THE FORENSIC MEDICAL CENTER

THE PENNSYLVANIA STATE UNIVERSITY – ARCHITECTURAL ENGINEERING

SENIOR THESIS

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KEENAN S. YOHE – STRUCTURAL OPTION

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APRIL 9, 2008

THE FORENSIC MEDICAL CENTER


Courtesy Gaudreau, Inc.

PRIMARY PROJECT TEAM

owner:	Office of the Chief Medical Examiner
architect:	Gaudreau, Inc./McClaren, Wilson, & Laurie
geotechnical engineer:	TLB Associates, Inc.
civil engineer:	Gower Thompson, Inc.
structural engineer:	Hope Furrer Associates, Inc.
landscape:	Mahan Rykiel Associates, Inc.
mechanical/security:	Syska Hennessey Group
fire/lighting/plumbing:	Johnson Consulting Engineers, Inc.
data/telecom:	Sidhu Associates, Inc.
acoustics:	Convergent Technologies Design Group, Inc.

GENERAL INFORMATION

building function:	Administrative Space for offices, classrooms, conferences; Autopsy spaces; Biosafety Laboratories
size:	121,000 sq. ft.
height:	5 stories plus Mechanical Penthouse / 105 ft. above grade
overall project cost:	$45 million
construction dates:	July 2008 to May 2010
delivery method:	Construction Manager at Risk

ARCHITECTURE

Part of new Medical Campus – designed to fit in with master plan for campus
Brick cavity walls with precast concrete bands and accents, polished granite veneer at base
First floor parking garage and drive-through delivery area
Autopsy cooler and freezer storage rooms, High-Security BioSafety Level 3 laboratory

STRUCTURAL SYSTEM

Ground-floor 6” slab-on-grade with minimum 30” deep grade beams
24” by 24” cast-in-place concrete columns with 48” diameter drilled pier foundations
11” thick, two-way, flat plate, normal weight concrete slab typical floor system, 25’ x 22’ to 30’ x 27’ bays
Concrete shearwall lateral load resisting system with 54” drilled pier foundations

MECHANICAL SYSTEM

Three 28,000 CFM, 100% outdoor air AHUs w/ 2 position constant volume distribution for laboratory spaces
Two 17,500 CFM AHUs w/ 100% outdoor/100% return air economizers and VAV distribution for office spaces
Two 365 ton, 30% ethylene glycol chillers; Two 250 BHP fire-tube boilers

LIGHTING / ELECTRICAL SYSTEM

Three-phase, four-wire, 480/277 V, 3000 A building service
Distributed to each level via standard conduit & wire distribution risers
Step-down transformer on each level for 208/120 V requirements
Emergency 1500 kW, 408/277 V diesel generator
All lighting fixtures are 277 V
Recessed fluorescent lighting with high-efficiency T8 lamps
Compact fluorescent downlights, incandescent fixtures for dimming


Courtesy Gaudreau, Inc.

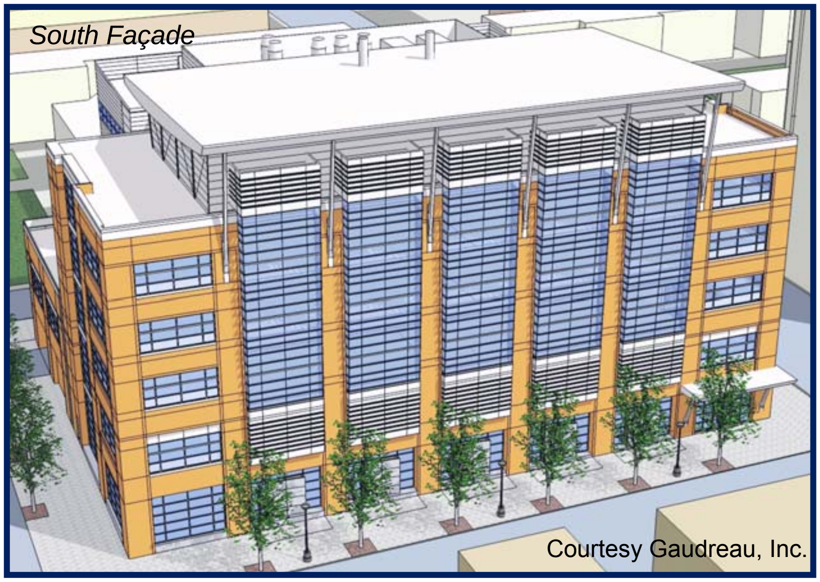
KEENAN YOHE

STRUCTURAL OPTION

http://www.engr.psu.edu/ae/thesis/portfolios/2008/ksy113

TABLE OF CONTENTS

EXECUTIVE SUMMARY


South Façade

Courtesy Gaudreau, Inc.

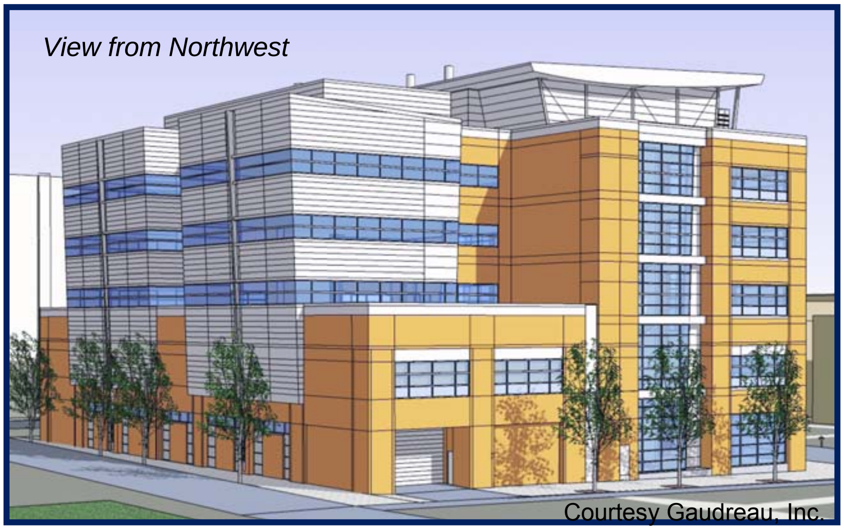
The Forensic Medical Center is a proposed, five-story state-of-the-art laboratory and office building. It will contain a small parking garage for staff and a drive-through delivery area on the ground floor. Autopsy rooms and their support spaces would make up the second floor, along with a high-security BioSafety Level 3 laboratory. On the third floor are histology, toxicology, and neuropathology laboratories, while the fourth floor houses the public reception area, along with an investigations suite, photography suite, IT suite, and training rooms. On the fifth floor are administrative offices, medical records, and a library/conference room. This floor will also house the Chief Medical Examiner's office suite. As designed, the building would include 121,000 square feet of space, and would rise to 105 feet above grade. The cost is estimated at $45 million, with construction scheduled to begin in July 2008 and continuing to May 2010.

