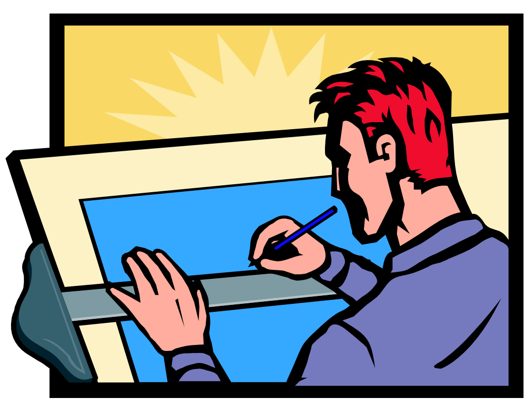
# THE EARTH AND ENGINEERING SCIENCES BUILDING

**Justin Strauser**

**STRUCTURAL OPTION**

**SPRING 2006**

**Advisor: Professor Parfitt**



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Structural Option

Pennsylvania State University

# Earth & Engineering Sciences Building

## University Park, PA

## Project Overview:
- 4 Story Educational/Laboratory Facility
- 106,000 Sq. Ft. Floor Space
- Houses College of Engineering and College of Earth & Mineral Sciences
- Construction: TBA
- Project Cost: TBA

## Project Team:
- Owner: Pennsylvania State University
- Architect: Herbert Beckhard & Frank Richlan
- Structural/MEP Engineers: L. Robert Kimball
- General Contractor: Leonard S. Fiore Inc.

## Architectural:
- Natural Lighting is Main Theme
- Windows Represent Diverse Functions
- Grand Lobby Unites Separate Wings

## Structural:
- Foundation: Concrete Footers/Grade Beams/Slab on Grade
- Superstructure: Steel Columns Encased in Concrete/Steel Girders & Beams
- Floor: Concrete Slab on Composite Metal Deck
- Envelope: Precast Concrete Panels/ Brick Infill/ Concrete Screens

## Electrical/Lighting:
- 12.47KV-480/277 Volt, 3 Phase-3 Wire with Ground
- 240/120V Emergency Electric System
- 208/120V 3 Phase- 4 Wire Secondary Voltage
- Lighting is Predominately Fluorescent

## Mechanical:
- 5 Air Handling Units
- Reverse Osmosis Unit
- Chilled Water Available in All Labs

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# Executive Summary

This report will examine the Earth and Engineering Sciences building and document the various systems within its walls. The purpose is to demonstrate how alternate floor systems affect the entire structure. While problems may occur from these changes, great benefits can also be achieved and will be discussed.

The primary focus of this report is to attempt to resolve an issue that may have occurred during the original design. In the original design of this building, it was believed that the mechanical equipment could be placed at the roof level; however, due to height restrictions this could not be done. It will be shown throughout this report how the roof height could be lowered by using a shallower floor system.

The floor system selected for design is prestressed hollow core plank flooring. Hollow core plank is capable of carrying high loads, while remaining relatively light weight and thin. The hollow core will allow the same floor to ceiling height, while minimizing the mean roof height. It is this characteristic that will allow mechanical equipment to be placed on the roof.

The entire structural system will be changed to 50 ksi steel and redesigned based on new loadings. All of the loadings, required for design, are produced according to ASCE 7-02 code and reflect a redistribution of the weight from the mechanical system. The design of the steel within the structural system will be done with the aid of a structural analysis program. Software selected for use in this analysis was the *RAM Structural* analysis program. The hollow core was sized according to design specifications from the *PCI Handbook* and the Nitterhouse Concrete Products website.

The final part of the investigation is to determine how the new structural system will affect the mechanical systems. A cost analysis and time schedule was also created in order to compare the new construction sequence to that of the original. From these studies and the structural study, it was determined whether the new design was feasible.

The new design proved to be less costly and more time efficient than the original design. There were a few issues in moving the mechanical equipment, but they were adequately dealt with and will be explained in the report. All of the results within this investigation suggest a fairly successful solution.

# Introduction

Located in University Park, Pennsylvania, Penn State University is home to some of the more unique buildings the industry has to offer. The western part of this campus is rapidly expanding to include buildings such as the Information Sciences and Technology building that spans across Atherton Street, as well as a new addition to the Recreational Hall building. Another structure that catches

the eye is the Earth and Engineering Sciences building. From its' prominent façade to its' unique individual interior spaces the EES building has become one of the most intriguing additions to the Penn State campus. As students cross over the IST Bridge or golfers play a few holes at the campus golf course, all can appreciate the fine architecture and playful geometry of this signature building.

The following report will examine this building in detail and document the various systems possessed within its' walls. Included in this investigation are the results of a year long design of an efficient alternate floor system. The following data provided illustrates how the EES building was analyzed in all functional aspects and then redesigned as a new entity. A hollow core floor system will be introduced as the new existing system. All steps in choosing and designing this system are documented within this report to clarify the effects on the other structural components involved. In addition to structural building elements, there is also a look into the effects on alternate systems such as the mechanical equipment that will be directly effected by the new floor system. The purpose of the report is to demonstrate how alternate floor systems affect the entire structure, and while problems may occur from these changes, great benefits can also be achieved. All calculations are based on stated assumptions, legitimate design methods, and stated assumptions. This report and the images contained therein are property of the Pennsylvania State University.

# BUILDING STATISTICS

*Location:*

The EES rests on the western most part of Penn State's University Park campus. Vehicle access to the building is found off of Atherton Street (PA Business 322) on white course drive. Upon entrance to White Course Drive several athletic fields can be seen to the right, as well as, one of Penn State's two golf courses. The Earth and Engineering Sciences building offsets the IST building to the west; it is from the IST building that students can access the EES building from the rest of campus by foot. The area surrounding the EES building is very open and provides little natural coverage. The most unobstructed view can be found from the golf course located to the north.

*Project Team:*

- Owner: The Pennsylvania State University
- Architect: Herbert Beckhard and Frank Richlan / Joint Venture with L. Robert Kimball and Associates
- MEP Engineers: L. Robert Kimball and Associates
- General Contractor: Leonard S. Fiore Inc.
- Structural Engineers: L. Robert Kimball and Associates

## *Project Information:*

The Earth and Engineering Sciences building is a four story laboratory and educational facility. The total floor space occupies in excess of 106,000 square feet. The construction of this project was set in motion upon the acceptance of the winning bid placed in January of 1998. The ground was broken and construction began in early May of 1998, with final completion of the project occurring in December of 1999. The project was done in a design-bid-build delivery method that was presented as four construction packages. Packages for this project included steel construction, general construction, plumbing/HVAC, and electrical work. The final gross cost for completion of the Earth and Engineering Sciences building was roughly 14 million dollars. Notable payouts include 9 million for the general contractor's duties, 2 million for heating equipment, 6.6 million for plumbing, and 1.7 million for electrical work.

## *Architecture:*

Originally meant to be a signature piece and part of his legacy; the late Herbert Beckhard tried to instill his unique style into the Earth and Engineering Sciences Building. Herbert Beckhard was mainly responsible for the architectural aspects that define the EES building. In a joint venture with L. Robert Kimball and Associates, Herbert Beckhard and Frank Richlan worked scrupulously to create a structure that would stand out, while fitting into the tight restrictions implied by the Pennsylvania State University. Beckhard and Richlan spearheaded the effort to complete this new design. Beckhard's "legacy" would be built on a newly developed section of the Penn State campus and would be one of the first buildings to bring character to the area. The original design was thought to be overdone and too large for the Penn State campus and, on numerous occasions, was requested to be scaled down. Beckhard cooperated with the requests and still managed to include many of the overall themes he wished to employ. The 4 story educational facility houses several offices, a large computer center, teaching and research laboratories, standard and special classrooms, as

well as a large lecture hall. Almost every office features a great view of either the quadrangle to the south or the golf course to the north.

The use of light can greatly impact the feel of any interior space. Beckhard realized this, and a number of window styles can be found throughout the building to utilize as much natural lighting as possible and to create a warm feeling. Each window was intended to reflect the diverse functions inside the building. All laboratories are equipped with windows and some form of natural ventilation.

One of the elements of the EES building that struggles to fit the scheme of the rest of the building is the large auditorium style lecture hall. Awkwardly jutting out from the main building, the auditorium becomes a “sidecar” that almost forms an individual structure. However an admirable effort was made to connect this element as part of the whole. Sharing a cut stone base, an aesthetic uncommon at Penn State, the auditorium is able to be identified as part of the whole structure.

The plan for the EES building had to compensate for a multiuse building. The building is shared by two separate colleges, each wanting their own identity but wishing to remain united. Beckhard had to connect two wings into one unified element. His original idea was to have a central core, which would share several core elements and a grand lobby area. The lobby area was to be made entirely of glass and feature several lounge spaces. However, due to design restrictions this had to be modified into a smaller space with more miniscule glass slivers. Although the lobby spaced was reduced, it still provides one of the most recognizable and enjoyable spaces of the building. The lobby area is a great addition to the grand scheme and architectural style desired by Beckhard.

*Building Envelope:*

The Pennsylvania State University has begun to impose a strict criterion that all facades include red brick. Although not part of Beckhard's vision the criterion was still in place and had to be met. Trying to bend this rule, Beckhard came up with a scheme that would add a bit of his personal touch and remain in the confines of the design criterion. The result was a façade that included precast concrete panels, brick infill, and granite. The use of the precast panels with "punch-outs" allowed the façade to include the brick elements that were required and at the same time provide a sleek feel to the exterior. The precast panels surrounding window openings eliminated the need for flashing and lintels, while relieving unwanted angles. The bricks in the façade are actually two distinct tones of brick that are laid in horizontal bands, going against the standard one tone brick façade criterion seen on most of Penn State's campus at the time. The base consists of a cut stone that sets off the remaining exterior elements. Concrete screens can be seen outside of some classrooms, these were intended to break the view of the façade and give a desired lighting effect inside the building. Using hollow tube steel and glass panels Beckhard was able to create several distinct points on the façade of the Earth and Engineering Sciences building. The lobby and stairwells are set of by this use of glass and green flashing. The main entrance is a double entrance providing an air and sound barrier. The doors are made of a dense aluminum and provide an almost airtight lock.

## Construction:

As design was under way many restrictions had to be accounted for pertaining to the way construction would take place. Being that the project was partially funded on behalf of the Department of General Services, the state of Pennsylvania would become a major authority on the design and construction criterion for this project. In addition, Penn State imposed its own set of criterion and standards that had to be met. The site was a new and virtually undeveloped piece of land with a few small parking areas. Geotechnical surveys had to be done to determine soil capacities. The restriction that proposed the greatest setback was the height restriction of 75' for this new part of the PSU campus. Construction was slowed as a result of the need to place the mechanical equipment in a suitable location. Originally planned to be placed on the roof, it was apparent that to conceal the mechanical equipment the building would indeed violate the height restriction. The final solution was to move the mechanical equipment into a basement area that would have to be added. Aside from the mechanical dilemma, budget issues also slowed the placement of the supercomputer causing further delays. Other delays resulted from issues with site connections and ventilation stacks.

## Electrical:

The electrical system begins with a main feed from a pad mounted transformer that provides 480/277 V phase current. This main transformer feeds into a main distribution panel. Current is then routed into an initial switchboard that provides power to significant areas within the building. It can be noted at this time that emergency power is supplied to the building by a second system. The first switchboard is the feed for 5 different panels: a 750 KVA transformer, basement distribution panel, outdoor lighting, the Cray Computer lab, and a 75 KVA transformer. The 750 KVA transformer feeds two additional distribution panels on the 1st and 3rd floors. The basement distribution panel provides power for corridor lighting, and each elevator.

## Lighting:

The use of natural lighting is prevalent within the Earth and Engineering Sciences building, but artificial lighting is also crucial to the interior and exterior of the building. Artificial lighting for the EES building is predominantly fluorescent.

Several types of fixtures can be found throughout the entire building. The lab and classroom spaces display rectangular louvered fixtures residing in a dropped ceiling. In the lobby, fixtures are recessed under a metal slat ceiling to help maintain a flat appearance. In the auditorium area wall washers and down lights are used to achieve a variety of different lighting appearances. The numerous corridor spaces utilize 2 X 2 recessed 9 cell parabolic lamp fixtures. In the core stairwells a standard sconce is used to provide lighting with the outermost stairwells utilizing large windows for additional natural lighting. Finally, in the Cray Computer lab, lighting fixtures similar to those found in the other classrooms are equipped with dimmable center lamp ballasts.

## *Fire Protection:*

The fire system for the EES building is designed according to code, with full compliance to ADA specifications. The entire building is equipped with full sprinkler systems and several standpipe locations. Building materials were required to all be noncombustible elements. Most structural elements consist of either concrete or encased steel. Steel that was not encased in concrete was coated with spray-on fire proofing. Special fire doors leading to several sections of the building are automated and are able to close in the event of a fire, preventing fires from spreading. Stairwells were either composed of stone or concrete as a means of fire protection. In the computer lab, chemical compounds are dispensed in place of water to prevent damage to the computing systems.

## *Transportation:*

The transportation systems for the Earth and Engineering Sciences building are located in the central core or at the Eastern and Western most tips. The elevators are located in the main lobby and can be accessed upon entry to the building from the south side. Elevators provide access to all floors as well as to the mechanical room in the basement. Also located in the

central core are two stairwells that provide transportation in the event of a fire. At each end of the building additional stairwells are located. The central stairwells are lighted by wall sconces and have circular cutouts in the walls exposing the next set of steps. The two outermost stairwells are more open to the floor below and allow outside light through the glass façade. All stairwells are fire resisting structures and are up to date with current fire codes.

## *Special Systems:*

The addition of the Cray Supercomputer lab leads to several special provisions on this project. Special systems had to be installed to maintain and protect this lab. The lab needed its own mechanical systems to assure the desired conditions for this space. Lebert systems were installed to properly meet this need. These systems helped to maintain a constant temperature and humidity level in the lab without relying on outside systems. Other systems were needed to help keep this lab up and running. Among these was an electrical system that was installed to provide an ample energy flow to the computing systems as well as protect against electrical surge. A chemical fire system was also placed in this space, as water would severely damage the expensive computing equipment.

In addition to the computer center, two other labs created issues. The first of which was a distance learning, which required a larger amount of telecommunications needs. A vibrations lab is present on the third floor of the complex. The large machine used to create the vibrations had to be placed on an isolation pad that would not induce seismic loads on the entire structure.

## *Mechanical:*

The mechanical systems for the Earth and Engineering Sciences building caused some initial headaches which will be discussed in further detail later. Ultimately the main mechanical equipment was placed in an added basement area to solve problems introduced in the original design. Providing air to maintain temperature throughout the entire building are five air handling units. The units are ducted together and move air from the basement to the upper floors with the exception of the Cray Supercomputer lab which has its own mechanical systems. There is a large mechanical room on the first floor that houses the large ductwork due to the entire air supply coming from the basement to the roof. Mechanical stacks are continuous from the basement level all the way to the roof. At the roof level several exhaust stacks aid in the removal of the unwanted air. Several ventilation fans provide the primary means of removing unwanted air from the building.

# Structural System

The structural system for the Earth and Engineering Sciences building is one that succeeds economically as well ergonomically. The use of redundancy throughout the structure allows for a design that can safely withstand the imposed loadings without an over elaborate scheme. With the use of composite elements, multiple shear walls, and various steel shapes, the structural system is a diverse display of structural techniques found throughout the industry. By employing these various options the EES building is able to achieve its brash look and functionality.

Any building must contain two primary structural systems: one that provides support for gravitational loading and another to resist lateral forces. The EES building boasts two well designed systems to account for both of the above mentioned situations. With a composite floor system and 36 ksi steel frame, gravitational loads are safely passed to the foundation. Meanwhile a shear wall and moment frame are presented to account for any lateral forces that may pose a threat. In the following subsections each aspect of the structural system will be investigated in more detail.

## *Floor System:*


The floor system found in the Earth and Engineering Sciences building is a common composite system. The system consists of concrete slabs poured over a galvanized steel deck. Each steel deck is then connected to a steel support beam by the means of shear studs. These shear studs will protrude into the concrete slab and are what allow for the composite action within the floor system. Floor systems designed in this manner allow for a higher loading pattern as they have an increased moment capacity.

The EES employs 36 ksi steel members within the general framework of the building. On top of these steel members a 3", 20 GA galvanized composite metal deck is placed. Several shear studs are exposed through the top of the decking that will be embedded within the poured concrete that is placed next. Lightweight concrete with a 4,000 psi compressive strength is poured onto the metal decking until it reaches a depth of 3 ¼ ". The concrete is reinforced with 6

x 6, W2.1 x W2.1 welded wire fabric which is placed before the pour. After the entire floor system is placed the slab will be a total thickness of 6 ¼ ".

