gamma	20.12
gamma' =	120
coefficient	1.3
coefficient	0.4
sigma zD'	720
Vesic Computation	
Nc =	30.14
sc =	1.61
dc =	1.17
Nq =	18.40
sq =	1.58
dq =	1.12
N gamma	22.40
s gamma	0.60
d gamma	1.00
B/L =	1
k =	0.42857
W sub f	0

***Figure 33*. The Terzaghi and Vesic method for the first column with the load of 1058.14 kips.**

BEARING CAPACITY OF SHALLOW FOUNDATIONS
Terzaghi and Vesic Methods

Date December 24, 2007
Identification Example 6.4

Input

Units of Measurement
E SI or E

Foundation Information

Shape	SQ	SQ, CI, CO, or RE
B =	11	ft
L =		ft
D =	3	ft

Soil Information

c =	0	lb/ft^2
phi =	30	deg
gamma =	120	lb/ft^3
Dw =	35	ft

Factor of Safety
F = 3

Results

	Terzaghi	Vesic
Bearing Capacity		
q ult =	18,705 lb/ft^2	20,143 lb/ft^2
q a =	6,235 lb/ft^2	6,714 lb/ft^2
Allowable Column Load		
P =	754 k	812 k

Unit conve	1000
Gamma w	62.4
phi (radiar	0.5236
Terzaghi Computatior	
a theta =	3.3508
Nc =	37.16
Nq =	22.46
N gamma	20.12
gamma' =	120
coefficient	1.3
coefficient	0.4
sigma zD'	360
Vesic Computation	
Nc =	30.14
sc =	1.61
dc =	1.11
Nq =	18.40
sq =	1.58
dq =	1.08
N gamma	22.40
s gamma	0.60
d gamma	1.00
B/L =	1
k =	0.27273
W sub f	0

***Figure 34*. The Terzaghi and Vesic method are used for the second column with the load of 627.1 kips.**

BEARING CAPACITY OF SHALLOW FOUNDATIONS
Terzaghi and Vesic Methods

Date	December 24, 2007	
Identification	Example 6.4	

Input			**Results**		
Units of Measurement				Terzaghi	Vesic
	E	SI or E	Bearing Capacity		
			q ult =	15,045 lb/ft^2	15,433 lb/ft^2
Foundation Information			q a =	5,015 lb/ft^2	5,144 lb/ft^2
Shape	SQ	SQ, CI, CO, or RE			
B =	10	ft	Allowable Column Load		
L =		ft	P =	502 k	514 k
D =	2	ft			
Soil Information					
c =	0	lb/ft^2			
phi =	30	deg			
gamma =	120	lb/ft^3			
Dw =	35	ft			
Factor of Safety					
F =	3				

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Unit conve	1000
Gamma w	62.4
phi (radiar	0.5236
Terzaghi Computations	
a theta =	3.3508
Nc =	37.16
Nq =	22.46
N gamma	20.12
gamma' =	120
coefficient	1.3
coefficient	0.4
sigma zD'	240
Vesic Computation	
Nc =	30.14
sc =	1.61
dc =	1.08
Nq =	18.40
sq =	1.58
dq =	1.06
N gamma	22.40
s gamma	0.60
d gamma	1.00
B/L =	1
k =	0.2
W sub f	0

***Figure 35*. The Terzaghi and Vesic method for the third column with the load of 381.16 kips.**

As it is shown in Figure 33, Figure 34 and Figure 35, for the selected sizes of the spread footings, all of the column loads are smaller than the Allowable column loads and also the bearing pressure of them are smaller than the Allowable bearing capacity. So these sizes satisfy the requirements for Terzaghi and Vesic method.

4.3 Cost Estimation

In this project, the “Unit-Quantity Method” was used. The detailed estimation may be an issue but since our team has limited time, we consider preparing a cost analysis of concrete and steel structure (itself) of the building.

After finishing the last phase of the design of a 23'x18' bay, the first floor part, our team was able to determine and examine the cost of this specific bay then apply the results obtained to the whole building.

In modern construction industry, there are many ways to build the structure but two construction materials are commonly used which are concrete and steel; furthermore in this project, comparison of the cost analysis of steel and concrete structure were studied.

5.0 *Discussion*

This section includes the results obtained from the computed calculation when following the procedures set out in the methodology section.

Appendix D includes detailed tables (Table 14, Table 15, Table 16 and Table 17) that include the actual designed member sizes of all the beams and girders that were analyzed. The tables in the Appendix D also include the Moment Capacity given by the AISC Steel Manual for each selected size. The final member sizes that were selected were obtained according to the moment capacity, where the designed members' sizes were categorized, having the members with approximately same moment capacity in the same category. Table 6 shows the final beams and girders sizes obtained for the section that was designed; however Table 7 shows the amount of members needed for the whole structure.

Table 6

Beams needed for the designed section.

Member size	Number needed For the left side section based on Figure 13	Amount needed for the middle section based on Figure 13
W10x12	31	27
W12x16	9	4
W12x26	9	6
W18x35	6	8
W24x55	3	5
W33x118	1	-
W27x48	1	-

Table 7

Beams needed for the entire building.

Member size	Number needed for the left side based on Figure 13	Amount needed for the middle side based on Figure 13	Amount needed for the whole building
W10x12	496	216	**712**
W12x16	144	32	**176**
W12x26	144	48	**192**
W18x35	96	64	**160**
W24x55	48	40	**88**
W33x118	16	-	**16**
W27x48	16	-	**16**

Therefore 1360 steel beams are required to construct the New WPI Residence Hall. Two main column sizes were selected to be used; W 12x58 for the third through the fifth floor and W12x65 for the first and second floor. Column F-3.2 in bay 4 required a different column size, because the two sizes selected are not adequate for one of the girders acting on the designed column; where b_f of the girder is bigger than b_f of the column(10 in and 12 in). Therefore, W12x96 was used for the five floors with b_f equal to12.2 in.

For the design of the floor plate, B-Lock composite decking 22-Gage was used. The properties of this gage provided in Table 8, were obtained from the United Steel Deck website.

Table 8
***Deck engineering properties*.**

DECK PROPERTIES									
Gage	t	w	As	I	S_p	S_n	R_b	ϕV_n	studs
22	0.0295	1.6	0.470	0.165	0.195	0.206	1320	2620	0.43
20	0.0358	1.9	0.570	0.212	0.247	0.260	1880	3170	0.52
19	0.0418	2.3	0.670	0.260	0.292	0.304	2500	3680	0.61
18	0.0474	2.6	0.760	0.308	0.337	0.349	3200	4160	0.69
16	0.0598	3.3	0.960	0.400	0.434	0.439	4750	5210	0.87

Calculation of the concrete is based on cubic yard method and labor, equipment, material for making and placing the concrete is added to the concrete cost in order to find the exact cost of specific bay. Detail calculation can be found in Appendix B.

Because of the huge variation among the loads acting on the columns, ranging between 28.72 kips and 1058.14 kips. As it was explained in the methodology of the foundation, there were 3 different footings considered for 3 different loading ranges of columns in this project;

0 kips – 381.16 kips. 10’ x 10’ and a thickness of 2’.

381.16 kips – 627.1 kips. 11’ x 11’ and a thickness of 3’.

627.1 kips – 1058.14 kips. 14’ x 14’ and a thickness of 6’.

The results for the footing sizes are shown in Table 9.

Table 9
Footing sizes.

Column location	Applied load (K)	Foundation size.
J-2	46.14	10’ x 10’, 2’ Thick
J-3	110.48	10’ x 10’, 2’ Thick
H-1	214.62	10’ x 10’, 2’ Thick
G-1.2	381.16	10’ x 10’, 2’ Thick
E.3-1.2	470.67	11’ x 11’, 3’ Thick
G-4.9	202.01	10’ x 10’, 2’ Thick
F-4.9	438.96	11’ x 11’, 3’ Thick
F-3.2	1058.14	14’ x 14’, 6’ Thick
H.1-2.7	217.86	10’ x 10’, 2’ Thick
G.1-2.7	28.72	10’ x 10’, 2’ Thick
C.5-6	220.72	10’ x 10’, 2’ Thick
E-6	464.26	11’ x 11’, 3’ Thick
C.5-7	245.66	10’ x 10’, 2’ Thick
E-7	446.71	11’ x 11’, 3’ Thick
F.5-6	135.53	10’ x 10’, 2’ Thick
F.5-7	182.05	10’ x 10’, 2’ Thick
C.5-8	239.13	10’ x 10’, 2’ Thick

E-8	434.37	11' x 11', 3' Thick
F.5-8	260.58	10' x 10', 2' Thick
C.5-9	517.1	11' x 11', 3' Thick
E-9	627.1	11' x 11', 3' Thick
F.5-9	216.58	10' x 10', 2' Thick

Here are some important facts about the concrete structure cost analysis:

1. Labor is limited to the following workers for the specific bay; two Carpenter ($23.7/h), three Helper ($22.1/h), one Foreman ($21.45/h).
2. 23'x18' bay has; four columns, three beams and 4.5" thickness and needs 8 hours to finish whole bay.
3. Additional materials are limited as follows: Lumber ($0.86/unit), Nails ($1.29/unit), Form Oil ($17.65/gallon), Shores ($8.25/unit)
4. Concrete price is $200 per ton
5. Total cost of 23'x18' bay, itself, is **$50,552.00**
6. Total cost of the concrete building, itself, is **$6,596,166**

If the building will be a steel structure then different approach needs to be done in order to estimate the cost of the building.

The cost analysis of the steel is made similar as concrete cost analysis with different variables. As mentioned before, 23'x 18' bay design is taken based on the steel cost analysis.

Here are some facts of steel structure cost analysis of the WPI New Residence Hall:

1. Major steel sizes are; W 10 x 12 for beams, W8 x 31 for columns, W 24 x 55 for girders

2. Cost of steel is $2000 per ton
3. Labor force is limited as follows; Foreman ($ 25.10/h), Crane Operator ($ 22.0/h), Ironworker ($17.35/h)
4. Butt-weld joints are used with 3/16"
5. Girders, H columns used as fabricated
6. Shop paint costs are: Beams ($85.00), Girders ($58.72), Columns ($93.00)
7. Total cost of the 23'x18' bay, itself, is **$23,777**
8. Total cost of whole building, itself, is **$5,950,568**

Below is a list of some facts about the Time and Scheduling process of the WPI-New Residence Hall project:

1. Project started on February 7th 2007 and will be finished on August 22nd 2008,which includes approximately 399 work days
2. There are 10 milestones that need to be accomplishing in order to finish the building:
    - Project Starts
    - Design Kick of Meeting
    - Design Completed
    - Demolition the existing building
    - Foundation Completed
    - Flush Building
    - Substantial Completion
    - Final Inspection & Approval
    - Building Enclosed
    - Project Ends
3. Project Management started on May 8th 2007 and will be done on august, 1st 2008
4. Building design started on April 7th, 2007 and will be done on December 13th, 2007

5. Site work and Excavation started on February 7th, 2007 and will be done on September 4th,2007
6. Concrete Work started on June 29th, 2007 and will be done on August 13th,2007
7. Precast Concrete work started on July 2nd,2007 and will be done August-2nd,2007
8. Masonry work started on July 18th, 2007 and will be done on January 24th, 2008
9. Metals work started on August 16th, 2007 and will be done on April 28th,2008
10. Carpentry work started on March 10th,2008 and will be done on May 7th, 2008
11. Roof & Moisture Protection started on February 6th,2008 and will be done on June 5th,2008
12. Door & Windows installments started on November 7th,2007 and will be done on June 10th,2007
13. Specialties started on May 7th, 2008 and will be done on July 22nd,2008
14. Elevator work started on May 26th, 2008 and will be done on June 24th,2008
15. Mechanical work started on December 17th,2007 and will be done by March 20th,2008
16. Electrical work started on April 2nd,2008 and will be done on July 11th,2008
17. Finishes started on December 5th,2007 and will be done on August 9th,2008

6.0 Conclusion

Every year, WPI expects more incoming students and it is obvious that current accommodation is not satisfying the number of incoming students. WPI decision makers thought that there would be a need for a new residence hall for a long term prospective. So they decided to come up with idea of WPI New Residence Hall.

In this Major Qualifying Project, the goal was to come up with an adequate building process which includes structural design and project management activities that would help to understand the civil engineering aspects of the WPI New Residence Hall.

After receiving the architectural design of the residence hall a structural design was developed which includes steel and foundation design of the building and it was combined with project management topics such as cost estimation, time and scheduling, in order to come up with an efficient understanding of the building process.

In the designing of the steel structure beams, girders, floor plates were analyzed and there were some challenges such as designing of staircase structure and elevator shaft because of their complex structure. In addition, for the foundation design, choosing and designing the right type of the foundation were the main concerns.

Furthermore, in project management, cost estimation of steel and concrete structure and comparison of the cost of two methods are the main challenges in this project. In addition permits and time & scheduling were other important issues that were brainstormed.

As a result of this unique project, it was decided to use steel structure other than concrete structure based on lower cost, flexible scheduling and more convenient way to built.

We believe that this Major Qualifying Project will give an extraordinary understanding of civil engineering vision for the WPI New Residence Hall Project to all readers.

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Appendices

Appendix A: Loads Used

(Loads were obtained from the Commonwealth of Massachusetts, State Building Code- sixth Edition)

1. Floor Dead Load

Table 10
***Floor dead load*.**

Dead load	Pounds per square foot (psf)
Concrete slab (4.5 in)	12
Steel decking	2
Floor Finish (0.5in)	4
Cement tiles	16
Interior walls	33
Exterior walls	66
MEP and suspended ceiling	6

All dead loads used were multiplied by a safety factor of 1.1.

2. Roof Dead Load

Table 11
***Roof dead load*.**

Dead Load	Pounds per square foot (psf)
Roof decking	40
Structural steel	18
MEP and suspended ceiling	6
Exterior wall when applicable	66

3. Stairs Landing Dead Load

Table 12
***Stairs landing dead load*.**

Dead load	Weight psf
Concrete slab 2”	12
Steel plate	6
Finish floor	2.5
Steel beam for stairway	12

4. Floor Live Load

Table 13
***Floor live load*.**

Occupancy	Live Loads in pounds per square foot(psf)
bedrooms	40
Kitchen/ Living rooms	100
HVAC	125
Electrical room	125
Corridor	80
Lounge	100
Stairs	100
Elevators	

5. Roof Live Load

Loads acting on the roof can either be caused by snow 35psf for the Worcester zone or by the roof live load 20psf for the designed building. Since the snow load is the most critical, it will be considered as the main load acting on the roof.

Appendix B: Sample Calculation

Design Sample Calculation

The design sample calculations were conducted on Bay 1 of the side part of the building. The sample calculation provided shows the method used to design typical beams, girders, cantilever beams, and columns. A sketch of bay 1 that includes all the members is provided in Figure 36.

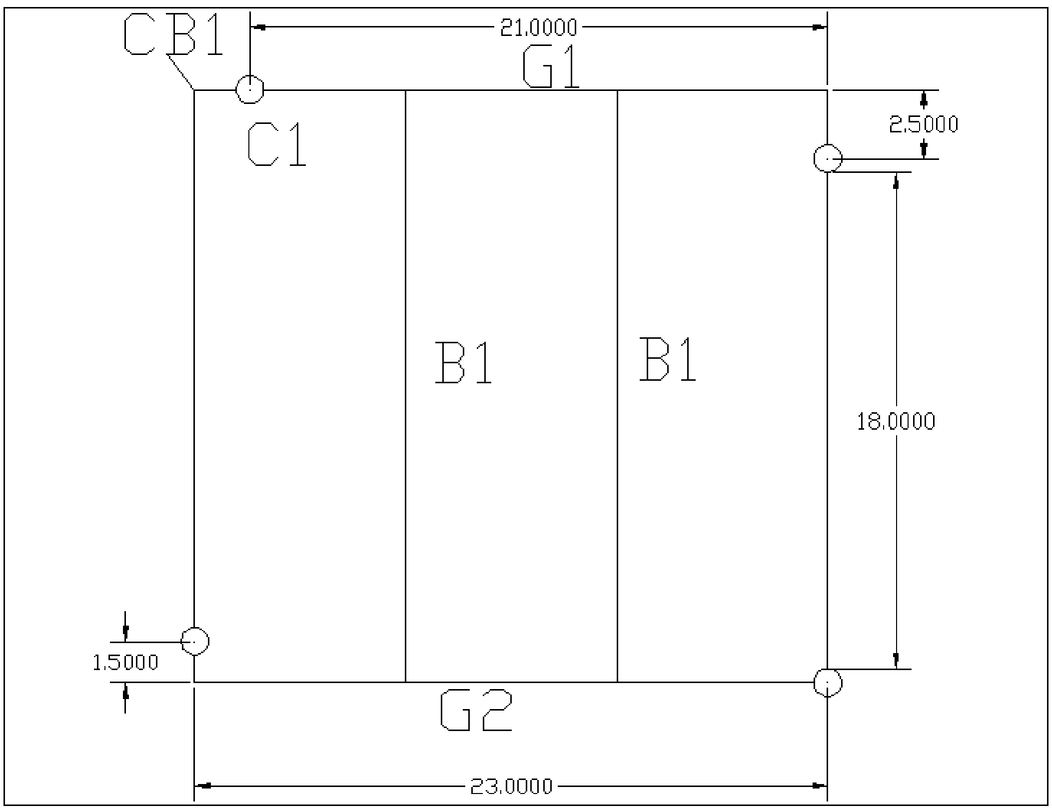
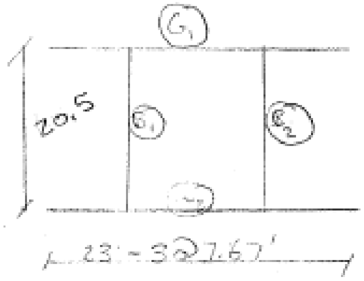


***Figure 36*. Bay 1 (Left Side) layout.**

Beam Design

Sample Calculation

Beam Design



- Assuming 4.5" slab Thickness

Dead Load:

Concrete Load: 4.5x12x1.1 = 59.4
MEP: [illegible] x1.1 = 8.8
Floor [illegible]: 4x0.5x1.1 = 2.2
Cement tiles: 16 x 1.1 = 17.6
Interior Walls: 33 x1.1 = 36.3

} Σ = 124.3 psf

• 1.1 is a safety factor.

Total DL = 124.3 x 7.67 = 953.381 lbs/ft

Live Load: Since there is no specification [illegible] residence halls, we decided to use the specification [illegible] for hotels.

This bay will be used as a Living Room/ [illegible] ∴ Specification for public Rooms will be used

LL = 100 psf ⟶ LL = [illegible] = 767 lbs/ft

Load Combinations:

$1.2DL + 1.6LL = 1.2(953.381) + 1.6(767) = 2371.25$ lbs/ft

Fixed end Moment $= M_u = \frac{1}{8} wL^2$

$= \left(\frac{1}{8}(2371.25)(20.5^2)\right) / 10$

$M_u = 124.57$ k.ft

Assuming a = 1".

$y/2 = t_s - a/2 = 4.5'' - 1''/2 = 4.00''$

Table 8.19 of manual:

Choose W 12X14	M_n = 155.00 K.Ft

Weight = 14 x 1.2 = 16.8 lbs/ft

→ Total Weight = 2371.25 + 16.8 = 2388.1 lbs/ft

T. Weight = 2.38 k/ft

$M = \frac{1}{8}(2.38)(20.5)^2 = 125.45$ k.ft

125.45 k.ft < 155 k.ft ∴ O.K

$a = \frac{\Sigma QN}{0.85 f'_c . be}$

$= \frac{208}{0.85(3)(61.5)} = 1.33$

$\Sigma QN = 208^k$

1) be = 7.67 X 12 = 92.04"

2) $be = \frac{1}{4} \times 20.5 \times 12 = 61.5$ ✓

$Y_2 = 4.5 - \frac{1.33}{2} = 3.83$

f'_c = 3.0 k

Interpolate between 3.5 & 4.0

Y = 3.5	147.00
Y = 4.0	155.00
Y = 3.83	152.39

$\phi M_n = \phi T e$

$= \phi A_s f_y (d/2 + t - a/2)$

$= (0.9)(4.16)(50)(11.90/2 + 4.5 - 1.33/2)$

ϕM_n = 11831.75 in. K = 152.65 ft.K

→ ϕM_n = 155 k' > 152.65 k' O.K

$F_u = 60$ Ksi

$T = C = A_s f_y \longrightarrow T = C = (4.16)(50) = 208^{K}$

\# of shear studds $N = \frac{V_n}{Q_n}$

$Q_n = 0.5 A_{sc} \sqrt{f'_c \cdot E_c}$ $\qquad A_{sc} = \frac{\pi d^2}{4}$ Use 3/4" stud

$Q_n = 0.5(0.44)\sqrt{(3)(3024)}$ $\qquad \rightarrow A_{sc} = 0.44 \text{ in}^2$

$Q_n = 20.95$

$Q_n = 20.95 \leq (0.44)(65) = 28.6$

\# of studds $= \frac{208}{20.95} = 9.93$

| $N = 10$; \# of studds $= 20$ |

Spacing $\frac{20.5 \times 12}{20} = 12.3''$/studd

min spacing $= 6 \times (3/4) = 4.5''$ O.K.

max spacing $= 8t = 36''$ O.K.

Deflection check?

$y_c = d + t_s - a/2$

$= 11.90 + 4.5 - 1.33/2 = 15.74''$

$A_s = 4.16\ in^2$

I = ??

Use table 3.20 to find I   W12x14

y_2	I
3.5	274
4.0	295.
3.84	287.83

Dead Load Deflection:

$$\Delta_D = \frac{5 w_D L^4}{384 E I}$$

$$= \frac{5(0.953)(20.5^4)(1728)}{384(29000)(287.83)}$$

$$= 0.46\ in < \frac{L}{360} = \frac{20.5 \times 12}{360} = 0.68\ in$$

$$\Delta_{LL} = \frac{5 W_L L^4}{384 E I} = \left(\frac{(5 \times 0.767 \times 20.5^4)(1728)}{384 \times 29000 \times 287.83}\right)/2 = 0.18\ in$$ ✓

During construction

$$\Delta_C = \frac{5 w_C L^4}{384 E I} \left(= \frac{5 \times 0.767 \times 20.5 \times 1728}{384 \times 29000 \times 638.9}\right)/2 = 0.59$$ ✓

Partial composite

$M_u = 124.57$ K.Ft.

$Y_2 = 3.84$

Choose TFL = 6

$a = \frac{\Sigma Q_N}{0.85 f'_c b_e} = \frac{85.2}{0.85(3)(61.5)} = 0.54$

$Y_2 = 4.5 - \frac{0.54}{2} = 4.23$

y	Mu
4	115.00
4.5	119.00
4.23	116.83

# of shear studds:

$N = \frac{V_h}{Q_n} = \frac{85.20}{20.95} = 4.1 \sim 5 \rightarrow$ 10 studds

Spacing $\frac{20.5 \times 12}{8} = 30.75''$

$4.5 < 30.75 < 36''$

Deflection in use

$\Delta_\Delta = \frac{5 w_L L^4}{384 E I}$

$\frac{5 \times 0.96 \times 20.5}{384 \times 29000 \times 213.94} =$

$= 0.62$ OK.

TFL 6

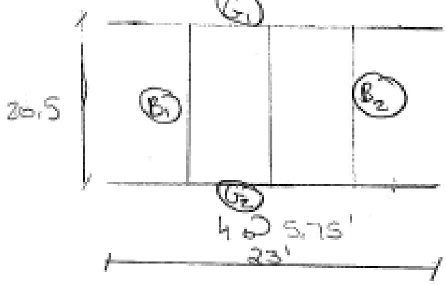
y	I
4	208.00
4.5	221.00
4.23	213.94

$$\Delta_{LL} = \frac{5 \times 0.767 \times 26.5^4 \times 1728}{384 \times 29000 \times 21394} = 0.25$$ ✓

During Construction Δ_{LL} is the same as full composite

Beam design!

This is only a sample calculation. Our design includes Two Beams Not Three



Dead Load

Concrete Load: 4.5 x 12 x 5.75 x 1.1 = 341.55
MEP = 8 x 5.75 x 1.1 = 50.6
Floor Finish = 4 x 0.5 x 5.75 x 1.1 = 12.65
Cement tiles = 16 x 5.75 x 1.1 = 101.2
Interior wall = 33 x 5.75 x 1.1 = 208.725

DL = 12635 → !

Total DL = 715 lb/ft →

LL = 100 psf → For Public Rooms in hotels.

100 x 5.75 = 575 lb/ft

Load combination

$1.2DL + 1.6LL = 1.2(715) + 1.6(575) = 1778\ lb/ft$

Fixed end moment → $M_u = \frac{1}{8} wL^2$

$= \left(\frac{1}{8}(1778)(20.5^2)\right)/1000$

$M_u = 93.4$

Assume a = 1''

$Y_2 = t_s - a/2 = 4.5 - 1/2 = 4''$

Table 3.19 of manual:

Choose W12x14	M = 155 kip-ft

Weight = 14 x 1.2 = 16.8 lb/ft

w = 1778 lb/ft + 16.8 lb/ft = 1794.8 lb/ft

$M = \frac{1}{8}(1794.8) \times 20.5^2 / 1000 = 94.28$ 'K

94.28 'K < 155 'K	O.K.

$a = \frac{\Sigma Q_N}{0.85 f'_c \cdot b_e}$

$= \frac{208}{0.85(3)(61.5)} = 1.32$

$\Sigma Q_N = 208^K$

$b_e = 5.75 \times 12 = 69$

$\frac{1}{4} \times 20.5 \times 12 = 61.5$

$f'_c = 3000$ psi

$Y_2 = 4.5 - \frac{1.32}{2} = 3.83$

interpolate between 3.5 & 4

y = 3.5	147
y = 4.0	155
y = 3.83	152.28

$\phi M_n = \phi T e$

$= \phi A_s f_y (d/2 + t - a/2)$

$= (0.9)(4.16)(50)(11.9/2 + 4.5 - \frac{1.51}{2})$

$\phi M_n = 1814.9$ in. K

$\rightarrow \phi M_n = 151.25$ ft-K > 72.69 ft-K

$F_u = 60$ ksi

$T = C = A_s f_y \longrightarrow T = C = (4.16)(50) = 208^K$

# of shear studds $N = \frac{V_N}{Q_n}$

$Q_n = 0.5 A_{sc} \sqrt{f'_c E_c}$

$Q_n = 0.5 (0.44) \sqrt{(3)(3024)}$

$Q_n = 20.95$

$Q_n = 20.95 < (0.44)(65) = 28.6$

$A_{sc} = \frac{\pi d^2}{4}$ use 3/4" studd

$\rightarrow A_{sc} = 0.44 \text{ in}^2$

$E_c = W^{1.5} \sqrt{f'_c} = 145^{1.5} \sqrt{3}$

$E_c = 3024$ ksi

# of studds $= \frac{208}{20.95} = 9.92$

N = 10 ; # of studds = 20

Spacing $\frac{20.5 \times 12}{20} = 12.3$ "/studd

min spacing $= 6 \times (3/4) = 4.5$" O.K

max spacing $= 8t = 36$" O.K

Deflection Check!

$y_c = d + t_s - a/2$

$= 11.9 + 4.5 - 1.51/2 = 15.645''$

$A_s = 4.16 \text{ in}^2$

$I = ??$

Use table 3.20 to find I.

	y_2	I
W12x14	3.5	274
	4.0	295
	3.83 →	287.9 in⁴

$F(x) = \left(\frac{295-274}{4-3.5}\right)(x-3.5)+27$

$F(x) = 287.9$

Dead Load deflection:

$\Delta_D = \frac{5 w_D L^4}{384 EI}$

$= \frac{5(6.729)(20.5^4) \times 1728}{384(29000)(284.10)} = 0.35 < \frac{20.5 \times 12}{360} = 0.68$

Deflection Limit? $\frac{L \times 12}{360} = \frac{20.5 \times 12}{360} = 0.68$

Live Load deflection:

$\Delta_{LL} = \frac{5 w_L L^4}{384 EI} = \left(\frac{5 \times 0.574 \times 20.5^4 \times 1728}{384 \times 29000 \times 284.10}\right)/2 = 0.13$ L

During Construction

$\Delta_c = \frac{5 W_c L^4}{384 EI}$

$W_c = 341.55 + 14 = 355.55$

$I = 88.6$

$= \frac{5 \times 0.341 \times 20.5^4 \times 1728}{384 \times 29000 \times 88.6} = 0.31$

$0.31 \times 75\% = 0.23$

$0.23 < 1.5$

Partial Composite

$M_u = 72''^{k}$

$y_2 = 3.76$

Choose TFL = 6

$$a = \frac{\Sigma Q_N}{0.85 f'_c b_e} = \frac{85}{(0.85)(3)(56)} = 0.61$$

$$y_2 = 4.5 - \frac{0.61}{2} = 4.2$$

y	Mu
4	115
4.5	119
4.2	116.6

$$F(x) = \left(\frac{119-115}{4.5-4.0}\right)(X-4.0) + 115$$

$$F(x) = 116.6$$

$$116.6 > 72''^{k}$$

# of shear studds =

$$N = \frac{V_n}{Q_n} = \frac{852}{20.95} = 4.1 \approx 4 \text{ studds}$$

Use 8 studds

$$\text{Spacing } \frac{20.5 \times 12}{8} = 30.75''$$

$$4.5'' < 30.75'' < 36''$$

OK

Deflection in Use.

TFL 6

$$\Delta_D = \frac{5 w_d L^4}{384 EI}$$

y	I
4	197
4.5	208
4.2	201.4

$$\Delta_D = \frac{5 w_d L^4}{384 EI}$$

$$= \frac{5(0.729)(20.5)^4 \times 1728}{384(29000)(201.4)} = 0.49 \quad \text{OK}$$

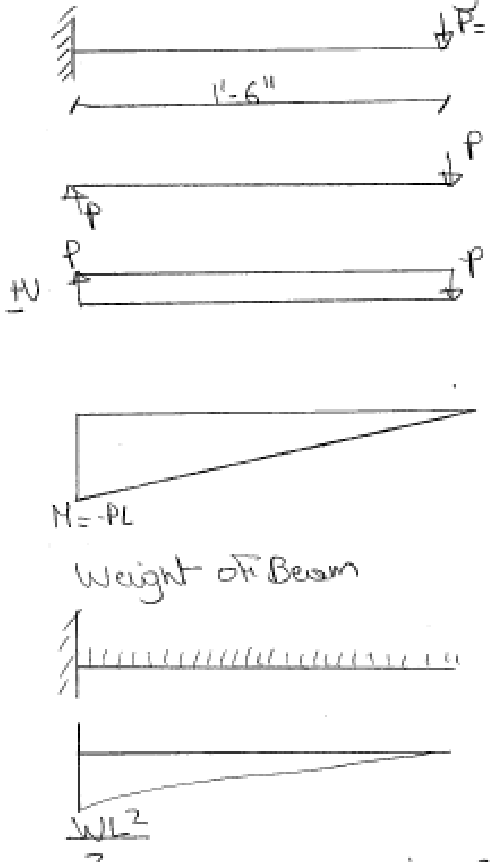
$$\Delta_{LL} = \left(\frac{5 \times 0.574 \times 20.5 \times 1728}{384 \times 29000 \times 201.4}\right) / 2 = 0.19 \quad \text{OK.}$$

During construction

Δ_{LL} is the same.

Cantilever Beam Design

Cantiliver Beam Design



Unfactored $P = 9.82^k$

Factored $P = 13.11$

P = to the Load applied by the Girder B3.

$M = PL = (13.11)(1.5)$

$= 19.67$ K.ft

Choose W10x12

$M = 118$ K.ft

Weight $= 12 \times 1.2 = 14.4$ lbs/ft

$M = \frac{14.4 \times 1.5^2}{2} = 0.0162$ K.ft

Unfactored weight = 12 lbs/ft

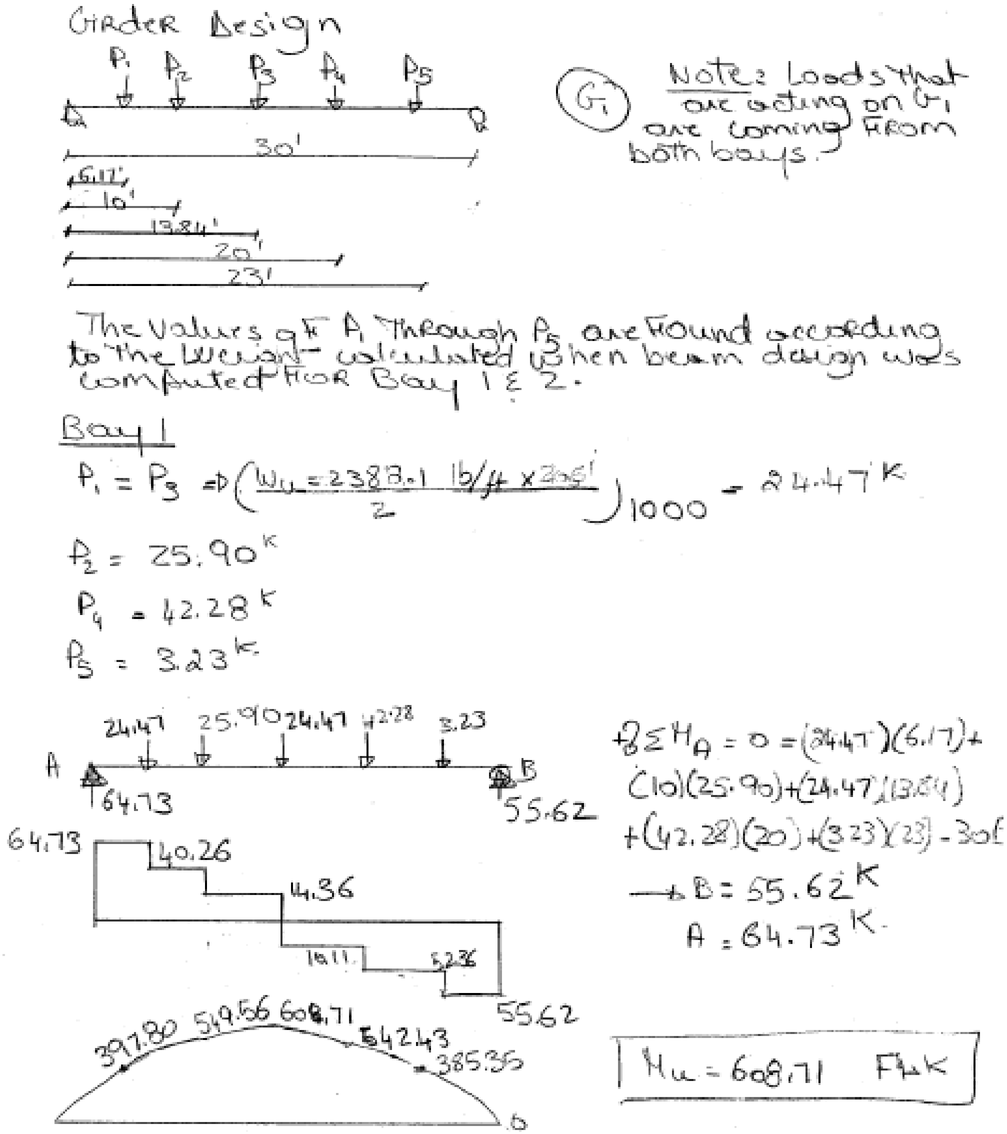
Max moment $= 19.67 + 0.0162 = 19.68$ K.ft

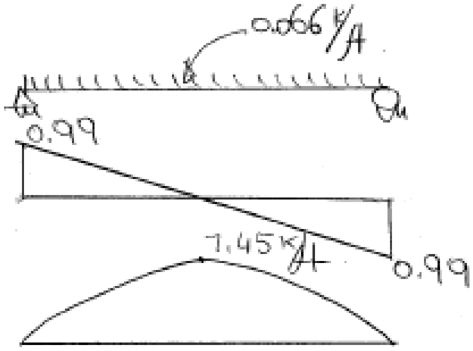
Deflection Check:

$$\frac{PL^3}{3EI} + \frac{wL^4}{8EI} = \frac{(9.82/12)(1.5\times 12)^3}{3\times 29000\times 53.8} + \left(\frac{12\times 1.5^4}{8(29000)(53.8)}\right)/12000$$

$$= 0.001 < 0.05 = \frac{L\times 12}{360} \checkmark$$

Girder Design





Choose W 24x55

$M_n = 959.00$ ft.k

$W = 55 \times 1.2 = 66$ k/ft

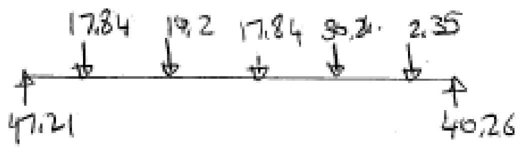
$$\frac{wL^2}{8} = \frac{(0.066)(30^2)}{8}$$

$$= 7.452 \text{ k.ft}$$

Final moment = 616.13 k.ft

As in Beam design a was assumed to be equal to 1" and the same steps were followed to check if the chosen W-member is adequate.