The structure of The Forensic Medical Center was designed as a two-way, flat-plate concrete system, with a dual moment frame and shearwall lateral system. This report investigates the feasibility as well as the cost and schedule implications of changing this system to a composite steel system with concentric braced frames. Because the building houses high-tech laboratory equipment, a vibration study was required to ensure it would function properly. The existing concrete system was designed for vibration using methods originally developed for steel, because a standard for the design of concrete for vibrations does not exist. Using these methods required many conservative assumptions, which may have possibly led to an over-conservative structure. However, the system was only designed for slow to moderate walking, and not fast walking, which may not be adequate in this case.

The structural redesign was performed according to ASCE 7-05 and IBC 2006, with the assistance of a RAM Structural System model. AISC Design Guide 11 "Floor Vibrations Due to Human Activity" was used to design and analyze the vibration-critical fifth floor of the building. The results were W16 beams framing into W18 girders on typical floors, with much larger sizes on the fifth floor. The loads were carried to the foundation by W10 and W12 columns. Braced frames consisted of wide-flange columns (W10) and beams (W8 to W16). Rectangular hollow structural sections were used as the braces, with sizes ranging from HSS12x4x3/8 to HSS16x8x1/2.

A construction management study was performed to determine the cost and schedule impact of the redesigned steel system. The steel system was estimated to cost approximately $1.4 million less than the concrete system, while being completed three months sooner.

Original plans for The Forensic Medical Center included an Alternative Care Facility on the ground floor. The facility would involve the conversion of the parking garage area into a triage unit in the case of a local catastrophic event, such as an accident, natural disaster, or terrorist attack. These plans were dropped because of budget concerns. A study was conducted on the feasibility of adding such a facility, including architectural, mechanical, lighting, and electrical requirements, and a rough estimate of their costs. The study concluded that such a facility would add a significant cost to the overall price of the building, and it would be up to the owners to determine whether the facility should be implemented.

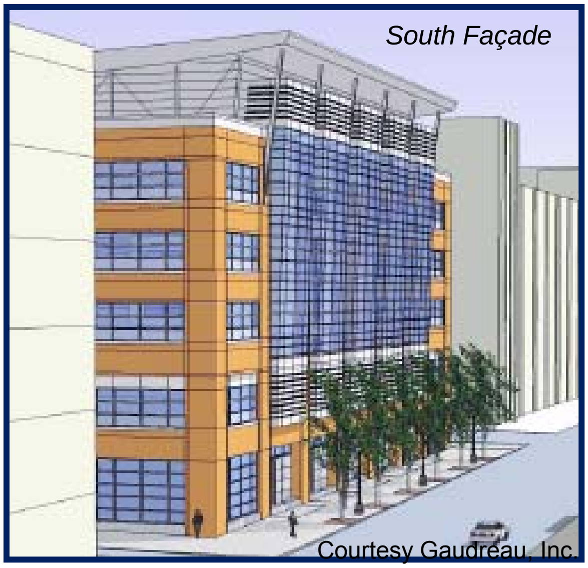

View from Northwest
Courtesy Gaudreau, Inc.

BUILDING OVERVIEW

Function

The Forensic Medical Center has five floors, each with a slightly different function. The first floor contains a small parking garage for staff parking and a drive-through delivery area, as well as the main pedestrian and service entrances. The second floor consists of autopsy rooms and their support spaces (coolers, freezers, storage, etc.), and a high-security BioSafety Level 3 laboratory. On the third floor are histology, toxicology, and neuropathology laboratories, and instrument and record storage areas. The fourth floor houses the public reception area and a pathology exhibit, as well as an investigations suite, photography suite, IT suite, and training rooms. On the fifth floor are administrative offices, medical records, and a library/conference room. On top of the building is a mechanical penthouse.

Architecture


South Façade

Courtesy Gaudreau, Inc.

As a part of a new medical campus currently under construction, the exterior of The Forensic Medical Center was designed to fit in with the master plan of the campus. This plan calls for six-story block-like structures, all aligned along a main street to form a regular streetscape that matches University building guidelines. As a result, brick, precast concrete, stone, metal panels, and glass are all important façade materials. On the south façade, which is along this main street, brick and glass curtain wall piers match those of the first two buildings to be built on the campus. The north façade of the building faces a residential area, so a smaller scale articulated curtain wall is used on this side.

Mechanical System

The mechanical systems in The Forensic Medical Center must meet the differing requirements of its spaces. In general, the building is divided into two areas. The first, second, and third levels are mainly used for autopsy rooms, laboratory spaces (including the Biosafety Level 3 suite), and their required support spaces. These spaces have very specific needs, and must be under strict control at all times. The fourth and fifth levels consist of offices and administrative spaces; therefore, they use a more conventional mechanical system.

The air handling units for the first, second, and third levels are designed as three units, each at 50% capacity. This allows one unit to still be at full reserve if one of the other two should fail. Each is a 28,000 CFM unit supplying 100% once-through outdoor air.

Air distribution on these three levels is two position constant volume, with a total distribution of 56,000 CFM.

The offices and administration spaces on the fourth and fifth levels require two 17,500 CFM air handling units. These AHUs have 100% return air/100% outdoor air economizer capability. These levels use a conventional variable air volume distribution system, supplying 17,500 CFM at each level.

The building mechanical system is designed to be positively pressurized to help control airborne contaminants in the laboratory areas. The first, second, and third levels (with the exception of the Biosafety Level 3 suite) are 100% exhausted by three 30,000 CFM exhaust fans. Due to its hazardous contents, the BSL-3 suite has a separate exhaust system, with two 8,000 CFM fans, each containing a 99.99% HEPA DOP filter.

Cooling for most of the building is provided by two closed-loop, 30% ethylene glycol-air cooled water chillers, each supplying a 365 ton output. Two low-temperature 30% ethylene glycol chillers, each with 20 tons of capacity, are used to cool the body storage coolers and freezers on the second level. A low roof on level two houses two blower coil indoor modules with remote air-cooled condensing units.

The building is heated by two closed-loop, 250 BHP fire-tube water boilers capable of supplying 8,300 MBH at 80% efficiency. These boilers are dual-fuel compatible, with natural gas as the primary fuel and #2 fuel oil stored on-site for emergency backup. The water leaves the boilers at 180°F and is circulated to the heating coils in the AHUs. A separate set of pumps circulates the water from the boilers to re-heat coils on each floor.

Lighting and Electrical Systems


South Façade Courtesy Gaudreau, Inc.