The floor system mainly functions as a gravitational loading element. However, it also plays an important role in the lateral stability of the building. The slab helps to provide what is known as a rigid diaphragm. This diaphragm is imperative to the lateral system as it is the main path for lateral loads to be transferred from the exterior walls and framing elements into the shear walls. It is important that this transfer exists otherwise immense loads will be left within a frame that cannot support them.

Aside from the structural function of the floor system other important functions can be seen. The floor system is finished by placing tile upon the slab and hanging acoustical tile from the bottom of the system. The acoustical tile ceiling hides elements for other systems such as mechanical, electrical, and plumbing systems. Lighting fixtures are also suspended from the floor system and fit neatly through the acoustical tile creating a neat finished look.

This floor system is often used in office buildings and educational structures. It is rather efficient to construct and fairly economical. Ultimately, the greatest benefits seen by this system is the added stability and improved performance over other non-composite systems.

## *Framing Elements:*

The backbone of the Earth and Engineering Sciences building is the steel frame system. This steel "skeleton" provides support for the entire floor system as well as exterior walls and façade elements. In general 36 ksi steel is used throughout the building and is often the primary gravitational support for that portion of the building.

A number of different sized columns can be found on each floor, with larger sizes found on the lower levels. All columns are composed of 36 ksi steel and are oriented with the strong axis in the North-South direction. Most of the columns are considered sway columns, as they are not connected in a way that would prevent lateral movement. However there are a few columns that are part of a moment frame helping to support against East and West lateral loads. These moment connections are found in the frame of the Southern most wall. Columns in this building are continuous from the basement to the 2nd floor, where they are spliced with a new column that continues to the roof level.

The second part of the gravity frame is beams. Throughout the building a number of different sizes of beams can be found. On most locations beams are spaced at 10 feet on center and span no more than 32 feet. This small spacing

allows for a longer span and smaller beam members. In most sections of the building repetition of beam sizes can be found as loads and spacing remains the same. In some limited cases A572 Grade 50 steel was used for beams, but for the majority of the project A36 grade steel is used. The beams in the EES building gain an additional moment capacity from the composite action from the decking explained in the previous section. These beams are connected to the above metal decking by ¾" diameter 5 ¼" length shear studs.

### *Foundation:*

The structural system all starts with a solid foundation. The EES building has split foundation elements. The basement only exists under half of the total footprint of the building, as a result foundational supports are found in the basement and under part of the first floor. However, the same types of elements are present in both areas.

Spread footings are located throughout the foundation to help walls distribute loads to the soil. There are eight different footings used to complete this task. Reinforcing in these footings spans in each direction and varies in the number and size of bars used. Anywhere from 3 to 9 bars may be used ranging in sizes of #5 to #9 bars. In one incident top steel is added to a footing to provide further support.

The columns from the above floors also need a mechanism to transfer gravity loads into the soil. To conduct this transfer of loading column piers a put into effect. Eleven types of piers are used in order to accommodate for the various columns that exist. These piers all vary in size as well as reinforcement required. Piers range in size from 18" x 18" to 2'-2" x 2' in size. The reinforcement for each pier has a different number of bars used and the size of the bar can range from #6 to #8.

Slabs are also placed at the foundation level to provide a base for a floor. Typically mechanical equipment will be placed on the slab in the basement and the first floor slab will be finished with tile. The slab on grade that comprises most of the floor is 5" thick concrete placed on 6" of crushed stone. The slab is reinforced with 6 x 6, W2.1 x W2.1 welded wire fabric. Another slab found at the basement level is an 8" normal weight concrete slab reinforced with #4's at 12" O.C. each way on top and bottom. This slab is located in the stairwell to provide landing spaces.

The final element to the foundation is reinforced concrete walls. These walls provide an exterior barrier that primarily serves as a soil retention mechanism. These walls also must bear the loads from the columns and exterior

walls that are imposed by upper floors. These walls are typically 12" thick and are reinforced by #5 bars at 8" spacing in each direction.

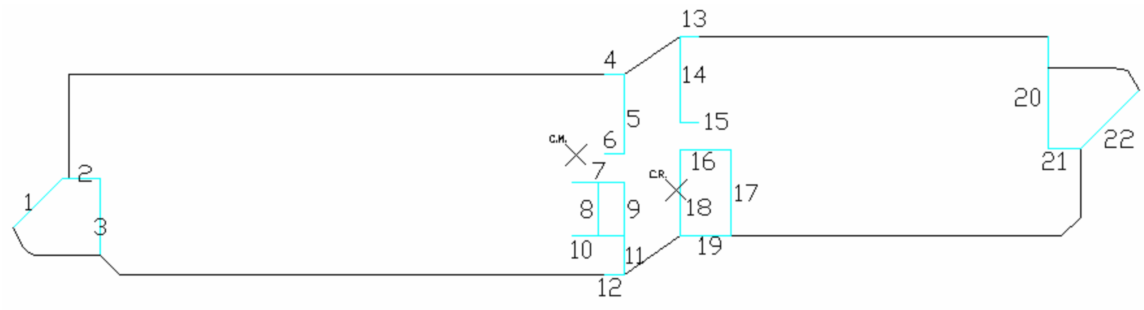
## *Lateral System:*

The lateral system for the Earth and Engineering Sciences building takes advantage of redundancies that provide lateral support without excessive measures. By utilizing several locations where massive walls would be needed for alternate functions a network of shear walls is created. This network of shear walls limits how much total force is seen by each lateral element. In this case the shear walls are composed of reinforced concrete. The location of the shear walls is illustrated in the plan shown below. These locations are around stairwells, mechanical chase shafts, and the two elevator shafts. The location of the shear walls provides great lateral resistance as several of the walls are far from the center of rigidity and can handle forces caused due to lateral torsion. The direct shear components are also small as there are several shear walls in each primary loading direction. The small forces seen by each element allows for a wall that does not need to be extremely large. Each wall is 12" thick and reinforced by #5 steel bars at 12" spacing on each face in each direction. The shear walls due need a little extra rebar as they also serve the function of bearing some additional gravitational loads.

In addition to the various shear walls, a moment frame also exists along the Southern face of the building. The State College area receives high velocity winds from the North-West and West. These higher wind speeds put more load on the East-West axis of the EES building otherwise seen as the long direction. As a result this moment frame is used in addition to the shear walls to pick up any uncommonly high loadings. Once again redundancy is employed to provide total safety.

Looking at the load path through the building we can see how lateral loads arrive at the lateral resisting elements. As loads are applied to the exterior walls, the walls begin to deform and transfer loads into the steel framing members. The columns are the first to see this load and respond almost the same manner as the exterior wall. The load is then transferred into the steel beams which are tied to the slab through the shear studs. The slab on deck then provides are rigid diaphragm that transfers loads to the shear walls via more shear studs. In the case of the moment frame the transfer is more direct. As loading is imposed on the East-West walls the load is transferred from the walls directly into the moment frame.

*Plan of existing shear walls:*




The wall to the far right in this picture is the shear wall labeled number 1 in the plan of the existing shear walls. This wall is located in the western stairwell.

# Problem Statement

As the Earth and Engineering Sciences building was still in the design phase decisions had to be made in regards to the building's mechanical equipment. It was believed that the air handling units needed to maintain interior conditions could be placed on the roof. Plans were made in order to achieve this goal. After several attempts it was decided that this could not be done. The EES building was already approaching the strict height limitation of 75'. In order to place the air handling units in the desired location a screen would need to be put in place it conceal the units. Engineers and architects believed that in order to achieve the visual effect parapets would become high enough to just violate the height restriction. The other consideration was that raising the parapets or adding a screen would detract form the overall theme of the façade.

The proposed solution was to move the air handling units to an alternate location. After several options were exhausted it was agreed on that a new space would have to be created in order to meet the needs of the mechanical equipment. A large basement area was added below grade and the air handling units were placed there to fix the problem. This solution resulted in a delay in construction as the contractor would have to be notified of these new changes and prepare accordingly. To add this new basement additional funding would be needed to cover the cost of the excavation, as well as CMU for the basement walls and steel columns to support the floor above. Also more steel deck would be needed for this area as a result of placing a floor deck system as opposed to slab on grade.

In the end this solution became a costly one in multiple ways. Time and money were both lost to accomplish what had to be done. The remainder of this report will explore another approach to solving this problem. The goal of this investigation will be to show that this alternate solution would have been a feasible choice and may have been a better choice.

# Proposed Solution

The height restriction posed a formidable dilemma to the design of the Earth and Engineering Sciences building. Even though the solution presented was a logical one and could be implemented somewhat tactfully, it may have not been the best approach. Adding an additional basement space would prove to be quite costly. In order to try to save money and stick more to the original design of the mechanical system an alternate solution needs to be presented.

In order to leave the air handling units on the roof there would need to be a way to comply with the local height restriction. The total building is already at a height of just over 66' leaving approximately eight feet of unused eight. It is virtually impossible to conceal an air handling unit with only 8'. The typical AHU on this project is a 7.5' in height and would need a clear space of approximately 12" to construct an isolation pad. Knowing this there would need to be some additional space created in order to place the equipment and hide it behind a parapet.

Space could be created by using a floor system that would be less deep than the existing slab on deck, and maintain the same floor to floor height. After an in depth investigation of several floor systems that may be able to be installed in the EES building, it was determined that hollow core plank would be the most viable solution. By installing hollow core plank within the web of steel framing members an additional 6 1/4" of depth would be eliminated from each floor. Additional height is saved at the roof level as steel joists will be eliminated as well as roof deck that produced an extra amount of unused depth.

Installing the hollow core plank will allow the roof line to be dropped and parapets to be built to the required height needed to conceal the AHU's. The height restriction will not be violated and the mechanical equipment will be placed on the roof level. By moving the mechanical equipment the need for a large basement space will be eliminated. Theoretically money will be saved by eliminating extra excavation and additional structural steel.

The remainder of this report will examine the validity of the proposed solution. A structural analysis and design will be performed to show that precast hollow core plank will be a suitable floor system. Other studies will include the effects on the mechanical equipment and building acoustics. Then, finally, a cost estimate and construction sequence will be generated to determine a final conclusion.

# Redesign of Structural System

## *Suggested Loading:*

A set of design loadings must be stated to determine what structural elements will be needed for construction. Below will be a summary of the various loads found on the building. The live loading will not be changed in from what already exists, but changes will need to be made to the dead loading. The reasons for the change in dead loading is that an new floor system is being used for each floor as well as increased load at the roof due to the mechanical equipment. Snow loading and wind loading do not change drastically and will be taken as previously calculated. Seismic loading will change based on a redistribution of weight throughout the building and will be discussed in a later section.

1. **Dead**

- **$1^{st}$ – $4^{th}$ Floor:**

| | |
|---|---|
| Hollow core Plank | – 57.5 psf |
| Spray-on Fireproofing | – 4 psf |
| Mech/Elec | – 10 psf |
| Sprinklers | – 5 psf |
| Ceiling | – 5 psf |
| | 81.5 psf |

- **Roof:**

| | |
|---|---|
| Hollow core Plank | – 57.5 psf |
| Mechanical Equipment | – 24.5 psf |
| Roofing | – 2 psf |
| Insulation | – 2 psf |
| Spray-on Fireproofing | – 4 psf |
| Mech/Elec | – 10 psf |
| Sprinklers | – 5 psf |
| Ceiling | – 5 psf |
| | 110 psf |

It must be noted that there were significant changes in the dead loading form that of the original design. There was an increase on the dead loading for each floor of 11.5 pounds per square foot and increase at the roof level of 80 pounds per square foot. This will result in larger members needed within the steel frame.

**2. Live (See Appendix A for diagrams)**

- 150 psf for Mechanical Areas
- 125 psf for Laboratory Areas
- 100 psf for Stairs and exits
- 80 psf for Corridors above first floor in schools
- 60 psf for Assembly areas and theatres with fixed seating

**3. Snow (ASCE7-02)**

- $S = .7C_eC_tC_sp_gI$
    i. $C_e = .9$ from Table 7-2
    ii. $C_t = 1$ from Table 7-3
    iii. $C_s = 1$ for flat roof from Fig. 7-2
    iv. $P_g = 40$ psf from Fig. 7-1
    v. $I_s = 1$ for Cat. II from Table 7- 4

  S = 25.2 psf

Wind loading will not be considered at this time as it did not have any significant changes. It has also been determined that seismic loading causes greater forces on the lateral system than wind loading. For this reason, wind will not be discussed, but calculations can be seen in Appendix B. Seismic loads will be talked about in greater detail in the lateral analysis section of this report.

## *Investigation of Alternate Floor Systems:*

The loadings in the previous section were determined based on a precast hollow core plank placed on a structural steel frame. The decision to use this system came from a study done of four alternate structural floor systems. Each system was part of a pro/con study weighing the benefits versus the drawbacks. The first alternative was to simply change the grade of steel from 36 ksi to 50 ksi. The benefit of this system was obviously increased strength. However, using the slab on deck with the higher grade steel still resulted in a deep floor system. The second system was to place hollow core plank on a steel frame. The advantages of hollow core is that it is easy to erect, relatively lightweight, causes few delays in construction as it is precast, but most of all provides a shallow floor system. A one way pan joist was studied as the third option. This system was quickly ruled out as it weighed significantly more than the other systems and caused more issues in construction. Ultimately the pan joist could be eliminated as it provided no means to eliminate floor system depth. The final option viewed was open web steel joists. Steel joists are great building tools in that they are lightweight, easily erected, and provide ample space for mechanical equipment. However, the large depth of the joists would not aid in the reduction of floor space.

After weighing all the options an alternate floor system was selected. The 50 ksi steel frame was a good option to gain some strength in the structure. The slab on metal deck would be eliminated clearing just over 6 inches from the depth of the floor. In its' place a hollow core plank floor could be placed within the web of the steel beams and girders. The connection elements could be welded to the beam webs at the fabrication shop and help erection time be minimized. The higher loads would cause slightly larger beam and girder sizes, but this will not be a concern as an acoustical tile ceiling will be suspended below the beam flanges. All the mechanical ductwork, plumbing, and electrical wiring will remain unaffected. This system will achieve the reduction desired at each floor level.

## *Design of Hollow Core Plank:*

The first step in the design of the new structural system will be to determine how the building will support itself under gravity loading. Live loads and dead loads have already been determined for the main floor system. In order to begin the design process hollow core planks must be sized to withstand this loading. The hollow core will be shipped in from the nearest precast plant, it is for this reason that the specifications of that companies product should be used in the design. In the case of the EES Building Nitterhouse Concrete Products will be the supplier of the hollow core. After a hollow core plank size is determined, the self weight of the plank can be used to design the steel gravity frame.

Some basic assumptions need to be made in order to properly size the plank. The main assumptions include span and direction of the plank. It will be assumed for this design that the hollow core will be placed on a typical bay size of the existing frame. Bays for the EES building are twenty feet by approximately thirty two feet with a beam in the long direction that bisects girders in the short direction. This results in a maximum span of ten feet or thirty two feet depending on span direction. The original design calls for metal decking to span in the short direction. In order to maintain a proper diaphragm the hollow core will span in this direction as well, resulting in a design span of ten feet.

The next step is to determine what size plank will be needed to carry the loads specified above. There may need to be a different size at the roof level, but at a ten foot span a large plank shouldn't be needed. Looking at the specifications for Nitterhouse 8" untopped hollow core plank it is clear that for a ten foot span all loads can be safely carried. This plank with four prestressing strands of ½" diameter can safely carry 441 psf which is much greater than the 110 psf required. This size plank will be connected to the web of the framing members with angles, plates, and studs as illustrated in the diagram below.

## *Design of 50 ksi Steel Frame:*

In the original schematics for the Earth and Engineering Sciences building A36 grade steel was called out for the brunt of the structural frame. A few incidences of 50 ksi did occur, but now the entire frame will be designed with this grade of steel. With the substitution of hollow core plank instead of metal decking the steel frame loses its' composite action. Therefore there is a reduced amount of capacity from each individual steel member and larger sizes will need to be specified. The use of 50 ksi grade steel will help to limit how much the size of these members must increase.

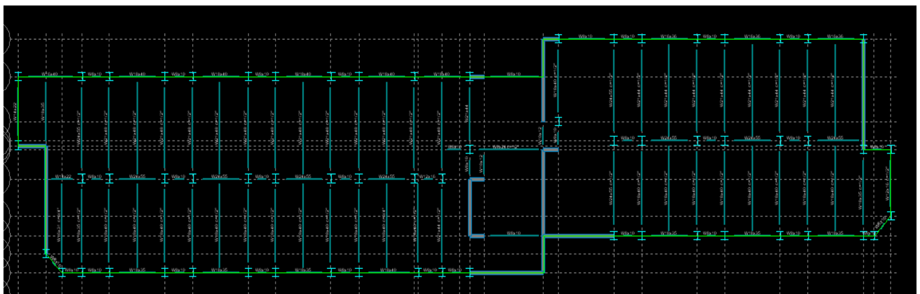
The design of a steel frame can be a tedious task. A helpful tool to aid in this design is a software program capable to perform the analysis. In this instance the structural software RAM will be used to carry all calculations and choose appropriate member sizes. The EES building was recreated within the RAM model function. Generic elements were created to represent all influential structural components. The model was then loaded according to the above stated loadings. Each floor was subjected to 82.5 psf and the roof saw a loading of 110 psf. The live loads were distributed according to the diagrams referenced in Appendix A.