Unfactored Load are needed to calculate deflection



Max moment = 419.27 k.ft

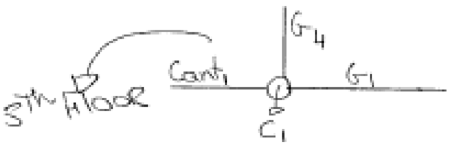
$$\Delta = \frac{ML^2}{C_1 I_x} + \frac{5wL^4}{384EI}$$

$C_1 = 158$

Column Design for Third Floor

Design of columns for 3rd Floor

• Column will be designed to resist load from 3rd, 4th, 5th Floor as well as Roof



Reactions

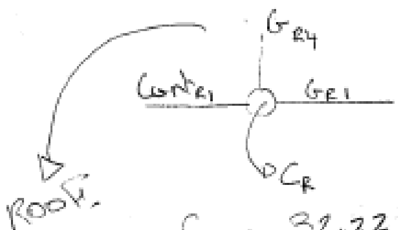
$G_1 = 64.75 + 0.99 = 65.73^k$

$G_4 \Rightarrow W = 1481.30\ lbs/ft \longrightarrow Load = 17.77^k$

$Cant_1 \Rightarrow f_{weight} = (14.4 \times 1.5)/1000 = 0.0216^k$

$\rightarrow 0.0216 + 0.01311 = 0.03471^k$

$\Sigma P = 83.61$



$G_{R1} = 32.22 + 0.63 = 32.85^k$

$G_{R4} = 1154.80\ lbs/ft \longrightarrow Load = 13.86^k$

$Cant_{R1} = 0.0216 + 0.00731 = 0.02891^k$

$\Sigma P = 46.73^k$

∴ Total Load acting on column is

$(83.61 \times 2) + 46.73 = 213.9^k$

K = 0.65 → Rotation Fixed & Translation Free.

K.L = 6.5

Table 4.1 of manual

Choose : W 12x58 $\phi P_n = 714.5^k$

$\frac{KL}{R_x} = \frac{6.5 \times 12}{5.28} = 14.77 < 113.4$

$\frac{KL}{R_y} = \frac{6.5 \times 12}{2.51} = 31.1 < 113.4$

$\phi P_n = \phi F_{CR} \cdot A_g$

$F_{CR} = \left[0.658^{F_y/F_e}\right] F_y$

$F_e = \frac{\pi^2 E}{\left(\frac{KL}{R}\right)^2} = \frac{\pi^2 \times 29000}{(31.1)^2} = 296.1$

$F_{CR} = \left(0.658^{50/296.1}\right) 50 = 46.58$

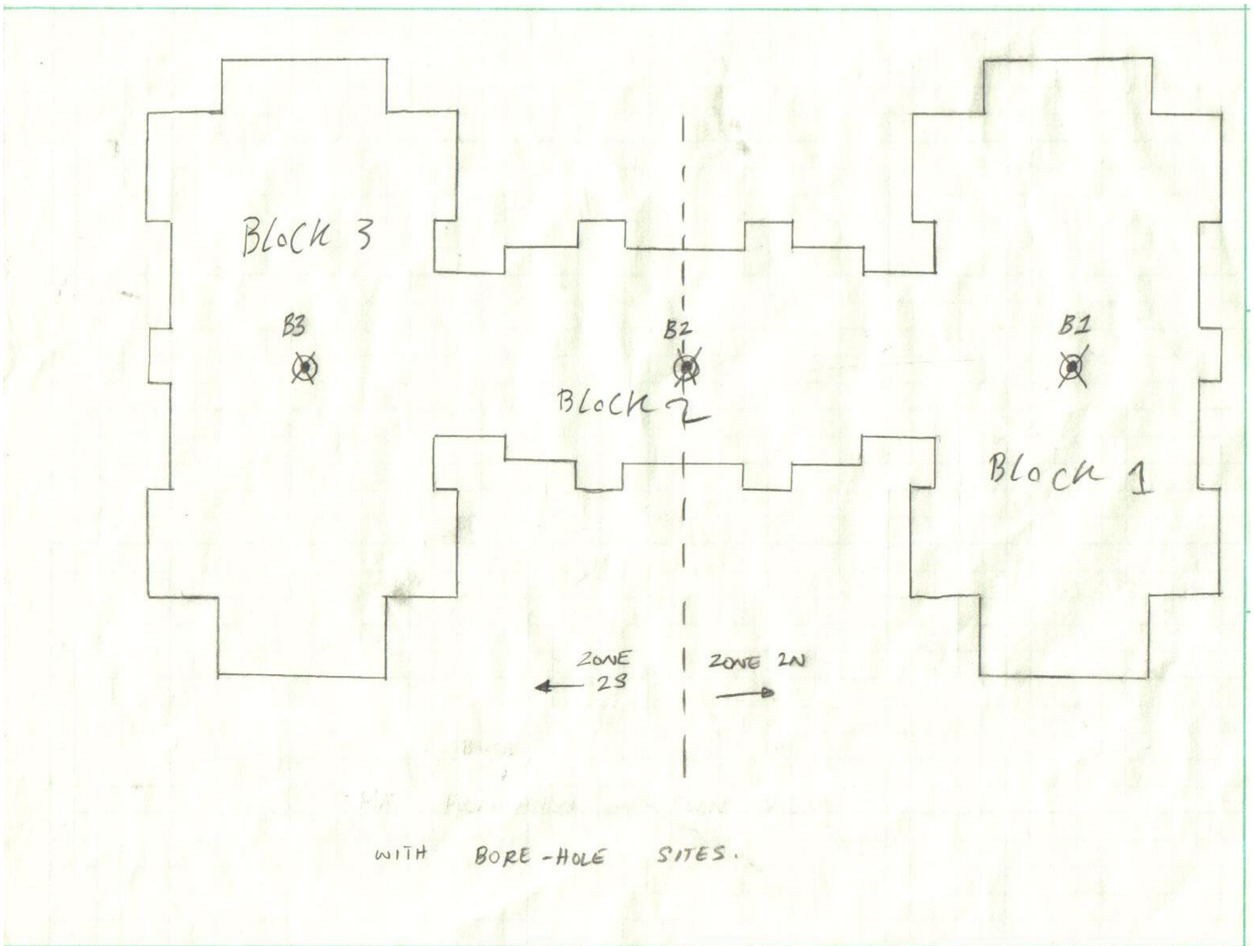
$\phi P_n = (0.9)(46.58)(A_g = 17) = 713$

$\frac{P_u}{\phi P_n} = \frac{220.51}{713} = 0.3$

$\frac{P_u}{\phi P_n} + \frac{8}{9}\left(\frac{M_{ux}}{\phi M_n} + \frac{M_{ux}}{\phi M_{ny}}\right) = 0.3 < 1$ ok.

W12.58 is adequate

Foundation Sample Calculation



* 1.

loads: the most critical column load:

factored: 1058.14 K ; unfactored: 777.94 k

$M_u = 4 \times 1556.86 + 772.8 = 7000.24$ ft.K   4 floors and the roof

* 2. factored net soil pressure

allowable net soil pressure ← $q_n = q_a - $ (weight of footing, soil and Floor) − Pressure of moment ($\frac{MY}{I}$)

Allowable bearing pressure = 8000 PSF

foundation thickness:

6' = 72"

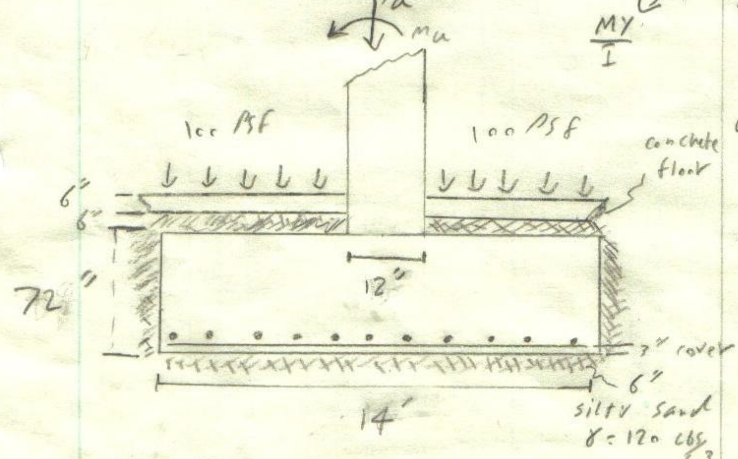
weight of concrete:

150 PCF

$f'_c = 3000$ PSi

$M_u = 7000.24$ ft.K

$f_y = 60000$ PSi



$q_n = 8 - \left[(6' \times 0.15) + (0.5 \times 0.12) + (0.5 \times 0.15) + (0.1)\right] - \left[\frac{(7000.24)(\frac{16}{2})}{(16^4)/3}\right]$

$= 4.31$ KSf

$\frac{777.94}{4.31} = 180.92\ ft^2 < 14 \times 14 = 196\ ft^2$

ok ✓

try footing 14' square

* 3. Check thickness for 2-way shear:

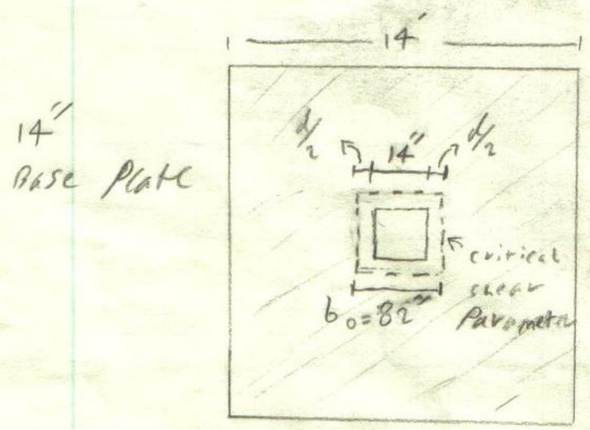
2-way shear governs for thickness of spread footing

check $\frac{d}{2}$: $d = T - 3\text{ in} - d_b$

Average $d = 72 - (3\text{ in. cover}) - (1\text{ bar diameter})$

$= 68\text{ in.} \Rightarrow \boxed{d = 68\text{ in}}$

4. the critical shear perimeter is shown with dashed line in the figure below



factored net soil pressure:

$\frac{1058.14}{14 \times 14} = 5.4\text{ ksf}$

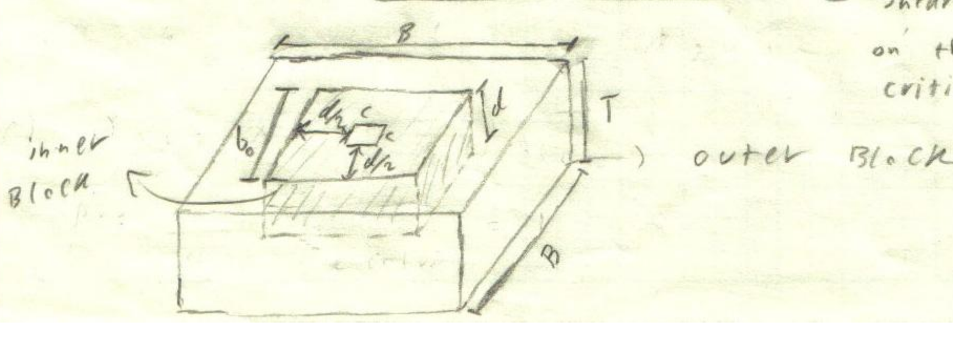
$$\boxed{\left(\frac{B^2 - (c+d)^2}{B^2}\right)}$$

$$V_{uc} = \left(\frac{P_u}{4} + \frac{M_u}{c+d}\right)\left(\frac{\text{base area of outer Block}}{\text{total base area}}\right)$$

$$= \left(\frac{1058.14}{4} + \frac{7000.24}{\left(\frac{14''}{12}\right) + \left(\frac{68''}{12}\right)}\right)\left(\frac{14^2 - \left(\frac{14}{12} + \frac{68}{12}\right)^2}{14^2}\right)$$

$$= \boxed{981.88\text{ kips}}$$

→ the factored shear force on the most critical face



- nominal two-way shear capacity on critical :

$V_{nc} = 4 b_o d \sqrt{f'_c}$

$b_o = c + d$ ⟹ $V_{nc} = \dfrac{4(82)(68)\sqrt{3000}}{1000}$

$b_o = 14'' + 68 = 82''$ $\boxed{V_{nc} = 1221.64 \text{ kips}}$

0.85 ← $\phi V_{nc} > V_u$ 1038.39 K > 981.88 K

capacity applied

* 4. check one way shear : ok ✓

$V_{uc} = \left(\dfrac{B - C - 2d}{B}\right)\sqrt{\left(P_u + \dfrac{6 M_u}{B}\right)^2 + V_u^2}$ → 0

$V_{uc} = \dfrac{14' - \left(\frac{14''}{12}\right) - \left(2 \times \frac{68''}{12}\right)}{14'} \sqrt{\left[1058.14 + \dfrac{6(7000.24)}{14}\right]^2 + 0}$

$= \boxed{434.81 \text{ kips}}$

- nominal one-way shear load capacity :

$V_{nc} = 2 b_w d \sqrt{f'_c}$ ⟹ $V_{nc} = \dfrac{2(28' \times 12)(68)\sqrt{3000}}{1000}$

$b_w = 2B$

$b_w = 28'$ $\boxed{V_{nc} = 2502.87}$

0.85 ← $\phi V_{nc} > V_{uc}$

2127.44 k > 434.81 k ✓ OK ✓

* 5. Design flexural reinforcement:

$$M_{uc} = \frac{P_u l^2}{2B} + \frac{2 M_u l}{B}$$

l for steel:

$$l = (2B - (c + c_p))/4$$

c_p in here is Base Plate width and c is the column width

$$l = \frac{(2\times(14\times12) - (12+14))}{4} = 77.5 \text{ in}$$

$$M_{uc} = \frac{1058.14\left(\frac{77.5}{12}\right)^2}{2\times14} + \frac{2(7000.24)\left(\frac{77.5}{12}\right)}{14}$$

$$= 1576.25 + 6458.55 = \boxed{8034.8 \text{ K.ft}}$$

$$A_s = \left(\frac{f'_c b}{1.176 f_y}\right)\left(d - \sqrt{d^2 - \frac{2.353 M_{uc}}{\phi f'_c b}}\right)$$

$$= \left(\frac{(3000)(14\times12)}{1.176(60000)}\right)\left(68 - \sqrt{(68)^2 - \frac{2.353(8034.8\times12000)}{0.9(3000)(14\times12)}}\right)$$

$$= 71.43 \times 3.78 = \boxed{27.02 \text{ in}^2}$$

min Required $A_s = \rho B T$

ρ is steel ratio using grade 60 bars it is 0.0018

$\Rightarrow A_s = 0.0018(14\times12)(6\times12)$

$= 21.77 \text{ in}^2 < \boxed{27.021 \text{ in}^2}$ Governs

$$\frac{27.02}{0.79} = 35$$

#8 bar:

cross Area: 0.79 in^2

diameter: 1.00 in

* 35 #8 bars required.

clear spacing between bars:

$$\frac{(14 \times 12)}{36} - 1 = \boxed{3.67 \text{ in}}$$ ok ✓

ACI sec 7.6.5 max spacing is 18"

check development length:

$$(l_d)_{supplied} = L - 3 \text{ in} = 77.5 - 3 = 74.5 \text{ in}$$

$$\frac{c + K_{tr}}{d_b} = \frac{2.33 + 0}{1} = 2.33 < 2.5$$

use 2.33

distance from cover to center of closest rebar:

$$\frac{(14 \times 12)}{36} = 4.667 \text{ in}$$

center to center of rebars

$$\left(\frac{1}{2}\right)\frac{14 \times 12}{36} = 2.33 \text{ in}$$

2.33 in < 4.67 in

c = 2.33in Governs

$$\frac{l_d}{d_b} = \frac{3}{40}\left(\frac{f_y}{\sqrt{f'_c}}\right)\left(\frac{\alpha \beta \gamma \lambda}{\left(\frac{c + K_{tr}}{d_b}\right)}\right)$$

$$= \frac{3}{40} \frac{60000}{\sqrt{3000}} \frac{(1)(1)(1)(1)}{2.33}$$

$$= 35.21$$

$$l_d = 35.21\,(d_b) = 35.21 \text{ in}$$

$$(l_d)_{supplied} > l_d$$

74.5 in > 35.21 in ok ✓

Bearing Pressure:

Eccentric e $e = \frac{M}{P + W_f} = \frac{7000.24}{(1058.14)(191.1)} = 0.03 < 2.33$

$e < \frac{B}{6}$

$W_f = (6.5')(14')(14')(150 \frac{lb}{ft^3}) = \frac{191100 \text{ lbs}}{1000} = 191.1 \text{ k}$

$\Rightarrow q_{min} = \left(\frac{P + W_f}{A} - u_D\right)\left(1 - \frac{6e}{B}\right)$

$q_{max} = \left(\frac{P + W_f}{A} - u_D\right)\left(1 + \frac{6e}{B}\right)$

$q_{min} = \left(\frac{1058.14 + 191.1}{(14 \times 14)} - 0\right)\left(1 - \frac{6 \times 0.03}{14}\right)$

$= 6.29$ ksf

$q_{max} = \left(\frac{1058.14 + 191.1}{(14 \times 14)} - 0\right)\left(1 + \frac{6 \times 0.03}{14}\right)$

$= 6.46$ ksf

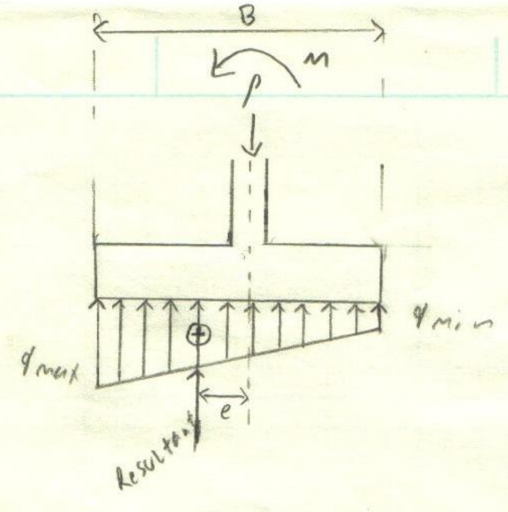
q_a assumed $= 8$ ksf > 6.46 ksf

ok

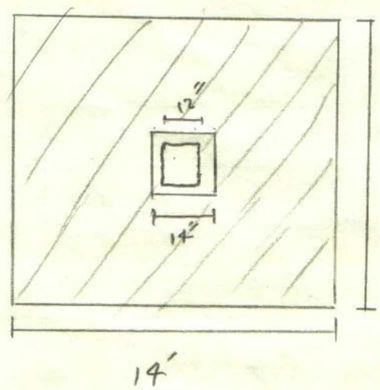
Big column

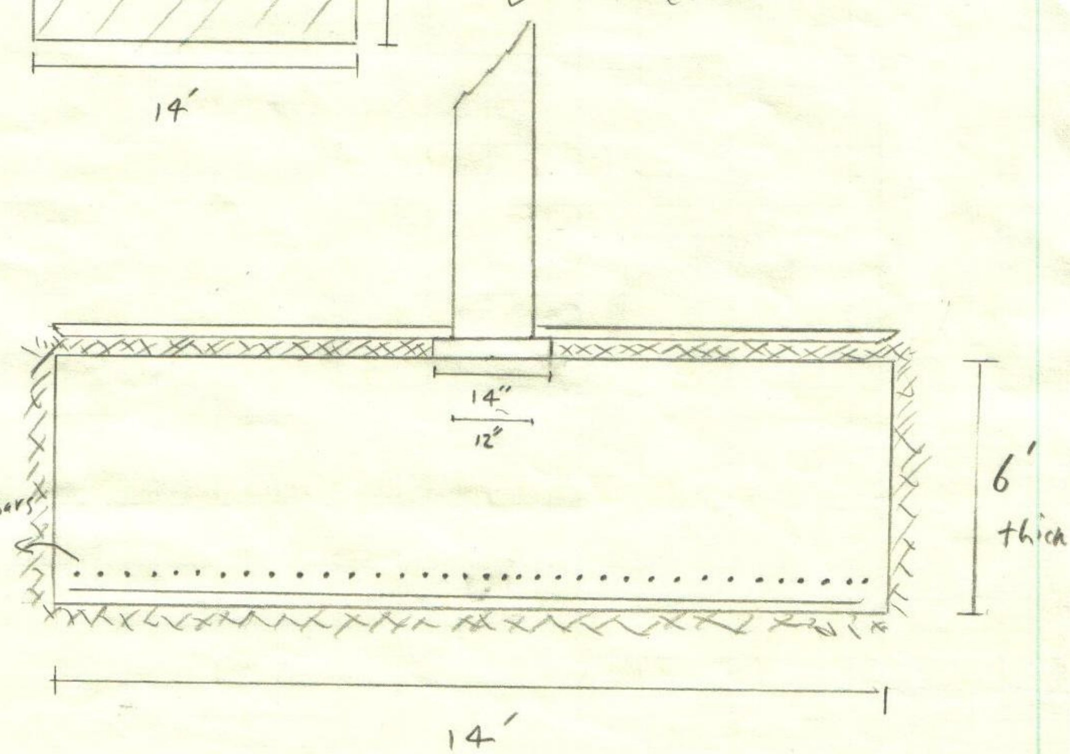
Load:

1058.14 K



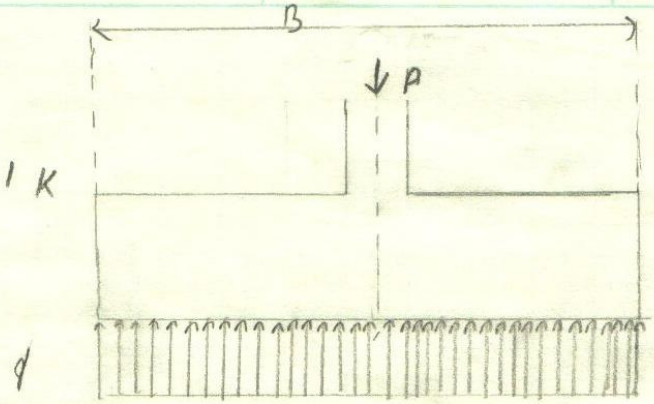
if $e \leq B/6$

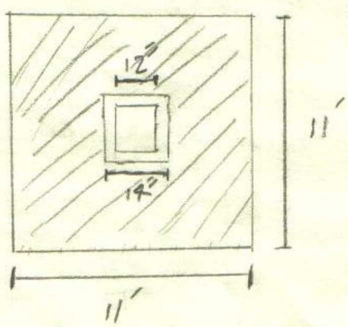


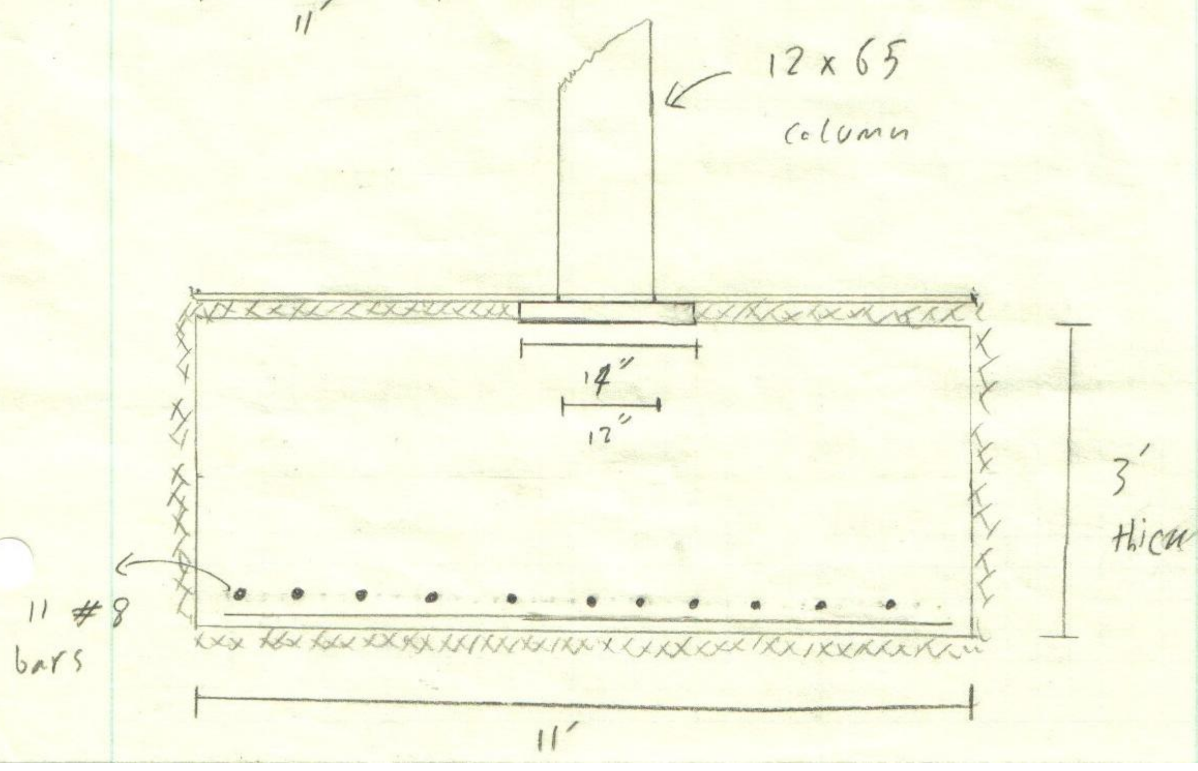


second column

Load: 627.1 K

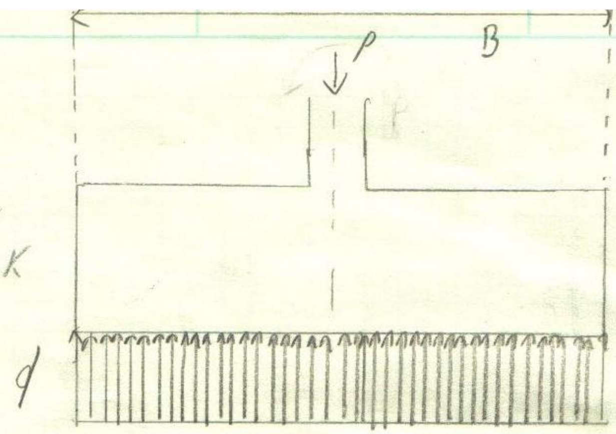


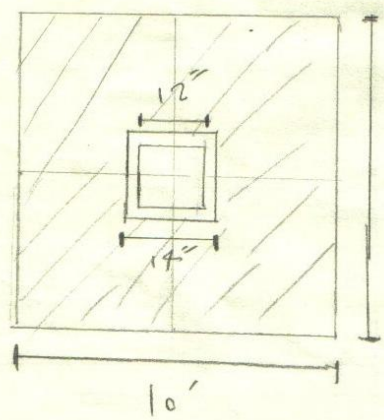


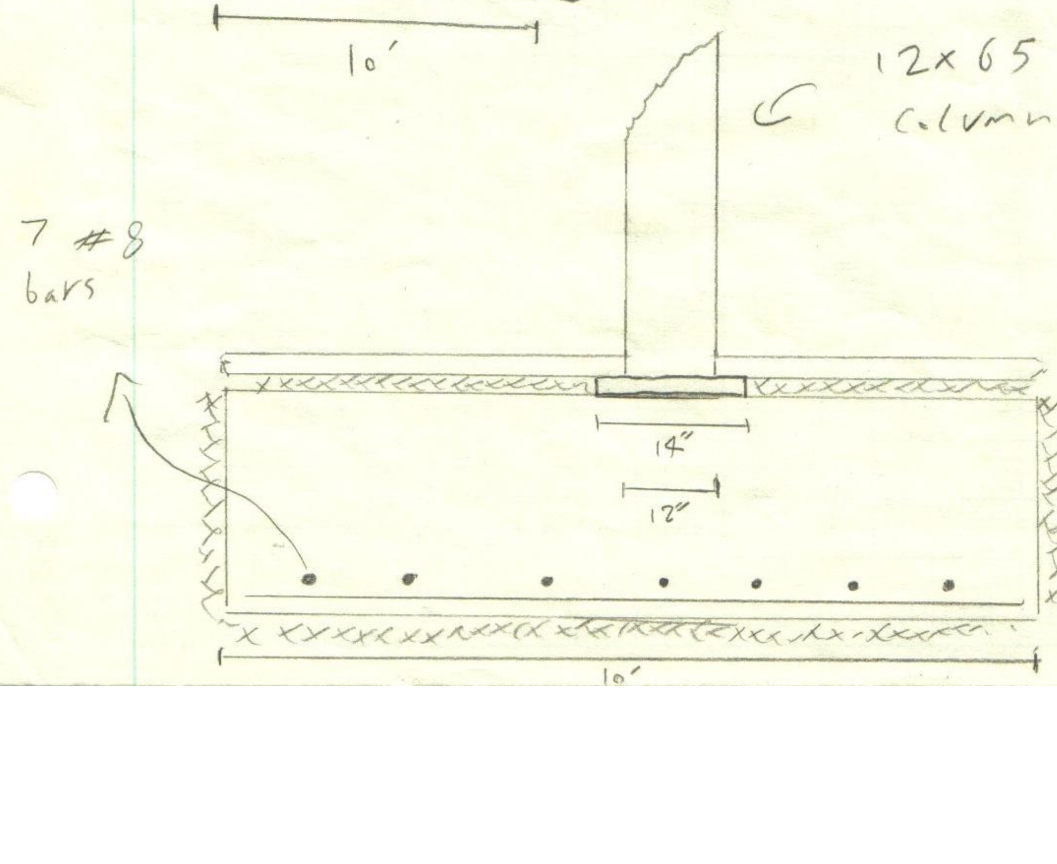


third column

Load: 381.16 K







settlement:

$\delta \leq \delta_a$

- induced stress:

$$\Delta\sigma_z = \left[1 - \left(\frac{1}{1+\left(\frac{B}{2z_f}\right)^2}\right)^{1.76}\right](q - \sigma'_{zD})$$

$q = 6.46$ ksf

$\sigma'_{zD} = \gamma D - u = (120 \frac{lbs}{ft^3})(6.5) - 0 = 780 \frac{lbs}{ft^2}$

Assuming $z_f = 2'$

$$\Delta\sigma_z = \left[1 - \left(\frac{1}{1+\left(\frac{14}{2\times2}\right)^2}\right)^{1.76}\right](6.46 - 0.78)$$

$= (0.99)(5.68) = \boxed{5.62 \text{ ksf}}$

- effective stress:

$\sigma'_{zf} = \sigma'_{z0} + \Delta\sigma_z$

$\sigma'_{z0} = \gamma H - u = (120)(20) = 2400 \frac{lbs}{ft^2} = \boxed{2.4 \frac{k}{ft^2}}$

$\sigma'_{zf} = 2.4 + 5.62 = \boxed{8.02 \text{ ksf}}$

$$\delta_c = r \sum \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_{zf}}{\sigma'_{z0}}\right)$$

$r = 0.85$ table 7.1 Donald P. Coduto

$\frac{C_c}{1+e_0} = 0.006$ table 3.5, 3.7 from Donald P. Coduto

$$\delta_c = 0.85(0.006)(20)\log\left(\frac{8.02}{2.4}\right)$$

$\delta_c = 0.64$ in $= \delta$

$\delta_a = 1$ in table 2.1 Donal P. Coduto

$\delta \le \delta_a$ ok ✓

0.64 in < 1 in

Cost Estimation Sample Calculation

Concrete Structure

If the building will be a concrete structure the following items and quantities must be considered:

COST OF 23’x18’ Bay

20 Columns; 12' height, and a size of 16”x 16”

Contact area (ft2)	64
Total Area of column forms (ft2)	1280
Area of forms fabricated (ft2)	256

Cost of 20 Columns	**Quantity and Unit Price**	**Cost in $**
Lumber	1280*1.8=2304 @$0.48/5 uses	$353.21