All of the lights in The Forensic Medical Center are 277 volt fixtures. In general, recessed fluorescent fixtures use energy efficient T8 lamps with electronic ballasts. Downlights are compact fluorescent lamps with electronic ballasts. Areas where dimming is required will use incandescent sources. Kitchens, restrooms, locker rooms, corridors, and storage areas use fluorescent fixtures with prismatic lenses. Mechanical and electrical rooms use industrial-type four-foot fluorescent fixtures with guards. High-Intensity-Discharge (HID) metal halide lamps with shatter-proof lenses are used in the garage area. Paths of egress are lit by night lights and marked with LED exit signs to meet required building codes.

The electrical service for the building is 3000 A, three-phase, four-wire, 480/277 volts, coming into the building at a service rated switchboard. This switchboard has a fixed mounted 3000 A main circuit breaker with integral solid-state tripping and ground-fault sensors. Power is distributed throughout the building using standard conduit and wire distribution risers. Each floor has an electrical closet, which contains most of the major distribution panelboards and equipment for that floor. In addition, the laboratory and autopsy areas on levels two and three have their own local area panels. Each level also has a step-down dry-type transformer to serve lab, electronic, and office type equipment requiring 208/120 volt service.

Because of the nature of the building, standby power is necessary, and there are three power distribution systems: normal, life safety, and critical. The normal system supplies power to all of the lighting and non-essential building services. The life safety system supplies power to emergency lighting for egress, alarms, and essential mechanical systems. The critical system contains all of the loads considered essential to continued operation of the Medical Examiner's functions. Backup power is supplied by a 1500 KW, 480/277 V diesel-powered generator located in the penthouse.

EXISTING CONDITIONS

Foundation

The foundation of The Forensic Medical Center consists of drilled piers under each column and under the shearwalls, as recommended by the geotechnical report prepared by T.L.B. Associates, dated April 18, 2007. The drilled piers are typically 48” in diameter, with 54” diameter piers under the shearwalls. The concrete strength is 3500 psi, with 12 #11 bars for the top third of the depth. The piers extend from the first level elevation of 76.25’ Mean Sea Level (MSL) to roughly 25’ MSL, where they are socketed into bedrock.

Columns

All of the columns in the building are normal weight concrete with a strength of 5000 psi. Typically, the columns are 24” by 24”, except for ten 34” diameter circular columns in the parking garage area. Exterior columns are reinforced with eight #8 bars and #4 ties at 12” on center. Interior columns are reinforced with eight #10 bars and #4 ties at 12” on center.

Slabs

The ground floor parking garage level of The Forensic Medical Center is a 6” thick, normal weight concrete slab-on-grade, with a concrete strength of 3500 psi. At the edges of this slab are concrete grade beams that are 30”-36” deep, with a concrete strength of 3000 psi.

The floor systems of levels two through five are typically 11” thick, two-way, flat-plate, normal weight concrete slabs with 26” wide by 36” deep concrete perimeter beams. Slab reinforcement is typically #5 bars at 15” on center, each way, top and bottom at mid-span, with heavier reinforcement at the columns. Typical slab spans range from 22’-6” to 30’-0”.

Variations on the typical floor slab include large recessed slab areas for body storage coolers and freezers on level two. These slabs are 11” thick, one-way slabs, and are supported by monolithically-poured concrete beams with sizes ranging from 18” to 40” wide by 11” to 26” deep. On level three, there are two 9” thick, two-way slab sections that serve as low roofs. Also, a high-density file storage area requires two 24”x18” concrete beams under the mid-span of the slabs, between grid lines 3 and 4.

The penthouse level floor slab consists of two areas. The roof areas are an 8” thick, two-way, flat-plate, normal weight concrete slab with #5 bars, typically spaced at 16”, each way, top and bottom for reinforcement. The slab under the mechanical equipment is increased to 15” thick, with #5 bars at 11” each way, top and bottom, for typical reinforcement. A steel-framed mechanical penthouse sits on the top of this level. The HSS 14”x14”x½” columns are cantilevered from the concrete floor slab and extend 20’ to the roof.

Lateral System

The lateral force resisting system of The Forensic Medical Center is a dual-system, consisting of four ordinary reinforced concrete shearwalls with an ordinary reinforced concrete moment frame.

Shearwalls 1 and 4 are oriented east-west, and are tied to an exterior column. On the interior side of these walls is a 4'-6" boundary element containing 12 #9 bars for vertical reinforcement, with #4 ties at 12" on center. The webs of these walls contain the minimum amount of reinforcement for ρ = 0.0025, which is #5 bars at 18" on center each way, in each face.

Shearwalls 2 and 3 are oriented north-south. At both ends of these walls are 6'-0" boundary elements with 14 #9 bars for vertical reinforcement and #4 ties at 12" on center. The webs of these walls also contain the minimum amount of reinforcement, #5 bars at 18" on center each way, in each face.