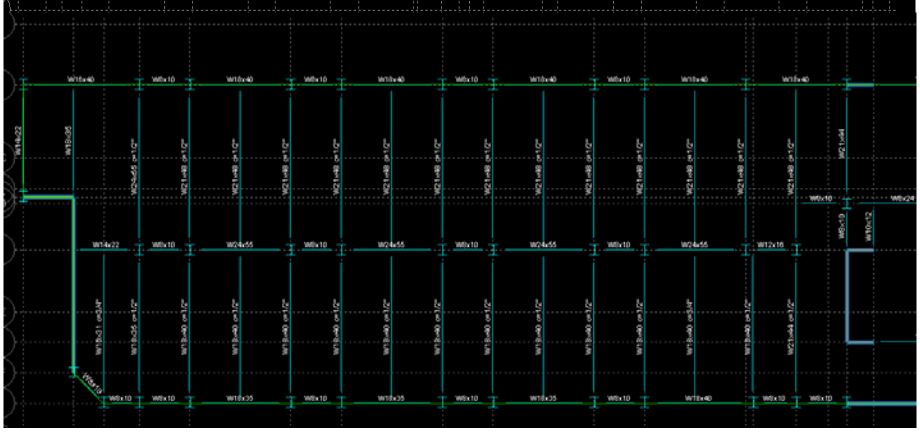
The software performed a full gravity analysis and estimated sizes for all steel members. Analysis was not done for the shear walls or foundations. Shear wall size and reinforcement verification will be discussed in a later section. A summary of common sizes for both beams and columns can be seen in the chart below. A full summary of all column and beam sizes are presented in Appendix C. For the most part sizes did increase but the use of a suspended acoustical tile ceiling allows the use of larger members without adding depth to the floor system on the whole. A quick spot check for a typical beam can be seen in Appendix D.

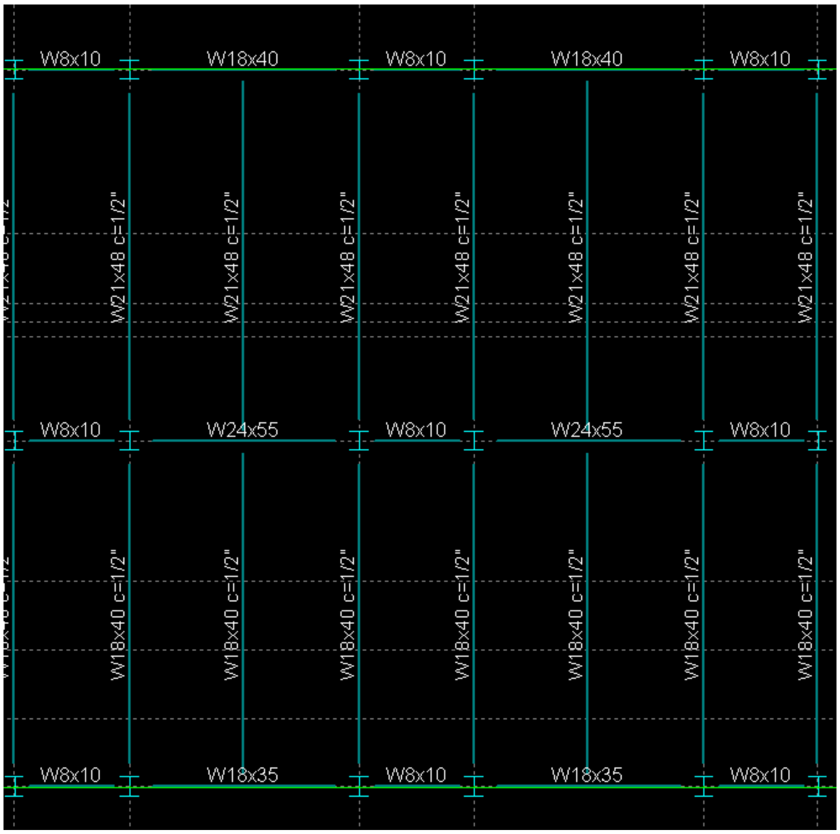
| Summary of Beam and Girder Sizes Typical to Each Story | | | | | |
|---|---|---|---|---|---|
| | Story | | | | |
| | 1 | 2 | 3 | 4 | Roof |
| Beam 1 | | W18x35 | W18x40 | W18x40 | W21x44 |
| Beam 2 | | W18x40 | W21x44 | W21x44 | W21x44 |
| Beam 3 | | W21x48 | W21x48 | W21x48 | W21x44 |
| Girder | | W24x55 | W24x55 | W24x55 | W24x55 |
| Column 1 | | W10x49 | W10x49 | W10x33 | W10x33 |
| Column 2 | | W12x58 | W12x58 | W12x40 | W12x40 |

The columns, beams, and girders on the first floor are eliminated as this will become slab on grade.

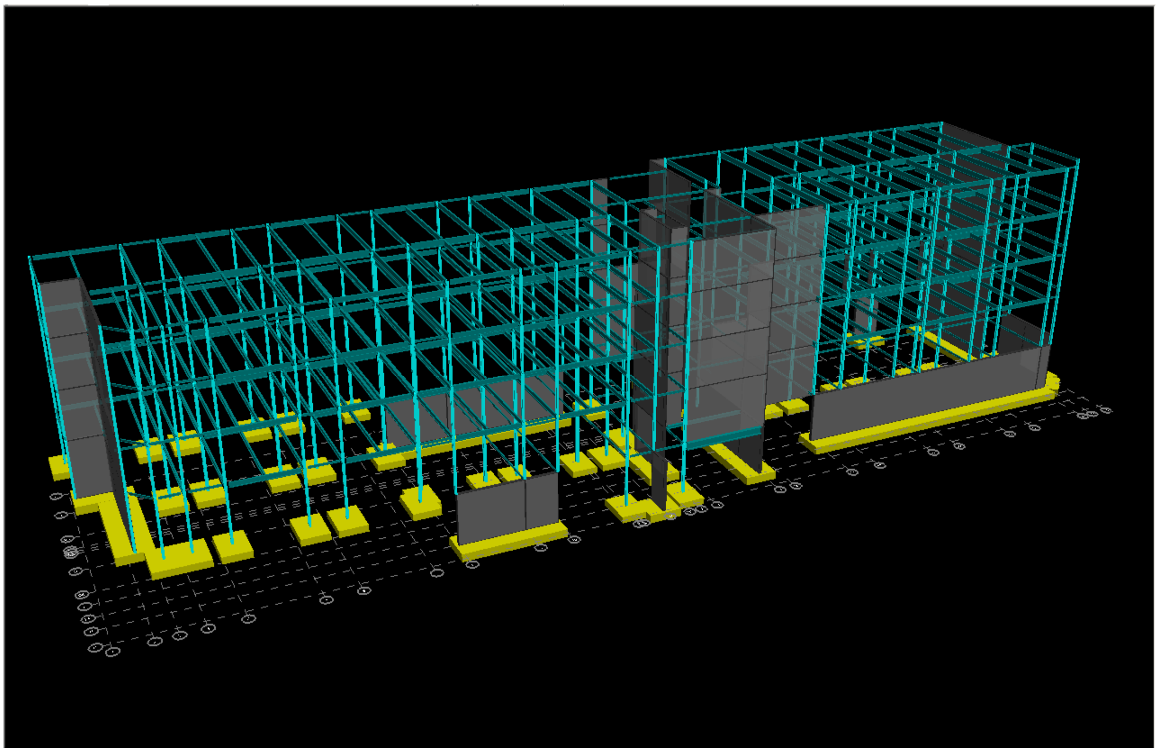
Typical floor layouts were generated by RAM and an example is shown below. A closer view of a few typical bays is also displayed. All sizes seem reasonable and a spot check was done to verify that the sizes are accurate.








This view represents a typical bay for the West Wing of the EES building.



**3D View of Steel Frame (Gray areas represent concrete walls, Yellow areas indicate foundations)**

## *Lateral Analysis of Shear Walls:*

In addition to gravitational loading lateral forces are also imposed on the building. These loads are caused due to wind and seismic disruptions. Due to the EES buildings weight and location it is influenced more by seismic loads than wind loads. It is for this reason that the shear walls will be designed according to the seismic loads on the building as they are more critical.

The shear walls in the EES building already need to be quite massive to withstand gravity loads that are placed on them. In an attempt to reduce unnecessary costs it will be investigated whether or not the shear walls can resist higher lateral loads without needing to become larger or adding more reinforcement. A spreadsheet has been produce to document the calculations of seismic story forces. Seismic forces were determined by ASCE 7-02 and use of the Equivalent Lateral Force Procedure in Sec. 9.5.5. A second spreadsheet was developed to aid in the distribution of these story forces in each shear wall. Both spreadsheets appear below.

| | | | | | |
|---|---|---|---|---|---|
| Roof DL | 110 psf | | | | |
| Floor DL | 82.5 psf | T | 0.656 | V | 369768.5 lbs |
| Ext Walls | 15 plf | $C_s$ | 0.05 | | |
| snow | 25.2 psf | $W_{roof}$ | 2191914 lbs | | |
| | | $W_1$ | 1745548 lbs | | |
| B | 62.5 ft | $W_2$ | 1745548 lbs | | |
| L | 307 ft | $W_3$ | 1712360 lbs | | |
| h | 62 ft | Σ | 7395370 lbs | | |
| # of stories | 4 | ΣW'h' | 306364988 | | |
| SUG | 1 | $C_{roof}$ | 0.444 | $F_{roof}$ | 164.18 kips |
| Imp | 1 | $C_1$ | 0.27 | $F_1$ | 99.84 kips |
| Site classification | C | $C_2$ | 0.186 | $F_2$ | 68.78 kips |
| $S_s$ | 0.17 | $C_3$ | 0.1 | $F_3$ | 36.98 kips |
| $S_1$ | 0.06 | | | | |
| $f_a$ | 1.2 | | | | |
| $f_v$ | 1.7 | | | | |
| $S_{ds}$ | 0.204 | | | | |
| $S_{d1}$ | 0.102 | | | | |
| r | 3 | | | | |

From this table it is seen that the higher forces occur when reaching the roof level. This is cause by the added weight of the mechanical equipment at that level.

The following tables are part of a distribution of lateral forces. The final table represents a summary of the total force in which each wall must be designed.

| H/L | | | | |
|---|---|---|---|---|
| Wall | 1st Floor | 2nd Floor | 3rd Floor | 4th Floor |
| 1 | 0.788 | 0.667 | 0.667 | 0.667 |
| 2 | 1.444 | 1.222 | 1.222 | 1.222 |
| 3 | 0.722 | 0.611 | 0.611 | 0.611 |
| 4 | 2.889 | 2.445 | 2.445 | 2.445 |
| 5 | 0.693 | 0.587 | 0.587 | 0.587 |
| 6 | 2.889 | 2.445 | 2.445 | 2.445 |
| 7 | 1.083 | 0.917 | 0.917 | 0.917 |
| 8 | 1.019 | 0.863 | 0.863 | 0.863 |
| 9 | 1.019 | 0.863 | 0.863 | 0.863 |
| 10 | 1.083 | 0.917 | 0.917 | 0.917 |
| 11 | 1.444 | 1.222 | 1.222 | 1.222 |
| 12 | 2.889 | 2.445 | 2.445 | 2.445 |
| 13 | 2.889 | 2.445 | 2.445 | 2.445 |
| 14 | 0.642 | 0.543 | 0.543 | 0.543 |
| 15 | 2.889 | 2.445 | 2.445 | 2.445 |
| 16 | 1.083 | 0.917 | 0.917 | 0.917 |
| 17 | 0.642 | 0.543 | 0.543 | 0.543 |
| 18 | 0.642 | 0.543 | 0.543 | 0.543 |
| 19 | 1.083 | 0.917 | 0.917 | 0.917 |
| 20 | 0.491 | 0.415 | 0.415 | 0.415 |
| 21 | 1.733 | 1.467 | 1.467 | 1.467 |
| 22 | 0.665 | 0.564 | 0.564 | 0.564 |

| K - Rigidities | | | | |
|---|---|---|---|---|
| Wall | 1st Floor | 2nd Floor | 3rd Floor | 4th Floor |
| 1 | 4.180 | 4.827 | 4.827 | 4.827 |
| 2 | 1.079 | 1.371 | 1.371 | 1.371 |
| 3 | 4.933 | 5.615 | 5.615 | 5.615 |
| 4 | 0.166 | 0.225 | 0.225 | 0.225 |
| 5 | 5.317 | 6.014 | 6.014 | 6.014 |
| 6 | 0.166 | 0.225 | 0.225 | 0.225 |
| 7 | 2.141 | 2.605 | 2.605 | 2.605 |
| 8 | 2.451 | 2.953 | 2.953 | 2.953 |
| 9 | 2.451 | 2.953 | 2.953 | 2.953 |
| 10 | 2.141 | 2.605 | 2.605 | 2.605 |
| 11 | 1.079 | 1.371 | 1.371 | 1.371 |
| 12 | 0.166 | 0.225 | 0.225 | 0.225 |
| 13 | 0.166 | 0.225 | 0.225 | 0.225 |
| 14 | 6.098 | 6.818 | 6.818 | 6.818 |
| 15 | 0.166 | 0.225 | 0.225 | 0.225 |
| 16 | 2.141 | 2.605 | 2.605 | 2.605 |
| 17 | 6.098 | 6.818 | 6.818 | 6.818 |
| 18 | 6.098 | 6.818 | 6.818 | 6.818 |
| 19 | 2.141 | 2.605 | 2.605 | 2.605 |
| 20 | 9.442 | 10.171 | 10.171 | 10.171 |
| 21 | 0.676 | 0.878 | 0.878 | 0.878 |
| 22 | 5.705 | 6.415 | 6.415 | 6.415 |

| Components for Center of Rigidity | | | | |
|---|---|---|---|---|
| Wall | X | Y | | |
| 1 | 0.000 | | 4.180 | 4.827 |
| 2 | | 30.167 | 1.079 | 1.371 |
| 3 | 27.500 | | 4.933 | 5.615 |
| 4 | | 62.660 | 0.166 | 0.225 |
| 5 | 191.500 | | 5.317 | 6.014 |
| 6 | | 37.660 | 0.166 | 0.225 |
| 7 | | 29.000 | 2.141 | 2.605 |
| 8 | 183.500 | | 2.451 | 2.953 |
| 9 | 191.500 | | 2.451 | 2.953 |
| 10 | | 12.000 | 2.141 | 2.605 |
| 11 | 191.500 | | 1.079 | 1.371 |
| 12 | | 0.000 | 0.166 | 0.225 |
| 13 | | 75.000 | 0.166 | 0.225 |
| 14 | 209.000 | | 6.098 | 6.818 |
| 15 | | 48.000 | 0.166 | 0.225 |
| 16 | | 39.000 | 2.141 | 2.605 |
| 17 | 225.000 | | 6.098 | 6.818 |
| 18 | 209.000 | | 6.098 | 6.818 |
| 19 | | 12.000 | 2.141 | 2.605 |
| 20 | 324.500 | | 9.442 | 10.171 |
| 21 | | 39.333 | 0.676 | 0.878 |
| 22 | 353.000 | | 5.705 | 6.415 |
| | | | 53.850 | 60.772 |
| | | | 11.149 | 13.793 |

| | Center of Rigidity | | | | |
|---|---|---|---|---|---|
| | 1st Floor | 2nd Floor | 3rd Floor | 4th Floor | |
| $X_{cr}$ | 209.436 | 207.740 | 207.740 | 207.740 | |
| $Y_{cr}$ | 26.296 | 26.516 | 26.520 | 26.520 | |

| Eccentricities | |
|---|---|
| $E_x$ (ft) | -31.240 |
| $E_y$ (ft) | 11.000 |

| Torsional Moment for Each Floor | | | | |
|---|---|---|---|---|
| | 1st Floor | 2nd Floor | 3rd Floor | 4th Floor |
| $M_t$ (ft-kips) | -1155.880 | -2149.312 | -3117.752 | -5129.608 |