Nails	2304*15-per1,000=34.56lb @$0.90	$21.15
Form Oil	1280/400=3.2gal @$13.65	$67.32
Power Saws	2304/400ft2/h=5.76h@$3.75	$25.27
Column Claps	20*8=160@$0.85	$273.36
Carpenter Making	256ft2*3h/100ft2=7.5h@23.7	$158.45
Carpenter Erecting	1280ft2*6h/100ft2=74h@16.70	$1,964.92
Helper Making	256ft2*1h/100ft2=2.56@$22.10	$56.58
Helper Erecting	1280ft2*4.5h/100ft2=55.5h@12.10	$671.55
Foreman (Based on 5)	(7.5h+74h)/5=16.7@18.30	$342.38

	20 Columns Total	$3,934.18

4Colums = $786

3 Concrete Beams; 16" deep, 23 feet long	**Quantity and Unit Price**	**Cost in $**
The area of the beams ft2	219	
Lumber	219ft2*3.5fbm/ft2=766.5 fbm@$0.8	$613.20
Nails	766.5fbm*15lb/1000fbm=11.5lb@$0.95	$11.00
Form Oil	219ft2/400fbm/h=0.55gal@$13.65	$7.51
Power Saw	3000/400=7.5h@5.16	38.7
Carpenters	219ft2*10h/100ft2=21.9@23.70	519.03

Helpers	219ft2*5.75/100ft2=12.6@22.10	278.46
Foreman	21.9/6=3.65@21.45	78.2925
Concrete Floors		**Cost in $**
Lumber for Slab	414ft2x2.3fbm/ft2=952.2@0.98	1171.206
Nails	414ft2x12lb/1000=5lb@1.34	6.7
Form Oil	414ft2/400ft2/gal=1.035gal*@13.65	14.12775
Shores	414ft2/24ft2/shore=17.25@5.25	90.5625
Carpenter	414ft2x5h/100ft2=20.7@23.70	490.59
Helpers	414ft2x3h/100ft2=12.42h@22.10	274.482
Foreman	20.7/5@21.45	88.803

23’x 18’ Total **$2,234.75**

WHOLE CONCRETE BUILDING

FLOOR

Section A

Width (Feet)	Length (Feet)	Depth (Inches)	Clear
38.66	13.76	5	8.21cy

Approx. cubic yards required:

Width (Feet)	Length (Feet)	Depth (Inches)	Clear
61.3	20.88	5	19.75cy

Approx. cubic yards required:

Total 27.96cy

Section B

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
56.5	28	5	24.41cy

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
58.5	14	5	12.64cy

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
56.5	11	5	9.59 cy

Approx. cubic yards required:

Total 46.64cy

Section C

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
56.5	11	5	
			9.59cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
58.5	21	5	
			18.96cy

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
38	14	5	
			8.21cy

Approx. cubic yards required:

Total 36.76cy

Section D

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
53	10	5	8.18cy

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
69	18	5	19.17cy

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
73.4	14	5	15.86cy

	Width	Length	Depth	Clear
	(Feet)	(Feet)	(Inches)	
	69	18	5	19.17cy

Total **62.38cy** **Cost $**

TOTAL FLOOR CONCRETE **347.48** **$69,496**

Concrete FLOOR LABOR + Equipment + Transportation **$169,632**

Total Floor Cost in $ **$239,128**

WALLS

Section A-B-C

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	12.88	.67	0.32*3

Approx. cubic yards required: 0.96cy

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	12	.67	0.3*3*2

Approx. cubic yards required: 1.8cy

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
20.88	12	.67	0.52*6

Approx. cubic yards required: 3.12cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
10.64	12	.67	0.26*5

Approx. cubic yards required: 1.3cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	28	.67	0.69

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	20	.67	0.5

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	12	.67	0.3*3

Approx. cubic yards required: 0.9 cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	14	.67	0.35

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	16	.67	0.4*4

Approx. cubic yards required: 1.6 cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	19	.67	0.47

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	18	.67	
			0.45

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	24	.67	
			0.6

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	26	.67	
			0.65

Approx. cubic yards required:

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	14	.67	0.35*2

Approx. cubic yards required: 0.7 cy

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	24	.67	0.6*2

Approx. cubic yards required: 1.2 cy

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	11	.67	0.27*7

Approx. cubic yards required: 1.89cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	12.7	.67	
			0.32

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	24	.67	
			0.6

Approx. cubic yards required:

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	11	.67	
			0.27*4

Approx. cubic yards required: 1.08cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	21	.67	
			0.52*5

Approx. cubic yards required: 2.6 cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	49.5	.67	
		1.23	

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	26.7	.67	
			0.66*2

Approx. cubic yards required: 1.32cy

Width	Length	Depth	Clear
(Feet)	(Feet)	(Inches)	
12	14	.67	
			0.35*14

Approx. cubic yards required: 4.9cy

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	12	.67	
			0.3

Approx. cubic yards required:

Section D

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	10	.67	
			0.25*3

Approx. cubic yards required: 0.75cy

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	

12	53	.67	
			1.32

Approx. cubic yards required:

Clear

Width **Length** **Depth**

(Feet) (Feet) (Inches)

12	18	.67	
			0.45*8

Approx. cubic yards required: 3.6cy

Width **Length** **Depth** Clear

(Feet) (Feet) (Inches)

12	8	.67	
			0.2*3

Approx. cubic yards required: 0.6 cy

Width **Length** **Depth** Clear

(Feet) (Feet) (Inches)

12	28	.67	
			0.69*2

Approx. cubic yards required: 1.38 cy

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	20	.67	
			0.5*2

Approx. cubic yards required: 1 cy

Width	**Length**	**Depth**	Clear
(Feet)	(Feet)	(Inches)	
12	18	.67	
			0.45*19

Approx. cubic yards required: 8.55cy

TOTAL 17.2cy

Concrete FLOOR LABOR + Equipment + Transportation **$169,632**

TOTAL COST= Cost of Concrete + Labor + Transportation + Equipment

	TOTAL COST
BEAMS	**$1,076,016**
Floor	**$2,391,280**
Wall	**$422,870**
Columns	**$1,906,000**
Reinforced Steel	**$800,000**
TOTAL	**$6,596,166**

Steel Structure.

Major Steel Sizes for 23’x18’ bay

W 10x12--> Beams

W8x31--> Columns

W24x55--> Girders

Cost Analysis

Steel Size	Weight (lbs)	
W10x12	432	
W8x31	1488	
W24x55	2530	
	1980	
		Cost $
Total Weight (lbs)	6430	10095.1

Representative Size extra charges over vase price for Steel

		Cost in
W10	2.1 per 100	9.072
W8	2.1 per lbs	31.248
W24	3.6 per lbs	91.08

	Cost in $
Total weight=6430lbs	1607.5

	Cost in $
Shop Drawings	880

	Labor Cost in $	Equipment Cost$
Punching butt-weld Joints 3/16"	55.5	31.6366

	Cost $	Transportation$
Punching and framing beams and channels with end Connectors	456.48	1268

	Cost $	Labor + Equipment in $	$ Trans.
Framing Beams with Plates and Channels	1109.5	11.412	1141.2

Material + Labor Cost
$ 1085.04

Fabricating Built and Girders

	Total	1386.44			
		2471.48			
			Cost $		**Transportation Cost in $**
fabricating H Columns (including bases+ Splices+ Milling)			363.072		468
		Cost $			
Cost of Applying a shop coat of Paint		Paint	Beams	Total	
	Labor	70	15	85	
	Girders	45	13.72	58.72	
	Columns	55	38	93	

		Cost $ 50hours	
Labor Force	Foreman		1250
	Crane	1100	
	Crane oiler	750	
	Iron Works	350	

Total Cost ($) of Steel for 23'x18'	$23,777

TOTAL COST= 103610 sqf; (23’*18’)→$23,777= $ *5,950,568*

Appendix C: Sample Excel Spreadsheet

Member Design spreadsheets

Bay 1 left side shown in Figure 37 - Third Floor

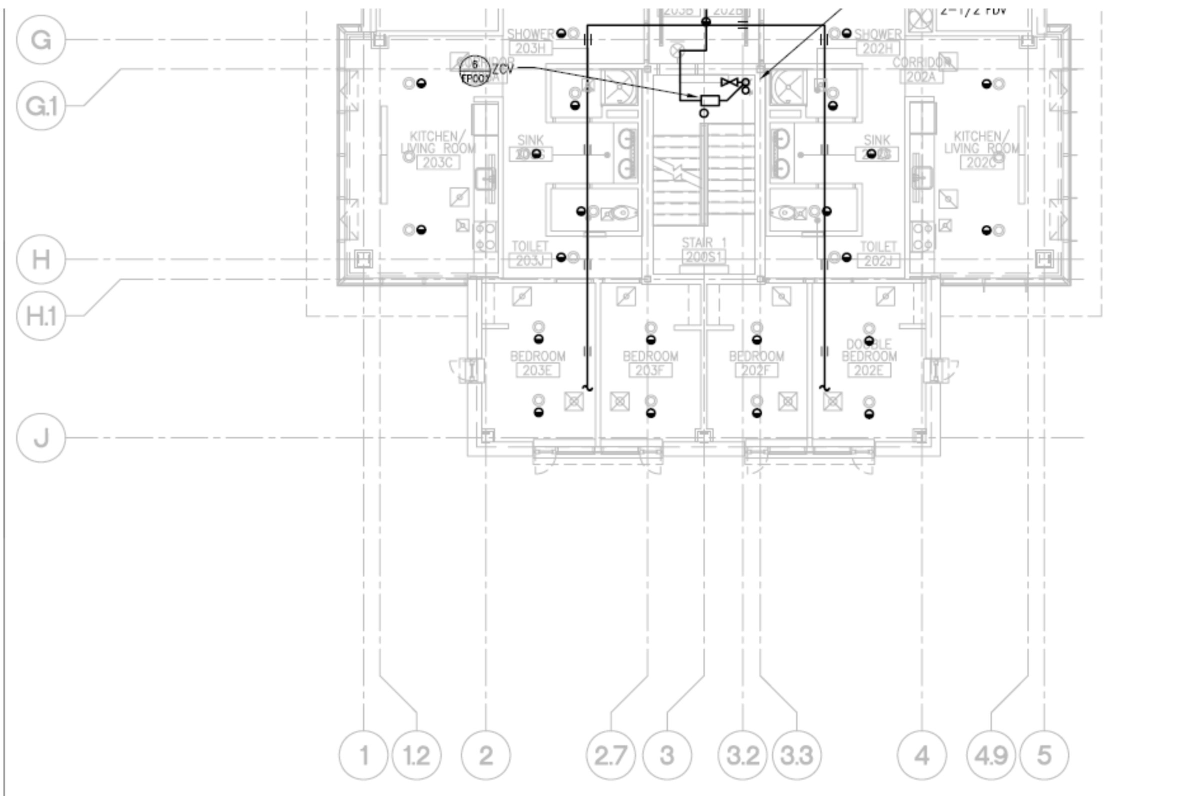


***Figure 37*. Bay 1 (Left Side).**

Infill Beams

Scheme 1	20.5X23

Tributiry width	Length	Live Load	Dead Load	Wu	Required Mu
7.67	20.50	767.00	953.38	2371.26	124.57

Be	Be	be Value
92.04	61.50	61.50

Estimated a		Ts	Y2
	1.00	4.50	4.00
	1.00	4.50	4.00

beam size	∑ Qn	Wbeam	W final	req Mu
W12X14	208.00	14.00	2388.06	125.45

Beam Mn
155.00

a	Y2
1.33	3.84

Depth	As	Ys	Ix
11.90	4.16	5.95	88.60

Interpolation

Y2	Mu
3.50	147.00
4.00	155.00
3.84	152.39

Vn	Qn	N	N needed
208.00	21.04	9.89	10.00
			20.00

spacing	Min Spacing	Max Spacing
12.30	4.50	36.00

Deflection

Yc	ACS	Y bar	I
15.74	4.16	10.84	287.83

WL	WD

0.77	0.97

DL Deflection	LL Deflection	Const. Deflection	deflection limit
0.46	0.18	0.59	**0.68**

Partially	∑ Qn	a	Y2	# of Shear studs	N nedded
TFL 6	85.20	0.54	4.23	4.05	5.00
					10.00

Y2	Mn
4.00	115.00
4.50	119.00
4.23	116.83

Spacing	Min Spacing	Max Spacing
24.60	4.50	36.00

DL Deflection
0.62
LL Deflection
0.25
Constr. Deflection
0.59

Y2	I
4.00	208.00
4.50	221.00
4.23	213.94

Cost
Full-Beams(Cost/SF)
2.66
Partial-Beams(Cost/SF)
2.47

Small Beam G- 2.7 to G.1- 2.7

Scheme 1	20.5X23

Tributiry width	**Length**	**dead load**	**live load**
8.34	2.50	124.30	100.00

DL-Weight	**LL-weight**	**T. unfactored weight**	**Total Factored weight**	**T. factored weight**
1036.04	833.50	1869.54	2576.85	**2591.25**

Mu due to weight of beam	**Mu due to distributed load**
0.011	2.01

beam size	**Beam Mn**	**W beam**	**W final**	**Total Mu**
W10X12	118.00	12.00	14.40	2.02

Depth	**As**	**Ix**
9.87	3.54	53.80

Total Mu	**check**
2.02	ok

total Unfactored weight
1881.541

DL deflection	**Deflection limit**	Check
0.0006	0.08	OK

LL deflection
0.000234767

Top cantilever G-1 to G-1.2

Scheme 1	Tributiry width	Unfactrored Load	load	Length	Mu due to concentrated load
20.5X23		11.07	14.71	1.50	22.07

beam size	Beam Mn	W beam	W final	Depth	As	Ys
W10X12	118.00	12.00	14.40	9.87	3.54	4.94

Total Mu	check
22.08	ok

Mu due to weight of beam
0.016

Ix
53.80

Deflection	Deflection limit	Check
0.0011	0.05	OK

Left Girder G-1 to H-1

Scheme 1	20.5X23

Tributiry width	Length	Live Load	Dead Load	Wu	Required Mu
3.83	18.50	383.00	801.94	1575.13	67.39

Be	Be	be Value
46.00	55.50	46.00

Estimated a		Ts	Y2
	1.00	4.50	4.00
	1.00	4.50	4.00

beam size	∑ Qn	Wbeam	W final	req Mu
W10X12	177.00	12.00	1589.53	68.00

Beam Mn
118.00

a	Y2
1.51	3.75

Depth	As	Ys	Ix
9.87	3.54	4.94	53.80

Interpolation

Y2	Mu
3.50	112.00
4.00	118.00
3.75	114.95

Vn	Qn	N	N needed
177.00	21.04	8.41	9.00
			18.00

spacing	Min Spacing	Max Spacing
12.33	4.50	36.00

Deflection

Yc	ACS	Y bar	I
13.62	3.54	9.28	187.17

WL	WD
0.38	0.81

DL Deflection	LL Deflection	Constr. Deflection	deflection limit	Check
0.40	0.09	0.32	**0.62**	OK

Partially	∑ Qn	a	Y2	Nb of Shear studs	N nedded
TFL 6	68.90	0.59	4.21	3.27	4.00
					8.00

Y2	Mn
4.00	84.20
4.50	86.80
4.21	85.27

Spacing	Min Spacing	Max Spacing
27.75	4.50	36.00

DL Deflection	
0.51	
LL Deflection	
0.12	
Constr. Deflection	**check**
0.32	**Ok**

Y2	I
4.00	142.00
4.50	152.00
4.21	146.13

Cost
Full-Beams(Cost/SF)
4.67
Partial-Beams(Cost/SF)
4.25

Bottom Cantilever H-1 to H.1-1

Scheme 1	Unfactrored Load	load	Length
20.5X23	24.19	32.60	2.00

Mu due to concentrated load
65.20

beam size	Beam Mn	W beam	W final	Depth	As	Ys
W10X12	118.00	12.00	14.40	9.87	3.54	4.94

Total Mu	check
65.23	ok

Mu due to weight of beam
0.029

Ix
53.80

Deflection	Deflection limit	Check
0.0060	0.07	OK

Top Girder G-1 to G-3.0

Girders: 24X30

	Ru1 F	**Ru2 F**	**Ru3 F**	**Ru4 F**	**Ru5 F**
	24.48	25.90	24.48	42.28	3.23
Tributary width	**Ru1 Dist**	**Ru2 Dist**	**Ru3 Dist**	**Ru4 Dist**	**Ru5 Dist**
22.50	6.17	10.00	13.84	20.00	23.00
	By	**Ay**			
	55.63	**64.75**		**Girder Length**	**Required Mu**
				30.00	608.92

			Be	**Be**	**be Value**
Estimated a	**Ts**	**Y2**	270.00	90.00	90.00
1.00	4.50	4.00			
1.00	4.50	4.00			
			Byu	**Ayu**	**Moment unfactored**
			40.26	**47.21**	**442.83**
	Uf 1	**Uf 2**	**Uf 3**	**Uf4**	**Uf5**
	17.84	**19.20**	**17.84**	**30.24**	**2.35**

beam size	**∑ Qn**	**Wbeam**	**Wfinal**	**req Mu**	**unfactored W**
W24X55	810.00	55.00	0.07	616.35	**0.06**
Beam Mn					
959.00		**a**	**Y2**		
		3.53	2.74		

Beam weight Moment	**Final Moment**				
7.43	**616.35**	**Depth**	**As**	**Ys**	**Ix**
		23.60	16.20	11.80	1350.00
Interpolation					
	Y2	**Mu**		Y2	I
	2.50	868.00		2.50	3000
	3.00	898.00		3.00	3120.00
	2.74	882.12		2.74	3056.47

	Vn	**Qn**	**N**	**N needed**
	810.00	20.95	38.66	39.00
				78.00

Conc. Deflection
0.83
Distr. Weight Deflection
0.0113
Total Deflection
0.84

deflection limit	check
1.00	**OK**

spacing	Min Spacing	Max Spacing
4.62	4.50	36.00

Partially

TFL 4

∑ Qn	a	Y2	# of Shear studs	N nedded
545.00	2.37	3.31	25.90	26.00
				52.00

Spacing	Min Spacing	Max Spacing
6.92	4.50	36.00

Y2	Mn
3.00	835.00
3.50	855.00
3.31	847.51

Y2	I
3.00	2770.00
3.50	2870.00
3.31	2832.53

Conc. Deflection	Distr. Deflection	Total Deflection
0.890529608	**0.012202762**	**0.90273237**

Full-Girder(Cost/SF)
3.40
Partial-Girder(Cost/SF)
3.29

Bottom Girder

		Ru1 F	Ru2 F	Ru3 F	Ru4 F
Girders:		24.48	4.87	24.48	9.23
Scheme 1	Tributary width	Ru1 Dist	Ru2 Dist	Ru3 Dist	Ru4 Dist
18x13	16.75	6.17	10.00	13.84	19.00
	By	Ay			
	31.04	**32.02**			
			Be	Be	be Value
	Girder Length	Required Mu	201.00	69.00	69.00
	23.00	236.70			
Estimated a	Ts	Y2			
1.00	4.50	4.00			
1.00	4.50	4.00	Byu	Ayu	Moment unfactored
			23.53	**23.73**	**176.21**
	Uf 1	Uf 2	Uf 3	Uf4	Uf5
	17.84	**3.97**	**17.84**	**7.61**	**0.00**

beam size	∑ Qn	Wbeam	Wfinal	req Mu	unfactored W
W14x38	558.00	38.00	0.05	239.72	**0.04**
Beam Mn					
463.00	a	Y2			
	3.17	2.91			
		Depth	As	Ys	Ix
		14.10	11.20	7.05	385.00
Interpolation					
	Y2	Mu		Y2	I
	2.50	400.00		2.50	894
	3.00	421.00		3.00	949.00
	2.91	417.40		2.91	939.58

Vn	Qn	N	N needed
558.00	20.95	26.63	27.00
			54.00

Beam weight M	Final Moment		spacing	Min Spacing	Max Spacing
3.02	**239.72**		5.11	4.50	36.00

Concent. Deflection	Dist Weight Defl.	T. Deflection	deflection check

0.63	**0.0088**	**0.64**	**0.77**

Partially

TFL 4

∑ Qn	A	Y2	Number of Shear studs	N needed
297.00	1.69	3.66	14.12	15.00
				18.00

Spacing	Min Spacing	Max Spacing
15.33	4.50	36.00

Y2	Mn
3.50	369.00
4.00	380.00
3.66	372.43

Y2	I
3.50	817.00
4.00	858.00
3.66	829.79

Concentrated Deflection	Distr. Deflection	T. Deflection	Check
0.710983388	**0.009942825**	**0.720926213**	**Ok**

Full-Girder(Cost/SF)
3.26
Partial-Girder(Cost/SF)
2.98

Roof

Infill Beam

Scheme 1	20.5X23

Tributary width	**Length**	**Live Load**	**Dead Load**	**Wu**	**Required Mu**
7.67	20.50	268.45	539.97	1077.48	56.60

Be	**Be**	**be Value**
92.04	61.50	61.50

Estimated a		**Ts**	**Y2**
	1.00	4.50	4.00
	1.00	4.50	4.00

beam size	**∑ Qn**	**Wbeam**	**W final**	**required Mu**
W10X12	177.00	12.00	1091.88	57.36

Beam Mn
118.00

a	**Y2**
1.13	3.94

Depth	**As**	**Ys**	**Ix**
9.87	3.54	4.94	53.80

Interpolation

Y2	**Mu**
3.50	112.00
4.00	118.00
3.94	117.23

Vn	**Qn**	**N**	**N needed**
177.00	21.04	8.41	9.00
			18.00

spacing	**Min Spacing**	**Max Spacing**
13.67	4.50	36.00

Deflection

Yc	**ACS**	**Y bar**	**I**	**WL**	**WD**
13.81	3.54	9.37	193.08	0.27	0.55

DL Deflection	**LL Deflection**	**Constr. Deflection**	**deflection limit**
0.39	0.10	0.34	**0.68**

Partially	∑ Qn	A	Y2	Nb of Shear studs	N needed
TFL 7	44.20	0.28	4.36	2.10	3.00
					6.00

Y2	Mn
4.00	73.20
4.50	74.80
4.36	74.35

Spacing	Min Spacing	Max Spacing
41.00	4.50	36.00

DL Deflection
0.62
LL Deflection
0.15
Constr. Deflection
0.34

Y2	I
4.00	117.00
4.50	124.00
4.36	122.03

Cost
Full-Beams(Cost/SF)
2.30
Partial-Beams(Cost/SF)
2.07

Small Beam G- 2.7 to G.1- 2.7

Scheme 1	20.5X23

Tributary width	Length
8.34	2.50

dead load	live load	DL-Weight	LL-weight	total weight
124.35	35.00	1036.46	291.73	1328.18

Total Factored weight	T W
1710.51	**1724.91**

Mu due to distributed load
1.34

beam size	Beam Mn	W beam	W final	Total Mu
W10X12	118.00	12.00	14.40	1.35

Depth	As	Ix
9.87	3.54	53.80
Total Mu	**check**	
1.35	ok	

Mu due to weight of beam
0.011

total Un-factored weight
1340.182

DL deflection	Deflection limit	Check
0.0006	0.08	OK
LL deflection		
8.21686E-05		

Top cantilever G-1 to G-1.2

Scheme 1	Tributary width	Unfactrored Load	load	Length	Mu due to concentrated load
20.5X23		6.42	8.20	1.50	12.30

beam size	Beam Mn	W beam	W final	Depth	As	Ys
W10X12	118.00	12.00	14.40	9.87	3.54	4.94

Total Mu	check
12.32	ok

Mu due to weight of beam
0.016

Ix
53.80

Deflection	Deflection limit	Check
0.0007	0.05	OK

Left Girder G-1 to H-1

Scheme 1	20.5X23

Tributary width	Length	Live Load	Dead Load	Wu	Required Mu
3.83	18.50	134.05	547.69	871.71	37.29

Be	Be	be Value
46.00	55.50	46.00

Estimated a		Ts	Y2
	1.00	4.50	4.00
	1.00	4.50	4.00

beam size	∑ Qn	Wbeam	W final	required Mu
W10X12	177.00	12.00	886.11	37.91

Beam Mn	a	Y2
118.00	1.51	3.75

Depth	As	Ys	Ix
9.87	3.54	4.94	53.80

Interpolation	Y2	Mu
	3.50	112.00
	4.00	118.00
	3.75	114.95

Vn	Qn	N	N needed
177.00	21.04	8.41	9.00
			18.00

spacing	Min Spacing	Max Spacing
12.33	4.50	36.00

Deflection	Yc	ACS	Y bar	I	WL	WD
	13.62	3.54	9.28	187.17	0.13	0.56

DL Deflection	LL Deflection	Constr. Deflection	Deflection limit
0.27	0.03	0.11	**0.62**

Partially	∑ Qn	a	Y2	of Shear studs	N needed
TFL 7	44.20	0.38	4.31	2.10	3.00
					6.00

Y2	Mn
4.00	73.20
4.50	74.80
4.31	74.20

Spacing	Min Spacing	Max Spacing
37.00	4.50	36.00

DL Deflection
0.44
LL Deflection
0.05
Constr. Deflection
0.11

Y2	I
4.00	110.00
4.50	117.00
4.31	114.36

Cost
Full-Beams(Cost/SF)
4.67
Partial-Beams(Cost/SF)
4.17

Bottom Cantilever H-1 to H.1-1

Scheme 1	Unfactrored Load	load	Length
20.5X23	13.11	17.04	2.00

Mu due to concentrated load
34.08

beam size	Beam Mn	W beam	W final	Depth	As	Ys
W10X12	118.00	12.00	14.40	9.87	3.54	4.94

Total Mu	check
34.11	ok

Mu due to weight of beam
0.029

Ix
53.80

Deflection	Deflection limit	Check
0.0032	0.07	OK

Top Girder G-1 to G-3.0

Girders:	Ru1 F	Ru2 F	Ru3 F	Ru4 F	Ru5 F	Girder Length
Scheme 1	11.19	17.06	11.19	17.06	1.48	30.00

Tributary width	Ru1 Dist	Ru2 Dist	Ru3 Dist	Ru4 Dist	Ru5 Dist	Required Mu
22.25	6.17	10.00	13.84	20.00	23.00	290.52

By	Ay
25.66	**32.32**

Be	Be	be Value
267.00	90.00	90.00

Estimated a	Ts	Y2
1.00	4.50	4.00
1.00	4.50	4.00

Byu	Ayu	Moment unfactored
19.30	**24.31**	**222.64**

Uf 1	Uf 2	Uf 3	Uf4	Uf5
8.41	**12.84**	**8.41**	**12.84**	**1.11**

beam size	∑ Qn	Wbeam	Wfinal	req Mu	unfactored W
W18X35	515.00	35.00	0.04	295.25	0.04

Beam Mn
496.00

a	Y2
2.24	3.38

Depth	As	Ys	Ix
17.70	10.30	8.85	510.00

Interpolation

Y2	Mu
3.00	457.00
3.50	477.00
3.38	472.12

Y2	I
3.00	1230
3.50	1300.00
3.38	1282.92

Vn	Qn	N	N needed	spacing	Min Spacing	Max Spacing
515.00	20.95	24.58	25.00	7.20	4.50	36.00
			50.00			

Beam weight Moment	Final Moment
4.73	**295.25**

Conc. Deflection	Distr. Weight Deflection	T. deflection	Deflection limit
0.99	**0.0171**	**1.01**	1.00

Partially	NOT Applicable

Bottom Girder

Girders:	Ru1 F	Ru2 F	Ru3 F	Ru4 F	Ru5 F	Girder Length
Scheme 1	11.19	17.06	11.19	17.06	1.48	30.00

Tributiry width	Ru1 Dist	Ru2 Dist	Ru3 Dist	Ru4 Dist	Ru5 Dist	Required Mu
22.25	6.17	10.00	13.84	20.00	23.00	290.52

By	Ay
25.66	**32.32**

Be	Be	be Value
267.00	90.00	90.00

Estimated a	Ts	Y2
1.00	4.50	4.00
1.00	4.50	4.00

Byu	Ayu	Moment unfactored
19.30	**24.31**	**222.64**

Uf 1	Uf 2	Uf 3	Uf4	Uf5
8.41	**12.84**	**8.41**	**12.84**	**1.11**

beam size	∑ Qn	Wbeam	Wfinal	req Mu	unfactored W
W18X35	515.00	35.00	0.04	295.25	0.04

Beam Mn
496.00

a	Y2
2.24	3.38

Depth	As	Ys	Ix
17.70	10.30	8.85	510.00

Interpolation

Y2	Mu
3.00	457.00
3.50	477.00
3.38	472.12

Y2	I
3.00	1230
3.50	1300.00
3.38	1282.92

Vn	Qn	N	N needed
515.00	20.95	24.58	25.00
			50.00

spacing	Min Spacing	Max Spacing
7.20	4.50	36.00

Beam weight Moment	Final Moment
4.73	295.25

Conc. Deflection	Distr. Weight Deflection	T. deflection	Deflection limit
0.99	0.0171	1.01	1.00

Partially **NOT Applicable**

Column G1.2

Bay 1

20.5X23

Length	K	KL
10	0.65	6.5

Floor rxn 1	floor rxn 2	floor rxn 3	floor load	Total all floors load
65.8	17.77	0.03631	83.60631	167.21262

roof rxn 1	roof rxn 2	roof rxn 3
32.85	13.86	0.0298

total roof load
46.7398

Total load acting on columns
213.95242

column size	Pn	Rx	Ry	Ag
W12x58	714.5	5.28	2.51	17

KL/Rx	KL/Ry	short/long
14.77272727	31.07569721	short

Fe	Fcr	Pn	Pu/Pn	check
296.0844038	46.58795763	712.7957517	0.300159505	OK

only Bf is adequate, therefore column should be adjusted to fit the top girder W24x55

Column H1

Bay 1

20.5X23

Length	K	KL
10	0.65	6.5

Floor rxn 1	floor rxn 2	floor rxn 3	floor load	Total all floors load
14.71	32.63	0	47.34	94.68

roof rxn 1	roof rxn 2	roof rxn 3
8.19	17.07	

total roof load
25.26

Total load acting on columns
119.94

column size	Pn	Rx	Ry	Ag
W12x58	714.5	5.28	2.51	17

KL/Rx	KL/Ry	short/long
14.77272727	31.07569721	short

Fe	Fcr	Pn	Pu/Pn	check
296.0844038	46.58795763	712.7957517	0.168266996	OK

First Floor Column G1.2

Bay 1

20.5X23

length	K	KL
12	0.65	7.8

Floor rxn 1	floor rxn 2	floor rxn 3	floor load	Total all floors load
65.8	17.77	0.03631	83.60631	334.42524

roof rxn 1	roof rxn 2	roof rxn 3		total roof load
32.85	13.86	0.0298		46.7398

Total load acting on columns
381.16504

column size		Pn	Rx	Ry	Ag
W12x58		800.6	5.28	3.02	19.1

KL/Rx	KL/Ry	short/long
17.72727273	30.99337748	short

Fe	Fcr	Pn	Pu/Pn	check
297.6593181	46.6053835	801.1465423	0.475774431	OK

only Bf is adequate, therefore column should be adjusted to fit the bottom girder W24x55

First Floor Column H1

length	K	KL
12	0.65	7.8

Floor rxn 1	floor rxn 2	floor rxn 3	floor load	Total all floors load
14.71	32.63	0	47.34	189.36

roof rxn 1	roof rxn 2	roof rxn 3
8.19	17.07	

total roof load
25.26

Total load acting on columns
214.62

column size	Pn	Rx	Ry	Ag
W12x65	800.6	5.28	3.02	19.1

KL/Rx	KL/Ry	short/long
17.72727273	30.99337748	short

Fe	Fcr	Pn	Pu/Pn	check
297.6593181	46.6053835	801.1465423	0.267891064	OK

only Bf is adequate, therefore column should be adjusted to fit the bottom girder W14x38

Foundation Spreadsheets

The same format used for the design of the members was also used for the design of the foundation. Where, the highlighted items needs to be inputted into the excel sheet.

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
1058.14	777.94	7000.24		6	16		
qa	qn						
8	4.301435547						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
13.44826757	14	1	68	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		82	0.85	Vuc		28	0.85
981.8823649				434.8117347			
ϕ Vnc	OK			ϕ Vnc	OK		
1038.394333				2127.442049			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
8034.808079	77.5	Bar Diameter	Bar Cross section Area	34.20288017	35		
As Required	min As Required	1	0.79				
27.02027533	21.7728						
			35 #8 bars				
As Governs							
27.02027533		Clear Spacing					
		3.666666667	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		2.333333333	4.666666667	2.333333333			
Ld supplied		2.5		Final C			
74.5		Final		2.333333333			
Ld		2.333333333					
35.21073584		Bearing pressure			q min (including moment)		
					6.29		
Ld Supplied > Ld	OK	Wf	q	qa	q max(including moment)		
		191.1	6.373673469	8	6.46		
				OK			
Settlement							
Zf	σ'zd	Δσz					
2	0.78	5.619848233					
Effective Stress							
σ'zf	σ'z0	H					
9.579848233	3.96	33					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.774846689	1 in						
OK							

Footing 1, Load (1058.14), Borehole #1.