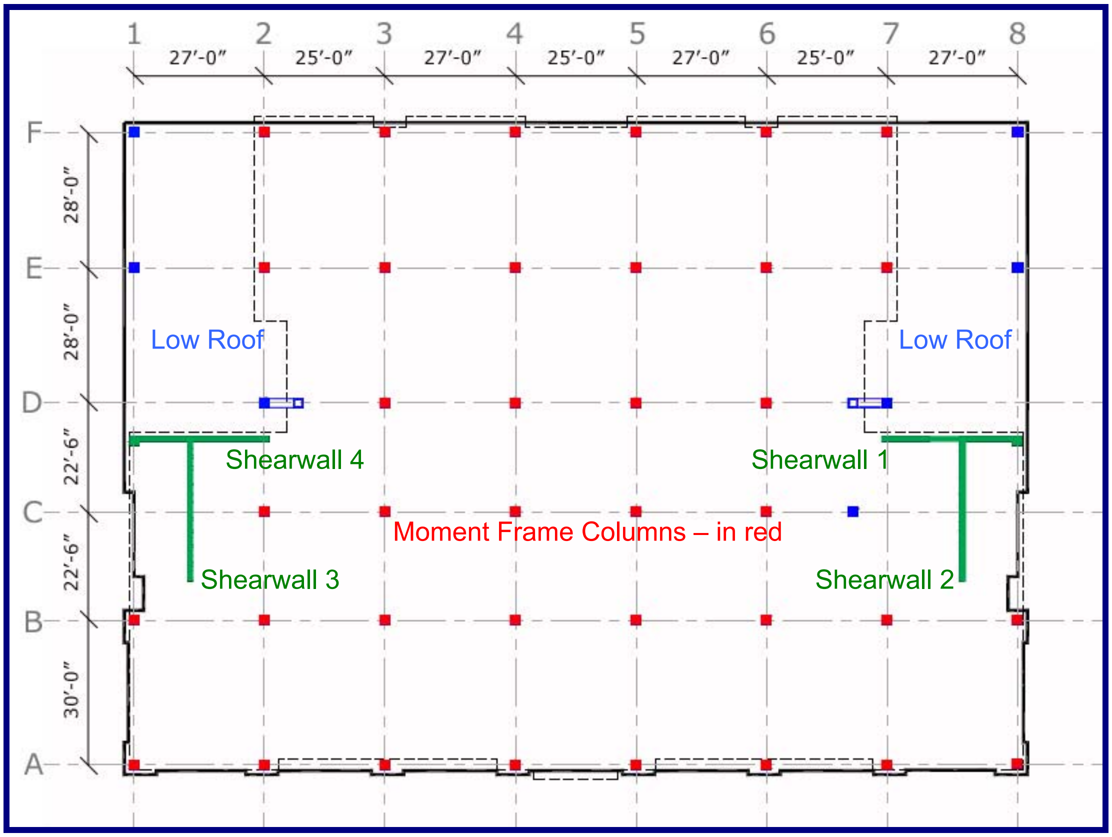


Figure 1 - Typical Floor Plan

PROBLEM STATEMENT

Because The Forensic Medical Center will be home to a modern, high-tech laboratory, with equipment that is very sensitive to motion, vibration concerns are critical to the structural system design. While a concrete structural system is generally a good choice to resist vibration problems, there are few guidelines for designing a concrete system for vibration. Typically, it is difficult to tell whether a concrete system will meet vibration criteria until the structure is already built. On the other hand, design guides have been published for vibrations in composite steel systems.

The budget of the building is also a concern. Any changes to the existing building structural design need to be of similar or lower cost. Based on previous technical reports, some parts of the concrete structural system appear to be larger than required. A steel system could be more efficient, reducing the amount of material used and thus reducing seismic loads as well, leading to a lighter lateral system.

PROPOSED SOLUTION

A composite steel structural floor system with steel columns is proposed, to be designed for vibration criteria. The concrete shearwalls will be replaced with steel braced frames. These changes can be done with little effect on the floor layout and architecture of the building, while making certain that vibration criteria are met.

According to Technical Report 2, typical beam and girder depths will be in the 16”-18” range, with a slab-on-deck thickness of 4”. This is a considerably thicker floor system than the 11” existing concrete slab, but The Forensic Medical Center is well within height restrictions. The new steel system may be more efficient than the existing concrete one, creating a lighter and possibly more cost-effective design.

To implement these changes, a computer model of the new gravity system will be constructed and tested in RAM Structural System. Since the new system will result in changes to the height, weight, and lateral system of the building, lateral loads will be recalculated and applied to a new lateral system model.

BREADTH TOPICS

Cost and Schedule

A Construction Management breadth study will be done on the new composite steel system. The cost, schedule, and constructability of the new system will be compared to the existing concrete system to determine feasibility, given the budget constraints of the project. R.S. Means and Microsoft Project will be used for this part of the analysis.

Alternative Care Facility

An original idea for The Forensic Medical Center was to include a temporary triage area in the ground floor parking lot, in case of a catastrophic event. The idea was shelved due to budget concerns. A main requirement for the triage area, or “Alternative Care Facility” is adequate lighting. Also required are electrical outlets, mechanical systems, and some temporary architectural elements that can be set up and removed quickly and easily. Research will be done on the specific requirements for a triage area, and the cost of implementing this idea will be investigated.

TASKS AND TOOLS

A list of tasks to be completed in the investigation of these proposals, as well as the tools required, is included below:

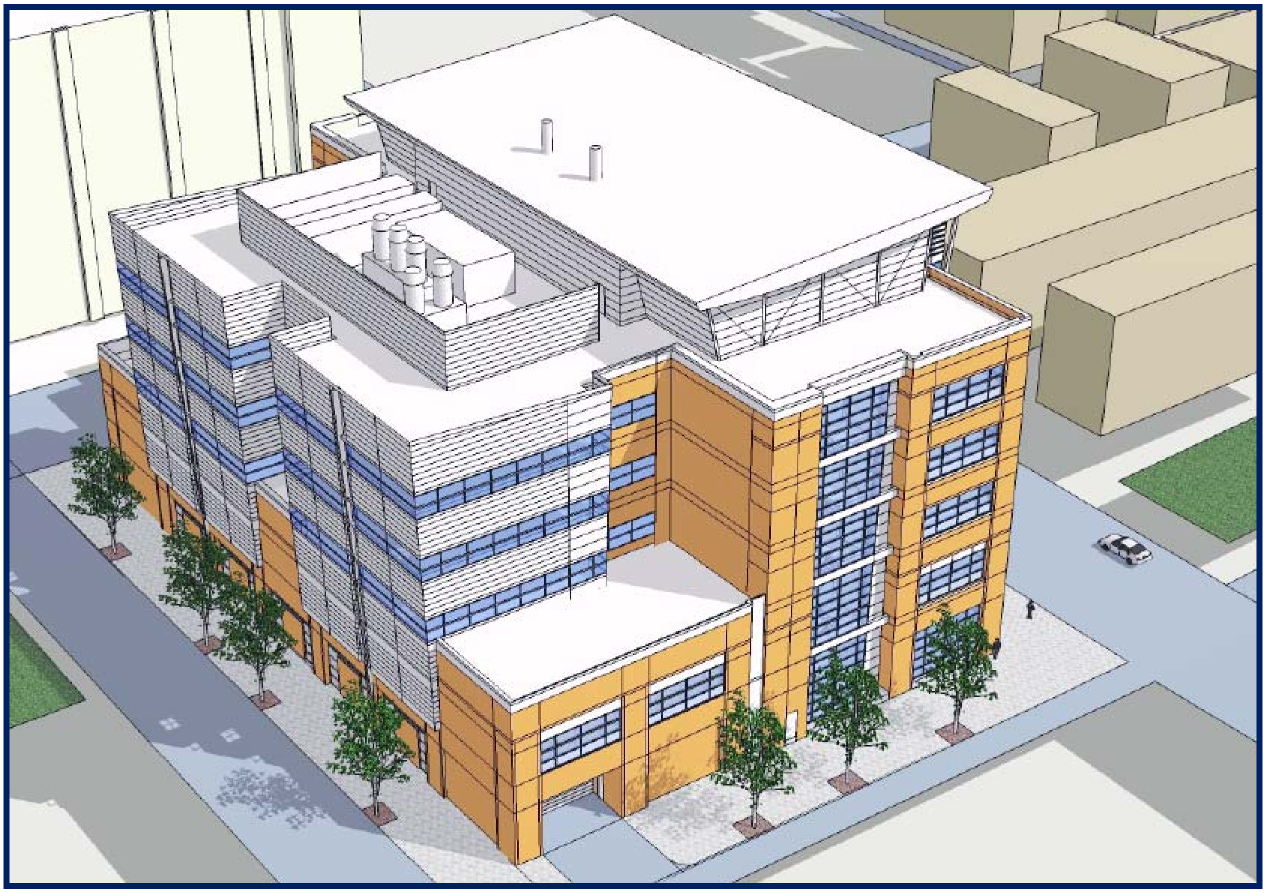
1. Gravity System
    - ASCE 7-05 for dead, live, snow loads
    - AISC Design Guide 11 for vibration design
    - Determine preliminary slab and member sizes
    - RAM model check of composite steel floor system
2. Lateral System
    - ASCE 7-05 for wind and seismic loads
    - Determine load distribution to steel braced frames
    - Determine member sizes for steel braced frames
    - Lateral system model – check strength and serviceability
3. Cost and Schedule
    - R.S. Means for cost/crew information
    - Microsoft Project for scheduling
4. Triage Area
    - Research triage requirements
    - Determine architectural requirements
    - Determine mechanical requirements
    - Determine size/type/quantity of lighting fixtures/electrical outlets
    - Determine new electrical load
    - Determine approximate costs