| | | | $1^{st}$ | $2^{nd}$ - $4^{th}$ |
|---|---|---|---|---|
| Wall | $d_i$ | $d_i^2$ | $Kd_i^2$ | $Kd_i^2$ |
| 1 | -207.740 | 43155.929 | 180391.785 | 208306.249 |
| 2 | 3.651 | 13.329 | 14.380 | 18.268 |
| 3 | -180.240 | 32486.477 | 160241.820 | 182427.354 |
| 4 | 36.144 | 1306.402 | 216.831 | 293.376 |
| 5 | -16.240 | 263.739 | 1402.241 | 1586.202 |
| 6 | 11.144 | 124.193 | 20.613 | 27.890 |
| 7 | 2.484 | 6.171 | 13.213 | 16.078 |
| 8 | -24.240 | 587.580 | 1439.981 | 1734.945 |
| 9 | -16.240 | 263.739 | 646.345 | 778.742 |
| 10 | -14.516 | 210.709 | 451.158 | 548.965 |
| 11 | -16.240 | 263.739 | 284.548 | 361.469 |
| 12 | -26.516 | 703.088 | 116.696 | 157.891 |
| 13 | 48.484 | 2350.717 | 390.163 | 527.896 |
| 14 | 1.260 | 1.587 | 9.680 | 10.823 |
| 15 | 21.484 | 461.570 | 76.610 | 103.654 |
| 16 | 12.484 | 155.855 | 333.708 | 406.053 |
| 17 | 17.260 | 297.906 | 1816.542 | 2030.990 |
| 18 | 1.260 | 1.587 | 9.680 | 10.823 |
| 19 | -14.516 | 210.709 | 451.158 | 548.965 |
| 20 | 116.760 | 13632.885 | 128716.250 | 138664.303 |
| 21 | 12.817 | 164.280 | 111.052 | 144.297 |
| 22 | 145.260 | 21100.452 | 120386.310 | 135362.609 |
| | | J ($ft^2$) = | 597540.761 | 674067.842 |

| $F_{torsion}$ (kips) | | | | |
|---|---|---|---|---|
| Wall | $1^{st}$ Floor | $2^{nd}$ Floor | $3^{rd}$ Floor | $4^{th}$ Floor |
| 1 | 1.680 | 3.197 | 4.638 | 7.631 |
| 2 | -0.008 | -0.016 | -0.023 | -0.038 |
| 3 | 1.720 | 3.227 | 4.681 | 7.702 |
| 4 | -0.012 | -0.026 | -0.038 | -0.062 |
| 5 | 0.167 | 0.311 | 0.452 | 0.743 |
| 6 | -0.004 | -0.008 | -0.012 | -0.019 |
| 7 | -0.010 | -0.021 | -0.030 | -0.049 |
| 8 | 0.115 | 0.228 | 0.331 | 0.545 |
| 9 | 0.077 | 0.153 | 0.222 | 0.365 |
| 10 | 0.060 | 0.121 | 0.175 | 0.288 |
| 11 | 0.034 | 0.071 | 0.103 | 0.169 |
| 12 | 0.009 | 0.019 | 0.028 | 0.045 |
| 13 | -0.016 | -0.035 | -0.050 | -0.083 |
| 14 | -0.015 | -0.027 | -0.040 | -0.065 |
| 15 | -0.007 | -0.015 | -0.022 | -0.037 |
| 16 | -0.052 | -0.104 | -0.150 | -0.248 |
| 17 | -0.204 | -0.375 | -0.544 | -0.895 |
| 18 | -0.015 | -0.027 | -0.040 | -0.065 |
| 19 | 0.060 | 0.121 | 0.175 | 0.288 |
| 20 | -2.132 | -3.787 | -5.493 | -9.038 |
| 21 | -0.017 | -0.036 | -0.052 | -0.086 |
| 22 | -1.603 | -2.971 | -4.310 | -7.091 |

| $F_{direct}$ (kips) | | | | |
|---|---|---|---|---|
| Wall | $1^{st}$ Floor | $2^{nd}$ Floor | $3^{rd}$ Floor | $4^{th}$ Floor |
| 1 | 2.872 | 5.464 | 7.927 | 13.042 |
| 3 | 3.389 | 6.357 | 9.222 | 15.173 |
| 5 | 3.653 | 6.809 | 9.877 | 16.250 |
| 8 | 1.684 | 3.343 | 4.849 | 7.978 |
| 9 | 1.684 | 3.343 | 4.849 | 7.978 |
| 11 | 0.741 | 1.552 | 2.251 | 3.703 |
| 14 | 4.190 | 7.718 | 11.196 | 18.420 |
| 17 | 4.190 | 7.718 | 11.196 | 18.420 |
| 18 | 4.190 | 7.718 | 11.196 | 18.420 |
| 20 | 6.487 | 11.515 | 16.703 | 27.482 |
| 22 | 3.920 | 7.263 | 10.535 | 17.333 |

| $F_{total}$ (kips) | | | | |
|---|---|---|---|---|
| Wall | $1^{st}$ Floor | $2^{nd}$ Floor | $3^{rd}$ Floor | $4^{th}$ Floor |
| 1 | 4.552 | 8.662 | 12.565 | 20.672 |
| 2 | 0.008 | 0.016 | 0.023 | 0.038 |
| 3 | 5.109 | 9.585 | 13.903 | 22.875 |
| 4 | 0.012 | 0.026 | 0.038 | 0.062 |
| 5 | 3.820 | 7.120 | 10.328 | 16.993 |
| 6 | 0.004 | 0.008 | 0.012 | 0.019 |
| 7 | 0.010 | 0.021 | 0.030 | 0.049 |
| 8 | 1.799 | 3.571 | 5.180 | 8.523 |
| 9 | 1.761 | 3.496 | 5.071 | 8.343 |
| 10 | 0.060 | 0.121 | 0.175 | 0.288 |
| 11 | 0.775 | 1.623 | 2.354 | 3.873 |
| 12 | 0.009 | 0.019 | 0.028 | 0.045 |
| 13 | 0.016 | 0.035 | 0.050 | 0.083 |
| 14 | 4.190 | 7.718 | 11.196 | 18.420 |
| 15 | 0.007 | 0.015 | 0.022 | 0.037 |
| 16 | 0.052 | 0.104 | 0.150 | 0.248 |
| 17 | 4.190 | 7.718 | 11.196 | 18.420 |
| 18 | 4.190 | 7.718 | 11.196 | 18.420 |
| 19 | 0.060 | 0.121 | 0.175 | 0.288 |
| 20 | 6.487 | 11.515 | 16.703 | 27.482 |
| 21 | 0.017 | 0.036 | 0.052 | 0.086 |
| 22 | 3.920 | 7.263 | 10.535 | 17.333 |

## *Design of Shear Walls*

*Overturning Moment:* Overturning Moment Check for shear wall 20

$M_{OT}$ = (27.5 x 62) + (16. 7 x 47.3) + (11.52 x 32.68) + (6.5 x 17.33) = 2984 ft-kip
$M_R$ = 150(1') (35') (62') (35'/2) = 5696 ft-kip > 2984 ft-kip

The self weight of the shear wall is enough to resist overturning moment; additional loads from the structure provide additional weight to provide stability. The reinforcement in the shear wall will also help to provide more strength against overturning. After investigation it does not appear that overturning moments will be a critical component in the design process.

*Drift:*

Drift in the Earth and Engineering Sciences Building is quite small as it should be. The building is a four story building and is quite massive in terms of weight. The number of shear walls in this building makes it quite rigid and able to significantly resist lateral forces. As a result the story drift and total drift are quite small. In this analysis is will be considered that the drift of the entire building will be equal to that of the critical shear wall. Each wall was evaluated considering two drift components: a shear and a bending component. Based on the formula, $\Delta_T$ = (1.5V/bE) [(h/l) + (h/l) ^3], values were computed for each wall at each level and a total drift at the roof line. The most critical wall is wall 11 which has a $\Delta_{T\ @\ roof}$ = .0385. An acceptable drift value would be equivalent to l/400 or in this case

(62')(12"/')/400 = 1.86 in

*Spot Check*: Design for Shear
• Check shear strength in 1st story of wall 20
Total shear = 27.5+ 16.7 +11.52 +6.5 = 62.2 kips
Per ACI 318-02 Sect. 9.2, Vu= 1.6 x 62.2 = 99.6 kips
ΦVc/2= 241.32 kips
Since Vu < φVc/ 2 => O.K.
Story 1 provides the most critical case. Other floors do not need to be considered since a minimum steel reinforcement is used at level one. Minimum steel should be continued to upper levels. For 12" wall, use No. 4 @ 12" each way on each face.

*Design for Flexure*
This design will be a continuance on the design for wall 20. The reinforcement needed from shear forces was a minimum. To perform this part of the analysis the reinforcement specified in the plan will be used to determine the strength of the wall.

When evaluating moment strength, the load combination given in ACI Eq. (9-6) will usually govern: U = 1.2D + E + .5L

• Dead load and seismic moment in 1$^{st}$ story

Tributary floor area = 100 ft$^2$
Wall dead load = [0.150(12 x 264)]/144 = 3.3 kips/ft wall height

Pu= 1.2[(0.11 x 100) + (0.082 x 100 x 3) + (3.3 x 62)] + .5[(.1 x 100)] = 293.24 kips
Mu= [(27.5 x 62) + (16. 7 x 47.3) + (11.52 x 32.68) + (6.5 x 17.33)] = 2984 ft-kips

$A_{st}$ = 35' x .465 = 16.28 in$^2$
w = ($A_{st}$ / $l_w h$) ($f_y$/$f'_c$) = .048
a = $P_u$ / ($l_w h$ $f'_c$) = .0145
c / $l_w$ = w + a / (2w + .85$b_1$) = .072
$\varphi M_n$ = φ [.5 $A_{st} l_w$ $f_y$ (1 + $P_u$ / ($A_{st}$ $f_y$)) (1 - c / $l_w$)] = 222,747 in-kips = 18,562 ft-kips > 2984 ft-kips

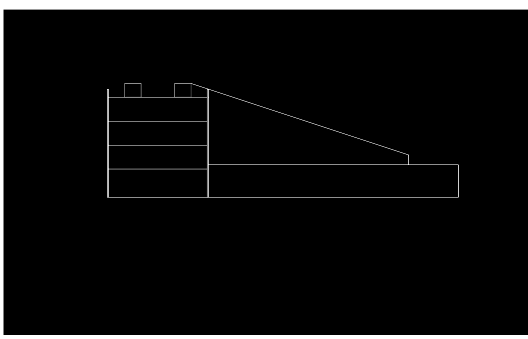
#5's @ 8 provide sufficient resistance to bending. The original shear walls are sufficient to resist the increased loading. The number of shear walls and size of each wall are what make this possible.

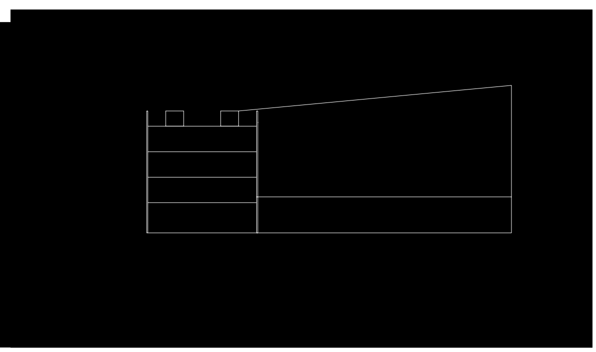
## *Parapet Design:*

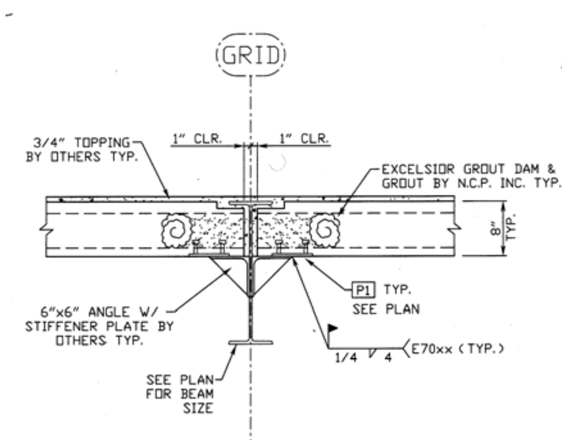
Some type of screen will need to be used to conceal the mechanical units. In this case the existing parapets will be raised to twice there existing height. As a result they will need to be grouted and reinforced to resist lateral loading. The 8" CMU parapets were designed as 8'-6" unsupported walls and determined to need a minimum of #6 bar steel reinforcing at no more than 40" spacing. The calculations for this design can be found in Appendix E.

## *Final Design:*

The resulting design for the Earth and Engineering Sciences building is roughly illustrated in the images below. The floor to ceiling height remains the same for each floor, with the depth of the floor system at each level reducing by 6 ¼”. The mean roof height now reaches sixty feet, and the total height of the building will reach 68’-6”. A quick investigation of sight lines show that at no point on the surrounding areas will someone reach ground high enough to detect the mechanical equipment. Along with these sketches is a cross section of how the hollow core plank will be attached to the steel beams and girders. The first diagram shows that a six foot tall person elevated 20’ could detect the equipment 122’ from the current building layout. While the diagram on the right shows that under the new layout a person would have to be elevated above the building to see the mechanical equipment.








SECTION 19
3/4" = 1'-0"

# Breadth Studies

## *Impact on Mechanical Systems:*

The mechanical systems will be greatly affected in this redesign as they were the main reason for redesign. The mechanical equipment will be placed on the roof and will result in several issues that must be accounted for. The first issue was the structural changes caused by this added weight. These changes were already dealt with in the structural section of this report. The second problem becomes the resizing of air handling units. The same air handling units from the basement can not be used again as they are indoor units and not designed for outdoor weather conditions. The other problem with moving the equipment will be where to locate them. Finally, after the equipment is dealt with it needs to be determined what will happen to the ductwork for each level. These problems will all be dealt with appropriately.

Sizing and selecting replacement units will be done through the use of an engineering tech guide. In this case the manufacturer will be York International. A packaged air handling unit will be selected to deal with the environmental change. To select the units it must be known what capacities are required to adequately service the building. The original units were used to calculate the amount of supply air, total cooling capacity, and tons needed.

| AHU | Supply Air (cfm) | Total Cooling Capacity (MBH) | Ton |
|---|---|---|---|
| 1 | 30,245 | 1741 | 145 |
| 2 | 21,990 | 1266 | 106 |
| 3 | 16,895 | 1219 | 102 |
| 4 | 18,960 | 1093 | 91 |
| 5 | 14,255 | 997 | 83 |

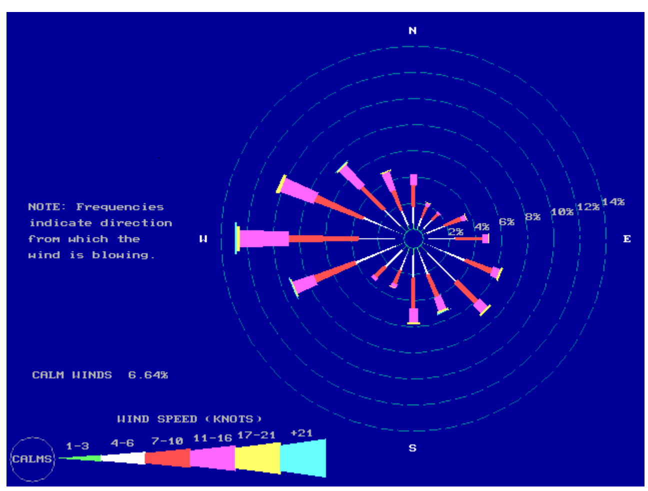
Based on these values alternate units are selected from the York International Engineers Guide for packaged units.

From this guide a 16,500 cfm unit was selected to account for AHU 3 and AHU 5, a 19,500 cfm for AHU 4, a 22,500 cfm for AHU 2, and a 30,500 cfm unit for AHU 1. Some of these units were originally ducted together and will be in the new layout as well. It is this stipulation that allows a selection of a unit slightly under capacity for AHU 3. AHU 3 will be ducted to AHU 5 which is over capacity. The largest unit will be AHU 1, with a height of 8.5' including an isolation pad; it will be the factor in mechanical screen size.