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
1058.14	777.94	7000.24		6	16		
qa	qn						
8	4.301435547						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
13.44826757	14	1	68	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		82	0.85	Vuc		28	0.85
981.8823649				434.8117347			
ϕ Vnc	OK			ϕ Vnc	OK		
1038.394333				2127.442049			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
8034.808079	77.5	Bar Diameter	Bar Cross section Area	34.20288017	35		
As Required	min As Required	1	0.79				
27.02027533	21.7728						
			35 #8 bars				
As Governs							
27.02027533		Clear Spacing					
		3.666666667	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		2.333333333	4.666666667	2.333333333			
Ld supplied		2.5		Final C			
74.5		Final		2.333333333			
Ld		2.333333333					
35.21073584		Bearing pressure			q min (including moment)		
					6.29		
Ld Supplied > Ld	OK	Wf	q	qa	q max(including moment)		
		191.1	6.373673469	8	6.46		
				OK			
Settlement							
Zf	σ'zd	Δσz					
2	0.78	5.619848233					
Effective Stress							
σ'zf	σ'z0	H					
8.739848233	3.12	26					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.711822202	1 in						
OK							

Footing 1, Load (1058.14), Borehole #2

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
1058.14	777.94	7000.24		6	16		
qa	qn						
8	4.301435547						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
13.44826757	14	1	68	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		82	0.85	Vuc		28	0.85
981.8823649				434.8117347			
ϕ Vnc	OK			ϕ Vnc	OK		
1038.394333				2127.442049			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
8034.808079	77.5	Bar Diameter	Bar Cross section Area	34.20288017	35		
As Required	min As Required	1	0.79				
27.02027533	21.7728						
			35 #8 bars				
As Governs							
27.02027533		Clear Spacing					
		3.666666667	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		2.333333333	4.666666667	2.333333333			
Ld supplied		2.5		Final C			
74.5		Final		2.333333333			
Ld		2.333333333					
35.21073584		Bearing pressure			q min (including moment)		
					6.29		
Ld Supplied > Ld	OK	Wf	q	qa	q max(including moment)		
		191.1	6.373673469	8	6.46		
				OK			
Settlement							
Zf	σ'zd	Δσz					
2	0.78	5.619848233					
Effective Stress							
σ'zf	σ'z0	H					
8.019848233	2.4	20					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.641320808	1 in						
OK							

Footing 1, Load (1058.14), Borehole #3

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
627.1	450	0		3	11		
qa	qn						
6	5.315						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
9.201415082	11	1	32	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		46	0.85	Vuc		22	0.85
137.7359791				256.5409091			
ϕ Vnc	OK			ϕ Vnc	OK		
274.1241856				786.6172282			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
700.7862295	59.5	Bar Diameter	Bar Cross section Area	10.82734177	11		
As Required	min As Required	1	0.79				
4.936485357	8.5536						
			11 #8 bars				
As Governs							
8.5536		Clear Spacing					
		10	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		5.5	11	5.5			
Ld supplied		2.5		Final C			
56.5		Final		5.5			
Ld		2.5					
32.86335345		Bearing pressure					
Ld Supplied > Ld	OK	Wf	q	qa			
		63.525	5.707644628	6			
Settlement				OK			
Zf	σ'zd	Δσz					
2	0.42	5.166895159					
Effective Stress							
σ'zf	σ'z0	H					
9.126895159	3.96	33					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.732363258	1 in						
OK							

Footing 2, Load (627.1), Borehole #1

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
627.1	450	0		3	11		
qa	qn						
6	5.315						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
9.201415082	11	1	32	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		46	0.85	Vuc		22	0.85
137.7359791				256.5409091			
ϕ Vnc	OK			ϕ Vnc	OK		
274.1241856				786.6172282			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
700.7862295	59.5	Bar Diameter	Bar Cross section Area	10.82734177	11		
As Required	min As Required	1	0.79				
4.936485357	8.5536						
			11 #8 bars				
As Governs							
8.5536		Clear Spacing					
		10	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		5.5	11	5.5			
Ld supplied		2.5		Final C			
56.5		Final		5.5			
Ld		2.5					
32.86335345		Bearing pressure					
Ld Supplied > Ld	OK	Wf	q	qa			
		63.525	5.707644628	6			
				OK			
Settlement							
Zf	σ'zd	Δσz					
2	0.42	5.166895159					
Effective Stress							
σ'zf	σ'z0	H					
8.286895159	3.12	26					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.675046313	1 in						
OK							

Footing 2, Load (627.1), Borehole #2

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
627.1	450	0		3	11		
qa	qn						
6	5.315						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
9.201415082	11	1	32	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		46	0.85	Vuc		22	0.85
137.7359791				256.5409091			
ϕ Vnc	OK			ϕ Vnc	OK		
274.1241856				786.6172282			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
700.7862295	59.5	Bar Diameter	Bar Cross section Area	10.82734177	11		
As Required	min As Required	1	0.79				
4.936485357	8.5536						
			11 #8 bars				
As Governs							
8.5536		Clear Spacing					
		10	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		5.5	11	5.5			
Ld supplied		2.5		Final C			
56.5		Final		5.5			
Ld		2.5					
32.86335345		Bearing pressure					
Ld Supplied > Ld	OK	Wf	q	qa			
		63.525	5.707644628	6			
				OK			
Settlement							
Zf	σ'zd	Δσz					
2	0.42	5.166895159					
Effective Stress							
σ'zf	σ'z0	H					
7.566895159	2.4	20					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.610416725	1 in						
OK							

Footing 2, Load (627.1), Borehole #3

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
381.16	280.23	0		2	10		
qa	qn						
5	4.465						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
7.922214221	10	1	20	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		34	0.85	Vuc		20	0.85
87.64033056				209.638			
ϕ Vnc	OK			ϕ Vnc	OK		
126.6334553				446.9416069			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
378.8108368	53.5	Bar Diameter	Bar Cross section Area	6.562025316	7		
As Required	min As Required	1	0.79				
4.301461438	5.184						
			7 #8 bars				
As Governs							
5.184		Clear Spacing					
		14	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		7.5	15	7.5			
Ld supplied		2.5		Final C			
50.5		Final		7.5			
Ld		2.5					
32.86335345		Bearing pressure					
Ld Supplied > Ld	OK	Wf	q	qa			
		37.5	4.1866	5			
				OK			
Settlement							
Zf	σ'zd	Δσz					
2	0.3	3.767647122					
Effective Stress							
σ'zf	σ'z0	H					
7.727647122	3.96	33					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.586395093	1 in						
OK							

Footing 3, Load (381.16), Borehole #1

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
381.16	280.23	0		2	10		
qa	qn						
5	4.465						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
7.922214221	10	1	20	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		34	0.85	Vuc		20	0.85
87.64033056				209.638			
ϕ Vnc	OK			ϕ Vnc	OK		
126.6334553				446.9416069			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
378.8108368	53.5	Bar Diameter	Bar Cross section Area	6.562025316	7		
As Required	min As Required	1	0.79				
4.301461438	5.184						
			7 #8 bars				
As Governs							
5.184		Clear Spacing					
		14	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		7.5	15	7.5			
Ld supplied		2.5		Final C			
50.5		Final		7.5			
Ld		2.5					
32.86335345		Bearing pressure					
Ld Supplied > Ld	OK	Wf	q	qa			
		37.5	4.1866	5			
				OK			
Settlement							
Zf	σ'zd	Δσz					
2	0.3	3.767647122					
Effective Stress							
σ'zf	σ'z0	H					
6.887647122	3.12	26					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.547239608	1 in						
OK							

Footing 3, Load (381.16), Borehole #2

Factored Load	Unfactored Load	Moment		T (Tickness)	B (Width)		
381.16	280.23	0		2	10		
qa	qn						
5	4.465						
Required Width	Final B (Width)	db	d	cp (base plate widht)	c (columns Width)		
7.922214221	10	1	20	14	12		
	OK						
Two Way Shear				One Way Shear			
		b0	ϕ			bw	ϕ
Vuc		34	0.85	Vuc		20	0.85
87.64033056				209.638			
ϕ Vnc	OK			ϕ Vnc	OK		
126.6334553				446.9416069			
Flexural Reinforcement			p (steel ratio)				
			0.0018				
Muc	L	# 8 Bar		# of Bars Required			
378.8108368	53.5	Bar Diameter	Bar Cross section Area	6.562025316	7		
As Required	min As Required	1	0.79				
4.301461438	5.184						
			7 #8 bars				
As Governs							
5.184		Clear Spacing					
		14	Less than 18"				
			OK				
Development Length		C + Ktr/db	C	C			
		7.5	15	7.5			
Ld supplied		2.5		Final C			
50.5		Final		7.5			
Ld		2.5					
32.86335345		Bearing pressure					
Ld Supplied > Ld	OK	Wf	q	qa			
		37.5	4.1866	5			
				OK			
Settlement							
Zf	σ'zd	Δσz					
2	0.3	3.767647122					
Effective Stress							
σ'zf	σ'z0	H					
6.167647122	2.4	20					
Settlement							
r	cc/(1+e0)						
0.85	0.006						
δ	δa						
0.50172773	1 in						
OK							

Footing 3, Load (381.16), Borehole #3

Appendix D: Beams and Girders Properties.

This appendix consists of detailed information about the beams and girders designed. A sketch of the designed section is provided in Figure 38 showing the location and the name of each designed member. It includes the actual member sizes computed, the final member sizes suggested to be used, and the moment capacity for each size; since the final member sizes were selected and categorized according to their moment capacity.

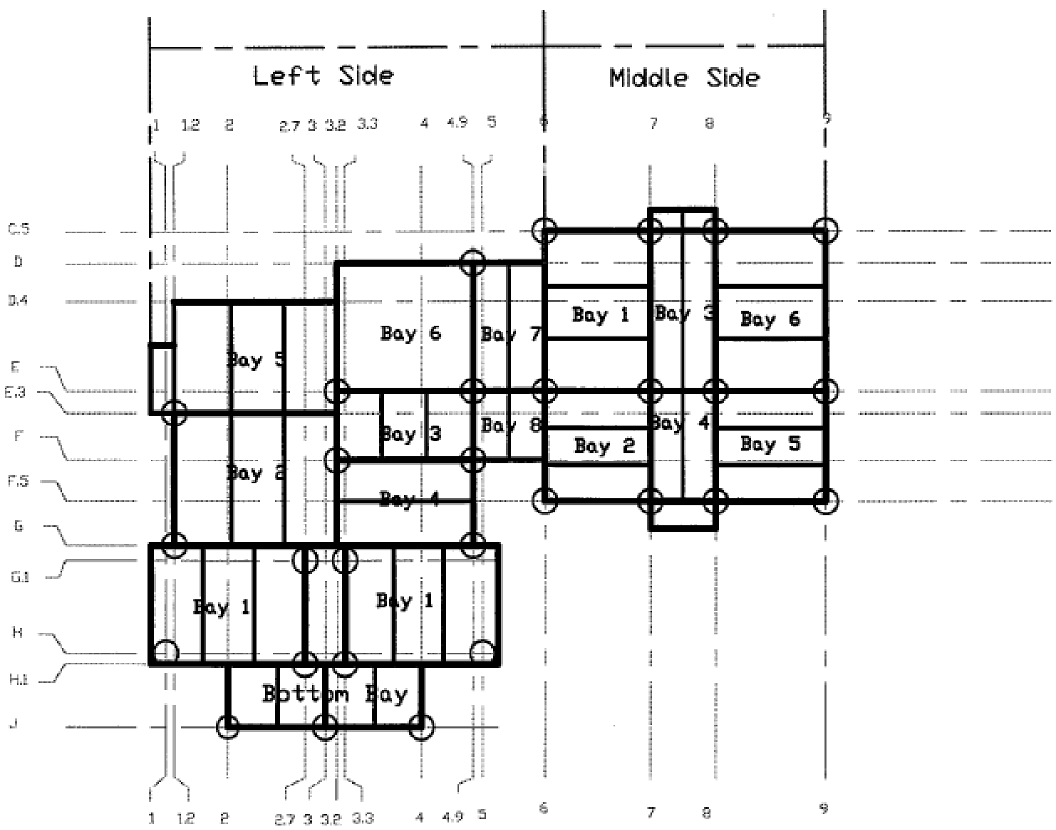


Figure 38. **Location of the designed members.**

Beam and Girder Design for Second to Fifth Floor
Left Side

Table 14
Beams and girders properties (Left side- second to fifth floor .

Bay	Member location	Actual Member size	Moment capacity	Final member size
Bottom Bay	Infill beam	W10x12	118	W10x12
	J-3 to H.1-3	W10x12	118	W10x12
	J-2 to H.1-2 J-2 to J-3	W10x12 W10x12	118 118	W10x12 W10x12
Bay 1	H.1-2 to H.1-3 Infill beams	W14x38 W12x14	463 155	W18x35 W12x16
	G-2.7 to G.1-2.7	W10x12	118	W10x12
	G-1 to G-1.2 G-1 to H-1	W 10x12 W10x12	118 118	W10x12 W10x12
	H-1 to H.1-1	W10x12	118	W10x12
Bay 2	Infill beam for bedroom Infill beam for HVAC	W12x22 W12x26	247 290	W12x26 W12x26
Bay 3	E.3-1.2 to G-1.2 G1.2 to G-3 Infill beams	W12x16 W24x55 W12x14	177 875 155	W12x16 W24x55 W12x16
	E-3.2 to F-3.2	W18x35	496	W18x35
	E-4.9 to F-4.9	W12x14	155	W12x16
Bay 4	Infill beams	W12x19	211	W12x26
	F-3.2 to F-4.9 F-4.9 to G-4.9	W16x31 W12x14	409 155	W18x35 W12x16
	G-3 to G-4.9	W18x35	496	W18x35
Bay 5	F-3.2 to G-3.2 Infill beams	W33x118 W10x22	2090 221	W33x118 W12x26
	D.4-1.2 to E.3-1.2	W10x12	118	W10x12
Bay 7	E.3-1.2 to E.3 3.2 Infill beams (1)	W24x55 W12x16	875 177	W24x55 W12x16
	D-5 to D-6	W10x12	118	W10x12
Bay 8	Infill beams (1) F-5 to F-6	W10x12 W10x12	118 118	W10x12 W10x12
	E-5 to F-6	W10x26	262	W12x26

Middle Side of the Building

Table 15
Beams and girders properties (Middle side-second to fifth floor).

	Member location	**Actual Member Size**	**Moment Capacity**	**Final Member Size**
Bay 1	Infill beam for bedroom	W10x12	118	W10x12
	Infill beam for Storage	W12x14	155	W12x16
	C.5-7 to E-7	W18x50	613	W24x55
	C.5-6 to C.5-7	W10x12	118	W10x12
	E-6 to E-7	W10x17	170	W12x16
	C.5-6 to E-6	W18x60	696	W24x55
Bay 2	Infill beam for bedroom	W10x12	118	W10x12
	Infill beam for storage	W10x15	149	W12x16
	E-6 to F.5-6	W16x31	409	W18x35
	E-7 to F.5-7	W16x26	341	W18x35
	F.5-6 to F.5-7	W10x12	118	W10x12
Bay 3	Infill beam (1)	W10x12	118	W10x12
	C.5-7 to C.5-8	W10x12	118	W10x12
Bay 4	Infill beam(1)	W10x26	262	W12x26
	F.5-7 to F.5-8	W10x12	118	W10x12
	E-7 to E-8	W10X22	221	W12x26
Bay 5	Infill beam bedroom	W10x12	118	W10x12
	Infill beam kitchen	W10x12	118	W10x12
	E-8 to E-9	W10x12	118	W10x12
	C.5-8 to C.5-9	W12x14	155	W12x16
	C.5-8 to E-8	W16x26	341	W18x35
	C.5-9 to E-9	W18x35	415	W18x35
Bay 6	Infill beam for bedrooms	W10x12	118	W10x12
	Infill beam for toilet	W10x22	221	W12x26
	E-8 to F.5-9	W18x50	613	W24x55
	E-8 to E-9	W10x12	118	W10x12
	E-9 to F.5-9	W18x60	868	W24x55

Beam and Girder Design for the Roof for the Left Side

Table 16
Beams and girders properties (Left side- roof).

	Member location	**Actual Member size**	**Moment capacity**	**Final member size**
Bottom Bay	Infill beam	W10x12	118	W10x12
	J-3 to H.1-3	W10x12	118	W10x12
	J-2 to H.1-2	W10x12	118	W10x12
	J-2 to J-3	W10x12	118	W10x12
	H.1-2 to H.1-3	W10x26	262	W12x26
Bay 1	Infill beams	W10x12	118	W10x12
	G-2.7 to G.1-2.7	W10x12	118	W10x12
	G-1 to G-1.2	W 10x12	118	W10x12
	G-1 to H-1	W10x12	118	W10x12
	H-1 to H.1-1	W10x12	118	W10x12
Bay 2	Infill beam	W12x14	155	W12x16
	Infill beam for HVAC	W12x26	290	W12x26
	E.3-1.2 to G-1.2	W12x14	155	W12x16
	G1.2 to G-3	W18x35	496	
Bay 3	Infill beams	W10x12	118	W10x12
	E-3.2 to F-3.2	W18x35	496	W18x35
	E-4.9 to F-4.9	W10x12	118	W10x12
Bay 4	Infill beams	W12x14	155	W12x16
	F-3.2 to F-4.9	W12x22	247	W12x26
	F-4.9 to G-4.9	W10x12	118	W10x12
	G-3 to G-4.9	W14x22	265	W12x26
	F-3.2 to G-3.2	W27x48	1340	W27x48
Bay 5	Infill beams	W10x12	118	W10x12
	D.4-1.2 to E.3-1.2	W10x12	118	W10x12
	E.3-1.2 to E.3 3.2	W18x46	661	W24x55
Bay 7	Infill beams (1)	W10x12	118	W10x12
	D-5 to D-6	W10x12	118	W10x12
Bay 8	Infill beams (1)	W10x12	118	W10x12
	F-5 to F-6	W10x12	118	W10x12
	E-5 to F-6	W10x12	118	W10x12

Middle Side

Table 17
Beams and girders properties(Middle side- roof).

	Member location	**Actual Member Size**	**Moment Capacity**	**Final Member Size**
Bay 1	Infill beam	W10x12	118	W10x12
	C.5-7 to E-7	W18x35	415	W18x35
	C.5-6 to C.5-7	W10x12	118	W10x12
	E-6 to E-7	W10x12	118	W10x12
	C.5-6 to E-6	W18x35	415	W18x35
Bay 2	Infill beam s	W10x12	118	W10x12
	E-6 to F.5-6	W12x26	290	W12x26
	E-7 to F.5-7	W12x26	290	W12x26
	F.5-6 to F.5-7	W10x12	118	W10x12
Bay 3	Infill beam (1)	W10x12	118	W10x12
	C.5-7 to C.5-8	W10x12	118	W10x12
Bay 4	Infill beam(1)	W10x12	118	W10x12
	F.5-7 to F.5-8	W10x12	118	W10x12
	E-7 to E-8	W10X12	118	W10x12
Bay 5	Infill beams	W10x12	118	W10x12
	E-8 to E-9	W10x12	118	W10x12
	C.5-8 to C.5-9	W10x12	118	W10x12
	C.5-8 to E-8	W14x22	265	W12x26
	C.5-9 to E-9	W16x26	341	W18x35
Bay 6	Infill beams	W10x12	118	W10x12
	E-8 to F.5-8	W16x36	473	W18x35
	E-8 to E-9	W10x12	118	W10x12
	E-9 to F.5-9	W16x45	600	W24x55

Appendix E: Primavera

This appendix consists of the primavera work computed for the WPI-New Residence Hall. This section includes two parts of the Time and Scheduling process which are date calculation of activities based on CSI index and schema of activity relationships with each other. Basically, date calculation of activities shows how many days each activity needs in order to be completed. However, the activity relationship shows how to properly follow the activity processes.

Activity ID	Planned Start	Planned Finish	Activity Name	Original Duration	Start	Finish	Total Float
WPI New Hall	07-Feb-07	22-Aug-08		399	07-Feb-07	22-Aug-08	0
Project Milestones	11-Apr-07	22-Aug-08		354	11-Apr-07	22-Aug-08	0
A1040	23-May-...	29-Jun-07	Foundation Completed	28	23-May-07	29-Jun-07	
A2450	11-Apr-07		Project Starts	0	11-Apr-07		
A2460	11-Apr-07		Design Kick-off Meeting	0	11-Apr-07		
A2470	11-Apr-07	22-Jun-07	Design Completed	53	11-Apr-07	22-Jun-07	
A2490		18-Aug-08	Building Enclosed	0		18-Aug-08	
A2500	23-Jul-08	04-Aug-08	Final Inspection & Approval	9	23-Jul-08	04-Aug-08	
A2510		10-Jul-08	Substantial Completion	0		10-Jul-08	
A2520	24-Jun-08	10-Jul-08	Flush Building	13	24-Jun-08*	10-Jul-08	
A2530		22-Aug-08	Project Ends	0		22-Aug-08	
A2800	13-Apr-07	23-May-07	Demolition and Clearing the site	29	13-Apr-07	23-May-07	
Project Management	08-May-...	01-Aug-08		320	08-May-07	01-Aug-08	0
A1090	13-Jun-07	19-Jun-07	Develop Work Plan	5	13-Jun-07*	19-Jun-07	
A1100	12-Jun-07	21-Jun-07	Forming of Project Team	8	12-Jun-07*	21-Jun-07	
A1110	14-Jun-07	28-Jun-07	Building Permits	11	14-Jun-07*	28-Jun-07	
A1120	11-Jul-07	19-Jul-07	Move In	7	11-Jul-07*	19-Jul-07	
A1130	08-May-...	01-Jun-07	Procure Contractor's Bids	19	08-May-...	01-Jun-07	
A1140	24-Jul-08	01-Aug-08	Handover	7	24-Jul-08*	01-Aug-08	
A1150	20-Jun-08	26-Jun-08	Punch List & Move	5	20-Jun-08*	26-Jun-08	
A1390	11-Jul-08	16-Jul-08	Erect Fence	4	11-Jul-08*	16-Jul-08	
A1444	11-Jul-08	17-Jul-08	Erosion Control	5	11-Jul-08*	17-Jul-08	
Design	17-Apr-07	13-Dec-07		172	17-Apr-07	13-Dec-07	0
A1170	14-May-...	13-Jun-07	Storm-Water Design	23	14-May-07	13-Jun-07	
A1180	17-Apr-07	30-Apr-07	Sanitary Sewer Design	10	17-Apr-07	30-Apr-07	
A1190	18-Apr-07	31-May-07	Architectural Design	32	18-Apr-07	31-May-07	
A1200	09-May-...	21-Jun-07	On-Site Utilities Design	32	09-May-07	21-Jun-07	
A1210	08-May-...	22-Jun-07	Mechanical Systems Design	34	08-May-07	22-Jun-07	
A1220	16-May-...	06-Jun-07	Electrical Systems Design	16	16-May-07	06-Jun-07	
A1470	07-Nov-...	13-Dec-07	Structural Design	27	07-Nov-...	13-Dec-07	
Sitework & Excavati	07-Feb-07	04-Sep-07		150	07-Feb-07	04-Sep-07	0
A1230	31-Jul-07	07-Aug-07	Backfill/Restore Grade	6	31-Jul-07	07-Aug-07	

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

TASK filter: All Activities

Activity ID	Planned Start	Planned Finish	Activity Name	Original Duration	Start	Finish	Total Float
A1240	22-Jun-07	29-Jun-07	Excavate Basement	6	22-Jun-07	29-Jun-07	
A1250	19-Jul-07	01-Aug-07	Install Sewer Line	10	19-Jul-07	01-Aug-07	
A1260	31-Jul-07	06-Aug-07	Backfill Interior Foundation Walls & U/G Duct	5	31-Jul-07	06-Aug-07	
A1270	18-Jul-07	27-Jul-07	Install Water Line/Tap	8	18-Jul-07	27-Jul-07	
A1280	25-Jun-07	29-Jun-07	Excavate for U/G Plumbing	5	25-Jun-07	29-Jun-07	
A1290	20-Jul-07	01-Aug-07	Backfill/Rgh Grade Foundation & Site	9	20-Jul-07	01-Aug-07	
A1310	03-Aug-07	13-Aug-07	Backfill/Prep Landing	7	03-Aug-07	13-Aug-07	
A1320	13-Aug-07	24-Aug-07	Final Paving	10	13-Aug-07	24-Aug-07	
A1330	22-Aug-07	04-Sep-07	Landscaping & Brick Paving	10	22-Aug-07	04-Sep-07	
A1400	30-Apr-07	24-May-07	Demolition of Existing Building	19	30-Apr-07	24-May-07	
A1480	24-May-...	22-Jun-07	Clearing site for New Construction	22	24-May-07	22-Jun-07	
A1490	07-Feb-07	14-Feb-07	Prep side for steel	6	07-Feb-07	14-Feb-07	
Concrete Work	29-Jun-07	13-Aug-07		32	29-Jun-07	13-Aug-07	0
A1340	03-Jul-07	17-Jul-07	Form/Place/Strip Balance of Footings	11	03-Jul-07	17-Jul-07	
A1350	10-Jul-07	20-Jul-07	Form/Place/Strip Basement Walls	9	10-Jul-07*	20-Jul-07	
A1360	29-Jun-07	05-Jul-07	Prep/Place Basement Slab On Grade	5	29-Jun-07	05-Jul-07	
A1370	17-Jul-07	26-Jul-07	Prep/Place Main Slab on Grade	8	17-Jul-07	26-Jul-07	
A1380	12-Jul-07	19-Jul-07	Prep/pour First Floor Slab On Deck	6	12-Jul-07	19-Jul-07	
A1410	03-Aug-07	13-Aug-07	Site Concrete- all Sides	7	03-Aug-07	13-Aug-07	
A1420	30-Jul-07	06-Aug-07	Place Exterior Slab	6	30-Jul-07	06-Aug-07	
A1600	16-Jul-07	25-Jul-07	Prep/pour SecondFloor Slab On Deck	8	16-Jul-07	25-Jul-07	
A1630	17-Jul-07	26-Jul-07	Prep/pour Third Floor Slab On Deck	8	17-Jul-07*	26-Jul-07	
A1870	18-Jul-07	20-Jul-07	Prep/pour Fourth Floor Slab On Deck	3	18-Jul-07	20-Jul-07	
A2440	19-Jul-07	24-Jul-07	Prep/pour First FifthSlab On Deck	4	19-Jul-07	24-Jul-07	
Precast Concrete	02-Jul-07	02-Aug-07		24	02-Jul-07	02-Aug-07	0
A1430	02-Jul-07	20-Jul-07	Fab & Del Precast	15	02-Jul-07	20-Jul-07	
A1440	25-Jul-07	02-Aug-07	Entrance Precast	7	25-Jul-07	02-Aug-07	
Masonry	18-Jul-07	24-Jan-08		134	18-Jul-07	24-Jan-08	0
A1450	18-Jul-07	31-Jul-07	Fab & Del Brick	10	18-Jul-07	31-Jul-07	
A1460	14-Aug-07	03-Sep-07	Install 1st & 2nd Floor Brick	15	14-Aug-07	03-Sep-07	
A2480	26-Jul-07	01-Aug-07	Install 1st & 2nd Floor Precast-East	5	26-Jul-07	01-Aug-07	
A2540	23-Jul-07	26-Jul-07	Install Gable Precast-East	4	23-Jul-07	26-Jul-07	
A2560	02-Aug-07	07-Aug-07	Install 1st & 2nd Floor Precast-West	4	02-Aug-07	07-Aug-07	

Actual Work — Critical Remaining Work — Summary
Remaining Work ◆ — ◆ Milestone

TASK filter: All Activities

Activity ID	Planned Start	Planned Finish	Activity Name	Original Duration	Start	Finish	Total Float
A2570	06-Aug-07	09-Aug-07	Install 1st & 2nd Floor Precast-North	4	06-Aug-07	09-Aug-07	
A2580	09-Aug-07	13-Aug-07	Install 1st & 2nd Floor Precast-South	3	09-Aug-07	13-Aug-07	
A2590	09-Jan-08	24-Jan-08	Install End Brick & Precast	12	09-Jan-08*	24-Jan-08	
A2600	10-Oct-07	18-Oct-07	Install 3rd & 4th Floor Brick-North	7	10-Oct-07	18-Oct-07	
A2610	19-Oct-07	24-Oct-07	Install 3rd & 4th Floor Brick-East	4	19-Oct-07	24-Oct-07	
A2620	25-Oct-07	30-Oct-07	Install 3rd & 4th Floor Brick-West	4	25-Oct-07*	30-Oct-07	
A2630	02-Nov-...	08-Nov-07	Install 3rd & 4th Floor Brick-North	5	02-Nov-...	08-Nov-07	
A2640	12-Sep-07	20-Sep-07	Install 3rd & 4th Floor Precast-East	7	12-Sep-07	20-Sep-07	
A2650	21-Sep-07	27-Sep-07	Install 3rd & 4th Floor Precast-North	5	21-Sep-07	27-Sep-07	
A2660	28-Sep-07	02-Oct-07	Install 3rd & 4th Floor Precast-South	3	28-Sep-07	02-Oct-07	
A2670	03-Oct-07	09-Oct-07	Install 3rd & 4th Floor Precast-West	5	03-Oct-07	09-Oct-07	
A2810	20-Nov-...	28-Nov-07	Install 5th Floor Brick	7	20-Nov-...	28-Nov-07	
A2820	05-Nov-...	12-Nov-07	Install 5th Floor Precast	6	05-Nov-...	12-Nov-07	
Metals	16-Aug-07	28-Apr-08		180	16-Aug-07	28-Apr-08	0
A1520	23-Aug-07	14-Sep-07	Fab & Del Deck	17	23-Aug-07	14-Sep-07	
A1530	16-Aug-07	20-Sep-07	Fabricate & Deliver Building Stair	26	16-Aug-07	20-Sep-07	
A1540	10-Oct-07	19-Oct-07	Survey Anchor Bolts	8	10-Oct-07	19-Oct-07	
A1550	20-Sep-07	09-Oct-07	Erect Steel Frame	14	20-Sep-07	09-Oct-07	
A1560	26-Mar-08	18-Apr-08	Erect Roof Steel	18	26-Mar-...	18-Apr-08	
A1570	08-Oct-07	16-Oct-07	Install Deck/Studs	7	08-Oct-07	16-Oct-07	
A1580	21-Apr-08	28-Apr-08	Install Roof & Attic Decking	6	21-Apr-08*	28-Apr-08	
A1590	30-Aug-07	17-Sep-07	Install Precast Supports & Adjust	13	30-Aug-07	17-Sep-07	
A1610	16-Jan-08	21-Feb-08	Fab & Del Steel	27	16-Jan-08*	21-Feb-08	
A1640	22-Aug-07	28-Sep-07	Fab & Del & Install Ladder & Handrail / Attic	28	22-Aug-07	28-Sep-07	
A1650	16-Jan-08	06-Feb-08	Install Stair Rails	16	16-Jan-08*	06-Feb-08	
A2680	11-Dec-07	21-Dec-07	Install Stairs - 1st Floor	9	11-Dec-...	21-Dec-07	
A2690	17-Jan-08	01-Feb-08	Install Stairs - 2nd Floor	12	17-Jan-08*	01-Feb-08	
A2700	05-Feb-08	15-Feb-08	Install Stairs- 3rd Floor	9	05-Feb-...	15-Feb-08	
A2710	26-Feb-08	20-Mar-08	Install Stairs - 4th Floor	18	26-Feb-...	20-Mar-08	
Carpentry	10-Mar-08	07-May-08		43	10-Mar-08	07-May-08	0
A1660	10-Mar-08	27-Mar-08	Fab & Del Millwork	14	10-Mar-...	27-Mar-08	
A1670	08-Apr-08	29-Apr-08	Install Millwork	16	08-Apr-08*	29-Apr-08	
A1680	28-Apr-08	07-May-08	Install Wood Paneling	8	28-Apr-08*	07-May-08	

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

TASK filter: All Activities

Activity ID	Planned Start	Planned Finish	Activity Name	Original Duration	Start	Finish	Total Float
A1690	24-Apr-08	29-Apr-08	Install Plywood / Attic	4	24-Apr-08*	29-Apr-08	
Roof & Moisture Pro	06-Feb-08	05-Jun-08		87	06-Feb-08	05-Jun-08	0
A2830	12-Mar-08	25-Mar-08	Fab & Del Slate Roofing	10	12-Mar-...	25-Mar-08	
A2840	02-Apr-08	11-Apr-08	Fab & Del EPDM Roofing	8	02-Apr-08*	11-Apr-08	
A2850	13-Feb-08	22-Feb-08	Fab & Del Slate Infills	8	13-Feb-...	22-Feb-08	
A2860	21-May-...	05-Jun-08	Dampproof & Insulate Foundation	12	21-May-...	05-Jun-08	
A2870	14-Apr-08	22-Apr-08	Install Roof Sheathing	7	14-Apr-08*	22-Apr-08	
A2880	23-Apr-08	29-Apr-08	Install Slate Shingles	5	23-Apr-08*	29-Apr-08	
A2890	06-Feb-08	14-Feb-08	Terminate Roofing Entrance	7	06-Feb-...	14-Feb-08	
A2900	21-Feb-08	26-Mar-08	Prep/Del Green Roof Material	25	21-Feb-...	26-Mar-08	
A2910	16-May-...	30-May-08	Install Green Roof	11	16-May-...	30-May-08	
Doors & Windows	07-Nov-...	10-Jun-08		151	07-Nov-07	10-Jun-08	0
A1800	07-Nov-...	29-Nov-07	Fab & Del Curtainwall	17	07-Nov-...	29-Nov-07	
A1810	15-Nov-...	23-Nov-07	Fab & Del Windows	7	15-Nov-...	23-Nov-07	
A1820	28-Nov-...	14-Dec-07	Fab & Del Wood Doors & Hardware	13	28-Nov-...	14-Dec-07	
A1840	28-Apr-08	09-May-08	Install Wood Doors / Hardware	10	28-Apr-08*	09-May-08	
A1860	17-Jan-08	22-Jan-08	Install Curtainwall	4	17-Jan-08*	22-Jan-08	
A1880	16-Apr-08	24-Apr-08	Install Alum Exterior Entrance Doors	7	16-Apr-08*	24-Apr-08	
A1890	07-May-...	29-May-08	Install Alum to Building	17	07-May-...	29-May-08	
A1900	07-May-...	21-May-08	Install Windows	11	07-May-...	21-May-08	
A2730	08-May-...	15-May-08	Install Plastic in Windows - 1st Floor	6	08-May-...	15-May-08	
A2740	11-Apr-08	16-Apr-08	Install Glass Handrail - 1st Floor	4	11-Apr-08*	16-Apr-08	
A2750	19-May-...	23-May-08	Install Glass Handrail - 3rd Floor	5	19-May-...	23-May-08	
A2760	15-May-...	22-May-08	Install Glass Handrail - 4th Floor	6	15-May-...	22-May-08	
A2770	16-May-...	21-May-08	Install Plastic in Windows - 2nd Floor	4	16-May-...	21-May-08	
A2780	21-May-...	29-May-08	Install Plastic in Windows - 3rd Floor	7	21-May-...	29-May-08	
A2790	29-May-...	03-Jun-08	Install Plastic in Windows - 4th Floor	4	29-May-...	03-Jun-08	
A2920	09-May-...	14-May-08	Install Glass Handrail - 2nd Floor	4	09-May-...	14-May-08	
A2930	23-May-...	29-May-08	Install Glass Handrail-5th floor	5	23-May-...	29-May-08	
A2940	05-Jun-08	10-Jun-08	Install Plastic in Windows- 5th Floor	4	05-Jun-08*	10-Jun-08	
Specialities	07-May-...	22-Jul-08		54	07-May-08	22-Jul-08	0
A2120	17-Jul-08	22-Jul-08	Final Paint	4	17-Jul-08*	22-Jul-08	
A2140	08-May-...	22-May-08	Fab & Del Folding Partition Wall & Rail	11	08-May-...	22-May-08	