PROJECT GOALS

The goal of the depth study of this thesis is to determine the feasibility of changing the structure of The Forensic Medical System from a two-way concrete slab system with shearwalls to a composite steel system with braced frames. This steel system will be checked for sensitive equipment vibration criteria where required.

The Construction Management breadth study will go hand-in-hand with the depth study. While the depth study examines the structural feasibility of a composite steel system, this breadth study will look into the cost and scheduling impact of this change, in order to determine the financial feasibility.

The Alternative Care Facility breadth study will examine the architectural, mechanical, lighting, and electrical requirements necessary for the inclusion of a temporary triage unit within the ground floor of The Forensic Medical Center. The goal of this study is to roughly determine the costs and planning that would need to go into such a facility.



STRUCTURAL DEPTH STUDY

Overview

The Forensic Medical Center was designed as a state-of-the-art laboratory building. Forensic laboratories contain powerful microscopes and other sophisticated equipment that is very sensitive to floor vibrations, however, the most sensitive equipment is installed with its own isolating system. For this reason, the actual laboratory levels on the second and third floors are not the vibration critical ones. According to the project engineers, the fifth floor, where the medical examiners' offices are located, is the only floor where the vibration criteria are critical, because there is a high-powered microscope in each examiner's office. The floor system on this level must meet at least Class A criteria for sensitive equipment, according to AISC Design Guide 11 - "Floor Vibrations Due to Human Activity."

The building was originally designed in concrete, but there is no established method for designing concrete structures to limit vibrations, as the AISC Design Guide was developed for use in the analysis of steel-framed systems. To ensure the system met Class A requirements on the fifth floor, Design Guide 11 was used during the design process, with many conservative assumptions being made to accommodate the fact that the system was concrete instead of steel. The structure was only designed for slow to moderate walking paces, but not fast walking, despite the long corridor located at midspan in one of the critical bays. The result of this design strategy is a concrete system that may or may not be acceptable for the required vibration criteria. It is possible that the floor system is over-conservative, but it is also possible that the system would not perform as required. Because budget is crucial to any construction project, finding the most economical solution to a design problem while still meeting the needs of the project is very important.

This depth study investigates a redesign of The Forensic Medical Center with a steel framing system, using both composite and non-composite floors and lightweight, 5 ksi concrete. This allows for the utilization of AISC Design Guide 11 for its intended application. The second, third, and fourth floors, as well as the penthouse level, were designed for strength and deflection and vibration-checked for human comfort, while the fifth floor was designed to meet the Class A Sensitive Equipment criteria, according to the Design Guide.

To accommodate the change of the floor system from concrete to steel, the columns were also redesigned as wide-flange steel shapes. The 12-inch-thick cast-in-place concrete shearwalls were replaced by concentric steel braced frames, with wide-flange columns and beams, and rectangular HSS braces. Because the existing architectural plans allow for a 24" x 24" square column, the W10 and W12 shapes used for the column redesign do not affect the layout of the spaces. To avoid any intrusion, the braced frames were designed such that the bracing members do not interfere with openings that were present in the existing shearwalls. All of the members of the braced frames were also designed to fit within the thickness of the existing shearwalls.

Design Procedure

To redesign the floor framing systems of the building, a preliminary framing plan layout was created. This was used to determine the best direction for beam spans, girder spans, and spacing of the members. Once the layout was determined, preliminary beam sizes for typical composite members on the second, third, and fourth floors were selected using Load and Resistance Factor Design (LRFD) methods, and the Thirteenth Edition AISC Steel Construction Manual. Deflection limits were as follows:

Live Load:	L/360
Total Load:	L/240
Pre-composite Construction Load:	L/360

After preliminary floor framing sizes were selected, the layout was entered into a RAM Structural System model. The beam sizes chosen by RAM's beam design module very closely resembled the preliminary designs that were determined by hand calculations.

Vibration criteria were checked for human comfort in typical bays on the second, third, and fourth floors of the building. The fourth floor layout, which is very similar to the layout of the fifth floor, was also analyzed for sensitive equipment vibrations. It was found that this floor was inadequate for Class A equipment; therefore it was clear that the fifth floor design would be controlled by vibration.

Once the floor systems were designed, preliminary column sizes were chosen. Several typical columns were designed by hand before RAM was used to check the designs.

The final part of the structural system to be designed was the lateral system, composed of ordinary concentric braced frames. These were added to the RAM Structural System model and designed in RAM Frame. According to ASCE 7-05, The Forensic Medical Center is considered as Seismic Design Category B, which allows for equivalent lateral force analysis. Lateral forces on the building were applied to the center of mass of the floor diaphragms, with an accidental eccentricity of 5%.

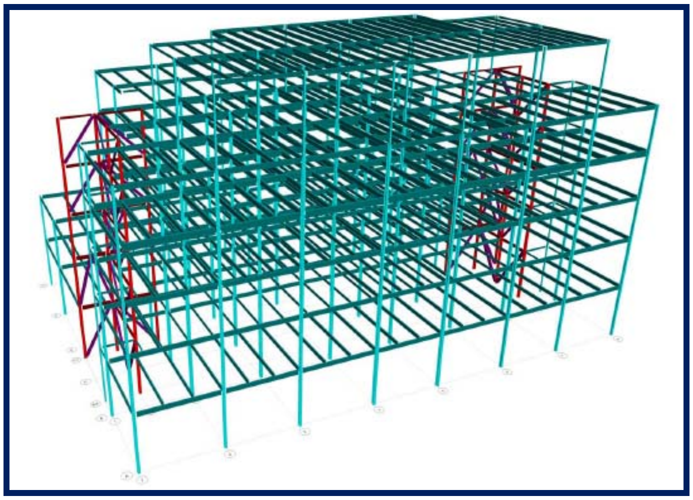


Figure 2 – RAM Structural System Model

Gravity Loads

The gravity loads used in the analysis of the structure were determined according to ASCE 7-05, and are as follows:

DEAD LOADS (psf)	
Slab + Deck	48
Superimposed M/E/P/L	12
TOTAL	**60 psf**

LIVE LOADS (psf)	
Laboratories / O.R.	60
Offices	50
Partitions	+20
Corridors	80
TYPICAL FLOORS	**80 psf**
HIGH DENSITY STORAGE	**250 psf**

ROOF LOADS (psf)	
Live	30
Snow	21

EQUIPMENT LOADS (psf)	
Air Handling Units	108
Chillers	160
Fans, Generator	200
Boilers	600

Dead loads include the self-weight of the concrete slab and metal deck, as well as other building systems permanently attached to the structure. The weight of the steel beams was not included in preliminary hand calculations, but was accounted for in the RAM model. Live loads were reduced as permitted according to ASCE 7, Section 1607.