QUICK SELECT TOOL – OPTIMAL SIZES

| CFM | H | W | COIL AREA | AF SQ. FT AREA | RF/FF SQ. FT AREA | MAX FC FAN | MAX AF FAN | MAX SWSI FAN |
|---|---|---|---|---|---|---|---|---|
| 900 | 27 | 27 | 1.8 | 4.4 | - | 7x7 | - | - |
| 1500 | 30 | 33 | 2.9 | 4.0 | 3.3 | 9x9 | - | - |
| 2000 | 36 | 33 | 4.0 | 8.0 | 4.0 | 12x9 | - | - |
| 2500 | 33 | 45 | 5.2 | 8.9 | 6.0 | 10x10 | - | 12 |
| 3500 | 36 | 48 | 6.9 | 11.1 | 6.0 | 12x12 | 12 | 12 |
| 4500 | 36 | 60 | 9.2 | 16.0 | 8.0 | 12x12 | 12 | 14 |
| 5500 | 42 | 60 | 10.8 | 16.0 | 10.7 | 15x15 | 15 | 18 |
| 6000 | 42 | 66 | 12.2 | 18.7 | 10.7 | 15x15 | 15 | 18 |
| 7000 | 42 | 72 | 13.5 | 26.7 | 13.3 | 15x15 | 15 | 18 |
| 8000 | 48 | 72 | 15.6 | 26.7 | 15.0 | 18x18 | 18 | 25 |
| 9000 | 48 | 78 | 17.9 | 35.6 | 15.0 | 18x18 | 18 | 25 |
| 10000 | 51 | 78 | 19.5 | 35.6 | 18.9 | 20x20 | 20 | 25 |
| 11500 | 57 | 78 | 21.8 | 35.6 | 22.7 | 22x22 | 22 | 28 |
| 13500 | 60 | 84 | 26.5 | 36.0 | 24.0 | 22x22 | 22 | 28 |
| 16500 | 66 | 96 | 32.1 | 53.3 | 31.1 | 28x28 | 28 | 35 |
| 19500 | 66 | 114 | 39.0 | 57.8 | 38.9 | 28x28 | 28 | 35 |
| 22500 | 72 | 120 | 45.0 | 62.2 | 45.0 | 32x32 | 32 | 39 |
| 26500 | 78 | 126 | 53.4 | 80.0 | 48.3 | 32x32 | 32 | 44 |
| 30500 | 90 | 120 | 60.0 | 93.3 | 60.0 | 36x36 | 36 | 49 |
| 34500 | 96 | 126 | 67.3 | 106.7 | 64.4 | 40x40 | 40 | 49 |
| 38500 | 108 | 126 | 75.2 | 106.7 | 77.3 | 40x40 | 40 | 49 |
| 42500 | 108 | 138 | 83.1 | 110.0 | 85.3 | 40x40 | 40 | 49 |
| 46500 | 114 | 144 | 94.0 | 151.1 | 91.7 | 40x40 | 40 | 49 |
| 50500 | 120 | 144 | 98.5 | 151.1 | 91.7 | 40x40 | 40 | 49 |
| 51500 | 126 | 144 | 103.0 | 151.1 | 104.7 | 40x40 | 40 | 49 |

The second problem with the new units aside from environmental conditions was where to locate them on the roof. The units need to be placed relatively close to the central core of the building. The mechanical chase is located near the core and each unit would need to have access to it. The five units were placed near the center of the building or close to the center on the West wing. With the exhaust air from the mechanical system also being at the roof level, the AHU's would need to be located 10' upwind to meet code. Using a wind rose to determine local wind patterns the direction that the most direct wind will come from is the Northwest. To meet code all the AHU's will be located 10' west of any exhaust point.



Finally, the ductwork will need to be changed in order to compensate for the changes made to the location of the equipment. The ductwork leading to all areas on each level will not change. However, the ductwork moving from the roof to the first level will need to be. Essentially what will be happening is a complete switch of what is happening in the original system. The riser diagram will be completely reversed with larger ductwork now at the top of the structure. The large mechanical room on the first level will no longer be needed as there won't be any ductwork passing beyond the ceiling level. The mechanical space at levels three and four will be significantly larger with not much change on level two. The mechanical chase will be reused. In essence everything will be taken from the original layout and flipped to run in the opposite direction.

The mechanical systems in the Cray supercomputer room will be untouched. These units are specifically designed for that space and do not tie in to the systems for the rest of the interior spaces. These independent systems will remain the same.

## *Cost Analysis and Alternate Construction Sequence:*

The changes made to the structural system to accommodate for the new location of mechanical equipment will directly impact the cost of construction. Several items were eliminated from the project, while others were added or changed. A study of how the cost of the building will change was conducted using R.S. Means and CostWorks software. The construction sequence and duration was also changed in accordance to the construction process for the new structural system. A schedule was made to estimate the duration of the new construction process. Certain aspects of the construction were compared to various portions of the original sequence.

The cost analysis seen in this section of the report is summarized in an Excel sheet documenting the base change in cost. Green values represent income, or money that was saved, from various eliminated items. The original steel members change throughout the building and were often switched to larger sizes. To represent this change the original steel was classified as an eliminated and the new steel was classified as expenditure. The other eliminated items are a result of no longer requiring a basement mechanical space. When using R.S. Means to perform this analysis, assumptions had to be made in order to determine the most accurate costs. In the case of the eliminated items assumptions were made to try to minimize costs. However, the items that were added were taken as base costs. This means for the additional work one crew or

piece of equipment at minimal size was used in construction. It is by doing this that the benefits of the new construction will be undoubtedly clear.

| Eliminated Items | | |
|---|---|---|
| Steel | 1,346 LF | $34,589 |
| Excavation-Backhoe | 7,826 CY | $10,956 |
| Excavation-Hauling | 7,827 CY | $17,295 |
| Slab on Deck | 70,308 SF | $735,737 |
| Roof Deck | 19,034 SF | $22,269 |
| 12" CMU wall | 8,704 SF | $49,265 |
| Original Steel | 12,570.5 LF | $283,018 |
| | | $1,153,129 |
| | Net = | $216,848 |

| Added Items | | |
|---|---|---|
| Slab on Grade | 13,206.5 SF | $18,489 |
| Hollowcore Plank | 76,136 SF | $605,281 |
| 8" CMU Wall | 2,952 SF | $12,044 |
| Steel | 10,135.5 LF | $300,467 |
| | | $936,281 |

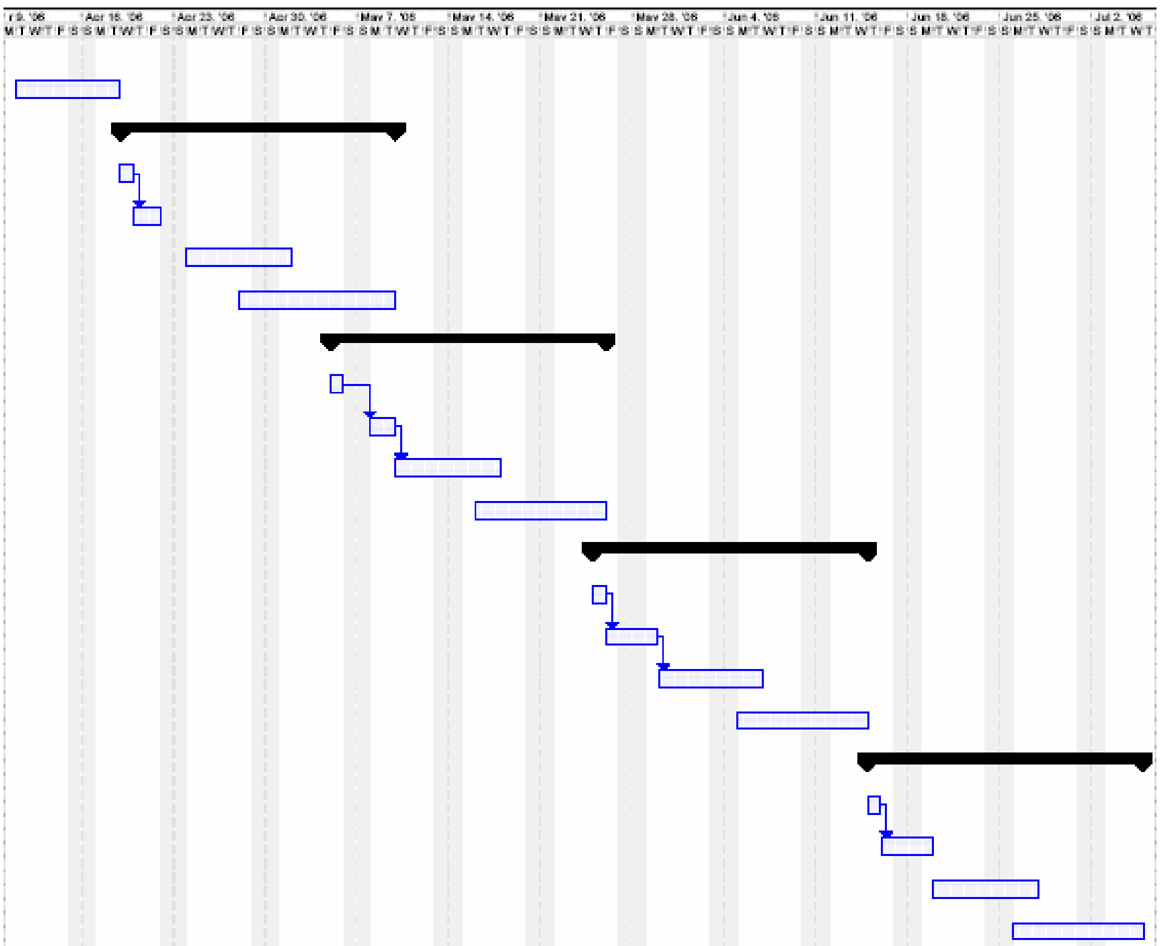
The excavation process detailed above was assumed to be done as two phases; the excavation by use of a backhoe and the hauling of the soil by truck. The excavation was assumed to be done by a track hoe with a 1 ½ cubic yard bucket capable of loading 100 cubic yards of soil an hour. The loose soil was assumed to be loaded onto 20 cubic yard trucks that had only to travel one mile round trips. The slab on deck represents 3”, 20 gauge steel deck with a 3 ¼”, 4,000 psi lightweight concrete topping. The concrete was assumed to be pumped during placement. The CMU walls in both columns include reinforcing and grouting costs in the totals listed. The slab on grade was priced as a 6” slab even though it will only be 5” in depth. A larger breakdown is shown in Appendix F.

Upon examination of the final costs it can be seen that the alternative structural system would have saved approximately $216,000. On what was roughly priced as a 1.3 million dollar portion of the project this savings is substantial. It is apparent that the alternate system would have saved money, but until further analysis it will not be know what the impact on the schedule would have been.

To determine the effects of the alternate system on the construction sequence a new schedule was produced. The schedule represents the project being erected on a floor by floor basis. However, with the building being separated into two wings and assuming enough crews were available it could have been coordinated to be done in sections. This option will be discussed after looking at the presented schedule.

For a direct comparison of the structural system the sequence will start after all site work has been completed. The first item will be the slab on grade. Following this each floor will be completed starting with the steel erection.

Columns are placed on the first day, with beams following on the next two days. Once the beams are placed the hollow core planks will be lifted into place and connected. This process will take six days. While the planks are being set fireproofing will begin on areas that are already completed. An additional crew will need to be present to do this, but it will help to condense the schedule. Fireproofing will last eight days. Erection of the steel on the next consecutive level will begin as soon as possible after all the hollow core is placed on the previous floor. This is done in order to minimize down time of the crane being used.



This schedule is based on a five day work week. Each phase of construction will last 15 days with the total sequence lasting 66 days. If more crews were used and an additional crane was present the construction could have been done

quicker if properly coordinated. However, for this investigation it was not done in this manner as simple comparisons were trying to be made.

Comparison of the original construction sequence to that of the one presented above can begin with the start date. After initial site work had been performed an excavation of the basement followed in the original sequence. Using two backhoes with 1.5 cubic yard buckets this excavation would have taken five days. This time is eliminated in the new schedule. Also to place the metal decking for each floor would have taken around eleven days this is five more days than it would take to place the hollow core plank. In all, the schedule will save in estimated thirty working days.

| ID | | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | Pour Slab on Grade | 6 days | Tue 4/11/06 | Tue 4/18/06 |
| 3 | | 1st Floor | 15 days | Wed 4/19/06 | Tue 5/9/06 |
| 4 | | Erect Columns | 1 day | Wed 4/19/06 | Wed 4/19/06 |
| 5 | | Erect Beams | 2 days | Thu 4/20/06 | Fri 4/21/06 |
| 6 | | Place Hollowcore Plank | 6 days | Mon 4/24/06 | Mon 5/1/06 |
| 7 | | Fireproof | 8 days | Fri 4/28/06 | Tue 5/9/06 |
| 8 | | 2nd Floor | 15 days | Fri 5/5/06 | Thu 5/25/06 |
| 9 | | Erect Columns | 1 day | Fri 5/5/06 | Fri 5/5/06 |
| 10 | | Erect Beams | 2 days | Mon 5/8/06 | Tue 5/9/06 |
| 11 | | Place Hollowcore Plank | 6 days | Wed 5/10/06 | Wed 5/17/06 |
| 12 | | Fireproof | 8 days | Tue 5/16/06 | Thu 5/25/06 |
| 13 | | 3rd Floor | 15 days | Thu 5/25/06 | Wed 6/14/06 |
| 14 | | Erect Columns | 1 day | Thu 5/25/06 | Thu 5/25/06 |
| 15 | | Erect Beams | 2 days | Fri 5/26/06 | Mon 5/29/06 |
| 16 | | Place Hollowcore Plank | 6 days | Tue 5/30/06 | Tue 6/6/06 |
| 17 | | Fireproof | 8 days | Mon 6/5/06 | Wed 6/14/06 |
| 18 | | 4th Floor | 15 days | Thu 6/15/06 | Wed 7/5/06 |
| 19 | | Erect Columns | 1 day | Thu 6/15/06 | Thu 6/15/06 |
| 20 | | Erect Beams | 2 days | Fri 6/16/06 | Mon 6/19/06 |
| 21 | | Place Hollowcore Plank | 6 days | Tue 6/20/06 | Tue 6/27/06 |
| 22 | | Fireproof | 8 days | Mon 6/26/06 | Wed 7/5/06 |

## Conclusion

It has been shown that this redesign would be a feasible option in solving the presented problem. It was cost efficient and provided a quick and easy construction method. The seismic impact was a definite concern but was not an issue that could not have been dealt with. The mechanical placement did not prove to cause many problems, but would need to be thought out. Isolation pads to eliminate noise and location of exhaust valves in relation to the air handling units were two concerns of the mechanical placement. Overall this investigation was successful; a great deal of knowledge was gained in relation to the effects of various structural elements. A better understanding of various floor systems was also obtained, while the benefits of one floor system over another in certain situations were demonstrated. In this case, a hollow core plank floor system allowed for the changes requested to the mechanical systems.

## Credits

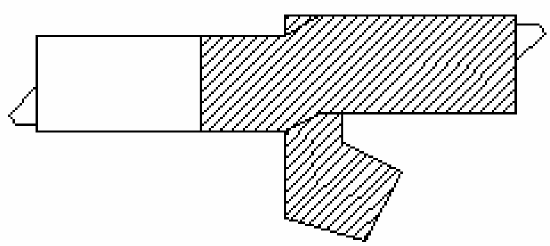
I would like to take this opportunity to thank the following people:

- The entire AE department staff for all the help and guidance
- Professor Parfitt for advice throughout this project
- John Jones, Mark Taylor, and the rest of the people at Nitterhouse Concrete Products for aid in the design of the hollow core system
- The people at L. Robert Kimball ,especially Dean Helsel, for their cooperation and use of company plans
- Eric Yanovich for his technical services
- My family and friends for support.