Actual Work · Critical Remaining Work · Summary · Remaining Work · Milestone

TASK filter: All Activities

WPI New Hall			Classic WBS Layout				18-Dec-07 14:03
Activity ID	**Planned Start**	**Planned Finish**	**Activity Name**	**Original Duration**	**Start**	**Finish**	**Total Float**
A2150	07-May-...	15-May-08	Install Folding Partition Support Wall & Rail	7	07-May-...	15-May-08	
A2160	14-May-...	22-May-08	Fab & Del Signage	7	14-May-...	22-May-08	
A2170	11-Jun-08	19-Jun-08	Install Signage in Building	7	11-Jun-08*	19-Jun-08	
A2260	29-May-...	05-Jun-08	Overhead Plumbing & Sprinkler & Heat Pipe	6	29-May-...	05-Jun-08	
Elavator	26-May-...	24-Jun-08		22	26-May-08	24-Jun-08	0
A2020	18-Jun-08	24-Jun-08	Install & Densdeck - Attic	5	18-Jun-08*	24-Jun-08	
A2180	26-May-...	11-Jun-08	Fab & Del Elevator	13	26-May-...	11-Jun-08	
A2190	12-Jun-08	19-Jun-08	Install Elevator	6	12-Jun-08*	19-Jun-08	
A2200	06-Jun-08	20-Jun-08	Elevator Machine Room Rough- (at Base...	11	06-Jun-08*	20-Jun-08	
Mechanical	17-Dec-07	20-Mar-08		67	17-Dec-07	20-Mar-08	0
A2210	08-Jan-08	18-Jan-08	MEP Slab on Grade Prep	9	08-Jan-08*	18-Jan-08	
A2220	18-Jan-08	23-Jan-08	MEP Floor Slab On Deck Prep	4	18-Jan-08*	23-Jan-08	
A2230	13-Feb-08	21-Feb-08	Install Roof Drains & Vents	7	13-Feb-...	21-Feb-08	
A2240	17-Dec-07	21-Dec-07	Fab & Del Duct	5	17-Dec-...	21-Dec-07	
A2250	06-Feb-08	14-Feb-08	Overhead Ductwork	7	06-Feb-...	14-Feb-08	
A2270	21-Feb-08	28-Feb-08	Plumbing & Mechanical Rough-in Mech & ...	6	21-Feb-...	28-Feb-08	
A2280	20-Feb-08	26-Feb-08	Plumbing in-Wall Rough	5	20-Feb-...	26-Feb-08	
A2300	25-Feb-08	28-Feb-08	Mechanical & Plumbing Rough-in Attic	4	25-Feb-...	28-Feb-08	
A2310	28-Feb-08	12-Mar-08	Sprinkler Rough-in Mech/Elect Rms	10	28-Feb-...	12-Mar-08	
A2320	12-Mar-08	20-Mar-08	Mechanical & Plumbing Finish	7	12-Mar-...	20-Mar-08	
A2330	26-Feb-08	04-Mar-08	Install Sprinkler Heads	6	26-Feb-...	04-Mar-08	
Electrical	02-Apr-08	11-Jul-08		72	02-Apr-08	11-Jul-08	0
A2290	05-May-...	21-May-08	Heat Rough-in Mech / Elect room	13	05-May-...	21-May-08	
A2340	09-Apr-08	16-Apr-08	Electric Relocation Work	6	09-Apr-08*	16-Apr-08	
A2350	02-Apr-08	10-Apr-08	Overhead Electric	7	02-Apr-08*	10-Apr-08	
A2360	07-May-...	16-May-08	Electrical In-Wall	8	07-May-...	16-May-08	
A2370	21-May-...	29-May-08	Control In-Wall	7	21-May-...	29-May-08	
A2380	04-Jun-08	12-Jun-08	Fire Alarm	7	04-Jun-08*	12-Jun-08	
A2390	26-May-...	30-May-08	Electrical Rough-in - Attic	5	26-May-...	30-May-08	
A2400	02-Jul-08	11-Jul-08	Electrical Finish	8	02-Jul-08*	11-Jul-08	
A2410	03-Jun-08	09-Jun-08	Del Main Transformer	5	03-Jun-08*	09-Jun-08	
A2420	11-Jun-08	19-Jun-08	R.I Lights Entrance	7	11-Jun-08*	19-Jun-08	
A2430	26-Jun-08	02-Jul-08	Electrical Coordination	5	26-Jun-08*	02-Jul-08	

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

Page 5 of 6

TASK filter: All Activities

Activity ID	Planned Start	Planned Finish	Activity Name	Original Duration	Start	Finish	Total Float
A2150	07-May-...	15-May-08	Install Folding Partition Support Wall & Rail	7	07-May-...	15-May-08	
A2160	14-May-...	22-May-08	Fab & Del Signage	7	14-May-...	22-May-08	
A2170	11-Jun-08	19-Jun-08	Install Signage in Building	7	11-Jun-08*	19-Jun-08	
A2260	29-May-...	05-Jun-08	Overhead Plumbing & Sprinkler & Heat Pipe	6	29-May-...	05-Jun-08	
Elavator	26-May-...	24-Jun-08		22	26-May-08	24-Jun-08	0
A2020	18-Jun-08	24-Jun-08	Install & Densdeck - Attic	5	18-Jun-08*	24-Jun-08	
A2180	26-May-...	11-Jun-08	Fab & Del Elevator	13	26-May-...	11-Jun-08	
A2190	12-Jun-08	19-Jun-08	Install Elevator	6	12-Jun-08*	19-Jun-08	
A2200	06-Jun-08	20-Jun-08	Elevator Machine Room Rough- (at Base...	11	06-Jun-08*	20-Jun-08	
Mechanical	17-Dec-07	20-Mar-08		67	17-Dec-07	20-Mar-08	0
A2210	08-Jan-08	18-Jan-08	MEP Slab on Grade Prep	9	08-Jan-08*	18-Jan-08	
A2220	18-Jan-08	23-Jan-08	MEP Floor Slab On Deck Prep	4	18-Jan-08*	23-Jan-08	
A2230	13-Feb-08	21-Feb-08	Install Roof Drains & Vents	7	13-Feb-...	21-Feb-08	
A2240	17-Dec-07	21-Dec-07	Fab & Del Duct	5	17-Dec-...	21-Dec-07	
A2250	06-Feb-08	14-Feb-08	Overhead Ductwork	7	06-Feb-...	14-Feb-08	
A2270	21-Feb-08	28-Feb-08	Plumbing & Mechanical Rough-in Mech & ...	6	21-Feb-...	28-Feb-08	
A2280	20-Feb-08	26-Feb-08	Plumbing in-Wall Rough	5	20-Feb-...	26-Feb-08	
A2300	25-Feb-08	28-Feb-08	Mechanical & Plumbing Rough-in Attic	4	25-Feb-...	28-Feb-08	
A2310	28-Feb-08	12-Mar-08	Sprinkler Rough-in Mech/Elect Rms	10	28-Feb-...	12-Mar-08	
A2320	12-Mar-08	20-Mar-08	Mechanical & Plumbing Finish	7	12-Mar-...	20-Mar-08	
A2330	26-Feb-08	04-Mar-08	Install Sprinkler Heads	6	26-Feb-...	04-Mar-08	
Electrical	02-Apr-08	11-Jul-08		72	02-Apr-08	11-Jul-08	0
A2290	05-May-...	21-May-08	Heat Rough-in Mech / Elect room	13	05-May-...	21-May-08	
A2340	09-Apr-08	16-Apr-08	Electric Relocation Work	6	09-Apr-08*	16-Apr-08	
A2350	02-Apr-08	10-Apr-08	Overhead Electric	7	02-Apr-08*	10-Apr-08	
A2360	07-May-...	16-May-08	Electrical In-Wall	8	07-May-...	16-May-08	
A2370	21-May-...	29-May-08	Control In-Wall	7	21-May-...	29-May-08	
A2380	04-Jun-08	12-Jun-08	Fire Alarm	7	04-Jun-08*	12-Jun-08	
A2390	26-May-...	30-May-08	Electrical Rough-in - Attic	5	26-May-...	30-May-08	
A2400	02-Jul-08	11-Jul-08	Electrical Finish	8	02-Jul-08*	11-Jul-08	
A2410	03-Jun-08	09-Jun-08	Del Main Transformer	5	03-Jun-08*	09-Jun-08	
A2420	11-Jun-08	19-Jun-08	R.I Lights Entrance	7	11-Jun-08*	19-Jun-08	
A2430	26-Jun-08	02-Jul-08	Electrical Coordination	5	26-Jun-08*	02-Jul-08	

Actual Work — Critical Remaining Work — Summary
Remaining Work ◆ — ◆ Milestone

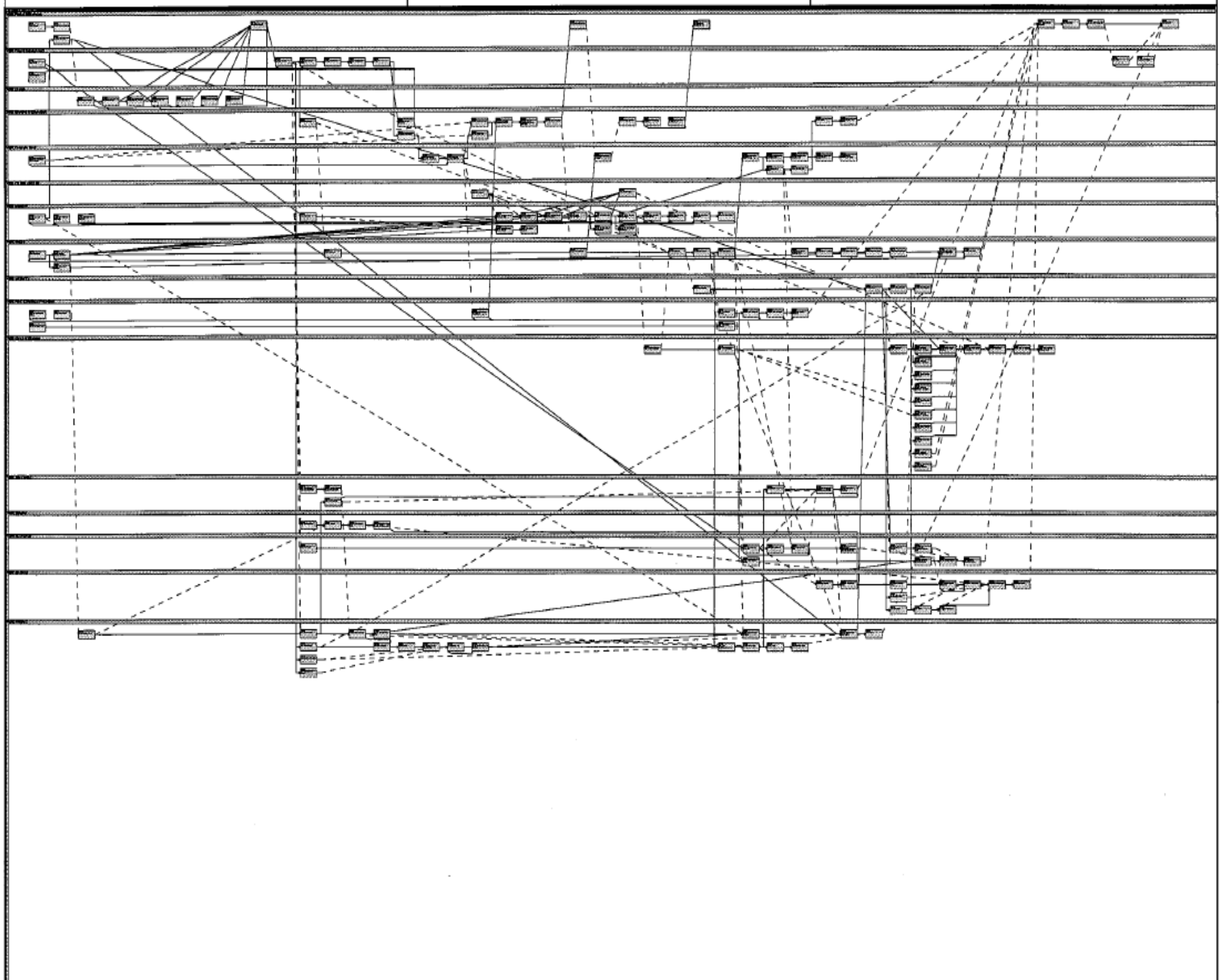
TASK filter: All Activities

Activity ID	Planned Start	Planned Finish	Activity Name	Original Duration	Start	Finish	Total Float
Finishes	05-Dec-07	19-Aug-08		182	05-Dec-07	19-Aug-08	0
A1790	16-Apr-08	24-Apr-08	Fab & Del Drs/Frames/Hardware	7	16-Apr-08*	24-Apr-08	
A1920	05-Dec-07	13-Dec-07	Fab & Del Drywall	7	05-Dec-...	13-Dec-07	
A1930	09-Apr-08	24-Apr-08	Fab & Del Painting	12	09-Apr-08*	24-Apr-08	
A1940	16-Apr-08	22-Apr-08	Fab & Del Act Ceil Grid	5	16-Apr-08*	22-Apr-08	
A1950	16-Jun-08	20-Jun-08	Fab & Del Vynil Tile, FEC	5	16-Jun-08*	20-Jun-08	
A1960	21-Apr-08	24-Apr-08	Fab & Del Custom Carpet	4	21-Apr-08*	24-Apr-08	
A1970	13-Jun-08	17-Jun-08	Install Exterior Studs/ Sheath	3	13-Jun-08*	17-Jun-08	
A1980	09-Jun-08	13-Jun-08	Install Interior Studs and Frames	5	09-Jun-08*	13-Jun-08	
A1990	17-Jul-08	23-Jul-08	Sheetrock Chases	5	17-Jul-08*	23-Jul-08	
A2000	02-Jun-08	06-Jun-08	Build Elevator Shaft	5	02-Jun-08*	06-Jun-08	
A2010	25-Jun-08	02-Jul-08	Insulate/Hang Drywall	6	25-Jun-08*	02-Jul-08	
A2030	24-Jul-08	30-Jul-08	Finish Drywal	5	24-Jul-08*	30-Jul-08	
A2040	24-Jul-08	31-Jul-08	Prime Paint	6	24-Jul-08*	31-Jul-08	
A2050	03-Jun-08	20-Jun-08	Install Ceiling Grid	14	03-Jun-08*	20-Jun-08	
A2060	03-Jun-08	12-Jun-08	Install Sheetrock & Tape Ceiling	8	03-Jun-08*	12-Jun-08	
A2070	14-Aug-08	19-Aug-08	Final Paint	4	14-Aug-...	19-Aug-08	
A2090	15-Jul-08	21-Jul-08	Ceramic Tile Toilet	5	15-Jul-08*	21-Jul-08	
A2100	25-Jun-08	03-Jul-08	Install Slate Flooring to Building	7	25-Jun-08*	03-Jul-08	
A2110	27-Jun-08	09-Jul-08	Flood Ceiling Tile	9	27-Jun-08*	09-Jul-08	

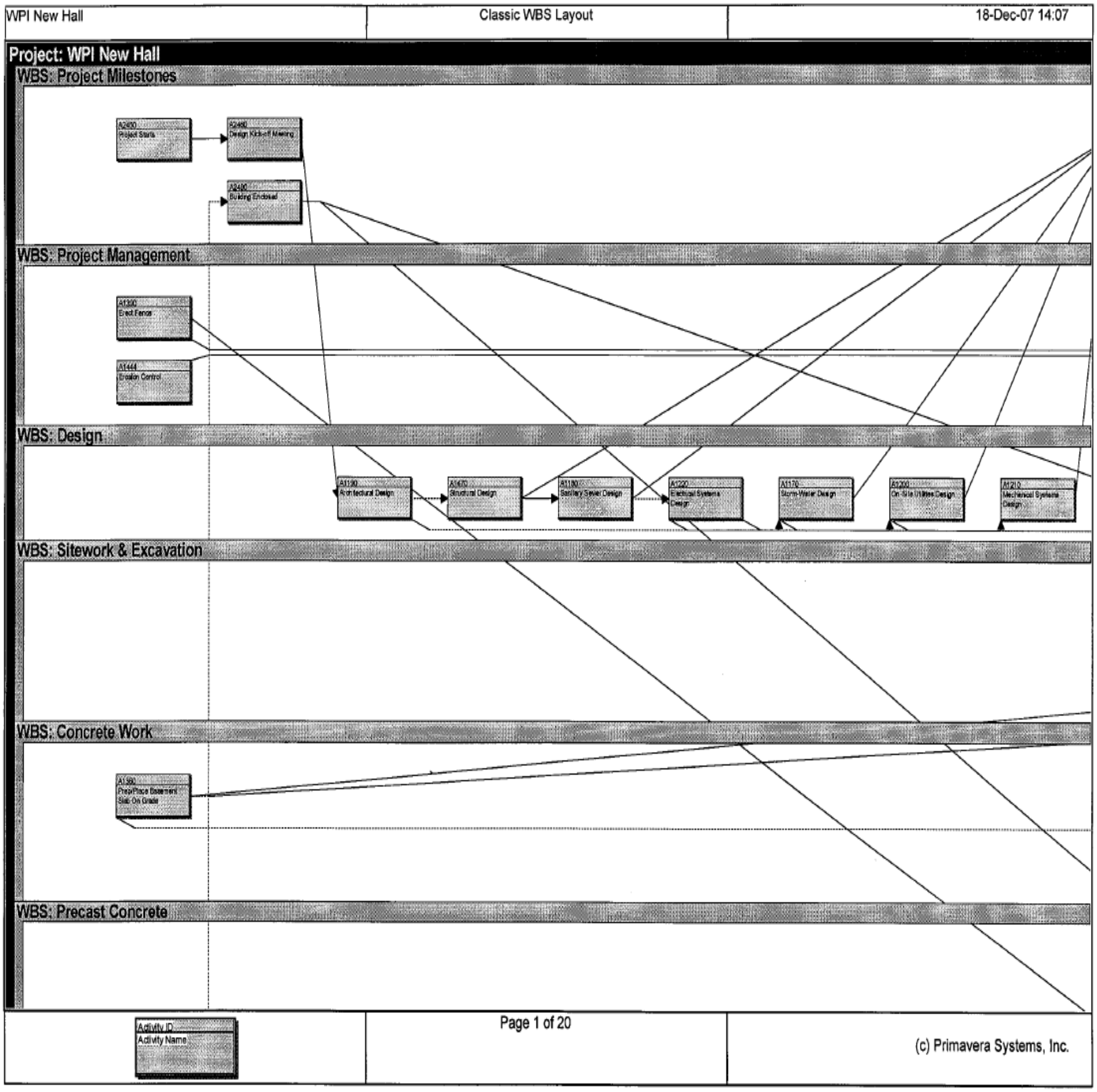
Actual Work | Critical Remaining Work | Summary
Remaining Work ◆ | ◆ Milestone

TASK filter: All Activities

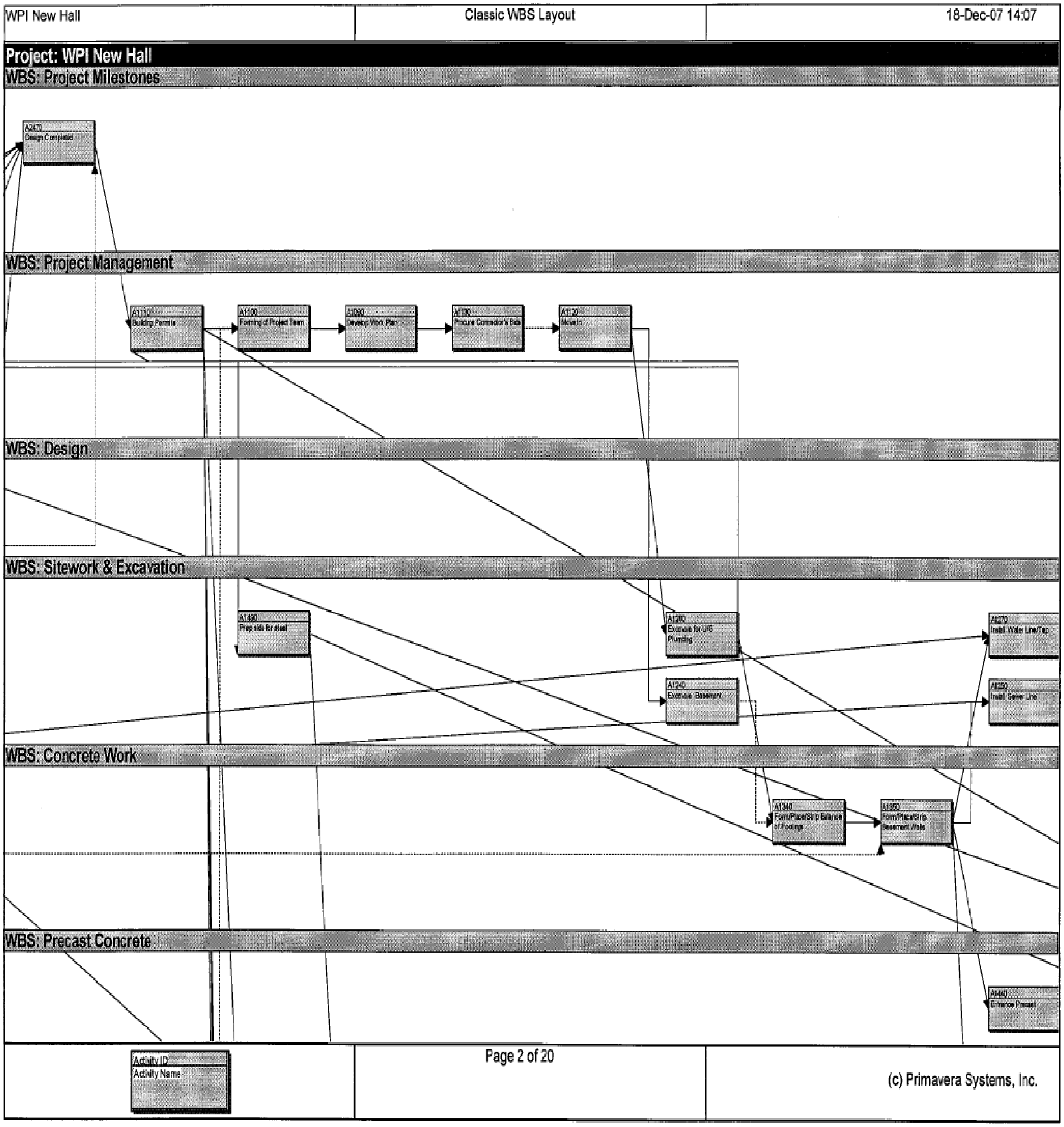
WPI New Hall	Classic WBS Layout	18-Dec-07 14:05



Activity ID Activity Name	Page 1 of 1	(c) Primavera Systems, Inc.



WPI New Hall
Classic WBS Layout
18-Dec-07 14:07
Project: WPI New Hall
WBS: Project Milestones
A2430
Project Starts
A2460
Design Kick-off Meeting
A2400
Building Enclosed
WBS: Project Management
A1330
Erect Fence
A1444
Erosion Control
WBS: Design
A1190
Architectural Design
A1470
Structural Design
A1180
Sanitary Sewer Design
A1220
Electrical Systems Design
A1170
Storm-Water Design
A1200
On-Site Utilities Design
A1210
Mechanical Systems Design
WBS: Sitework & Excavation
WBS: Concrete Work
A1360
Prep/Place Basement Slab-On Grade
WBS: Precast Concrete
Activity ID
Activity Name
Page 1 of 20
(c) Primavera Systems, Inc.



WPI New Hall
Classic WBS Layout
18-Dec-07 14:07
Project: WPI New Hall
WBS: Project Milestones
A2470
Design Completed
WBS: Project Management
A1110
Building Permits
A1100
Forming of Project Team
A1090
Develop Work Plan
A1130
Procure Contractor's Bids
A1120
Move In
WBS: Design
WBS: Sitework & Excavation
A1460
Prep site for steel
A1260
Excavate for U/G Plumbing
A1240
Excavate Basement
A1270
Install Water Line/Tap
A1250
Install Sewer Line
WBS: Concrete Work
A1340
Form/Place/Strip Balance of Footings
A1350
Form/Place/Strip Basement Walls
WBS: Precast Concrete
A1440
Entrance Precast
Activity ID
Activity Name
Page 2 of 20
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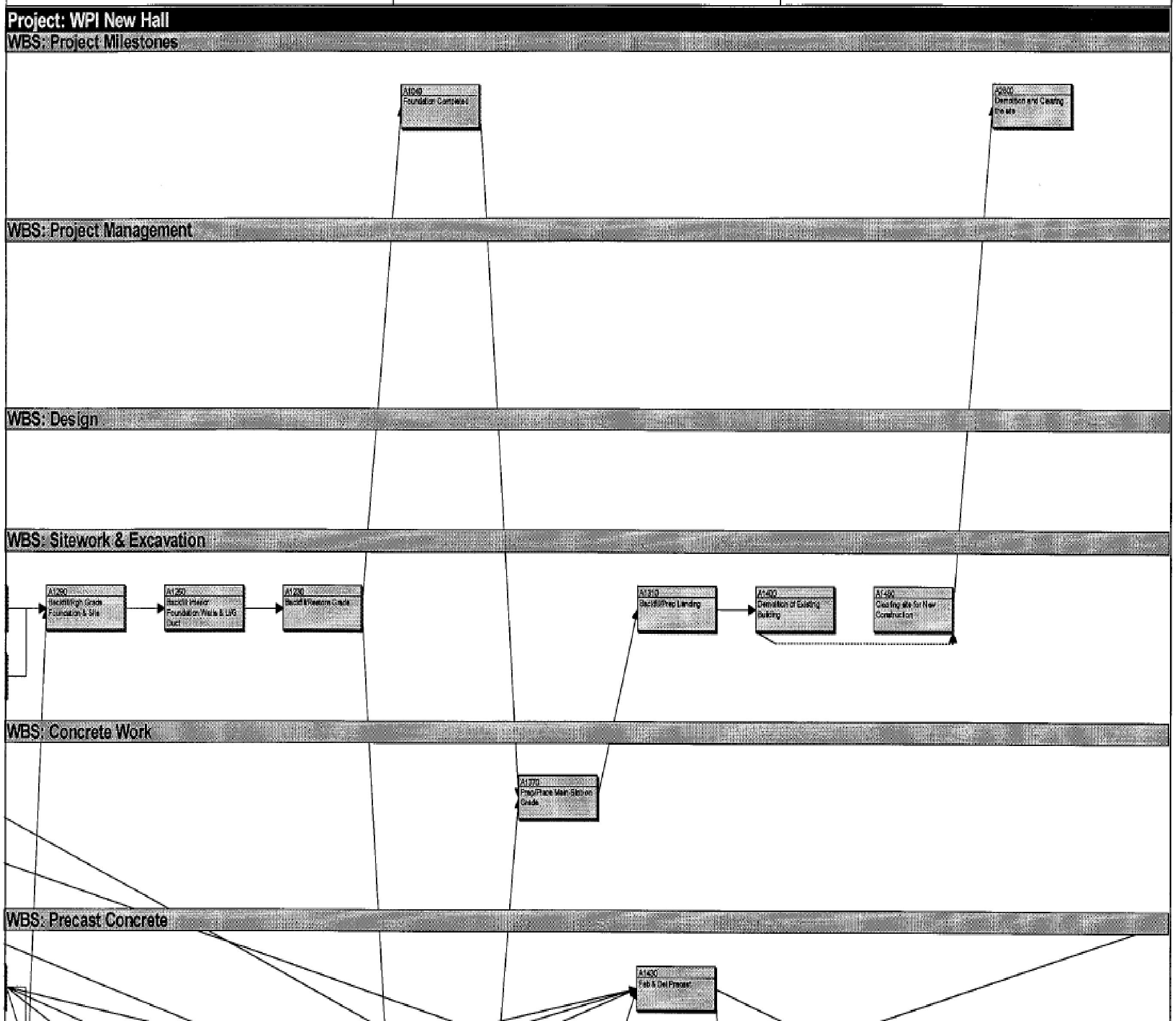
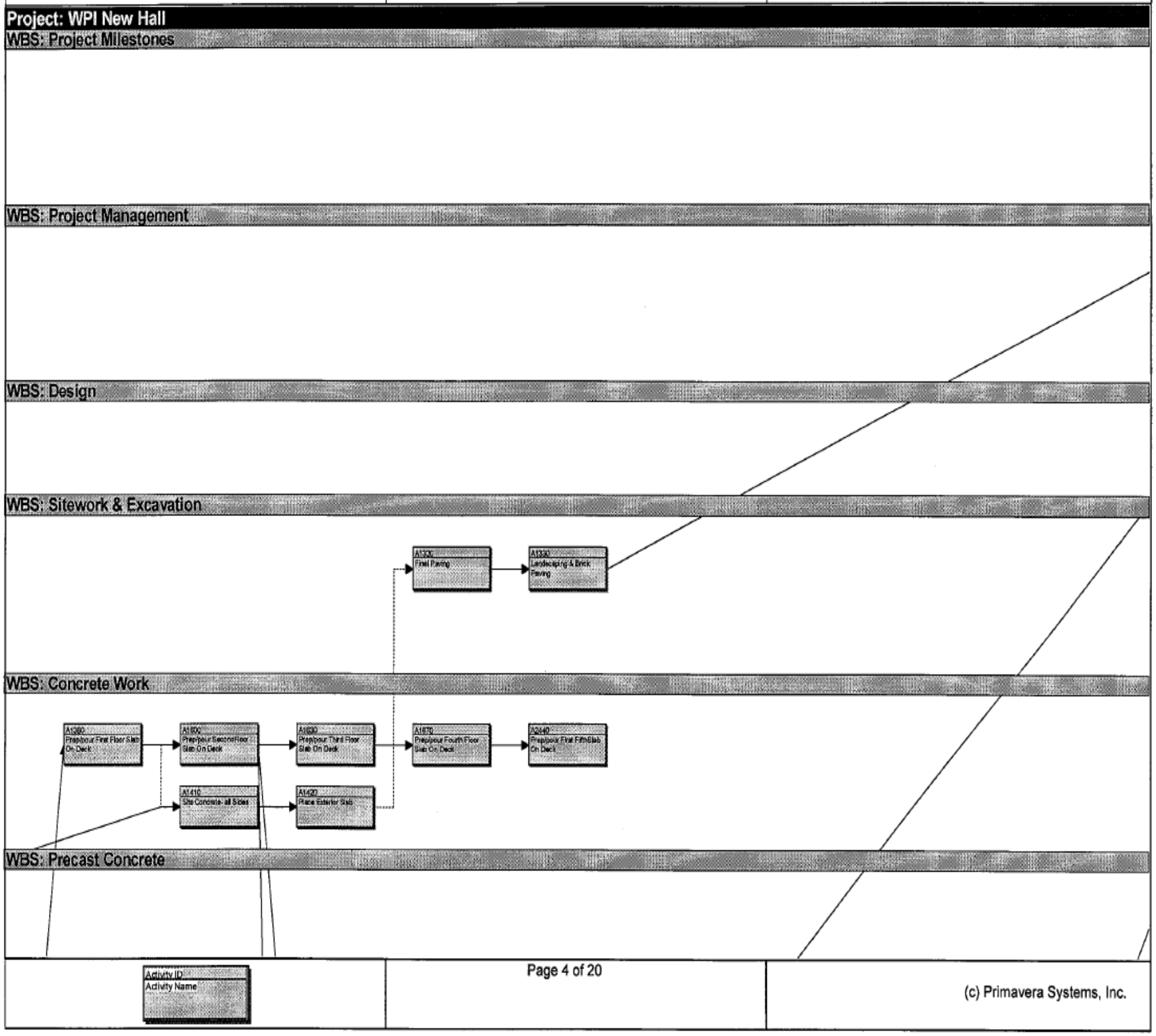
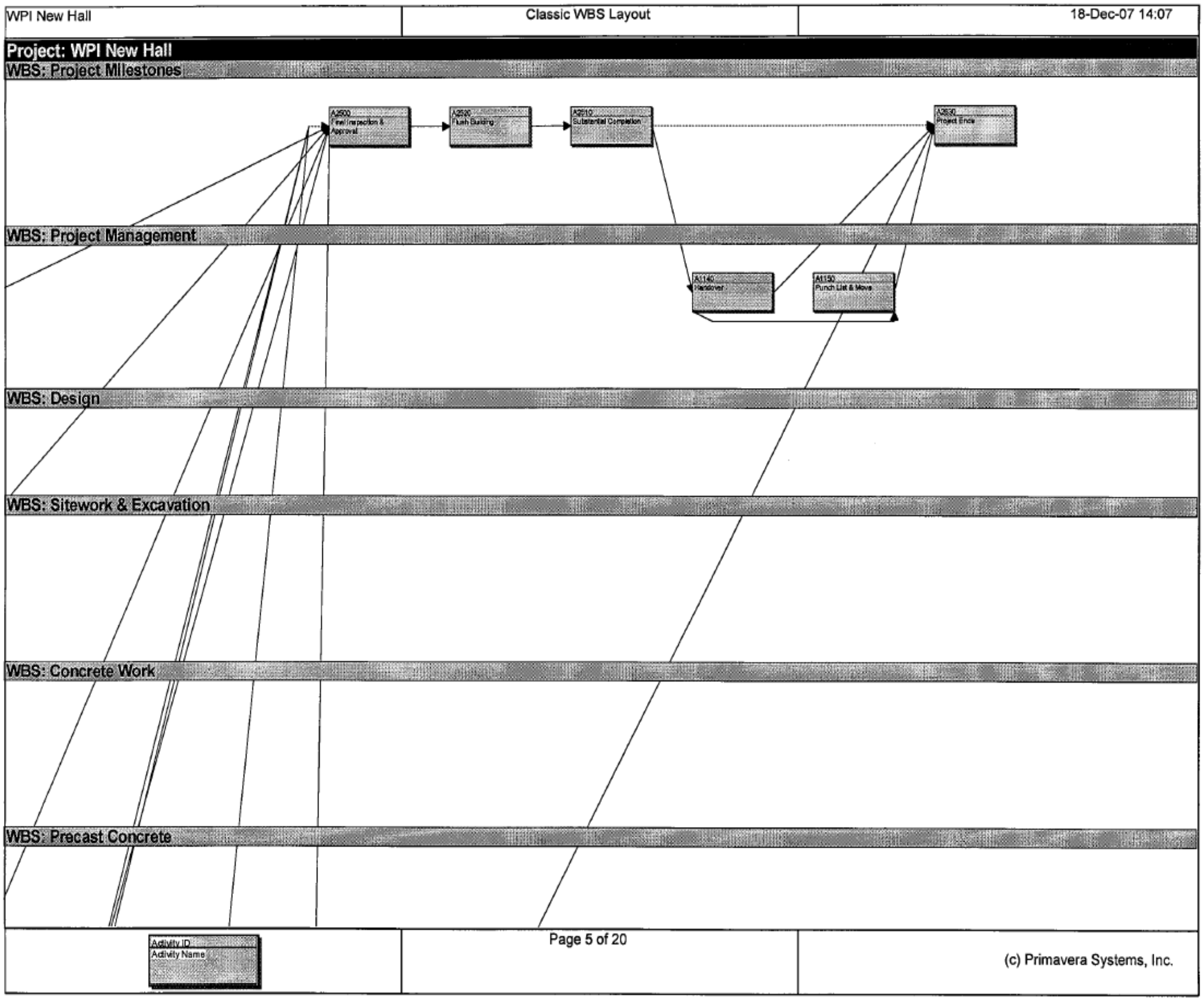
WPI New Hall	Classic WBS Layout	18-Dec-07 14:07

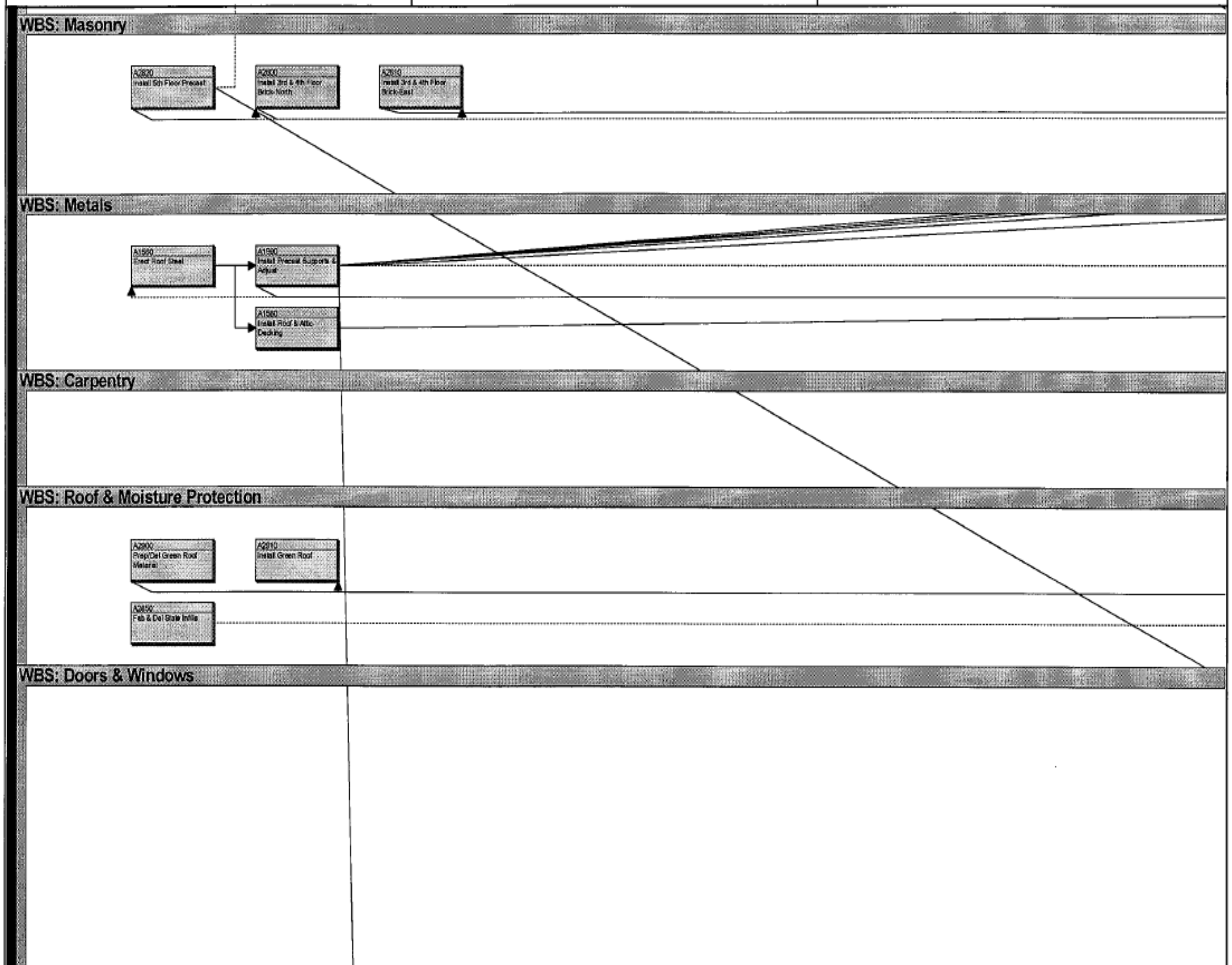


Activity ID Activity Name	Page 3 of 20	(c) Primavera Systems, Inc.