Lateral Loads

The lateral loads on the building included wind forces and seismic forces, according to ASCE 7-05. With the change to a lighter steel structural system from a concrete one, the seismic loads would be expected to decrease. The change from a shearwall and moment frame dual-system to concentric braced frames, however, causes a decrease in the R-factor from 5.5 to 3.25. The overall result of the changes is a reduction of the seismic base shear, from 309 kips to 261 kips. The increase in height due to the change to a steel structure did not result in a significant change in the calculated wind loads because the calculations from previous technical reports were conservative.

Because of the shape of the building and the reduced weight of the steel system, the wind loads generally control the design of the system. The lateral loads are calculated in Appendix A at the end of this report. A summary of the loads is included below.

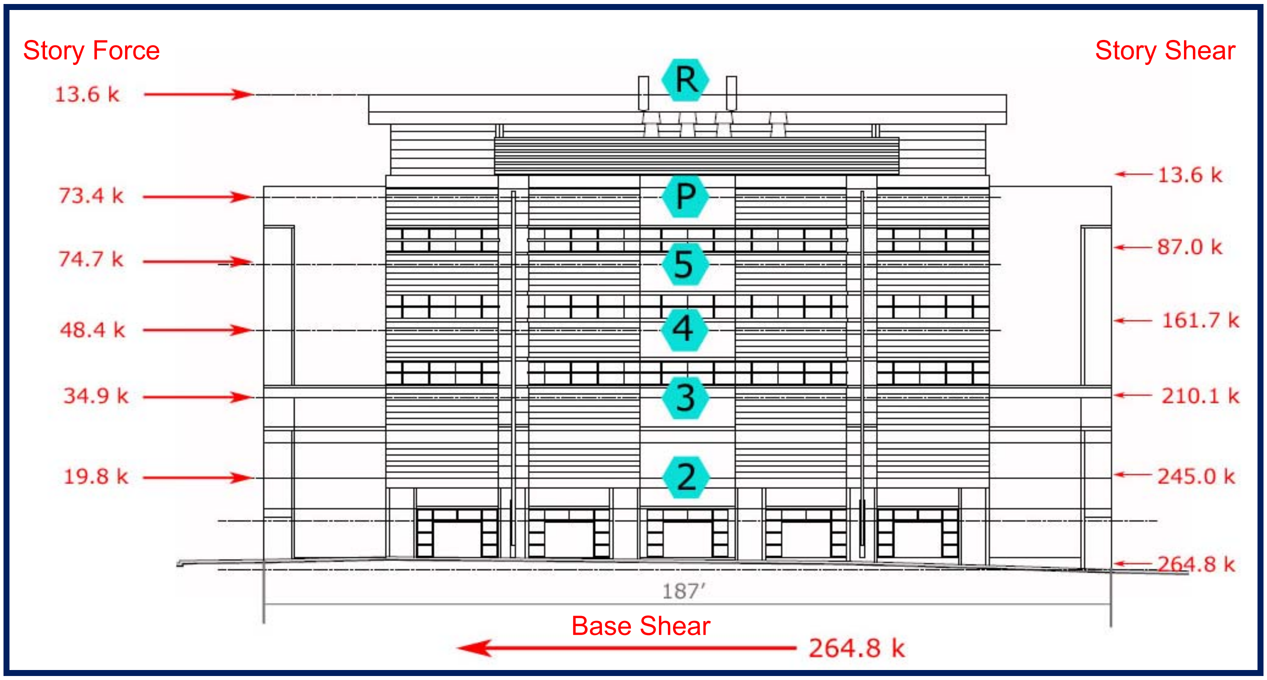


Figure 3 – Seismic Story Forces and Shears

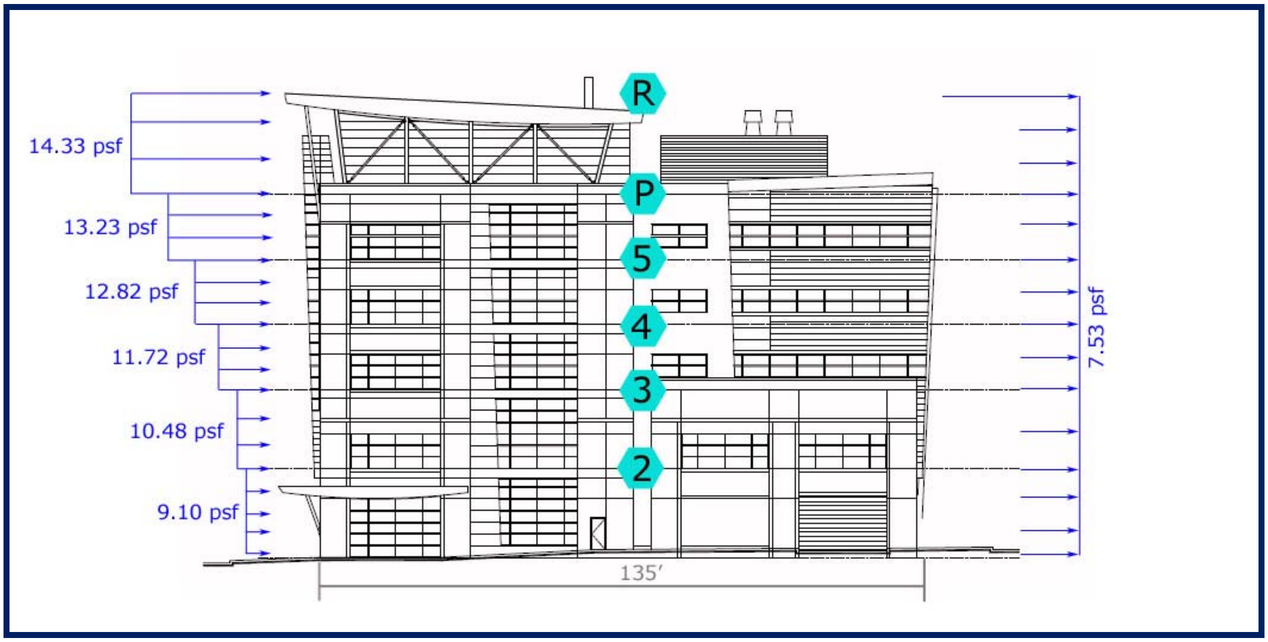


Figure 4 – North-South Wind Pressures

Deck, Beam, and Girder Design Details

Based on the developed layout, the composite metal deck under the slabs would need to span perpendicular to the infill beams, a maximum of nine feet. The deck and slab would also be required to support the 80 psf live load. The United Steel Deck design manual was used to find a deck that would meet this requirement. A 2” LOK-Floor composite steel deck was selected, with light-weight concrete. To ensure a two-hour fire rating for the slab without requiring fireproofing of the deck, and also to contribute to better vibration control, a total slab thickness of 6” (4” above the top of deck) was chosen.

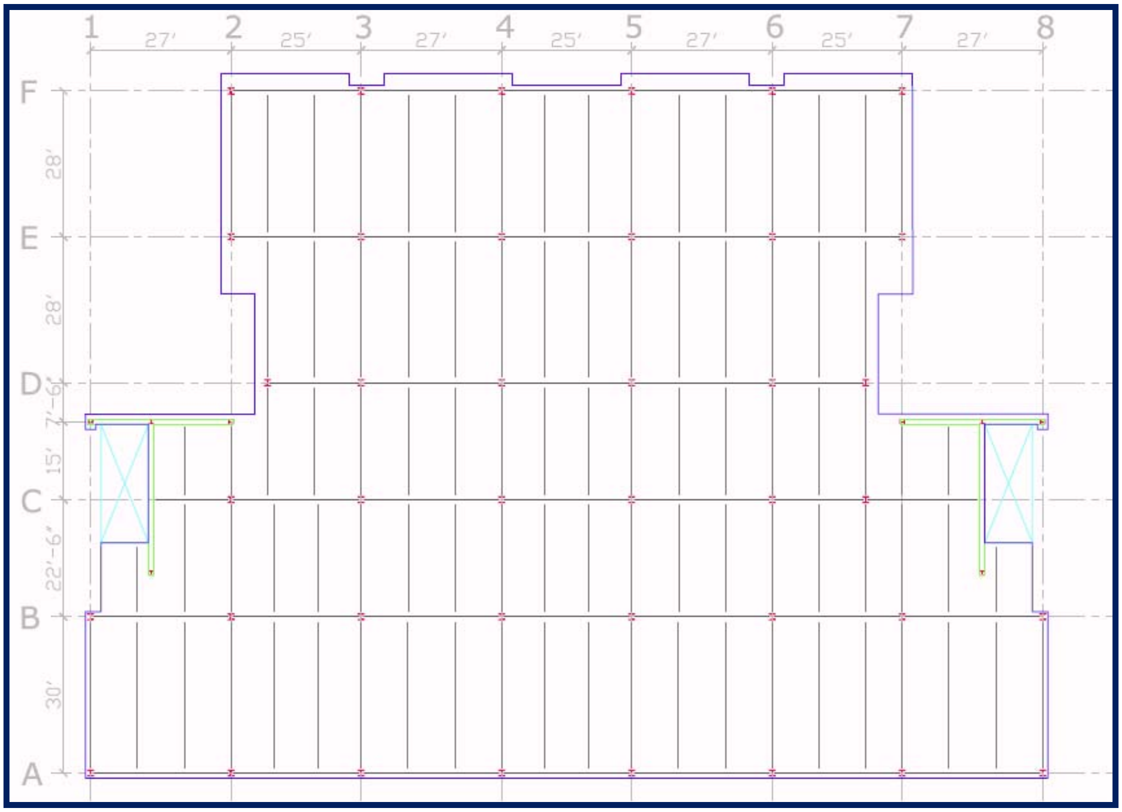


Figure 5 – Typical Framing Layout Plan

When the gravity loads were applied to typical beams, sizes and numbers of shear studs were selected to support the loads according to Thirteenth Edition AISC LRFD criteria. The load case that controlled in all of the gravity framing cases was 1.2 D + 1.6 L. Once a size was selected for strength, it was found that pre-composite construction load deflection controlled the design in many cases. Deflection of the beams during construction loading must be limited, as too much deflection would lead to the addition of extra concrete to the slab, thus increasing deflection even more. If this deflection is not limited, shoring of the beams is necessary during the concrete placement, which adds unnecessary costs and chance for error.

The design resulted in light W18 sizes for girders on the second, third, and fourth floors, with light W16 sizes as the infill beams. In some locations, due to the pre-composite deflection considerations, it was more economical to design the beams as non-composite, as the cost of installation for one shear stud is roughly equivalent to 10 pounds of steel.