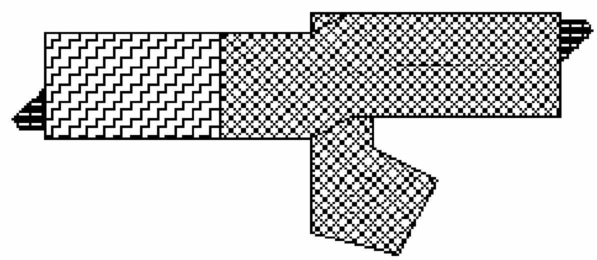
# Appendices

Appendix A: Live Load Diagrams

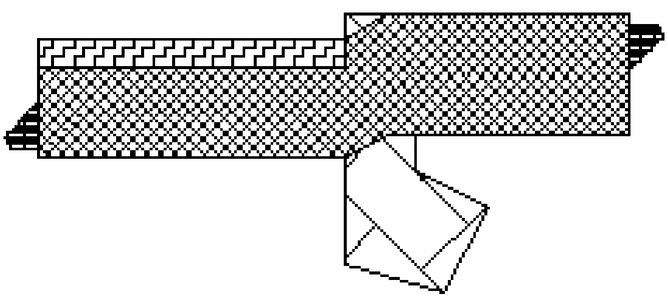
## Basement



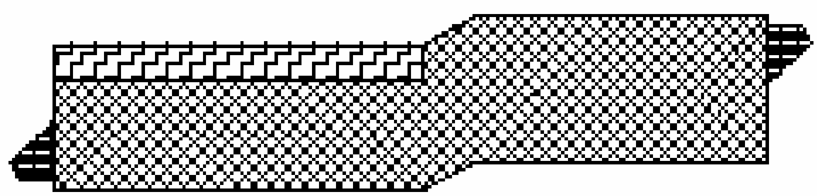
## 1st Floor

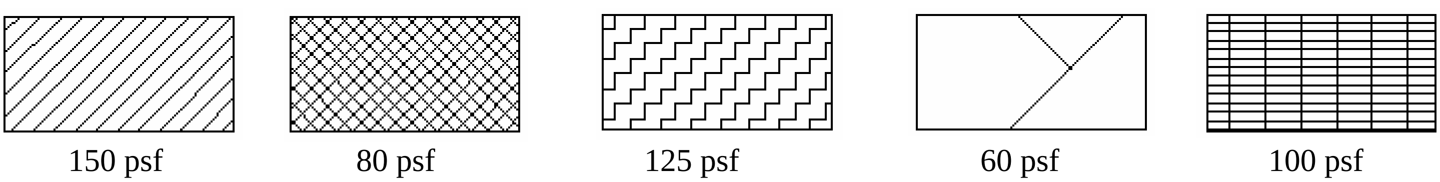


## 2nd Floor



## 3rd – 4th Floor





# Appendix B: Wind Load Calculations

| Velocity Pressure | | |
|---|---|---|
| $K_{zt}$ | 1 | From Fig. 6-4 |
| $K_d$ | 0.85 | From Table 6-4 |
| V | 90 | From Fig 6-1 |
| I | 1 | From Table 6-1 |

**Tab**

**le 1**

| External Pressure Coefficients | | | | | |
|---|---|---|---|---|---|
| | Windward Wall | | | | |
| | $C_p$ | 0.8 | From Fig. 6-6 | | |
| | Leeward Wall | | | | |
| N-S | length | 62.6 | $C_p$ | -0.5 | From Fig. 6-6 |
| | base | 307 | | | |
| | ratio l/b | 0.20 | | | |
| E-W | length | 307 | Cp | -0.2 | From Fig. 6-6 |
| | base | 62.6 | | | |
| | ratio l/b | 4.90 | | | |

| Gust Factor Calculator | | | |
|---|---|---|---|
| Frequency | 2.26 | | Rigid |
| $C_t$ | 0.02 | | |
| h | 62 | | |
| x | 0.75 | | |
| G | 0.85 | | |
| $z_{min}$ | 15 | | |
| c | 0.2 | | |
| l | 500 | | |
| ε | 0.200 | | |
| gq | 3.4 | | |
| gv | 3.4 | | |
| z | 37.2 | $z_h$ | 37.2 |
| h | 62 | | |
| $L_z$ | 512.12 | | |
| $I_z$ | 0.20 | | |
| | | | |
| Base | 307 | Q | 0.813126 |
| | | | |
| G | 0.833 | | |

| Z (ft) | $K_z$ (Table 6-3) | $q_z$ |
|---|---|---|
| 0-15 | 0.85 | 14.982 |
| 20 | 0.9 | 15.863 |
| 25 | 0.94 | 16.568 |
| 30 | 0.98 | 17.273 |
| 40 | 1.04 | 18.331 |
| 50 | 1.09 | 19.212 |
| 60 | 1.13 | 19.917 |
| 70 | 1.17 | 20.622 |
| 80 | 1.21 | 21.327 |
| 90 | 1.24 | 21.856 |
| 100 | 1.26 | 22.208 |
| 120 | 1.31 | 23.090 |
| 140 | 1.36 | 23.971 |
| 160 | 1.39 | 24.500 |

| Pressures | | |
|---|---|---|
| Z (ft) | N-S (psf) | E-W ( psf) |
| 0-15 | 9.99 | 10.45 |
| 20 | 10.57 | 11.06 |
| 25 | 11.04 | 11.55 |
| 30 | 11.51 | 12.04 |
| 40 | 12.22 | 12.78 |
| 50 | 12.81 | 13.39 |
| 60 | 13.27 | 13.89 |
| 70 | 13.75 | 14.38 |

| | |
|---|---|
| $q_h$ | 20.105 |

Interpolation at max. height

**Table 2**

| | Forces (kips) | | | | | |
|---|---|---|---|---|---|---|
| Story | N-S windward | N-S leeward | N-S total | E-W windward | E-W leeward | E-W total |
| 1 | 50.4 | 41.16 | 91.5 | 10.74 | 3.51 | 14.25 |
| 2 | 53.8 | 37.73 | 91.5 | 11.46 | 3.22 | 14.68 |
| 3 | 58.1 | 37.73 | 95.83 | 12.4 | 3.22 | 15.62 |
| 4 | 30.1 | 18.9 | 49 | 6.4 | 1.61 | 8.01 |

# Appendix C: RAM Output

# Beam Summary

RAM Steel v10.0
DataBase: EES
Building Code: IBC

03/30/06 14:30:54
Steel Code: ASD 9th Ed.

**STEEL BEAM DESIGN SUMMARY:**

**Floor Type: Fourth Floor**

| Bm # | Length ft | +M kip-ft | -M kip-ft | Seff in3 | Fy ksi | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 1 | 22.00 | 53.4 | 0.0 | 21.3 | 50.0 | W12X19 | |
| 71 | 23.00 | 126.9 | 0.0 | 54.6 | 50.0 | W14X38 | |
| 88 | 8.49 | 1.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 98 | 13.00 | 55.5 | 0.0 | 29.0 | 50.0 | W14X22 | |
| 107 | 22.00 | 116.7 | 0.0 | 47.2 | 50.0 | W16X31 | |
| 97 | 30.17 | 127.7 | 0.0 | 47.2 | 50.0 | W16X31 | |
| 38 | 7.00 | 0.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 2 | 30.17 | 163.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 39 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 3 | 32.50 | 246.1 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 56 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 72 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 4 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 40 | 20.00 | 134.1 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 5 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 57 | 20.00 | 261.9 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 73 | 20.00 | 144.4 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 109 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 108 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 6 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 41 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 7 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 58 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 74 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 8 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 42 | 20.00 | 134.1 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 9 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 59 | 20.00 | 261.9 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 75 | 20.00 | 144.4 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 111 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 110 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 10 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 43 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 11 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 60 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 76 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 12 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 44 | 20.00 | 134.1 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 13 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 61 | 20.00 | 261.9 | 0.0 | 115.0 | 50.0 | W24X55 | |

# Beam Summary



| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 77 | 20.00 | 144.4 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 113 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 112 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 14 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 45 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 15 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 62 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 78 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 16 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 46 | 21.50 | 154.1 | 0.0 | 64.7 | 50.0 | W16X40 | |
| 17 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 63 | 20.00 | 269.9 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 79 | 20.00 | 144.4 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 115 | 30.17 | 201.1 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 114 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 18 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 64 | 10.00 | 33.7 | 0.0 | 16.2 | 50.0 | W10X17 | |
| 80 | 20.00 | 144.5 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 89 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 47 | 8.50 | 0.2 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 19 | 30.17 | 251.2 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 48 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 90 | 32.50 | 217.7 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 91 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 99 | 9.16 | 13.8 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 21 | 23.34 | 196.7 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 106 | 26.50 | 45.5 | 0.0 | 20.9 | 50.0 | W8X24 | |
| 92 | 21.17 | 0.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 101 | 9.16 | 23.8 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 94 | 21.17 | 1.4 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 102 | 9.00 | 27.7 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 103 | 9.00 | 22.1 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 22 | 26.34 | 180.1 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 81 | 20.00 | 1.2 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 23 | 30.17 | 313.9 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 49 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 24 | 32.50 | 312.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 66 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 82 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 25 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 50 | 20.00 | 134.1 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 26 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 67 | 20.00 | 261.9 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 83 | 20.00 | 144.4 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 117 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |

# Beam Summary



| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 116 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 27 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 51 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 28 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 68 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 84 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 29 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 52 | 20.00 | 134.1 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 30 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 69 | 20.00 | 261.9 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 85 | 20.00 | 144.4 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 119 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 118 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 31 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 53 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 32 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 70 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 86 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 33 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 54 | 20.00 | 134.1 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 34 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 95 | 20.00 | 261.9 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 87 | 20.00 | 144.4 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 121 | 30.17 | 188.9 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 120 | 32.50 | 217.5 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 35 | 27.33 | 155.1 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 55 | 4.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 65 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 96 | 8.49 | 4.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 37 | 21.33 | 50.2 | 0.0 | 21.3 | 50.0 | W12X19 | |

**Floor Type: Third Floor**

| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| | ft | kip-ft | kip-ft | in3 | ksi | | |
| 69 | 22.00 | 63.8 | 0.0 | 29.0 | 50.0 | W14X22 | |
| 70 | 23.00 | 152.4 | 0.0 | 64.7 | 50.0 | W16X40 | |
| 73 | 8.49 | 1.7 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 71 | 13.00 | 52.8 | 0.0 | 29.0 | 50.0 | W14X22 | |
| 108 | 22.00 | 138.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 72 | 30.17 | 121.5 | 0.0 | 47.2 | 50.0 | W16X31 | |
| 74 | 7.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 28 | 30.17 | 153.4 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 45 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 29 | 32.50 | 271.4 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 53 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |

# Beam Summary



| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 61 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 30 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 46 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 31 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 54 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 62 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 110 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 109 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 32 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 47 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 33 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 55 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 63 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 34 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 48 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 35 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 56 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 64 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 112 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 111 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 36 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 49 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 37 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 57 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 65 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 38 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 50 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 39 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 58 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 66 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 114 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 113 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 40 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 51 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 41 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 59 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 67 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 42 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 52 | 21.50 | 145.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 43 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 60 | 20.00 | 265.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 68 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 115 | 30.17 | 186.3 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 116 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 44 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |

# Beam Summary



| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 76 | 10.00 | 31.9 | 0.0 | 17.1 | 50.0 | W12X16 | |
| 80 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 75 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 78 | 8.50 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 77 | 30.17 | 191.4 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 79 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 81 | 32.50 | 242.2 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 83 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 84 | 9.16 | 13.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 82 | 23.34 | 203.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 107 | 26.50 | 43.3 | 0.0 | 20.9 | 50.0 | W8X24 | |
| 88 | 21.17 | 0.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 93 | 9.16 | 22.6 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 103 | 21.17 | 0.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 94 | 9.00 | 26.5 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 91 | 9.00 | 21.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 92 | 26.34 | 166.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 90 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 1 | 30.17 | 285.1 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 5 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 2 | 32.50 | 284.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 6 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 7 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 3 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 16 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 4 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 20 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 24 | 20.00 | 136.6 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 118 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 117 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 8 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 17 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 9 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 21 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 25 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 10 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 18 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 11 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 22 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 26 | 20.00 | 136.6 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 120 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 119 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 12 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 19 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 13 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |

| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 23 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 27 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 14 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 98 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 15 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 95 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 96 | 20.00 | 136.6 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 122 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 121 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 97 | 27.33 | 145.4 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 99 | 4.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 102 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 100 | 8.49 | 3.7 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 101 | 21.33 | 46.8 | 0.0 | 17.1 | 50.0 | W12X16 | |

**Floor Type: Second Floor**

| Bm # | Length<br>ft | +M<br>kip-ft | -M<br>kip-ft | Seff<br>in3 | Fy<br>ksi | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 119 | 22.00 | 63.8 | 0.0 | 29.0 | 50.0 | W14X22 | |
| 2 | 23.00 | 152.4 | 0.0 | 64.7 | 50.0 | W16X40 | |
| 105 | 8.49 | 1.7 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 55 | 13.00 | 52.8 | 0.0 | 29.0 | 50.0 | W14X22 | |
| 121 | 22.00 | 138.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 54 | 30.17 | 121.5 | 0.0 | 47.2 | 50.0 | W16X31 | |
| 52 | 7.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 17 | 30.17 | 153.4 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 26 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 15 | 32.50 | 271.4 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 38 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 3 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 18 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 27 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 16 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 39 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 4 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 123 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 122 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 19 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 28 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 46 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 40 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 5 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 20 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 29 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 47 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |

# Beam Summary



| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 41 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 6 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 124 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 125 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 21 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 30 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 48 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 42 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 7 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 22 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 31 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 49 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 43 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 8 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 127 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 126 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 23 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 32 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 50 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 44 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 9 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 24 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 33 | 21.50 | 145.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 51 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 45 | 20.00 | 265.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 10 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 128 | 30.17 | 186.3 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 129 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 13 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 14 | 10.00 | 31.9 | 0.0 | 17.1 | 50.0 | W12X16 | |
| 11 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 25 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 34 | 8.50 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 36 | 30.17 | 164.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 35 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 57 | 32.50 | 242.2 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 56 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 37 | 12.00 | 52.5 | 0.0 | 21.3 | 50.0 | W12X19 | |
| 58 | 9.16 | 13.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 12 | 23.34 | 202.3 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 61 | 21.17 | 0.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 59 | 9.16 | 22.6 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 60 | 21.17 | 0.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 62 | 9.00 | 25.8 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 63 | 9.00 | 21.0 | 0.0 | 7.8 | 50.0 | W8X10 | |

# Beam Summary



| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 64 | 26.34 | 154.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 65 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 98 | 27.33 | 236.5 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 81 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 112 | 32.50 | 284.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 106 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 66 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 99 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 80 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 113 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 107 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 67 | 20.00 | 136.6 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 130 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 131 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 100 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 79 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 114 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 108 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 68 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 101 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 78 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 115 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 109 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 69 | 20.00 | 136.6 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 133 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 132 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 102 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 77 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 116 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 110 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 70 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 103 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 76 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 117 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 120 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 71 | 20.00 | 136.6 | 0.0 | 56.5 | 50.0 | W16X36 | |
| 135 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 134 | 32.50 | 202.0 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 104 | 27.33 | 145.4 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 75 | 4.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 72 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 74 | 8.49 | 3.7 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 73 | 21.33 | 46.8 | 0.0 | 17.1 | 50.0 | W12X16 | |

# Beam Summary



**Floor Type: First Floor**

| Bm # | Length ft | +M kip-ft | -M kip-ft | Seff in3 | Fy ksi | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 53 | 22.00 | 63.8 | 0.0 | 29.0 | 50.0 | W14X22 | |
| 54 | 23.00 | 152.4 | 0.0 | 64.7 | 50.0 | W16X40 | |
| 91 | 8.49 | 3.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 127 | 13.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 126 | 22.00 | 138.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 90 | 7.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 66 | 30.17 | 196.3 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 77 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 65 | 32.50 | 271.4 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 85 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 55 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 67 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 78 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 68 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 86 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 56 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 113 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 112 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 76 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 79 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 69 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 87 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 57 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 75 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 80 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 70 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 88 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 58 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 114 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 115 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 74 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 81 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 71 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 89 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 59 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 73 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 82 | 20.00 | 126.6 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 72 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 2 | 20.00 | 258.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 60 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 117 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 116 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |

# Beam Summary



| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 1 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 83 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 5 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 3 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 61 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 4 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 111 | 21.50 | 145.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 6 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 18 | 20.00 | 265.0 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 62 | 20.00 | 169.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 118 | 30.17 | 186.3 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 119 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 7 | 32.50 | 242.0 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 11 | 10.00 | 31.9 | 0.0 | 17.1 | 50.0 | W12X16 | |
| 63 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 8 | 30.17 | 175.6 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 9 | 8.50 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 10 | 30.17 | 164.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 17 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 12 | 32.50 | 242.2 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 51 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 64 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 19 | 12.00 | 52.5 | 0.0 | 21.3 | 50.0 | W12X19 | |
| 52 | 9.16 | 13.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 50 | 23.34 | 202.3 | 0.0 | 81.6 | 50.0 | W21X44 | |
| 108 | 21.17 | 0.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 106 | 9.16 | 22.6 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 107 | 21.17 | 0.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 110 | 9.00 | 25.8 | 0.0 | 10.9 | 50.0 | W10X12 | |
| 47 | 9.00 | 21.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 20 | 26.34 | 166.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 21 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 38 | 27.33 | 236.5 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 92 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 22 | 35.34 | 582.6 | 0.0 | 213.0 | 50.0 | W27X84 | |
| 24 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 101 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 37 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 93 | 20.00 | 114.5 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 23 | 35.34 | 515.0 | 0.0 | 213.0 | 50.0 | W27X84 | |
| 25 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 102 | 20.00 | 148.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 120 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 121 | 35.34 | 236.4 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 36 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |

# Beam Summary

| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 94 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 32 | 35.34 | 515.0 | 0.0 | 213.0 | 50.0 | W27X84 | |
| 26 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 103 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 35 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 95 | 20.00 | 114.5 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 31 | 35.34 | 515.0 | 0.0 | 213.0 | 50.0 | W27X84 | |
| 27 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 104 | 20.00 | 148.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 123 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 122 | 35.34 | 236.4 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 34 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 96 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 30 | 35.34 | 515.0 | 0.0 | 213.0 | 50.0 | W27X84 | |
| 39 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 105 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 41 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 97 | 20.00 | 114.5 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 42 | 35.34 | 515.0 | 0.0 | 213.0 | 50.0 | W27X84 | |
| 40 | 20.00 | 243.5 | 0.0 | 115.0 | 50.0 | W24X55 | |
| 49 | 20.00 | 148.9 | 0.0 | 68.4 | 50.0 | W18X40 | |
| 124 | 27.33 | 146.0 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 125 | 35.34 | 236.4 | 0.0 | 93.0 | 50.0 | W21X48 | |
| 33 | 27.33 | 145.4 | 0.0 | 57.6 | 50.0 | W18X35 | |
| 98 | 4.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 29 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 99 | 8.49 | 3.7 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 100 | 21.33 | 46.8 | 0.0 | 17.1 | 50.0 | W12X16 | |

**Floor Type: Foundation**

| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| | ft | kip-ft | kip-ft | in3 | ksi | | |
| 15 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 31 | 30.17 | 1.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 29 | 32.50 | 1.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 16 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 32 | 30.17 | 1.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 30 | 32.50 | 1.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 17 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 33 | 32.50 | 1.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 35 | 10.00 | 0.3 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 34 | 30.17 | 1.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 40 | 8.50 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 37 | 30.17 | 1.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 41 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |

# Beam Summary



| Bm # | Length | +M | -M | Seff | Fy | Beam Size | Studs |
|---|---|---|---|---|---|---|---|
| 36 | 32.50 | 1.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 38 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 42 | 12.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 44 | 26.50 | 687.2 | 0.0 | 414.0 | 50.0 | W27X146 | |
| 43 | 26.50 | 97.6 | 0.0 | 70.6 | 50.0 | W12X53 | |
| 47 | 9.16 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 39 | 23.34 | 0.7 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 45 | 26.50 | 388.3 | 0.0 | 157.0 | 50.0 | W14X99 | |
| 48 | 9.16 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 49 | 9.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 27 | 26.34 | 0.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 26 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 28 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 7 | 27.33 | 0.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 24 | 35.34 | 2.1 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 14 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 6 | 27.33 | 0.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 23 | 35.34 | 1.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 12 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 5 | 27.33 | 0.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 22 | 35.34 | 1.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 13 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 4 | 27.33 | 0.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 21 | 35.34 | 1.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 11 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 3 | 27.33 | 0.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 20 | 35.34 | 1.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 10 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 2 | 27.33 | 0.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 18 | 35.34 | 1.6 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 9 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 19 | 20.00 | 0.5 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 1 | 27.33 | 0.9 | 0.0 | 7.8 | 50.0 | W8X10 | |
| 8 | 10.00 | 0.0 | 0.0 | 7.8 | 50.0 | W8X10 | |

* after Size denotes beam failed stress/capacity criteria.
# after Size denotes beam failed deflection criteria.
u after Size denotes this size has been assigned by the User.