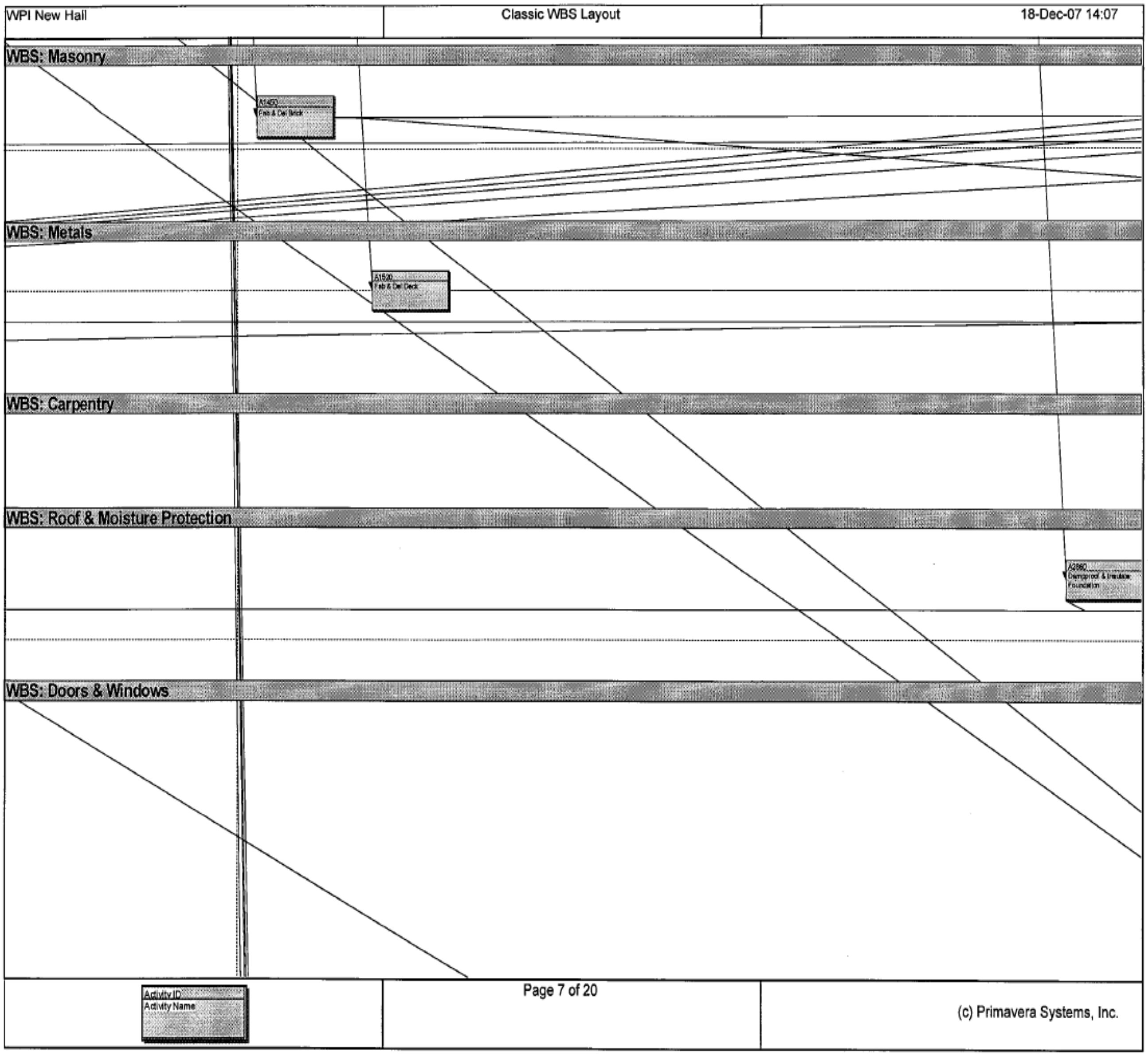

Project: WPI New Hall
WBS: Project Milestones
WBS: Project Management
WBS: Design
WBS: Sitework & Excavation
A1320
Final Paving
A1330
Landscaping & Brick Paving
WBS: Concrete Work
Prep/pour First Floor Slab On Deck
A1600
Prep/pour Second Floor Slab On Deck
A1630
Prep/pour Third Floor Slab On Deck
A1670
Prep/pour Fourth Floor Slab On Deck
A2440
Prep/pour Final Fifth Slab On Deck
A1410
Site Concrete- all Sides
A1420
Place Exterior Slab
WBS: Precast Concrete
Activity ID
Activity Name


WPI New Hall
Classic WBS Layout
18-Dec-07 14:07
Project: WPI New Hall
WBS: Project Milestones
A2500
Final Inspection & Approval
A2520
Flush Building
A2510
Substantial Completion
A2530
Project Ends
WBS: Project Management
A1140
Handover
A1150
Punch List & Move
WBS: Design
WBS: Sitework & Excavation
WBS: Concrete Work
WBS: Precast Concrete
Activity ID
Activity Name
Page 5 of 20
(c) Primavera Systems, Inc.

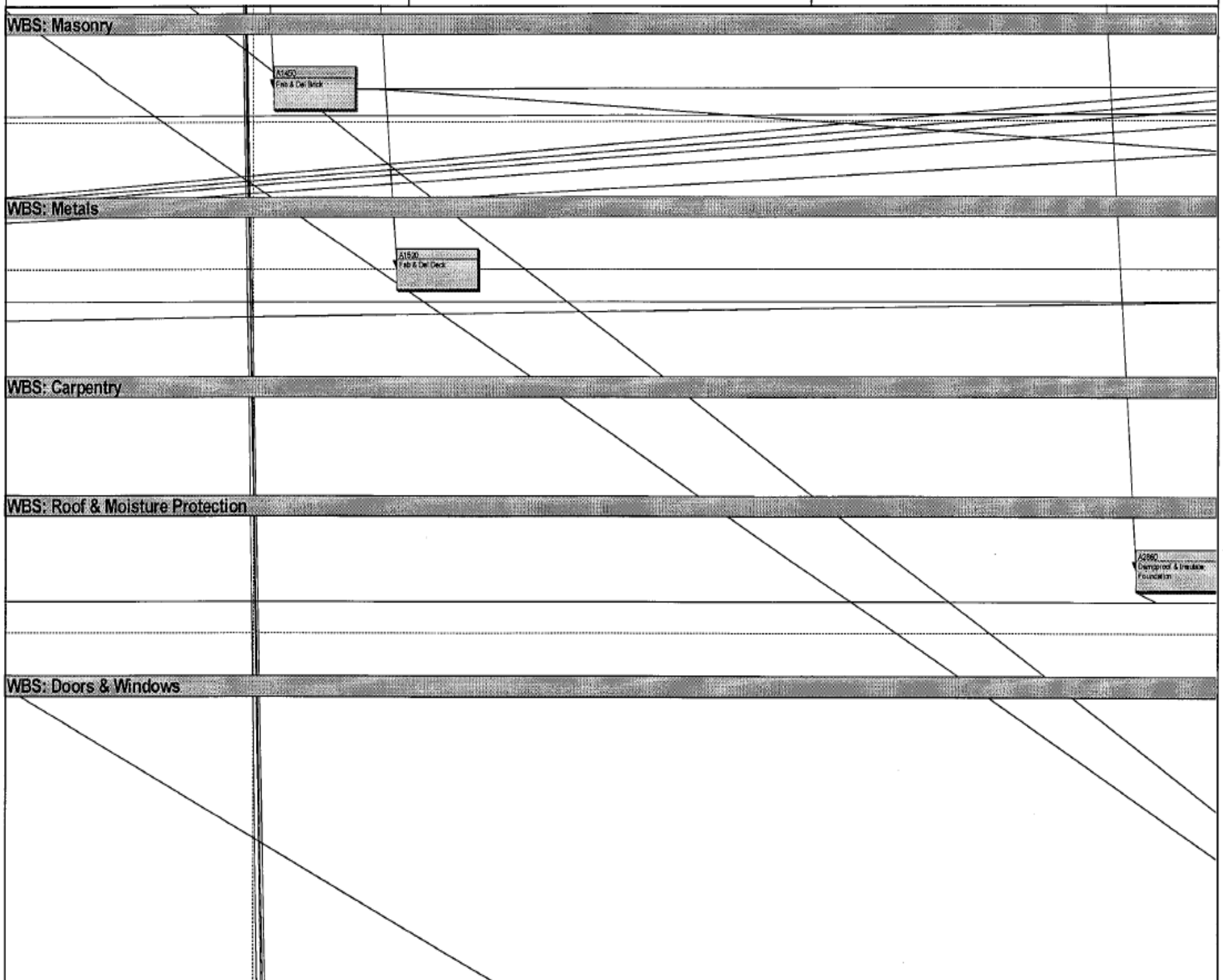
WPI New Hall	Classic WBS Layout	18-Dec-07 14:07



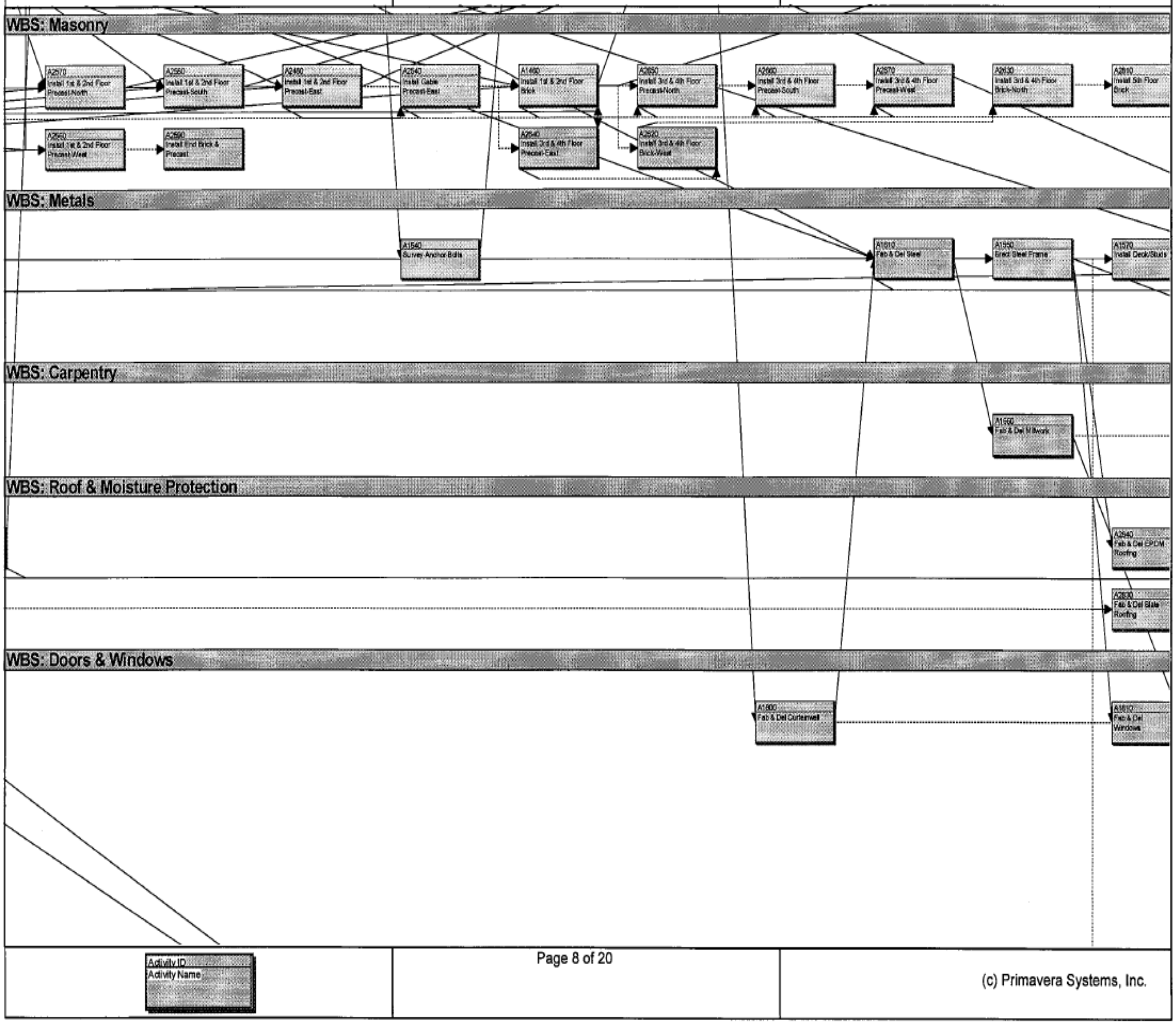
Activity ID / Activity Name	Page 6 of 20	(c) Primavera Systems, Inc.

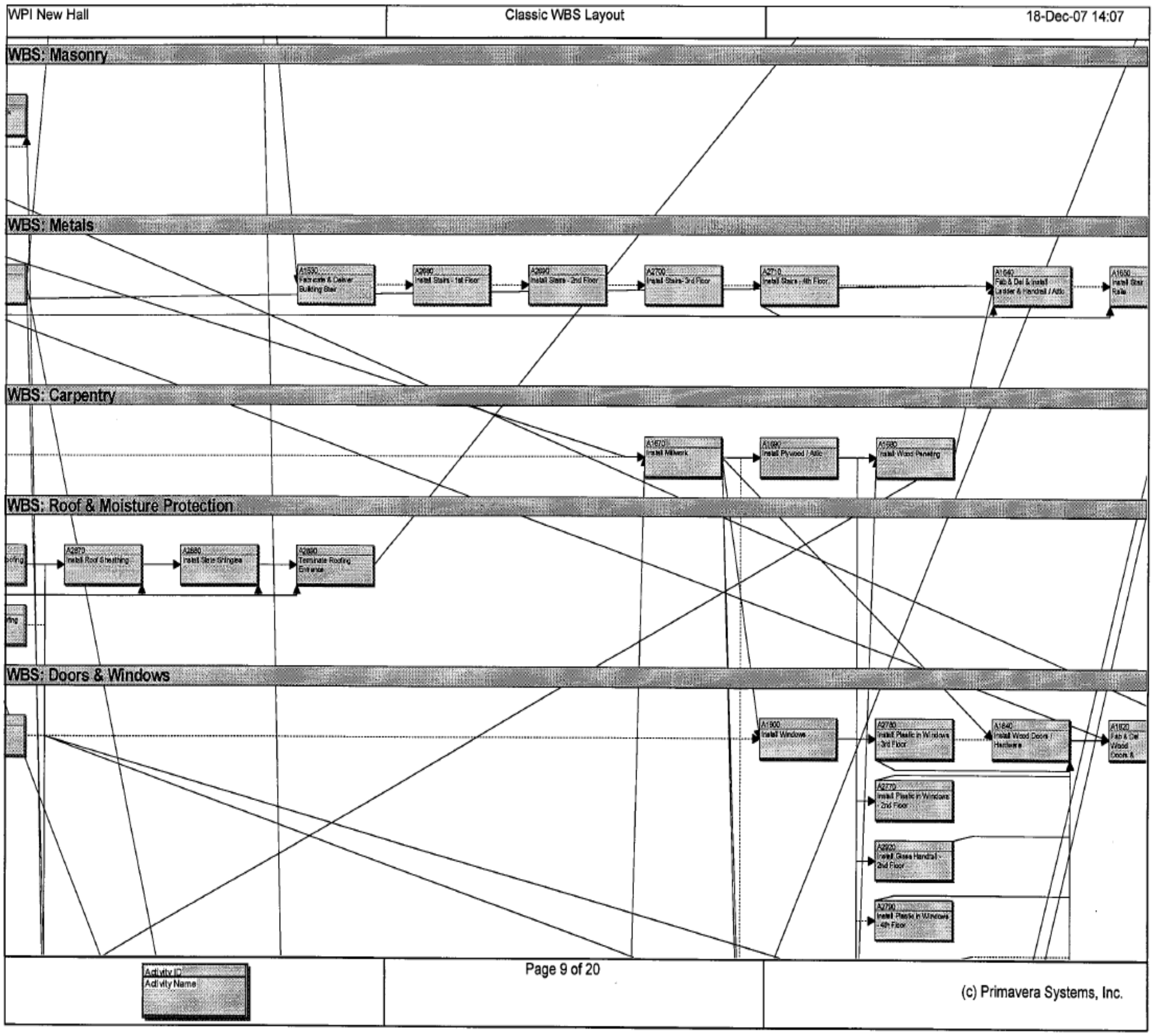


WPI New Hall
Classic WBS Layout
18-Dec-07 14:07
WBS: Masonry
A1450
Fab & Del Brick
WBS: Metals
A1520
Fab & Del Deck
WBS: Carpentry
WBS: Roof & Moisture Protection
A2860
Dampproof & Insulate Foundation
WBS: Doors & Windows
Activity ID
Activity Name
Page 7 of 20
(c) Primavera Systems, Inc.



Activity ID
Activity Name


WBS: Masonry
A2570
Install 1st & 2nd Floor
Precast-North
A2580
Install 1st & 2nd Floor
Precast-South
A2480
Install 1st & 2nd Floor
Precast-East
A2540
Install Gable
Precast-East
A1460
Install 1st & 2nd Floor
Brick
A2650
Install 3rd & 4th Floor
Precast-North
A2660
Install 3rd & 4th Floor
Precast-South
A2670
Install 3rd & 4th Floor
Precast-West
A2630
Install 3rd & 4th Floor
Brick-North
A2810
Install 5th Floor
Brick
A2560
Install 1st & 2nd Floor
Precast-West
A2590
Install End Brick &
Precast
A2640
Install 3rd & 4th Floor
Precast-East
A2620
Install 3rd & 4th Floor
Brick-West
WBS: Metals
A1540
Survey Anchor Bolts
A1510
Fab & Del Steel
A1550
Erect Steel Frame
A1570
Install Deck/Studs
WBS: Carpentry
A1560
Fab & Del Millwork
WBS: Roof & Moisture Protection
A2840
Fab & Del EPDM
Roofing
A2830
Fab & Del Slate
Roofing
WBS: Doors & Windows
A1800
Fab & Del Curtainwall
A1810
Fab & Del
Windows
Activity ID
Activity Name



WPI New Hall
Classic WBS Layout
18-Dec-07 14:07
WBS: Masonry
WBS: Metals
WBS: Carpentry
WBS: Roof & Moisture Protection
WBS: Doors & Windows
Activity ID
Activity Name
Page 9 of 20
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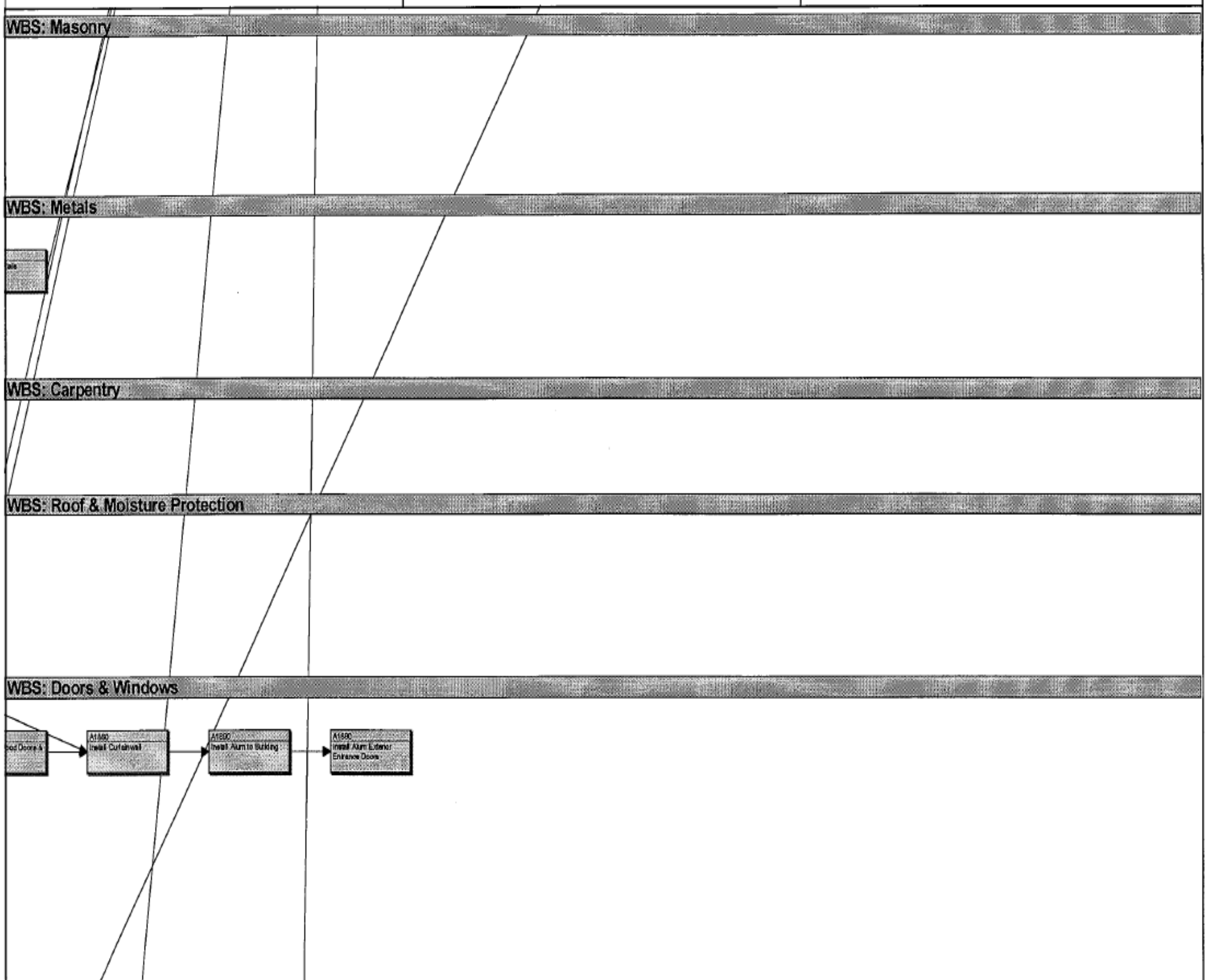


Activity ID
Activity Name

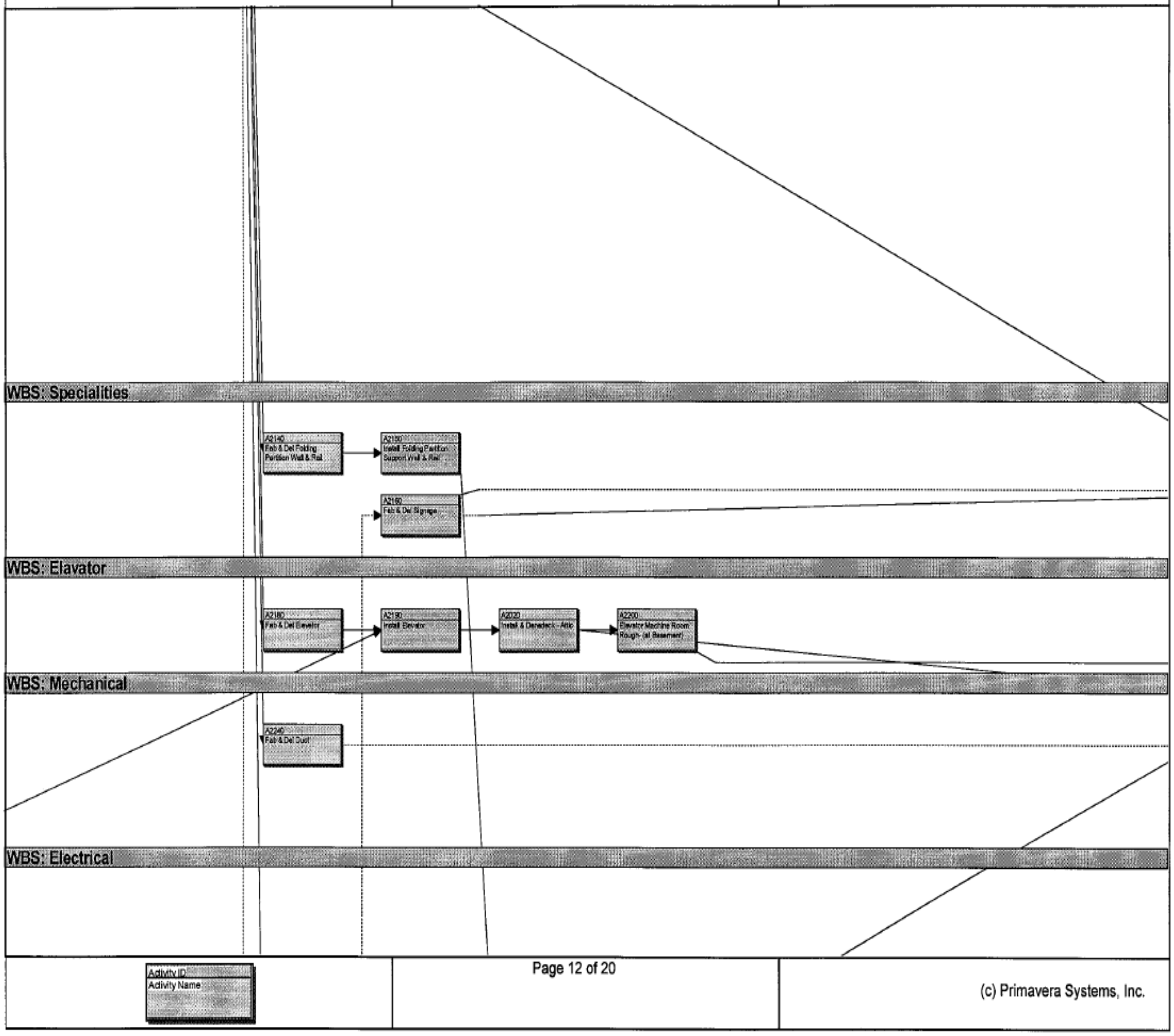
WBS: Specialities

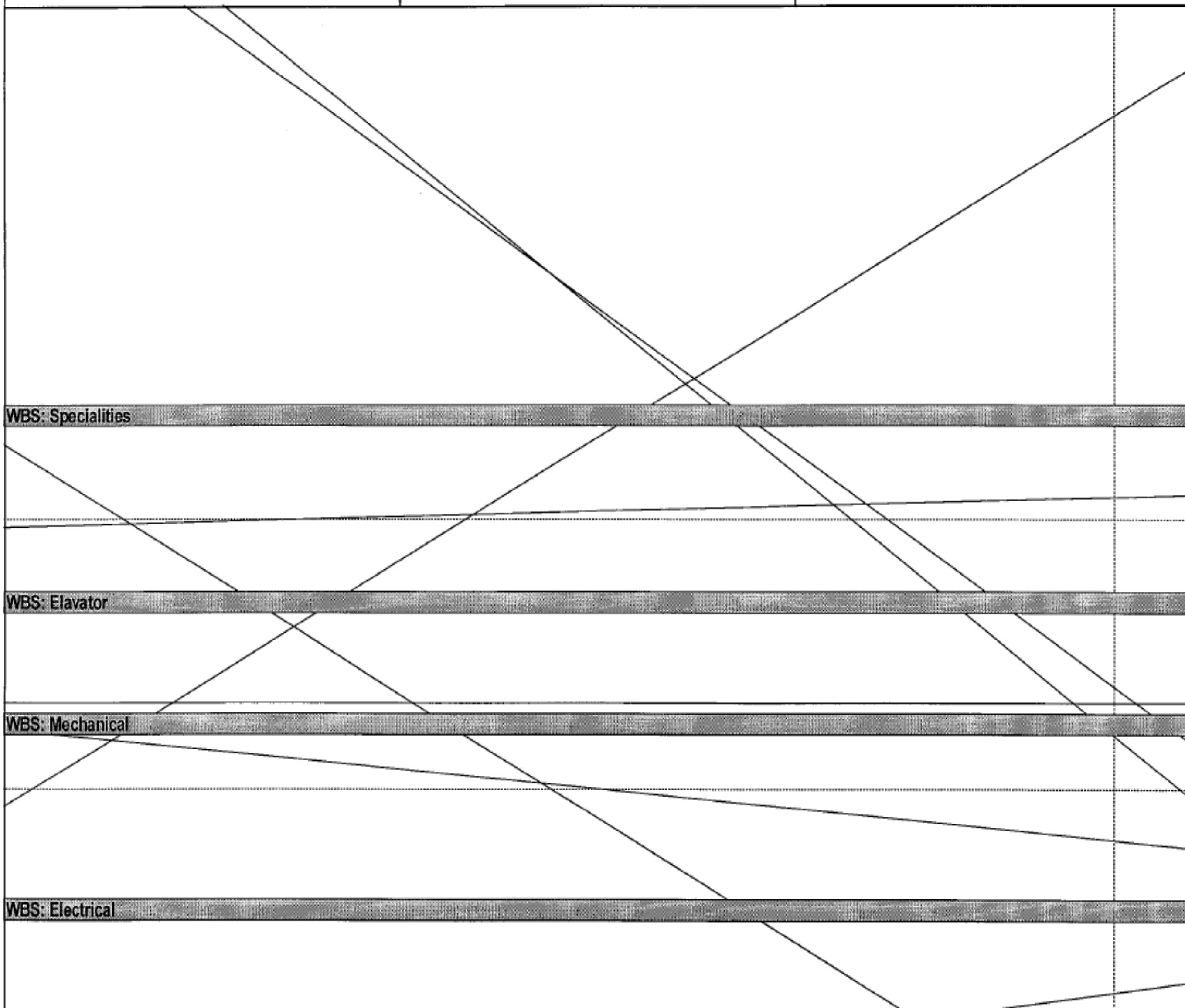
WBS: Elavator

WBS: Mechanical

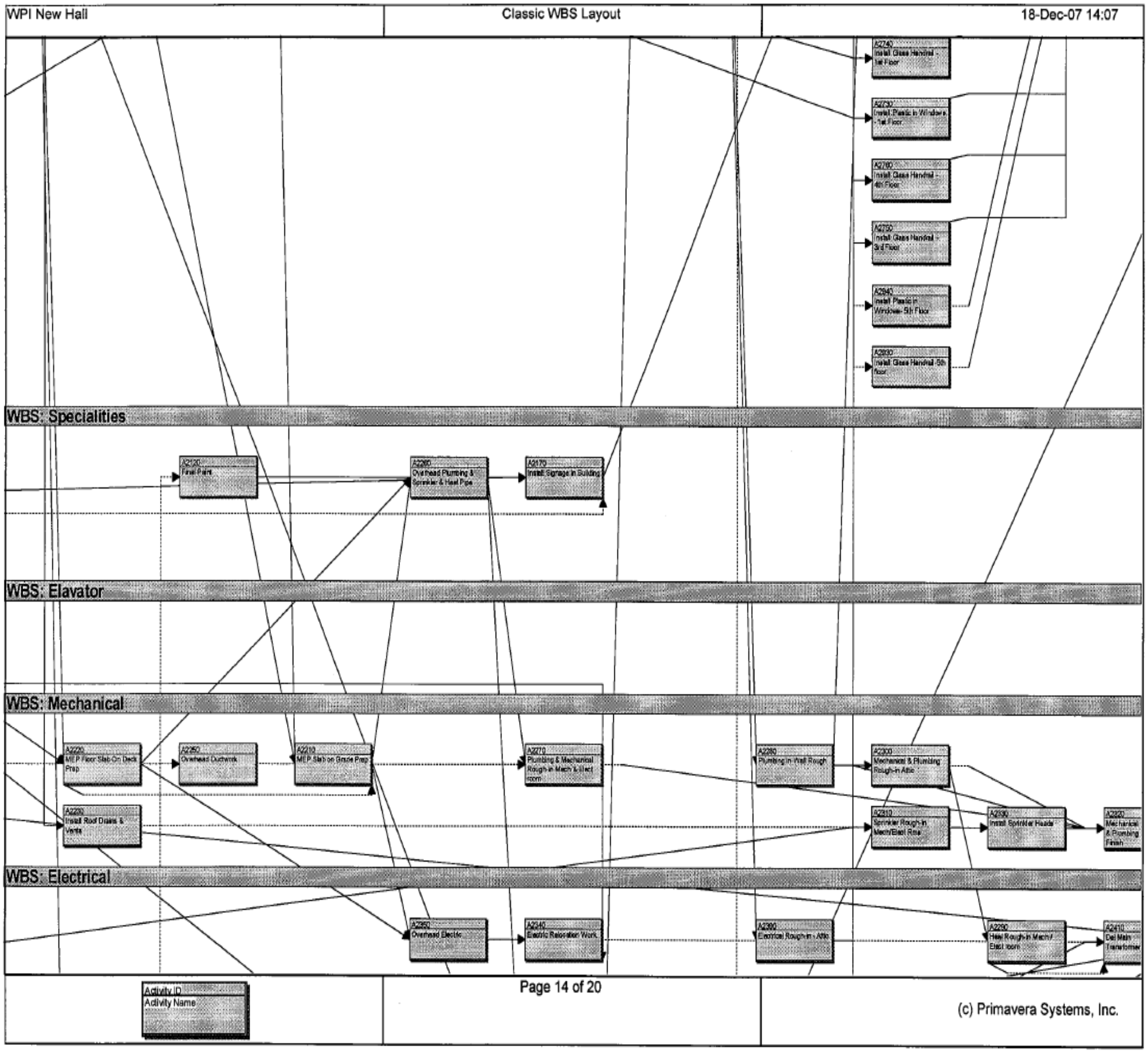
WBS: Electrical

Activity ID
Activity Name


WBS: Specialities
A2140
Fab & Del Folding Partition Wall & Rail
A2150
Install Folding Partition Support Wall & Rail
A2160
Fab & Del Signage
WBS: Elavator
A2180
Fab & Del Elevator
A2190
Install Elevator
A2020
Install & Danadeck - Attic
A2200
Elevator Machine Room Rough- (at Basement)
WBS: Mechanical
A2240
Fab & Del Duct
WBS: Electrical
Activity ID
Activity Name