Because of the extensive procedure required to calculate the vibration properties of a floor system, and the possibility that the design would go through many iterations before it was acceptable, a spreadsheet was created to assist in the design of the fifth floor. The Class A criteria required members that were much deeper and heavier than the beams and girders on the floors where vibration was not critical. The most critical area of the floor was the area between gridlines A and B, on the south face of the building (See Figure 5). This is where the Medical Examiners' offices are located. They are separated from their secretarial support areas by a long corridor, which runs directly through the center of the span of these bays.

This is the worst case scenario as far as vibration design, so these bays must be designed for "fast walking" according to Design Guide 11, which is 100 steps per minute. To make the beam sizes more manageable, the number of infill beams in these bays was increased from two at 9' on center to three at 6'-9" on center. The girders in these bays were selected to be W30x191s, with W27x129s as the infill beams. This allowed the floor to meet the Class A criteria of 2,000 μin/sec for fast walking. Fast walking was also considered for the other critical areas on the north side of the building, where W30x191 girders were used, along with W27x114 beams. The rest of the floor was not designed for fast walking, but was designed to meet 2,000 μin/sec for slow to moderate walking. This resulted in W24 girders, with W21 infill beams. This is reasonable because the corridors near these critical areas are not nearly as long, and are located along the column line, rather than over the middle of the bay span. Full-height partitions will also help to dampen some of the vibration.

A disadvantage of the steel structural system is the added depth of the members, which add to the floor-to-floor height. In order to avoid interference with mechanical systems and other ductwork, the floor-to-floor heights were increased by 12" in most cases, and by 18" between the fourth and fifth floors.

To create a more efficient design in steel, repetition is important. Using fewer numbers of different sizes cuts down on material costs for the structure, reduces the amount of coordination necessary in the field, and also reduces the chance of a mistake being made during construction. For this reason, member sizes were coordinated such that beams and girders in similar bays or in similar locations on different floors were the same size. This reduced the number of different sizes, and created typical details for similar areas of the floor. The calculations can be found in Appendix B, and the resulting designs can be found in Appendix C.