# Gravity Column Design Summary

RAM Steel v10.0
DataBase: EES
Building Code: IBC

03/30/06 14:30:19
Steel Code: ASD 9th Ed.

**Column Line 1 - CC**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 10.2 | 6.0 | 0.0 | 1 | 0.13 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 21.9 | 3.5 | 0.0 | 1 | 0.17 Eq H1-3 | 90.0 | 50 | W10X33 |
| Second Floor | 31.5 | 3.2 | 0.0 | 3 | 0.21 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 40.7 | 2.8 | 0.0 | 1 | 0.35 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 1 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 22.5 | 5.8 | 6.8 | 1 | 0.44 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 44.1 | 3.0 | 3.5 | 5 | 0.35 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 63.8 | 2.8 | 3.3 | 5 | 0.47 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 82.8 | 2.5 | 2.9 | 1 | 0.86 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 2 - EF**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 1.6 | 0.3 | 0.3 | 1 | 0.02 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 3.1 | 0.2 | 0.1 | 1 | 0.03 Eq H1-3 | 90.0 | 50 | W10X33 |
| Second Floor | 4.6 | 0.4 | 0.3 | 1 | 0.04 Eq H1-3 | 90.0 | 50 | W10X33 |
| First Floor | 7.3 | 0.3 | 0.3 | 1 | 0.07 Eq H1-3 | 90.0 | 50 | W10X33 |

**Column Line 22 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 16.9 | 9.8 | 0.1 | 10 | 0.22 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 30.3 | 4.2 | 0.1 | 3 | 0.21 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 42.7 | 4.0 | 0.1 | 4 | 0.30 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 44.2 | 0.1 | 0.1 | 1 | 0.35 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 3 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 22.4 | 13.3 | 0.0 | 6 | 0.29 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 39.8 | 5.6 | 0.0 | 3 | 0.27 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 56.3 | 7.0 | 0.0 | 1 | 0.38 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 75.7 | 5.7 | 0.0 | 1 | 0.67 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 3 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 55.8 | 5.5 | 3.8 | 3 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 102.3 | 3.0 | 1.6 | 3 | 0.70 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 147.0 | 2.9 | 1.8 | 3 | 0.53 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 190.8 | 1.1 | 0.0 | 1 | 0.72 Eq H1-1 | 90.0 | 50 | W10X49 |

# Gravity Column Design Summary

RAM Steel v10.0
DataBase: EES
Building Code: IBC

03/30/06 14:30:19
Steel Code: ASD 9th Ed.

**Column Line 3 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.3 | 18.1 | 4.9 | 10 | 0.51 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 76.4 | 9.0 | 2.5 | 2 | 0.58 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 111.1 | 8.8 | 2.4 | 2 | 0.54 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 144.9 | 7.8 | 2.1 | 1 | 0.98 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 4 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 6 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 4 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 94.4 | 6.1 | 2.7 | 4 | 0.46 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 122.0 | 5.5 | 2.4 | 1 | 0.80 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 4 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 3.8 | 13.0 | 5 | 0.66 Eq H1-1 | 90.0 | 50 | W12X40 |
| Third Floor | 131.6 | 3.2 | 5.7 | 5 | 0.83 Eq H1-1 | 90.0 | 50 | W12X40 |
| Second Floor | 189.4 | 3.3 | 6.4 | 5 | 0.59 Eq H1-1 | 90.0 | 50 | W12X58 |
| First Floor | 246.4 | 1.0 | 5.7 | 1 | 0.94 Eq H1-1 | 90.0 | 50 | W12X58 |

**Column Line 4 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 6 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 76.9 | 7.8 | 3.5 | 5 | 0.60 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 111.8 | 7.6 | 3.9 | 5 | 0.42 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 145.8 | 6.8 | 3.5 | 1 | 0.64 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 5 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 10 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 3 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 94.4 | 6.1 | 2.7 | 3 | 0.46 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 122.0 | 5.5 | 2.4 | 1 | 0.80 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 5 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 3.8 | 13.0 | 2 | 0.66 Eq H1-1 | 90.0 | 50 | W12X40 |
| Third Floor | 131.6 | 3.2 | 5.7 | 2 | 0.83 Eq H1-1 | 90.0 | 50 | W12X40 |
| Second Floor | 189.4 | 3.3 | 6.4 | 2 | 0.59 Eq H1-1 | 90.0 | 50 | W12X58 |
| First Floor | 246.4 | 1.0 | 5.7 | 1 | 0.94 Eq H1-1 | 90.0 | 50 | W12X58 |

# Gravity Column Design Summary



**Column Line 5 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 10 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 76.9 | 7.8 | 3.5 | 2 | 0.60 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 111.8 | 7.6 | 3.9 | 2 | 0.42 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 145.8 | 6.8 | 3.5 | 1 | 0.64 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 6 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 6 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 4 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 94.4 | 6.1 | 2.7 | 4 | 0.46 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 122.0 | 5.5 | 2.4 | 1 | 0.80 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 6 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 3.8 | 13.0 | 5 | 0.66 Eq H1-1 | 90.0 | 50 | W12X40 |
| Third Floor | 131.6 | 3.2 | 5.7 | 5 | 0.83 Eq H1-1 | 90.0 | 50 | W12X40 |
| Second Floor | 189.4 | 3.3 | 6.4 | 5 | 0.59 Eq H1-1 | 90.0 | 50 | W12X58 |
| First Floor | 246.4 | 1.0 | 5.7 | 1 | 0.94 Eq H1-1 | 90.0 | 50 | W12X58 |

**Column Line 6 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 6 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 76.9 | 7.8 | 3.5 | 5 | 0.60 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 111.8 | 7.6 | 3.9 | 5 | 0.42 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 145.8 | 6.8 | 3.5 | 1 | 0.64 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 7 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 10 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 3 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 94.4 | 6.1 | 2.7 | 3 | 0.46 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 122.0 | 5.5 | 2.4 | 1 | 0.80 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 7 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 3.8 | 13.0 | 2 | 0.66 Eq H1-1 | 90.0 | 50 | W12X40 |
| Third Floor | 131.6 | 3.2 | 5.7 | 2 | 0.83 Eq H1-1 | 90.0 | 50 | W12X40 |
| Second Floor | 189.4 | 3.3 | 6.4 | 2 | 0.59 Eq H1-1 | 90.0 | 50 | W12X58 |
| First Floor | 246.4 | 1.0 | 5.7 | 1 | 0.94 Eq H1-1 | 90.0 | 50 | W12X58 |

# Gravity Column Design Summary



**Column Line 7 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 10 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 76.9 | 7.8 | 3.5 | 2 | 0.60 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 111.8 | 7.6 | 3.9 | 2 | 0.42 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 145.8 | 6.8 | 3.5 | 1 | 0.64 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 8 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 6 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 4 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 94.4 | 6.1 | 2.7 | 4 | 0.46 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 122.0 | 5.5 | 2.4 | 1 | 0.80 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 8 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 3.8 | 13.0 | 5 | 0.66 Eq H1-1 | 90.0 | 50 | W12X40 |
| Third Floor | 131.6 | 3.2 | 5.7 | 5 | 0.83 Eq H1-1 | 90.0 | 50 | W12X40 |
| Second Floor | 189.4 | 4.2 | 6.4 | 5 | 0.59 Eq H1-1 | 90.0 | 50 | W12X58 |
| First Floor | 246.4 | 0.6 | 5.7 | 1 | 0.94 Eq H1-1 | 90.0 | 50 | W12X58 |
| Foundation | 247.4 | 0.6 | 0.0 | 1 | 0.74 Eq H1-1 | 90.0 | 50 | W12X58 |

**Column Line 8 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 6 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 76.9 | 7.8 | 3.5 | 5 | 0.60 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 111.8 | 7.6 | 3.9 | 5 | 0.42 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 145.8 | 6.8 | 3.5 | 1 | 0.64 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 9 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 10 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 3 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 94.4 | 6.1 | 2.7 | 3 | 0.46 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 122.0 | 5.5 | 2.4 | 1 | 0.80 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 9 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 3.8 | 13.0 | 2 | 0.66 Eq H1-1 | 90.0 | 50 | W12X40 |
| Third Floor | 131.6 | 3.2 | 5.7 | 2 | 0.83 Eq H1-1 | 90.0 | 50 | W12X40 |
| Second Floor | 189.4 | 3.3 | 6.4 | 2 | 0.59 Eq H1-1 | 90.0 | 50 | W12X58 |
| First Floor | 246.4 | 1.0 | 5.7 | 1 | 0.94 Eq H1-1 | 90.0 | 50 | W12X58 |
| Foundation | 247.8 | 0.0 | 0.0 | 1 | 0.74 Eq H1-1 | 90.0 | 50 | W12X58 |

**Column Line 9 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 10 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 76.9 | 7.8 | 3.5 | 2 | 0.60 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 111.8 | 7.6 | 3.9 | 2 | 0.42 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 145.8 | 6.8 | 3.5 | 1 | 0.64 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 10 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 38.8 | 14.7 | 7.7 | 6 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 69.3 | 6.2 | 3.2 | 4 | 0.52 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 98.7 | 6.1 | 3.1 | 4 | 0.48 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 127.7 | 5.4 | 2.8 | 1 | 0.86 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 10 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 72.5 | 3.8 | 13.5 | 5 | 0.68 Eq H1-1 | 90.0 | 50 | W12X40 |
| Third Floor | 132.9 | 3.2 | 5.9 | 5 | 0.85 Eq H1-1 | 90.0 | 50 | W12X40 |
| Second Floor | 191.4 | 3.3 | 6.6 | 5 | 0.59 Eq H1-1 | 90.0 | 50 | W12X58 |
| First Floor | 248.9 | 1.0 | 5.9 | 1 | 0.96 Eq H1-1 | 90.0 | 50 | W12X58 |
| Foundation | 250.3 | 0.0 | 0.0 | 1 | 0.75 Eq H1-1 | 90.0 | 50 | W12X58 |

**Column Line 10 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 6 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 76.9 | 7.8 | 3.5 | 5 | 0.60 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 111.8 | 7.6 | 3.9 | 5 | 0.42 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 145.8 | 6.8 | 3.5 | 1 | 0.64 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 11 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 64.8 | 17.2 | 5.5 | 11 | 0.57 Eq H1-1 | 90.0 | 50 | W12X40 |
| Third Floor | 122.2 | 7.8 | 2.9 | 11 | 0.78 Eq H1-1 | 90.0 | 50 | W12X40 |
| Second Floor | 178.6 | 7.6 | 3.1 | 11 | 0.62 Eq H1-1 | 90.0 | 50 | W12X53 |
| First Floor | 233.9 | 6.9 | 2.8 | 10 | 0.95 Eq H1-1 | 90.0 | 50 | W12X53 |
| Foundation | 239.6 | 0.1 | 0.0 | 1 | 0.79 Eq H1-1 | 90.0 | 50 | W12X53 |

**Column Line 11 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 48.4 | 15.4 | 1.8 | 7 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 94.6 | 7.6 | 1.4 | 7 | 0.73 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 145.5 | 7.4 | 4.1 | 5 | 0.56 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 179.0 | 6.6 | 3.4 | 1 | 0.78 Eq H1-1 | 90.0 | 50 | W10X49 |

# Gravity Column Design Summary



**Column Line 112 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 10 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.4 | 6.2 | 2.8 | 3 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 94.5 | 6.1 | 2.7 | 3 | 0.46 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 122.2 | 5.5 | 2.4 | 1 | 0.80 Eq H1-1 | 90.0 | 50 | W10X45 |
| Foundation | 123.1 | 0.0 | 0.0 | 1 | 0.59 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 115 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 42.1 | 25.4 | 0.0 | 6 | 0.46 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 64.6 | 7.2 | 0.0 | 3 | 0.44 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 82.0 | 5.6 | 0.0 | 3 | 0.53 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 99.3 | 5.0 | 0.0 | 1 | 0.85 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 115 - D**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 55.2 | 3.4 | 1.9 | 2 | 0.42 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 99.3 | 3.3 | 0.8 | 2 | 0.66 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 139.7 | 3.4 | 0.9 | 2 | 0.48 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 179.4 | 1.3 | 0.8 | 1 | 0.69 Eq H1-1 | 90.0 | 50 | W10X49 |
| Foundation | 180.6 | 0.0 | 0.0 | 1 | 0.63 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 115 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| First Floor | 31.1 | 18.7 | 0.0 | 1 | 0.44 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 12 - F**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 0.6 | 0.0 | 0.1 | 1 | 0.01 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 1.1 | 5.5 | 0.0 | 1 | 0.07 Eq H1-3 | 90.0 | 50 | W10X33 |
| Second Floor | 19.5 | 6.0 | 0.0 | 1 | 0.10 Eq H1-3 | 90.0 | 50 | W10X54 |
| First Floor | 34.3 | 4.5 | 31.1 | 1 | 0.63 Eq H1-3 | 90.0 | 50 | W10X54 |
| Foundation | 138.9 | 0.0 | 33.7 | 1 | 0.91 Eq H1-1 | 90.0 | 50 | W10X54 |

**Column Line 12 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 46.3 | 16.8 | 4.1 | 4 | 0.51 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 85.4 | 7.8 | 1.7 | 3 | 0.65 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 113.8 | 6.6 | 0.0 | 3 | 0.60 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 141.6 | 5.9 | 0.0 | 1 | 0.96 Eq H1-1 | 90.0 | 50 | W10X39 |
| Foundation | 142.4 | 0.0 | 0.0 | 1 | 0.81 Eq H1-1 | 90.0 | 50 | W10X39 |

# Gravity Column Design Summary

**Column Line 12 - B**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 46.4 | 20.1 | 7.1 | 1 | 0.64 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 87.8 | 9.3 | 3.5 | 2 | 0.68 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 127.1 | 9.2 | 3.9 | 2 | 0.35 Eq H1-1 | 90.0 | 50 | W10X68 |
| First Floor | 154.4 | 8.3 | 21.8 | 1 | 0.67 Eq H1-1 | 90.0 | 50 | W10X68 |
| Foundation | 227.7 | 0.0 | 23.6 | 1 | 0.86 Eq H1-1 | 90.0 | 50 | W10X68 |