Activity ID
Activity Name


WPI New Hall
Classic WBS Layout
18-Dec-07 14:07
A2740
Install Glass Handrail - 1st Floor
A2730
Install Plastic in Windows - 1st Floor
A2760
Install Glass Handrail - 4th Floor
A2750
Install Glass Handrail - 3rd Floor
A2840
Install Plastic in Windows- 5th Floor
A2830
Install Glass Handrail -5th floor
WBS: Specialities
A2120
Final Paint
A2260
Overhead Plumbing & Sprinkler & Heat Pipe
A2170
Install Signage in Building
WBS: Elavator
WBS: Mechanical
A2220
MEP Floor Slab-On Deck Prep
A2250
Overhead Ductwork
A2210
MEP Slab on Grade Prep
A2270
Plumbing & Mechanical Rough-in Mech & Elect room
A2280
Plumbing In-Wall Rough
A2300
Mechanical & Plumbing Rough-in Attic
A2230
Install Roof Drains & Vents
A2310
Sprinkler Rough-in Mech/Elect Rms
A2330
Install Sprinkler Heads
A2320
Mechanical & Plumbing Finish
WBS: Electrical
A2350
Overhead Electric
A2340
Electric Relocation Work
A2360
Electrical Rough-in - Attic
A2290
Heat Rough-in Mech / Elect room
A2410
Del Main Transformer
Activity ID
Activity Name
Page 14 of 20
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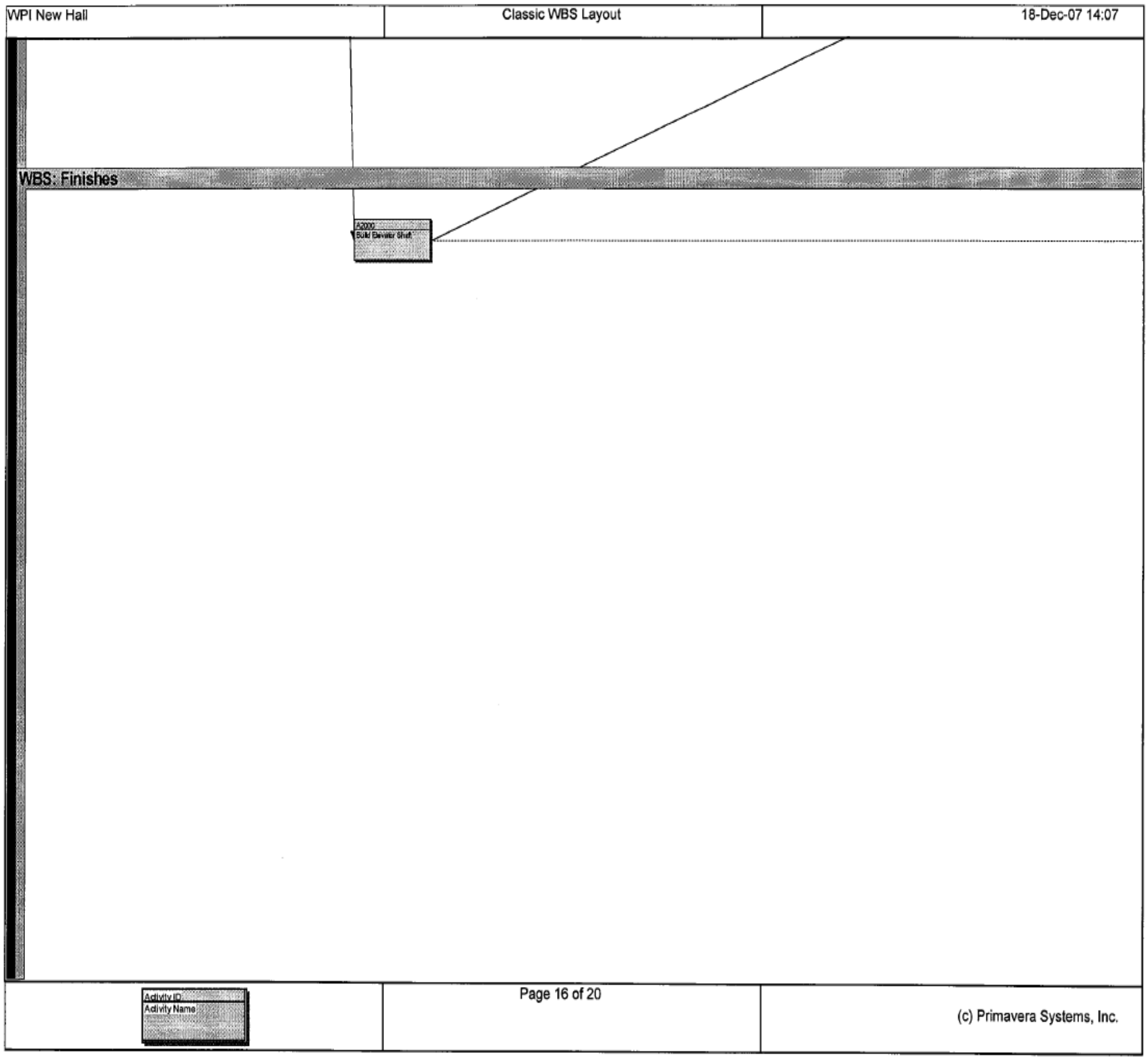
WPI New Hall
Classic WBS Layout
18-Dec-07 14:07
WBS: Finishes
A2000
Build Elevator Shaft
Activity ID
Activity Name
Page 16 of 20
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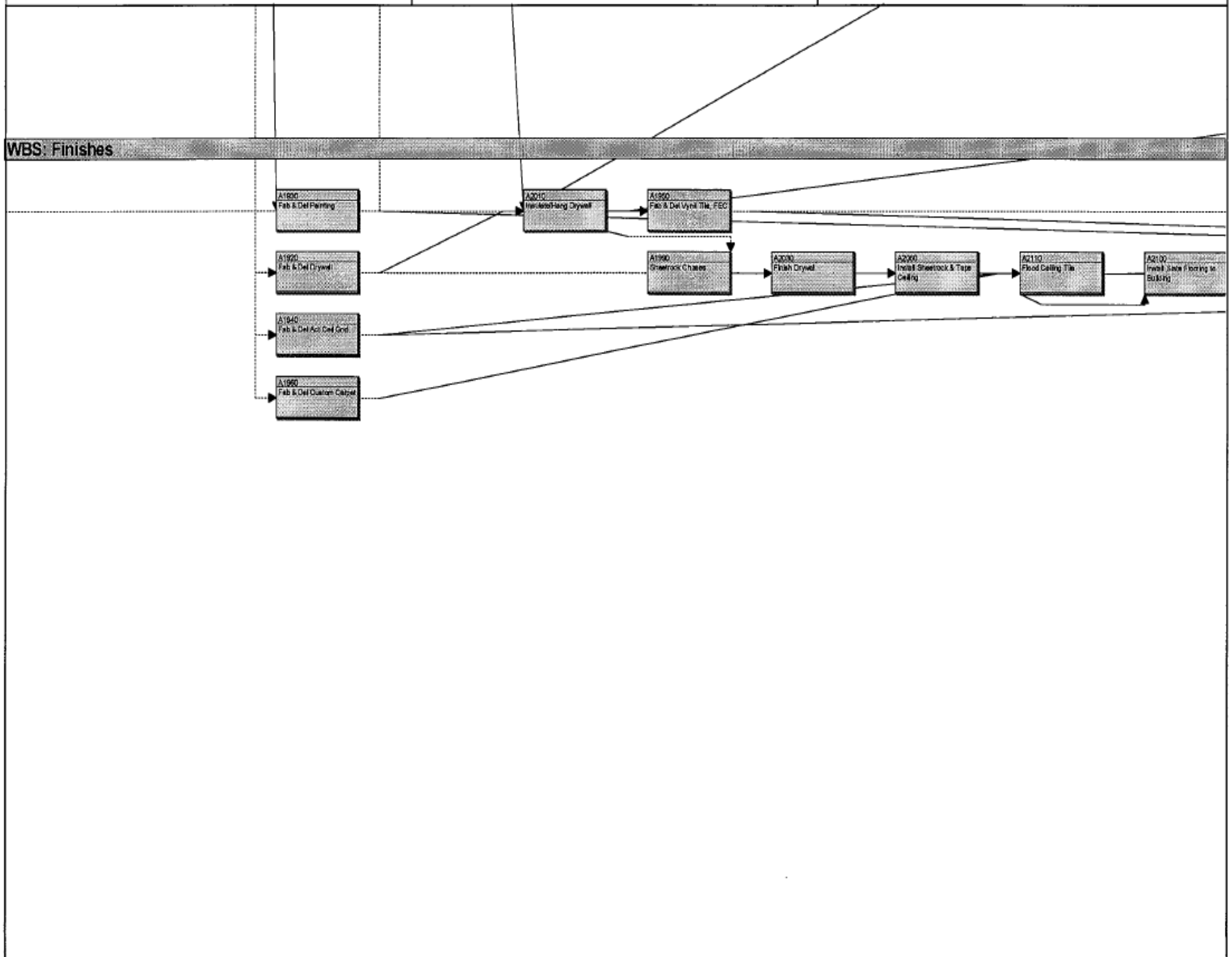
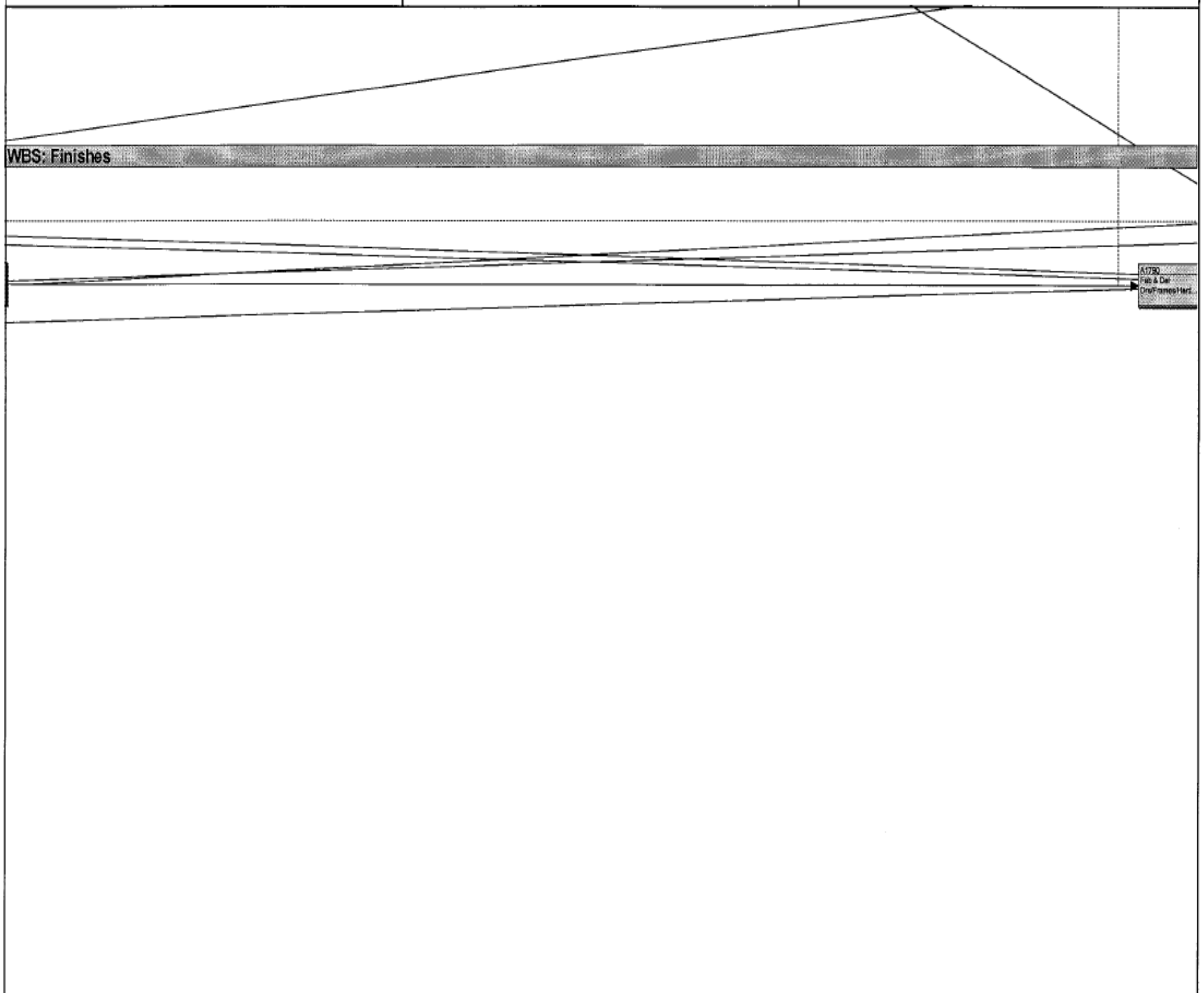
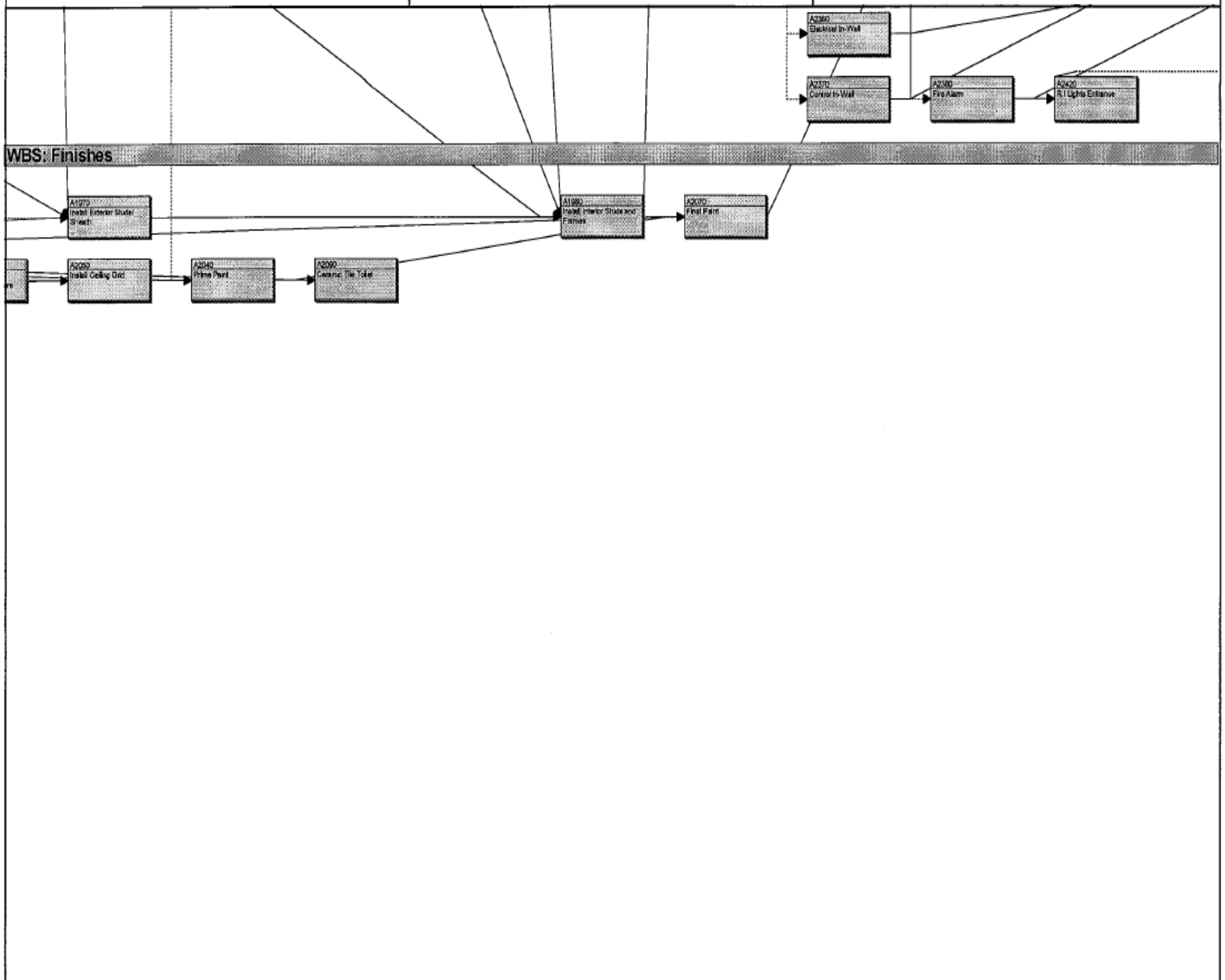


Activity ID
Activity Name


WBS: Finishes
A1790
Fab & Del
Drs/Frames/Hard...


A2360
Electrical In-Wall
A2370
Control In-Wall
A2380
Fire Alarm
A2420
R.I Lights Entrance
WBS: Finishes
A1970
Install Exterior Studs/ Sheath
A1980
Install Interior Studs and Frames
A2070
Final Paint
A2050
Install Ceiling Grid
A2040
Prime Paint
A2090
Ceramic Tile Toilet

WBS: Finishes

Activity ID
Activity Name

Appendix F: Permits

This appendix includes sample permits that are usually needed for residential construction.

Application to construct repair renovate change the use or occupancy of any building other than a one or two family dwelling

	The Commonwealth of Massachusetts **State Board of Building Regulations and Standards** **Massachusetts State Building Code** **780 CMR**	**City of Holyoke** **Department of Codes and Inspections** **20 Korean Veterans Plaza, room 300** **Holyoke, Massachusetts 01040** **Telephone: (413)-534-2193**

APPLICATION TO CONSTRUCT REPAIR RENOVATE CHANGE THE UES OR OCCUPANCY OF ANY BUILDING OTHER THAN A ONE OR TWO FAMILY DWELLING

This Section For Official Use Only

Building Permit Number: **Date Issued:**

Signature:_______________________________________ ________________

Building Commissioner / Inspector **Date**

SECTION 1-- SITE INFORMATION

1.1 Property Address: ________________________________	1.2 Assessor's Map, Block, and Lot Number: __________ __________ __________ Map Block Lot
1.3 Zoning Information: __________ ____________________ Zoning District Proposed Use	1.4 Property dimensions: Corner Lot ☐ ______________ ______________ Lot Area (sf) Frontage (ft)

1.6 Building Setbacks (ft)

Front Yards		Side Yards		Rear Yard	
Required	Provided	Required	Provided	Required	Provided
		/	/		

1.7 Water Supply (MGL c 40 § 54 Public ☐ Private ☐	1.5 Flood Zone Information: Zone______ Outside Flood Zone ☐	1.8 Sewage disposal system: Municipal ☐ On site disposal system ☐

SECTION 2-- PROPERTY OWNERSHIP / AUTHORIZED AGENT

2.1 Owner of Record:

________________________________ ________________________________

Name (Print) Address:

________________________________ ________________________________

Signature Telephone

22 Authorized Agent:

________________________________ ________________________________

Name (Print) Address:

________________________________ ________________________________

Signature Telephone

SECTION 3-- CONSTRUCTION SERVICES FOR PROJECTS LESS THAN 35,000 CUBIC FEET OF ENCLOSED SPACE

3.1 Licensed Construction Supervisor: ______________________ Licensed Construction Supervisor: ______________________ Address ______________ ______________ Signature Telephone	Not Applicable ☐ ______________ License Number ______________ Expiration Date
3.2 Registered Home Improvement contractor: ______________________ Company Name ______________________ Address ______________ ______________ Signature Telephone	Not Applicable ☐ ______________ License Number ______________ Expiration Date

SECTION 4-- WORKERS COMPENSATION INSURANCE AFFIDAVIT (M.G.L. C 152 § 25C(6)

Workers Compensation Insurance affidavit must be completed and submitted with this application. Failure to provide this affidavit will result in the denial of the issuance of the building permit. Signed Affidavit attached Yes ☐ No ☐

SECTION 5-- PROFESSIONAL DESIGN AQND CONSTRUCTION SERVICES FOR BUILDINGS AND STRUCTURES SUBJECT TO CONSTRUCTION CONTROL PURSUANT TO 780 CMR 116 (CONTAINING MORE THAN 35, OON C. F. OF ENCLOSED SPACE)

5.1 Registered Architect:

______________________ Name (Registrant): ______________________ Address ______________ ______________ Signature Telephone	Not Applicable ☐ ______________ Registration Number ______________ Expiration Date

5.2 Registered Professional Engineer(s):

______________________ Name ______________________ Address ______________ ______________ Signature Telephone	______________ Area of Responsibility ______________ Registration Number ______________ Expiration Date

Name Address Signature Telephone	Area of Responsibility Registration Number Expiration Date
Name Address Signature Telephone	Area of Responsibility Registration Number Expiration Date
Name Address Signature Telephone	Area of Responsibility Registration Number Expiration Date

5.3 General Contractor

Company Name Responsible in Charge of Construction Address Signature Telephone	Not Applicable ☐

SECTION 6-- DESCRIPTION OF PROPOSED WORK (check all applicable)

New Construction ☐	Existing Building ☐	Repairs ☐	Alterations ☐	Addition ☐
Accessory Building ☐	Demolition ☐	Other ☐ Specify		
Brief Description of Proposed Work				

SECTION 7-- USE GROUP AND CONSTRUCTION

USE GROUP (Check all that apply)					CONSTRUCTION TYPE	
A. Assembly	☐	A-1 ☐ A-4 ☐	A-2 ☐ A-5 ☐	A-3 ☐	1A 1B	☐ ☐
B. Business	☐				2A	☐
E. Educational	☐				2B	☐
F. Factory	☐	F-1 ☐	F-2 ☐		2C	☐
H. High Hazard	☐				3A	☐
I. Institutional	☐	I-1 ☐	I-2 ☐	I-3 ☐	3B	☐
M. Mercantile	☐				4	☐
R. Residential	☐	R-1 ☐	R-2 ☐	R-3 ☐	5A	☐
S. Storage	☐	S-1 ☐	S-2 ☐	S-3 ☐	5B	☐
U. Utility	☐	Specify:________________________________				
M. Mixed Use	☐	Specify:________________________________				
S. Special Use	☐	Specify:________________________________				

COMPLETE THIS SECTION IF EXISTING BUILDING UNDERGOING RENOVATIONS, ADDITIONS AND / OR CHANGE IN USE

Existing Use Group:______________________________	Proposed Use Group:________________________
Existing Hazard Index 780 CMR 34:_________________	Proposed Hazard Index 780 CMR 34:__________

SECTION 8-- BUILDING HEIGHT AND AREA

BUILDING AREA	EXISTING(if applicable)	PROPOSED
Number of floors or stories include Basement levels		
Floor Area per floor (sf)		
Total Area (sf)		
Total Height (ft)		

SECTION 9-- STRUCTURAL PEER REVIEW (780 CMR 110.11)

Independent Structural Engineering Structural Peer Review Required	Yes……☐	No……☐

SECTION 10A-- OWNER AUTHORIZATION TO BE COMPLETED WHEN OWNERS AGENT OR CONTRACTOR APPLIES FOR BUILDING PERMIT

I,____as Owner of the subject property

hereby authorize____ to act on my

behalf in all matters relative to work authorized by this building permit application.

____ _________________________

Signature of Owner Date

SECTION 10B-- OWNER / AUTHORIZED AGENT DECLARATION

I,____as Owner /Authorized Agent Hereby declare that the statements and information on the foregoing application are true and accurate to the best of my knowledge and belief. Signed under the pains and penalties of perjury.

____
Print Name

____ ____________________
Signature of Owner / Agent Date

SECTION 11 ESTIMATED CONSTRUCTION COSTS

Item	Estimated Cost (Dollars) to be completed by permit applicant	**Official Use Only**	
1. Building		(a)Building Permit Fee Multiplier	
2. Electrical		(b)Building Area from section 8 above	
3. Plumbing		Building Permit Fee	
4. Mechanical (HVAC)			
5. Fire Protection			
6. Total = (1 + 2 + 3 + 4 + 5)		Check Number	

__Tax Collector Affidavit__

This is to certify that, in accordance with Chapter 74 of the Acts of 1996, the persons and properties named herein have no uncollected taxes, fines, fees or other charges owing to the City o Holyoke that would prevent the issuance of permits.

____ ____________________
Holyoke Tax Collector or his designee Date

__Check List for Controlled Construction Building Permits__

1. Completed Construction Control Affidavit (780 CMR 116.2)
2. Completed Building Permit Application with signature of owner or owner's agent (780 CMR 110.1)
3. Three (3) sets of plans (780 CMR 110.87) with original stamp and signature of a Massachusetts registered professional engineer or architect on each page (780 CMR 110.8)
4. The cover page of the plans shall indicate the Edition of the code under which the permit is to be issued, Use Group, Construction Type, Fire Grading Maximum Live Load, and Occupancy Load of the structure.
5. Three (3) sets of sprinkler plans and calculations signed and stamped in original by a Massachusetts registered Professional engineer qualified to design sprinkler systems (780 CMR 110.0, 116.0, 903.1)
6. Fire protection construction documents listed in (780 CMR 903.1.1 (6th ed))
7. Payment of sewer entrance fees for new construction or new sewer service for renovations requiring such connections.
8. Payment of building permit fees in accordance with the Holyoke Code of Ordinances section 18-71 to 18-91
9. City Tax Collector Affidavit pursuant to Chapter 74 of the Acts of 1996

The Commonwealth of Massachusetts
Department of Industrial Accidents
Office of Investigations
600 Washington Street
Boston, Mass. 02111

Worker's compensation Insurance Affidavit

Application Information

Name

Location

City | Phone

☐ I am a homeowner performing all work myself.

☐ I am a sole proprietor and have no one working in any capacity.

☐ I am an employer providing worker's compensation for my employees working on this job.

Company Name

Address

City | Phone

Insurance Company | Phone

☐ I am a sole proprietor, general contractor, or homeowner (circle one) and have hired the contractors listed below who have the following worker's compensation:

Company Name

Address

City | Phone

Insurance Company | Policy Number

Company Name

Address

City | Phone

Insurance Company | Policy Number

Attach Additional Sheet if Necessary

Failure to secure coverage as required under Section 25A of MGL 152 can lead to the imposition of criminal penalties of a fine up to $ 1,500.00 and / or one year's imprison -ment as well as civil penalties in the form of a STROP WORK ORDER and a fine of $100.00 a day against me. I understand that a copy of this statement may be for -ward to the Office of Investigations of the DIA for coverage verification

. I do hereby certify under the pains and penalties of perjury that the information provided above is true and correct.

____

Signature Date

____

Print Name Phone

Official Use Only

City or Town: City of Holyoke, Dept of Codes and Inspections, Permit/License # ☐ Building Department

☐ Check if immediate response is required

Contact Person__________________________________Phone # _____________________

Code Enforcement Zoning Approval Form

Code Enforcement Zoning Approval Form

APPLICATION INFORMATION

ADDRESS ____

PROPOSED USE: ____

☐ EXISTING USE ☐ NEW USE ☐ CHANGE IN USE

STAMPED PLOT PLAN ATTACHED ☐ YES ☐ NO

DATE OF PLANNING BOARD APPROVAL _____ / _____ / ______

APPROVAL FORM ATTACHED? ☐ YES ☐ NO ☐ N/A

DATE OF ZONING BOARD APPROVAL _____ / ____ / ______

RECORDED APPROVAL FORM ATTACHED ☐ YES ☐ NO ☐ N/A

COPY OF PARKING LOT LICENSE PROVIDED ☐ YES ☐ NO ☐ N/A

PROPOSED OCCUPANCY RATING _________________PERSONS

SUBMITTED BY _____________________ (Property Owner or Legal Representative)

OFFICE USE ONLY

ZONE ________
USE COMPLIANCE ☐ YES ☐ SPECIAL PERMIT ☐ PRE-EXISTING
SETBACK COMPLIANCE ☐ YES ☐ VARIANCE
PARKING COMPLIANCE ☐ YES ☐ VARIANCE ☐ SPECIAL PERMIT
APPROVED OCCUPANCY ________________ PERSONS
HISTORIC DEMOLITION COMPLIANCE ☐ YES ☐ NO ☐ N/A
FLOOD PLAIN COMPLIANCE ☐ YES ☐ N/A

APPROVED BY ______________________ DATE ____ / _____ / _____

The Commonwealth of Massachusetts

State Board of Building Regulations and Standards
Massachusetts State Building Code
780 CMR

City of Worcester

Application for a Building Permit

Address ____________________

Application Entered By: ____________________ Application Date: ____________________

Plan Reviewed By: ____________________ Date: ____________________

Signature: ____________________ Date Issued: ____________________
Joseph R. Mikielian, Director Code

Zone: ________ **Proposed Use:** ________ **Census Tract:** ________

Lot Area: ________ square feet **Frontage:** ________ Zoning Review: ________ Zoning Officer

Front yard set back: ________ feet
Rear yard set back: ________ feet **Site Plan Approval:** ________
Side yard set back: ________ feet **Parking Approval:** ________
Side yard set back: ________ feet **ZBA Approval:** ________

Public Water: ________ **Flood Zone:** ________ **Sewer:** ________

Owner of Record: ____________________ **Phone Number:** ____________________
Address: ____________________ **Cell Number:** ____________________
____________________ **Signature:** ____________________

Engineer: ____________________ **Phone #:** ________ **Cell #:** ________
Architect: ____________________ **License Number:** ____________________
Address: ____________________
____________________ **Signature:** ____________________

Licensed Construction Supervisor: ____________________ **Phone #:** ________ **Cell#:** ________
License Number: ____________________
Address: ____________________
____________________ **Signature:** ____________________

Home Improvement Contractor: ____________________ **Phone #:** ________ **Cell#:** ________
License Number: ____________________
Address: ____________________
____________________ **Signature:** ____________________

City of Worcester

Page Two Building Permit Application

Worker's Compensation Insurance Affidavit Submitted: ____________

Description of PROPOSED Work: ____

____

____

Construction Type: ____________ Floor Area: __________ square feet

Number of Stories: ____________ Use Group: ____________

Office Use ONLY:
New Construction: ________ Existing Building: ________ Alteration: ________ Addition: ________
Repairs: ________ Accessory Bldg: ________ Demolition: ________ Other: ________
Building Permit Fee: By Office Permanent Record Retention Fee: By Office Sprinkler Fee: By Office
Other Fee: By Office

Estimated Construction Cost: $________.00 Total Fee: $________ Fee Received: ___/___/___
Received By: ____________

Owner Authorization:

I, ______________________, as owner of the subject property hereby authorize ______________________, to act on my behalf in all matters relative to work authorized by this building permit.

______________________________ ___/___/___

Signature of Owner Date

Owner/Authorized Agent Declaration:

I, ______________________ as Owner / Authorized Agent hereby declare that the statements and information on the foregoing application are true and accurate, to the best of my knowledge and belief.

Signed under the pains and penalties of perjury.

____

Print Name

______________________________ ___/___/___

Signature of Owner / Authorized Agent *Date*

Building Permit Number _______________

Street Address: ____

Do you intend to do interior work only? **Yes:** ________ **No:** ________

If Yes, you do not need to answer any of the questions below.
If No, please answer questions below.
****

If work includes exterior building activity and/or site work, please answer all the following questions.

1. Will any activity take place within 100 feet of a pond, lake, brook, stream, marsh or swamp?
YES: ______ NO: ______
2. Does this property fill up with water after a rainstorm and hold it for a while?
YES: ______ NO: ______
3. Will any activity take place within 100 feet of a storm drain component (catch basin, etc)?
YES: ______ NO: ______
4. Is the property within a flood plain designated under the National Flood Insurance Program?
YES: ______ NO: ______
5. Is this property steeply sloped? YES: ______ NO: ______
(over 15% slope - pre or post construction)
   a. If no, will activity alter at least 10,000 square feet of land?
   YES: ______ NO: ______
   b. If yes, will activity alter at least 5,000 square feet of land?
   YES: ______ NO: ______

____
Signature

__________________________________ __________________________
Print Name Telephone Number

IF YOU ANSWERED YES TO ANY OF THE ABOVE QUESTIONS, YOU MAY NEED APPROVAL FROM THE WORCESTER PLANNING BOARD OR CONSERVATION COMMISSION BEFORE YOU START WORK.
This is not a legal determination. If you have any doubts or questions, it is your responsibility to notify the office of Division of Land Use.

- -

For additional information regarding Local Wetlands Protection Ordinance and the Massachusetts Wetlands Protection act contact:

Department of Public Works
Engineering Division
20 East Worcester Street
Worcester, MA 01604
(508) 799-1454

City of Worcester
Department of Health and Human Services
Code Enforcement Division

James G. Gardiner, Acting Commissioner
Health and Human Services

Joseph R. Mikielian,
Director, Code Enforcement

Building Permit # _______ 20___ will be issued subject to compliance with the requirements of the Commonwealth of Massachusetts State Building Code and the City of Worcester Zoning Ordinance.

Section 114.9 Posting of Permits:

A copy of the building permit provided by the Code Enforcement Division shall be kept in view and protected from the weather on the site of operations, open to public inspection during the entire time of prosecution of the work and until the certificate of occupancy shall have been issued. The building permit shall serve as an inspection record card to allow the building official conveniently to make entries thereon regarding inspection of the work.

Section 114.10 Notice of Start:

At lease twenty-four (24) hours notice of start of work under a building permit shall be given to the building official.

READ BEFORE SIGNING

Signature: ____

Print Name: ____

Address & Zip Code: ____

Telephone: ____

25 Meade Street, Worcester, MA 01610-2715 Phone: (508) 799-8534 Fax: (508) 799-8544 code@ci.worcester.ma.us

City of Worcester
Department of Health and Human Services
Code Enforcement Division

James G. Gardiner, Acting Commissioner
Health and Human Services

Joseph R. Mikielian,
Director, Code Enforcement

AFFIDAVIT

In accordance with Article 1 Section 111.5 of the Massachusetts State Building Code, I certify that all debris resulting from work associated with Building Permit # ______________
at property ____
Will be properly disposed of at:

____,
A licensed solid waste disposal facility as defined by MGL C 111 & 150 A.

___________________ Date

_________________________________ Signature of Permit Applicant

_________________________________ Print Name of Applicant

_________________________________ Firm Name (if any)

_________________________________ Address

The Code Enforcement Division acting under Chapter 8, Article 7 of the 1996 Worcester Revised Ordinances requires proof of disposal of debris generated as a result of this permit. The proof shall be a dated and signed receipt from the licensed disposal facility containing the following information:

A description of the debris, the weight and volume of the debris and the location of the disposal facility. The receipt must also have a signature of the owner/operator of the disposal facility.

Failure to comply with requirements of this ordinance will result in enforcement action by the City of Worcester.

25 Meade Street, Worcester, MA 01610-2715 Phone: (508) 799-8534 Fax: (508) 799-8544 code@ci.worcester.ma.us

CONSTRUCTION CONTROL

PROJECT NUMBER: ____

PROJECT TITLE: ____

PROJECT LOCATION: ____

NAME OF BUILDING: ____

NATURE OF PROJECT: ____

In accordance with section 116.0 of the Massachusetts State Building Code, I,
________________________________ Registration No.________________________

Being a Registered Professional Engineer/Architect hereby certify that I have prepared or directly supervised the preparation of all design plans, computations and specification concerning:

___ENTIRE PROJECT ___ARCHITECTURAL ___STRUCTURAL

___MECHANICAL ____FIRE PROTECTION ___ELECTRICAL

___OTHER (SPECIFY)

For the above named project and that to the best of my knowledge, such plans, computations and specifications meet the provisions of the Massachusetts State Building Code, all acceptable engineering practices and all applicable laws and ordinances for the proposed use and occupancy. I further certify that I shall perform the necessary professional services and be present on the construction site on a regular periodic basis to determine that the work is proceeding in accordance with the documents approved for the building permit and shall be responsible for the following specified in Section 780 CMR 116.0, 6^{th} edition of the Massachusetts State Building Code.

SEAL

____
SIGNATURE

Subscribed and sworn to before me this _____ day of _______________2___

Notary public ______________________________

My Commission expires_______________

Print Form

Application for Mechanical Permit

TOWN OF LEXINGTON
APPLICATION FOR MECHANICAL PERMIT

1625 Massachusetts Avenue, Lexington, MA 02420
Ph: 781-862-0500 x-211 Fax: 781-861-2780

M

Date Received:	Type of Occupancy:	Permit #:
Building Location:		
Owner's Name:		
Installing Company Name:		Phone:
Company Street Address:	Town/City:	Zip:

Indicate total number of units in the applicable box below

	Basement	1st Floor	2nd Floor	3rd Floor	Roof	Ground*
Air Handling Units						
Baseboard Heat						
Boilers/Furnaces/Gas/Oil						
Central Air Conditioners						
Direct Vent Fireplace						
Draft Inducers						
Duct Coils						
Evaporative Coolers						
Fire Suppression						
Generators						
Heat Pumps						
Heating Zones						
Hydro Air Systems						
Incinerators						
Kickspace Heaters						
Kitchen Equipment						
No Vent Heaters						

	Basement	1st Floor	2nd Floor	3rd Floor	Roof*	Ground*
Pool Heater						
Process Piping						
Pumps						
Radiant Heat						
Radiators						
Range Hoods						
Refrigeration Units						
Roof Top Units						
Sprinkler Conn,						
Sprinkler Heads						
Sprinkler Hose Conn.						
Steam Generators						
Steam Kettles						
Ventilation Fans						

Describe Project: *Note: If any equipment is being placed outside of the footprint of the building, indicate setbacks to property line. A land survey may be required. Roof top units may require a Structural Engineer's review. Equipment that is visible from a public way and within a Historic District will require prior approval of the Historic Districts Commission. All equipment is subject to Lexington's Noise By-Law:

____

____

New Work ☐ Replacement ☐ Renovation ☐ Plans Submitted: ☐

I certify that I have the authority to make the foregoing application and that all of the information I have submitted (or entered) in the above application is true and accurate to the best of my knowledge, information and belief, and that all mechanical work and installations performed under the permit issued for this application will be in compliance with all pertinent provisions of the Massachusetts State Building Code, the ICC Mechanical Code, and all laws/bylaws/regulations of the Town of Lexington:

Signature: ______________ Print Name: ______________ Type of License: ______________ License #: ______________

For Office Use Only				
Insurance on File:	Will Fax:	Permit Fee: $	Receipt #:	Date Issued:

Application for Revision of Building Permit

City of Worcester
Department of Health and Human Services
Code Enforcement Division

James G. Gardiner, Acting Commissioner
Health and Human Services

Joseph R. Mikielian
Director, Code Enforcement

APPLICATION FOR REVISION OF BUILDING PERMIT

Address of work location: ___________________________________

Owner of Property: ____

Revision made by owner: ___________________________________

Contractor: ____

Engineer/architect: _______________________________________

Date of revised material received: ___________________________

Written scope of work attached: yes_________ or no_______________

Number of drawings sheets submitted: ________________________

Value of revised/additional work: ___________________________

Additional fee paid: _______________________________________

Planed revision: ____

Print Form

____

Record of review of revision to permit

______________________________ Zoning Officer
(Signature)

Application for Permit to Do Plumbing

MASSACHUSETTS UNIFORM APPLICATION FOR PERMIT TO DO PLUMBING
(Print or Type)

________ Worcester ________,Mass. Date____________20____ Permit #__________________

Building Location______________________________Owner's Name________________________

Owner Tel#______________________________Type of Occupancy____________________

New ☐ Renovation ☐ Replacement ☐ Plan Submitted: Yes ☐ No ☐

P

FIXTURES

	WATER CLOSETS	KITCHEN SINKS	LAVATORIES	BATHTUBS	SHOWER STALLS	DISHWASHER	DISPOSERS	LAUNDRY TRAYS	WASH MACH CONN	HOT WATER TANKS	TANKLESS	SLOP SINKS	FLOOR DRAINS	GAS TRAPS	URINALS	DRINKING FOUNTAIN	AREA DRAIN	WATER PIPING	ROOF DRAINS	BACKFLOW PREV.	OTHER FIXTURES					
SUB-BSMT																										
BASEMENT																										
1ST FLOOR																										
2ND FLOOR																										
3RD FLOOR																										
4TH FLOOR																										
5TH FLOOR																										
6TH FLOOR																										
7TH FLOOR																										
8TH FLOOR																										

Installing Company Name________________________________ Check one: Certificate

Address______________________________________ ☐ Corporation __________

____ ☐ Partnership __________

Business Telephone #____________________ ☐ Firm/Co. __________

Name of Licensed Plumber ______________________________

INSURANCE COVERAGE:
I have a current liability insurance policy or its substantial equivalent which meets the requirements of MGL Ch. 142.
Yes ☐ No ☐
If you have checked yes, please indicate the type coverage by checking the appropriate box.

A liability insurance policy ☐ Other type of indemnity ☐ Bond ☐

OWNER'S INSURANCE WAIVER: I am aware that the licensee does not have the insurance coverage required by Chapter 142 of the Mass. General Laws, and that my signature on this permit application waives this requirement.

Check one:
____ Owner ☐ Agent ☐
Signature of Owner or Owner's Agent

I hereby certify that all of the details and information I have submitted (or entered) in above application are true and accurate to the best of my knowledge and that all plumbing work and installations performed under the permit issued for this application will be in compliance with all pertinent provisions of the Massachusetts State Plumbing Code and Chapter 142 of the General Laws.

By____________________
Title____________________
City/Town________________
APPROVED (OFFICE USE ONLY)

____
Signature of Licensed Plumber

Type of License: Master ☐ Journeyman ☐

License Number____________________

Print Form

Application for Sunrooms

CONSUMER INFORMATION FORM - "SUNROOMS"

Massachusetts State Building Code (780 CMR, Appendix J, Section J1.1.2.3.1)

The Massachusetts State Building Code *(780 CMR)* includes provisions to ensure that houses and house additions meet energy efficiency standards. This supplemental CONSUMER INFORMATION FORM is to be filed as part of the building permit application when a builder/contractor or homeowner, constructing/installing a house addition with very large percentage of glass to opaque wall, seeks to utilize a special energy conservation exemption option for "sunroom" additions to an existing house (780 CMR, Appendix J, Section J1.1.2.3.1). This FORM is not intended to prevent a homeowner from selecting a "sunroom" of any size, configuration, orientation, form of construction or percent glazing, but rather is only intended to assist homeowners in becoming aware of some of the important energy conservation and year-round comfort considerations involved in selecting and utilizing a "sunroom" addition.

The connection of "sunroom" structures to residential buildings may create comfort and energy consumption issues due to uncontrolled solar gain or uncontrolled radiation cooling of the main house. In the selection and construction/installation of "sunrooms", included below is a non-required, open-ended list of product and design considerations that a homeowner may wish to consider before actually constructing/installing a "sunroom". It is recommended that consumers carefully review these options with their designer, builder, or contractor, in order to minimize potential energy consumption and/or house discomfort issues. In addition, the qualifications and reputation of the company or individuals to be hired are important considerations.

PRODUCT AND DESIGN CONSIDERATIONS RELATED TO "SUNROOMS"

- **Solar Orientation and Natural Shading**
- **Type of Glazing**
  - **Insulating value**
  - **Solar heat gain**
  - **Frame materials**
  - **Glazing to frame sealing and gasketing materials/ seal durability and/or weather tightness of the sunroom**
- **Adequate ventilation - Operable windows and fans**
- **Applied Shading Systems**
- **Insulation level in floors, walls, and ceilings**
- **Possible Sunroom isolation from the main house via a wall and/or door or slider**
- **Heating and Cooling Methods: Efficiency, Zoning and Controls**

Homeowner Acknowledgment

The Massachusetts State Building Code, Section J1.1.2.3.1, requires that the actual property owner (not the owner's agent or representative) acknowledge receipt of this CONSUMER INFORMATION FORM prior to issuance of a Building Permit for a project that includes "sunroom" additions to an existing residential building. In accordance with this requirement, the undersigned hereby acknowledges that she/he has read the information in this document concerning sunroom comfort and energy conservation.

______________________________ Signature of Actual Building Owner	______________________________ Date
______________________________ Print Name	______________________________ Address of Permitted Project
______________________________ Owner Address (if different than project location)	______________________________ Owner's telephone number

Print Form

Driveway Opening Procedure

DRIVEWAY OPENING PROCEDURES

Name: ______________________ Phone #: ____________________

DATE:____________________

ADDRESS:____

*** Is driveway opening on a State Highway? _____ Y ______ N
If so, applicant must file application with Mass Highway Department.

*** The maximum width of driveway openings shall be 20 feet in residential districts and 30 feet in all other districts.

1. Contact the Building Department for approval, located at City Hall on the first floor.

   APPROVED [ ] DENIED [ ]

   BY:____
   Building Commissioner

Contact the Traffic Commission for approval, the Traffic Commission Chairperson is Chief Sacco, located at the Police Station on Main Street.

   APPROVED [ ] DENIED [ ]

   BY:____
   Traffic Commissioner Chairperson

2. If approved, contact one of the suggested contractors listed below for competitive prices.

3. Obtain permit from Engineering Department, located at City Hall, Room 300. **NOTE:** A *$5,000* bond must be posted either by the Contractor or the owner at the time of applying for the permit.

4. Sidewalk and driveway apron must be put back to prior condition or better; i.e. 6" cement concrete removed, cement concrete put back.

CONTRACTORS FOR DROPSTONES

Mystic Paving Inc.
(781) 395-5275

J.A. DePrimeo, Jr. Co.
(781) 646-9563

Cooper Brothers Paving
Medford
(781) 393-9733

J. Donlon & Sons
Winchester
(781) 729-8286

PLEASE REMIT THIS SIGNED COPY TO THE ENGINEERING OFFICE TO RECEIVE PERMITS

Application for a Permit to Perform Electrical Work

Commonwealth of Massachusetts

Department of Fire Services

BOARD OF FIRE PREVENTION REGULATIONS

Official Use Only
Permit No. ______
Occupancy and Fee Checked ______
[Rev. 11/99] (leave blank)

APPLICATION FOR PERMIT TO PERFORM ELECTRICAL WORK

All work to be performed in accordance with the Massachusetts Electrical Code (MEC), 527 CMR 12.00

(PLEASE PRINT IN INK OR TYPE ALL INFORMATION) Date: ______

City or Town of: Worcester *To the Inspector of Wires:*

By this application the undersigned gives notice of his or her intention to perform the electrical work described below.

Location (Street & Number) ______

Owner or Tenant ______ Telephone No. ______

Owner's Address ______

Is this permit in conjunction with a building permit? Yes ☐ No ☐ (Check Appropriate Box)

Purpose of Building ______ Utility Authorization No. ______

Existing Service ______ Amps ___/___ Volts Overhead ☐ Undgrd ☐ No. of Meters ______

New Service ______ Amps ___/___ Volts Overhead ☐ Undgrd ☐ No. of Meters ______

Number of Feeders and Ampacity ______

Location and Nature of Proposed Electrical Work: ______

Completion of the following table may be waived by the Inspector of Wires.

No. of Recessed Fixtures	No. of Ceil.-Susp. (Paddle) Fans	No. of Transformers / Total KVA
No. of Lighting Outlets	No. of Hot Tubs	Generators / KVA
No. of Lighting Fixtures	Swimming Pool Above grnd. ☐ In-grnd. ☐	No. of Emergency Lighting Battery Units
No. of Receptacle Outlets	No. of Oil Burners	FIRE ALARMS / No. of Zones
No. of Switches	No. of Gas Burners	No. of Detection and Initiating Devices
No. of Ranges	No. of Air Cond. / Total Tons	No. of Alerting Devices
No. of Waste Disposers	Heat Pump Totals: / Number / Tons / KW	No. of Self-Contained Detection/Alerting Devices
No. of Dishwashers	Space/Area Heating KW	Local ☐ Municipal Connection ☐ Other
No. of Dryers	Heating Appliances KW	Security Systems: No. of Devices or Equivalent
No. of Water Heaters KW	No. of Signs / No. of Ballasts	Data Wiring: No. of Devices or Equivalent
No. Hydromassage Bathtubs	No. of Motors / Total HP	Telecommunications Wiring: No. of Devices or Equivalent
OTHER:		

Attach additional detail if desired, or as required by the Inspector of Wires.

INSURANCE COVERAGE: Unless waived by the owner, no permit for the performance of electrical work may issue unless the licensee provides proof of liability insurance including "completed operation" coverage or its substantial equivalent. The undersigned certifies that such coverage is in force, and has exhibited proof of same to the permit issuing office.

CHECK ONE: INSURANCE ☐ BOND ☐ OTHER ☐ (Specify:) ______ (Expiration Date)

Estimated Value of Electrical Work: ______ (When required by municipal policy.)

Work to Start: ______ Inspections to be requested in accordance with MEC Rule 10, and upon completion.

I certify, under the pains and penalties of perjury, that the information on this application is true and complete.

FIRM NAME: ______ LIC. NO.: ______

Licensee: ______ Signature ______ LIC. NO.: ______

(If applicable, enter "exempt" in the license number line.) Bus. Tel. No.: ______

Address: ______ Alt. Tel. No.: ______

OWNER'S INSURANCE WAIVER: I am aware that the Licensee *does not have* the liability insurance coverage normally required by law. By my signature below, I hereby waive this requirement. I am the (check one) ☐ owner ☐ owner's agent.

Owner/Agent Signature ______ Telephone No. ______ *PERMIT FEE: $*

Print Form

Fire Extinguishing Equipment New System Description Sheet

City of Worcester
Department of Health and Human Services
Code Enforcement Division

James G. Gardiner, Acting Commissioner
Health and Human Services

Joseph R. Mikielian
Director, Code Enforcement

Fire Extinguishing Equipment
New System Description Sheet

New Sprinkler Systems:

Total number of Sprinkler Heads __________ x $2.00 = $__________
\+ $125.00

Total Sprinkler Fee = $__________

New Standpipes:
List each standpipe individually

Standpipe Number	Number of Stories				Total
1	__________	-3 =	__________	x $50.00 + $125.00 =	__________
2	__________	-3 =	__________	x $50.00 + $125.00 =	__________
3	__________	-3 =	__________	x $50.00 + $125.00 =	__________
4	__________	-3 =	__________	x $50.00 + $125.00 =	__________
5	__________	-3 =	__________	x $50.00 + $125.00 =	__________
6	__________	-3 =	__________	x $50.00 + $125.00 =	__________
7	__________	-3 =	__________	x $50.00 + $125.00 =	__________
8	__________	-3 =	__________	x $50.00 + $125.00 =	__________
9	__________	-3 =	__________	x $50.00 + $125.00 =	__________
10	__________	-3 =	__________	x $50.00 + $125.00 =	__________
				Total Standpipe Fee	__________

Sprinkler Total $__________

Standpipe Total $__________

Total $__________

Print Form

Alteration of Existing Systems (Fire Extinguishing Equipment System Description Sheet)

City of Worcester
Department of Health and Human Services
Code Enforcement Division

James G. Gardiner, Acting Commissioner
Health and Human Services

Joseph R. Mikielian
Director, Code Enforcement

Alteration of Existing Systems
Fire Extinguishing Equipment
System Description Sheet

New Sprinkler Systems:

Total number of Sprinkler Heads __________ x $2.00 = $__________
\+ $75.00

Total Sprinkler Fee = $__________

New Standpipes:
List each standpipe individually

Standpipe Number			Number of Stories		Total
1	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
2	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
3	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
4	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
5	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
6	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
7	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
8	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
9	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
10	____________	- 3 =	______________	x $2.00 + $75.00 =	__________
				Total Standpipe Fee	__________

Sprinkler Total $__________
Standpipe Total $__________
Total Fire Extinguishing Fee $__________

Print Form

Massachusetts Uniform Application for Permit to Do Gas Fitting

G

MASSACHUSETTS UNIFORM APPLICATION FOR PERMIT TO DO GASFITTING

(Print or Type)

_____Worcester_____ ,Mass. Date__________20____ Permit #________________

Building Location________________________ Owner's Name____________________

Owner Tel#______________________________ Type of Occupancy__________________

New ☐ Renovation ☐ Replacement ☐ Plan Submitted: Yes ☐ No ☐

FIXTURES

	RANGES	HEATER RANGES	OVENS	GRILLES	HEATING BOILERS	FURNACES	UNIT HEATERS	WATER HEATERS	DRYERS	GAS GENERATORS	LABORATORY COCKS	CONVERSION BURNERS	ROOF TOP UNITS	VENTED ROOM HEATERS	DIRECT VENT HTRS	POOL HEATERS	TESTS	OTHER	FUEL LINES							
SUB-BSMT																										
BASEMENT																										
1ST FLOOR																										
2ND FLOOR																										
3RD FLOOR																										
4TH FLOOR																										
5TH FLOOR																										
6TH FLOOR																										
7TH FLOOR																										
8TH FLOOR																										

Installing Company Name______________________________

Address____

____

Business Telephone #__________________

Check one: Certificate

☐ Corporation __________

☐ Partnership __________

☐ Firm/Co. __________

Name of Licensed Plumber or Gas Fitter____

INSURANCE COVERAGE:
I have a current liability insurance policy or its substantial equivalent which meets the requirements of MGL Ch. 142.
Yes ☐ No ☐
If you have checked yes, please indicate the type coverage by checking the appropriate box.

A liability insurance policy ☐ Other type of indemnity ☐ Bond ☐

OWNER'S INSURANCE WAIVER: I am aware that the licensee does not have the insurance coverage required by Chapter 142 of the Mass. General Laws, and that my signature on this permit application waives this requirement.

Check one:
Owner ☐ Agent ☐

____
Signature of Owner or Owner's Agent

I hereby certify that all of the details and information I have submitted (or entered) in above application are true and accurate to the best of my knowledge and that all plumbing work and installations performed under the permit issued for this application will be in compliance with all pertinent provisions of the Massachusetts State Gas Code and Chapter 142 of the General Laws.

By___________________

Title__________________

City/Town______________

APPROVED (OFFICE USE ONLY)

Type of License:
- Plumber
- Gas fitter
- Master
- Journeyman

____
Signature of Licensed Plumber or Gas Fitter

License Number____________________

Print Form

Impervious Surface NEW		**Square Footage** The following square footages must also be provided on the plans	
Roof surface:	___________SF	Livable:	__________SF
Driveway:	___________SF	Garage (1) (2) (3)	__________SF
Side walks:	___________SF	Covered porch/ patios/decks:	__________SF
Decks/Patios:	___________SF	Uncovered Wood Decks:	__________SF
New Dwelling **TOTAL:**	___________SF	Basement:	__________SF
For additions only:		Remodels:	__________SF
Additional square feet to Impervious:	___________SF	Miscellaneous:	__________ SF

Grading Questionnaire

Do any of the following conditions apply to your site? Please check the appropriate response. (cut and fill inside the building foot print is not counted).

Yes	No	
☐	☐	1. Will there be fill greater than 50 cubic yards on any one lot (about 4 ½ - 10 wheeler loads)?
☐	☐	2. Will you be placing fill or creating a cut-slope near your property line (i.e. leveling lot)?
☐	☐	3. Will you be filling areas of your project outside the building footprint/foundation with imported fill material or existing material from excavations for basements, lower floors, foundations, retaining walls or other structures authorized by a valid building permit.
☐	☐	4. Will there be fill supporting a structure (must be engineered prior to commencing work)?
☐	☐	5. Will the placement of fill on your property obstruct or change the flow of an existing man-made or natural drainage course or divert runoff onto neighboring property?

A "**YES**" response to any question may require a grading permit, and must be shown on the site plans (existing contour lines and new proposed). Sections may be required. Please provide two (2) sets of the following:
- Shade the area to be cut and/or filled.
- Typical cross section for area to be cut and/or filled

Indicate quantities of cut __________ cyds.; fill __________ cyds. Estimate value of grading $ ________

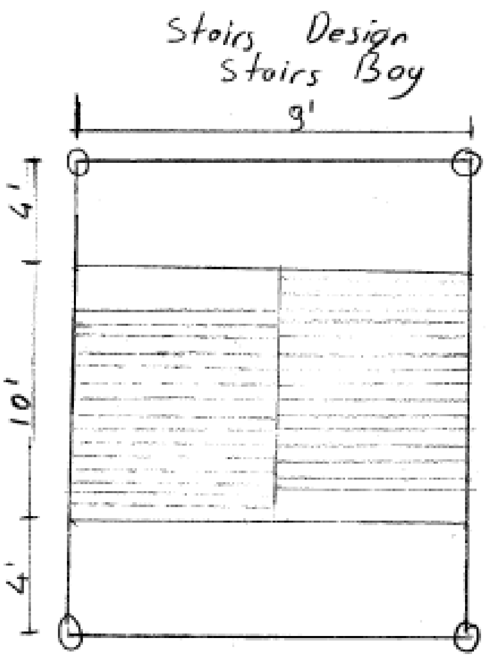
Plans for any retaining walls (if retaining greater than 48" or has a surcharge from a structure or parking area, the plans must be prepared by a professional engineer and stamped). Special inspection is required: yes / no

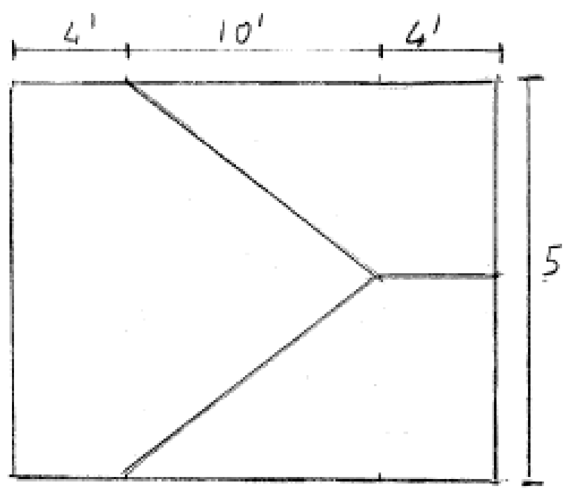
DEPOSIT SCHEDULE:

Project estimated value:		
	$ 0 - $ 4,999 …... $ 0.00 deposit	$ 25 - $ 49,999 ….. $ 175.00 deposit
	$ 5 - $ 9,999 …... $ 50.00 deposit	$ 50 - $ 99,999….. $ 300.00 deposit
	$ 10 - $ 24,999 …. $ 85.00 deposit	$100 ,000 & over…. $ 450.00 deposit

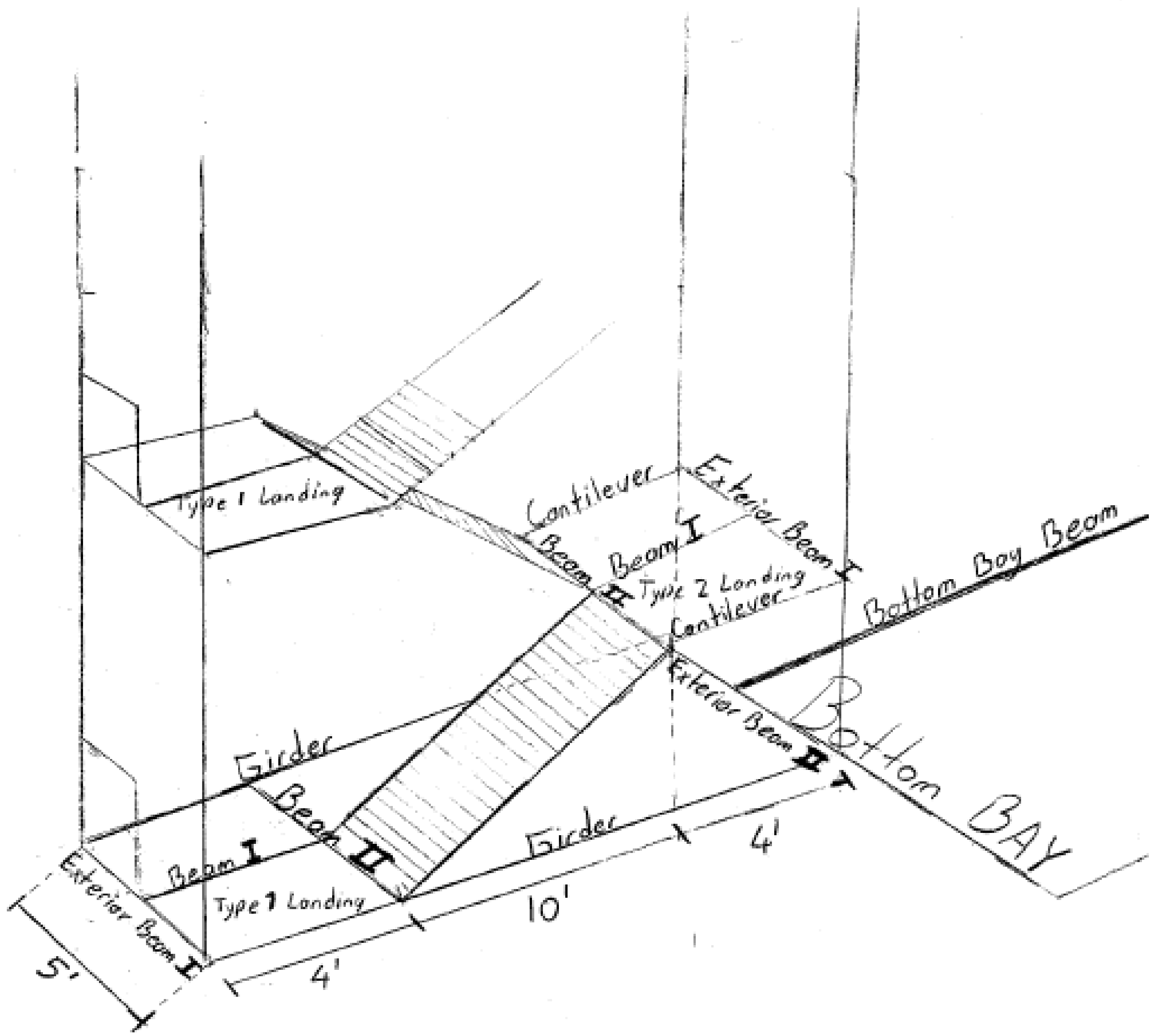
Appendix F: Stair Case and Elevator Drawings

Stair Case Drawings

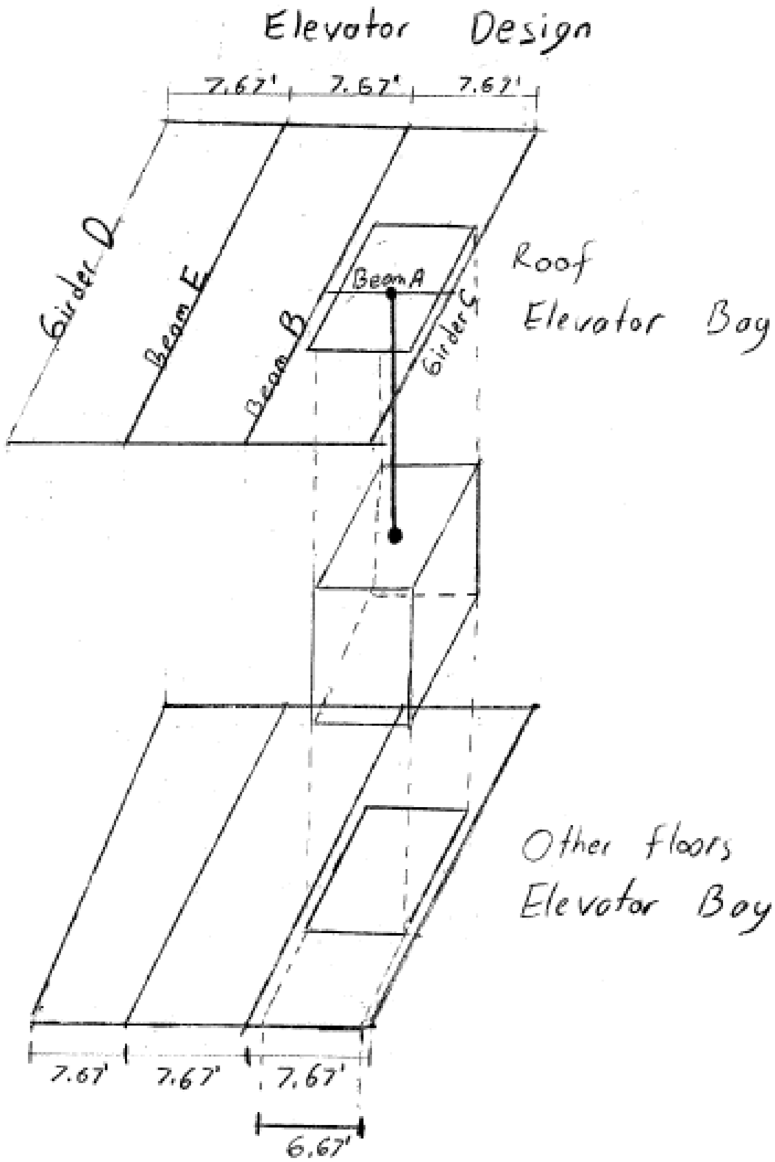




Stairs Design



Elevator Design Drawings



Appendix G: Building Drawings for Management Purposes