**Column Line 15 - BC**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 36.0 | 10.8 | 0.0 | 3 | 0.31 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 64.3 | 4.6 | 0.0 | 3 | 0.42 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 90.5 | 5.6 | 0.0 | 2 | 0.58 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 117.1 | 3.9 | 0.0 | 1 | 0.98 Eq H1-1 | 90.0 | 50 | W10X33 |
| Foundation | 117.9 | 0.0 | 0.0 | 1 | 0.81 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 15 - A**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 28.1 | 16.8 | 0.1 | 2 | 0.30 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 50.0 | 7.1 | 0.0 | 2 | 0.35 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 67.8 | 7.4 | 0.0 | 1 | 0.45 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 88.4 | 6.1 | 0.0 | 1 | 0.77 Eq H1-1 | 90.0 | 50 | W10X33 |
| Foundation | 89.1 | 0.0 | 0.0 | 1 | 0.62 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 16 - E**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 42.2 | 25.5 | 0.1 | 3 | 0.45 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 75.5 | 10.7 | 0.0 | 3 | 0.52 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 104.5 | 9.5 | 0.0 | 3 | 0.56 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 133.2 | 8.5 | 0.0 | 1 | 0.93 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 16 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Second Floor | 35.5 | 76.3 | 0.0 | 2 | 0.49 Eq H1-3 | 90.0 | 50 | W12X58 |
| First Floor | 242.6 | 50.9 | 0.0 | 1 | 0.96 Eq H1-1 | 90.0 | 50 | W12X58 |
| Foundation | 244.0 | 0.0 | 0.0 | 1 | 0.73 Eq H1-1 | 90.0 | 50 | W12X58 |

**Column Line 16 - C**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 75.4 | 3.1 | 0.0 | 2 | 0.50 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 135.4 | 0.6 | 0.0 | 1 | 0.84 Eq H1-1 | 90.0 | 50 | W10X33 |

# Gravity Column Design Summary



**Column Line 16 - A**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.2 | 23.6 | 0.1 | 10 | 0.41 Eq H1-1 | 90.0 | 50 | W10X33 |
| Third Floor | 70.0 | 9.9 | 0.0 | 2 | 0.48 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 99.8 | 16.3 | 0.0 | 1 | 0.48 Eq H1-1 | 90.0 | 50 | W10X45 |
| First Floor | 144.4 | 13.4 | 0.0 | 1 | 0.87 Eq H1-1 | 90.0 | 50 | W10X45 |

**Column Line 17 - E**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 6 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 4 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 92.5 | 5.4 | 2.7 | 4 | 0.53 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 117.5 | 4.9 | 2.2 | 1 | 0.95 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 17 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Second Floor | 22.2 | 71.2 | 8.6 | 2 | 0.61 Eq H1-3 | 90.0 | 50 | W10X60 |
| First Floor | 226.5 | 45.4 | 5.6 | 1 | 0.99 Eq H1-1 | 90.0 | 50 | W10X60 |
| Foundation | 228.0 | 0.0 | 0.0 | 1 | 0.65 Eq H1-1 | 90.0 | 50 | W10X60 |

**Column Line 17 - C**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 1.9 | 13.0 | 4 | 0.65 Eq H1-1 | 90.0 | 50 | W10X39 |
| Third Floor | 129.0 | 0.5 | 5.4 | 1 | 0.89 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 17 - A**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 6 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 71.0 | 6.6 | 3.0 | 5 | 0.53 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 101.2 | 12.5 | 4.0 | 1 | 0.39 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 146.5 | 10.2 | 3.2 | 1 | 0.66 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 18 - E**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 10 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 3 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 92.5 | 5.4 | 2.7 | 3 | 0.53 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 117.5 | 4.9 | 2.2 | 1 | 0.95 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 18 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Second Floor | 22.2 | 71.2 | 8.6 | 5 | 0.61 Eq H1-3 | 90.0 | 50 | W10X60 |
| First Floor | 226.5 | 45.4 | 5.6 | 1 | 0.99 Eq H1-1 | 90.0 | 50 | W10X60 |
| Foundation | 228.0 | 0.0 | 0.0 | 1 | 0.65 Eq H1-1 | 90.0 | 50 | W10X60 |

**Column Line 18 - C**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 1.9 | 13.0 | 3 | 0.65 Eq H1-1 | 90.0 | 50 | W10X39 |
| Third Floor | 129.0 | 0.5 | 5.4 | 1 | 0.89 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 18 - A**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 10 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 71.0 | 6.6 | 3.0 | 2 | 0.53 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 101.2 | 12.5 | 4.0 | 1 | 0.39 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 146.5 | 10.2 | 3.2 | 1 | 0.66 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 19 - E**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 6 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 4 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 92.5 | 5.4 | 2.7 | 4 | 0.53 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 117.5 | 4.9 | 2.2 | 1 | 0.95 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 19 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Second Floor | 22.2 | 71.2 | 8.6 | 2 | 0.61 Eq H1-3 | 90.0 | 50 | W10X60 |
| First Floor | 226.5 | 45.4 | 5.6 | 1 | 0.99 Eq H1-1 | 90.0 | 50 | W10X60 |
| Foundation | 228.0 | 0.0 | 0.0 | 1 | 0.65 Eq H1-1 | 90.0 | 50 | W10X60 |

**Column Line 19 - C**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 1.9 | 13.0 | 4 | 0.65 Eq H1-1 | 90.0 | 50 | W10X39 |
| Third Floor | 129.0 | 0.5 | 5.4 | 1 | 0.89 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 19 - A**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 6 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 71.0 | 6.6 | 3.0 | 5 | 0.53 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 101.2 | 12.5 | 4.0 | 1 | 0.39 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 146.5 | 10.2 | 3.2 | 1 | 0.66 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 20 - E**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 10 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 3 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 92.5 | 5.4 | 2.7 | 3 | 0.53 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 117.5 | 4.9 | 2.2 | 1 | 0.95 Eq H1-1 | 90.0 | 50 | W10X39 |

# Gravity Column Design Summary



**Column Line 20 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Second Floor | 22.2 | 71.2 | 8.6 | 5 | 0.61 Eq H1-3 | 90.0 | 50 | W10X60 |
| First Floor | 226.5 | 45.4 | 5.6 | 1 | 0.99 Eq H1-1 | 90.0 | 50 | W10X60 |
| Foundation | 228.0 | 0.0 | 0.0 | 1 | 0.65 Eq H1-1 | 90.0 | 50 | W10X60 |

**Column Line 20 - C**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 1.9 | 13.0 | 3 | 0.65 Eq H1-1 | 90.0 | 50 | W10X39 |
| Third Floor | 129.0 | 0.5 | 5.4 | 1 | 0.89 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 20 - A**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 10 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 71.0 | 6.6 | 3.0 | 2 | 0.53 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 101.2 | 12.5 | 4.0 | 1 | 0.39 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 146.5 | 10.2 | 3.2 | 1 | 0.66 Eq H1-1 | 90.0 | 50 | W10X49 |

**Column Line 21 - E**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 37.1 | 14.7 | 6.7 | 6 | 0.53 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 66.3 | 6.2 | 2.8 | 4 | 0.49 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 92.5 | 5.4 | 2.7 | 4 | 0.53 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 117.5 | 4.9 | 2.2 | 1 | 0.95 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 21 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Second Floor | 22.2 | 71.2 | 8.6 | 2 | 0.61 Eq H1-3 | 90.0 | 50 | W10X60 |
| First Floor | 226.5 | 45.4 | 5.6 | 1 | 0.99 Eq H1-1 | 90.0 | 50 | W10X60 |
| Foundation | 228.0 | 0.0 | 0.0 | 1 | 0.65 Eq H1-1 | 90.0 | 50 | W10X60 |

**Column Line 21 - C**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 71.8 | 1.9 | 13.0 | 4 | 0.65 Eq H1-1 | 90.0 | 50 | W10X39 |
| Third Floor | 129.0 | 0.5 | 5.4 | 1 | 0.89 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 21 - A**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 39.7 | 15.8 | 7.2 | 6 | 0.57 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 71.0 | 6.6 | 3.0 | 5 | 0.53 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 101.2 | 12.5 | 4.0 | 1 | 0.39 Eq H1-1 | 90.0 | 50 | W10X49 |
| First Floor | 146.5 | 10.2 | 3.2 | 1 | 0.66 Eq H1-1 | 90.0 | 50 | W10X49 |

# Gravity Column Design Summary



**Column Line 22 - E**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 33.7 | 12.6 | 6.8 | 10 | 0.50 Eq H1-2 | 90.0 | 50 | W10X33 |
| Third Floor | 60.2 | 5.3 | 2.8 | 3 | 0.45 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 85.6 | 5.2 | 2.7 | 3 | 0.49 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 109.7 | 4.6 | 2.2 | 1 | 0.87 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 22 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 23.3 | 13.9 | 0.1 | 1 | 0.30 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 41.5 | 5.9 | 0.0 | 2 | 0.29 Eq H1-1 | 90.0 | 50 | W10X33 |
| Second Floor | 58.9 | 5.7 | 6.4 | 5 | 0.47 Eq H1-1 | 90.0 | 50 | W10X39 |
| First Floor | 95.1 | 4.9 | 5.1 | 1 | 0.88 Eq H1-1 | 90.0 | 50 | W10X39 |
| Foundation | 96.0 | 0.0 | 0.0 | 1 | 0.54 Eq H1-1 | 90.0 | 50 | W10X39 |

**Column Line 22 - A**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 15.2 | 0.0 | 7.9 | 1 | 0.37 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 22.2 | 0.0 | 3.5 | 6 | 0.26 Eq H1-3 | 90.0 | 50 | W10X33 |
| Second Floor | 39.0 | 0.0 | 3.3 | 2 | 0.28 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 51.0 | 0.0 | 3.1 | 1 | 0.51 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 222 - E**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 2.2 | 0.5 | 0.4 | 6 | 0.03 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 4.2 | 0.2 | 0.2 | 1 | 0.04 Eq H1-3 | 90.0 | 50 | W10X33 |
| Second Floor | 6.2 | 0.2 | 0.2 | 1 | 0.05 Eq H1-3 | 90.0 | 50 | W10X33 |
| First Floor | 8.3 | 0.2 | 0.2 | 1 | 0.07 Eq H1-3 | 90.0 | 50 | W10X33 |

**Column Line 23 - DE**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 11.7 | 5.4 | 0.6 | 8 | 0.15 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 22.4 | 2.4 | 0.3 | 2 | 0.17 Eq H1-3 | 90.0 | 50 | W10X33 |
| Second Floor | 31.4 | 2.1 | 0.2 | 3 | 0.21 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 40.2 | 1.9 | 0.2 | 1 | 0.35 Eq H1-1 | 90.0 | 50 | W10X33 |

**Column Line 23 - CD**

| Level | P | Mx | My | LC | Interaction Eq. | Angle | Fy | Size |
|---|---|---|---|---|---|---|---|---|
| Fourth Floor | 10.0 | 5.8 | 0.1 | 1 | 0.13 Eq H1-3 | 90.0 | 50 | W10X33 |
| Third Floor | 19.1 | 2.7 | 0.0 | 1 | 0.15 Eq H1-3 | 90.0 | 50 | W10X33 |
| Second Floor | 26.8 | 2.5 | 0.0 | 2 | 0.18 Eq H1-1 | 90.0 | 50 | W10X33 |
| First Floor | 34.3 | 2.2 | 0.0 | 1 | 0.29 Eq H1-1 | 90.0 | 50 | W10X33 |

# Appendix D: Beam Spotcheck

1.2D+1.6L=1.2(82.5 psf) +1.6(100psf) = 259 psf
259 psf * 10 feet = 2,590 plf
M=wl^2/8= (2,590 plf * (30 ft)^2)/8 = 291 ft-k

Using Table 5-3 it is seen that a W18x40 would have been sufficient, the RAM model suggested that a W21x44 should have been used. The W21x44 is the most efficient beam in the next category up. It was probably suggested so to deflection criterion.

## Appendix E: Parapet Calculations

8” CMU, fully grouted, reinforced with #6’s at 40 in spacing

M=15 psf (8.5)(4.25)=541.9 ft-lb/ft

Compression check:
Fm={541(12)/12(3.81)^2}[2/.894(.319)]=261.36 psi < Fb=500 psi OK

Tension check:
.133(24,000)(.894)(3.8)/12=904 ft-lbs > 541.9 ft-lbs OK

# Appendix F: Cost Analysis

| Eliminated Items | | |
|---|---|---|
| Steel | Beams | |
| W12x16 | 122 | $1,830 |
| W16x26 | 296 | $5,757 |
| W16x31 | 357.5 | $8,201 |
| W18x35 | 175 | $4,569 |
| W18x40 | 91 | $2,695 |
| W21x50 | 32.5 | $1,113 |
| | | |
| Steel Columns | | |
| W10x33 | 48 | $1,078 |
| W10x39 | 32 | $864 |
| W10x45 | 32 | $1,010 |
| W10x68 | 160 | $7,472 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Excacation | Area | | Backhoe 100 CY/hr | | 20 CY truck 1 mile roud trip | | |
| Soil | 13206.5 | ft2 | | | | | |
| | 211304 | ft3 | | | | | |
| | 7826 | yard3 | $10,956 | | $17,295 | | |
| | | | | | | | |
| Metal Decking | | Area | | | Slab on Deck | | |
| | | 13206.5 | ft2 | $17,168 | 57102 | ft2 | $701,393 |
| | | | | | | | |
| Poured 3" Concrete | | Area | | | Roof Deck | | $22,269 |
| | | 193 | yd3 | $17,176 | 19034 | ft2 | ` |
| | | | | | | | |
| 12" CMU wall 16' height | | | | | | | |
| | 8704 | ft2 | $49,265 | | | | |

| Added Items | | | | | | | |
|---|---|---|---|---|---|---|---|
| Slab on Grade 5" conc | 13206.5 | ft2 | $18,489 | 8" CMU wall 4' | 2952 | ft2 | $12,044 |
| | | | | | | | |
| Hollowcore Plank | 76136 | ft2 | $605,281 | | | | |

| Steel change | | |
|---|---|---|
| 2nd Floor | | |
| W14x30 | 210 | $4,691 |
| W16x26 | 285 | $5,543 |
| W16x31 | 274 | $6,285 |
| W18x35 | 558 | $14,569 |
| W18x40 | 140 | $4,145 |
| W24x84(50) | 204 | $11,262 |
| | | |
| 3rd floor | | |
| W14x30 | 261 | $5,830 |
| W16x31 | 733 | $16,815 |
| W18x35 | 562 | $14,673 |
| W18x40 | 80 | $2,368 |
| | | |
| 4th Floor | | |
| W14x30 | 261 | $5,830 |
| W16x31 | 733 | $16,815 |
| W18x35 | 562 | $14,673 |
| W18x40 | 80 | $2,368 |
| | | |
| Roof | | |
| 18k5 | 60 | $319 |
| 22k5 | 144 | $813 |
| 22k6 | 135 | $783 |
| 26k7 | 723 | $4,700 |
| 28k7 | 1592.5 | $11,275 |
| W16x31 | 558 | $12,800 |
| W18x40 | 160 | $4,737 |
| | | $161,293 |

| Columns | | |
|---|---|---|
| W10x33 | 1261 | $28,309 |
| W10x39 | 1446 | $36,150 |
| W10x45 | 648 | $20,457 |
| W10x49 | 260 | $9,360 |
| W10x54 | 140 | $5,320 |
| W10x60 | 260 | $10,920 |
| W10x68 | 240 | $11,208 |
| | | $121,725 |

| 2nd Floor | | |
|---|---|---|
| W18x35 | 363 | $9,477 |
| W18x40 | 530 | $15,693 |
| W21x48 | 511.5 | $17,519 |
| W24x55 | 204 | $7,572 |
| | | |
| 3rd Floor | | |
| W16x31 | 30 | $688 |
| W16x36 | 60 | $1,500 |
| W18x35 | 332 | $8,668 |
| W18x40 | 59 | $1,747 |
| W21x44 | 260 | $7,865 |
| W21x48 | 416 | $14,248 |
| W24x55 | 64 | $2,375 |
| | | |
| 4th Floor | | |
| W16x31 | 30 | $688 |
| W16x36 | 60 | $1,500 |
| W18x35 | 197 | $5,143 |
| W18x40 | 696 | $20,608 |
| W21x44 | 286 | $8,651 |
| W21x48 | 416 | $14,248 |
| W24x55 | 59 | $2,190 |
| | | |
| Roof | | |
| W16x36 | 120 | $3,000 |
| W18x40 | 170 | $5,033 |
| W21x44 | 1280 | $38,720 |
| W24x55 | 150 | $5,568 |
| | | $192,701 |

| Columns | | |
|---|---|---|
| W10x33 | 1852 | $41,577 |
| W10x39 | 438 | $10,950 |
| W10x45 | 320 | $10,102 |
| W10x49 | 480 | $17,280 |
| W10x54 | 32 | $1,216 |
| W10x60 | 192 | $8,064 |
| W12x40 | 240 | $7,920 |
| W12x58 | 288 | $10,656 |
| | | $107,766 |

## References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- AISC Manual of Steel Construction 3rd Edition
- Nitterhouse Concrete Products Specifications
- York International Engineering Guide
- RS Means
- RAM Structural System
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- PCI Handbook