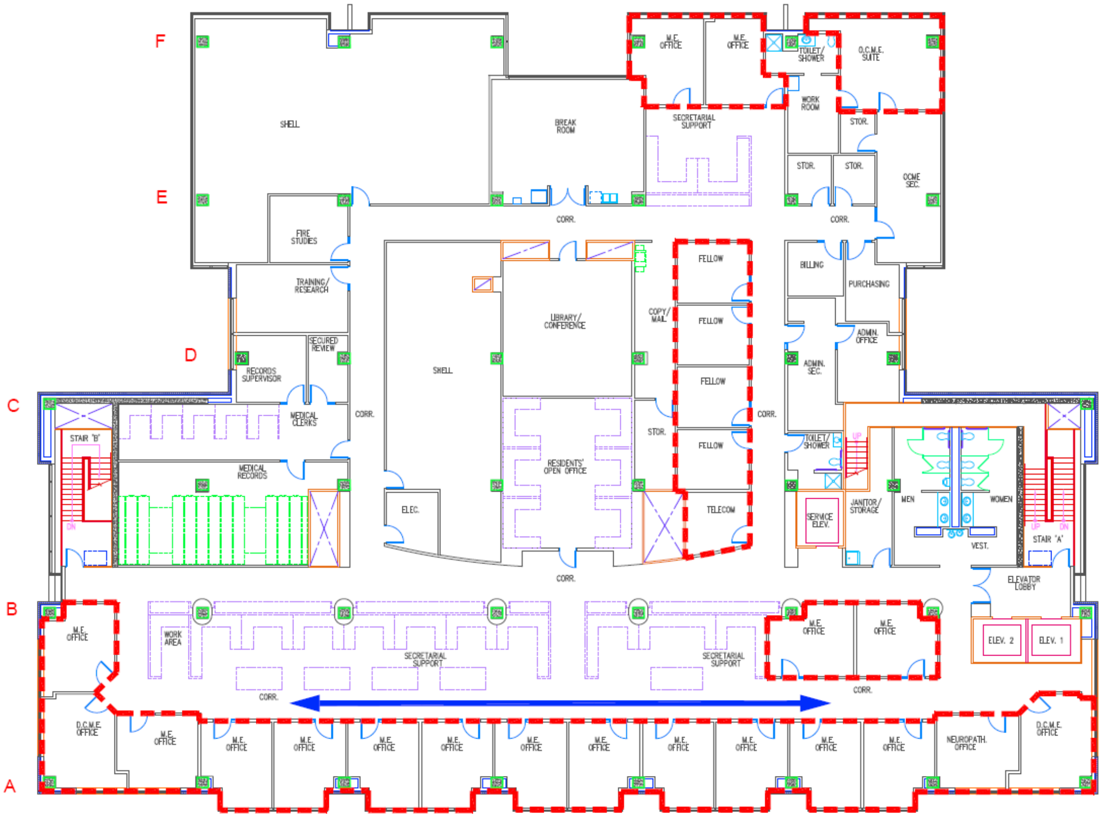


Figure 6 – Vibration Critical Areas-red dashed outline

Column Design

The gravity load of the building is first carried by the slab and deck, to the beams. These beams carry the load to the girders, which then frame into the columns. The columns then take this load to the ground, through the building's foundation. The columns of The Forensic Medical Center were designed for axial load and gravity-induced moments according to Thirteenth Edition AISC LRFD criteria. Tributary area was found on each floor for a given column, and the total axial load was determined. These designs were compared to the results from the RAM Structural System model.

To minimize architectural impact, all of the columns were designed as W10 sizes where possible. Because the original concrete system used 24" square columns, however, using any conventional steel column size would result in an increase in available floor area.

Just as with the beam sizes, the column sizes were adjusted to increase repetition and cut down on the number of different sections. The result is a total of six different column sizes used throughout the building for the gravity framing, ranging from W10x33 to W12x73. The calculations can be found in Appendix D, along with the resulting designs.

Lateral System Design

The lateral forces applied to the building are resisted by four sets of braced frames, arranged in T-shapes on either side of the building. The frames containing the braces also include moment connections between the vertical and horizontal members to provide additional lateral load resistance. The brace layouts were configured to avoid interfering with the doorways that were cut out of the shearwalls in the original design. Diagonal braces were placed in most panels of the frames, with chevrons next to panels that were left open for the doorways.

Because of the nearly symmetrical layout of The Forensic Medical Center, the center of mass is very close to the actual center of the building. The lateral system was then designed to be symmetric, thus placing the center of rigidity very close to the center of mass. This reduces the inherent torsion in the building when lateral loads are applied.

To design the lateral system, RAM Frame was used. The lateral loads determined according to ASCE 7 were applied to the structure, with the lateral loads being applied at the center of mass, with an accidental eccentricity of 5%. The following load cases were analyzed:

- 1.4 D
- 1.2 D + 1.6 W
- 1.2 D + 1.0 E
- 1.2 D + 1.6 L
- 0.9 D + 1.6 W
- 0.9 D + 1.0 E
- 1.2 D + 0.5 L + 1.6 W
- 1.2 D + 0.5 L + 1.0 E

The member sizes of the frames were limited to fit within the 12”-thick footprint of the shearwalls that were part of the existing concrete design. The vertical elements of the frames were all selected to be W10 shapes. Rectangular hollow structural steel sections were used as the diagonal bracing members, and were limited to 8” in width. Elevations of the frames along with sizes of the members can be found in Appendix E at the end of this report.

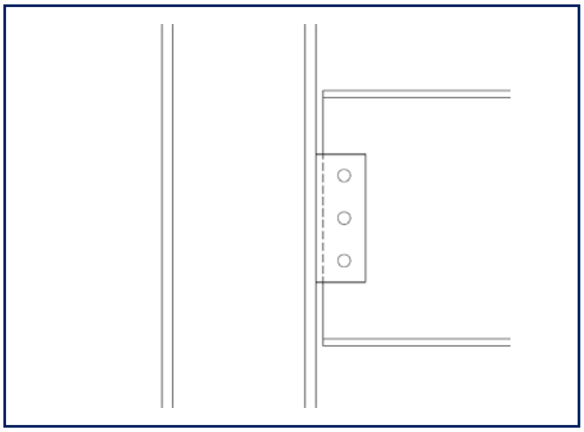
Story Displacement

The story displacement of The Forensic Medical Center with the redesigned steel structural system was determined by a RAM Structural System analysis. The worst case displacement of 1.56 inches is well within the allowed displacement of H/400, equal to 3.33 inches. A summary of the worst case drifts and displacements follows:

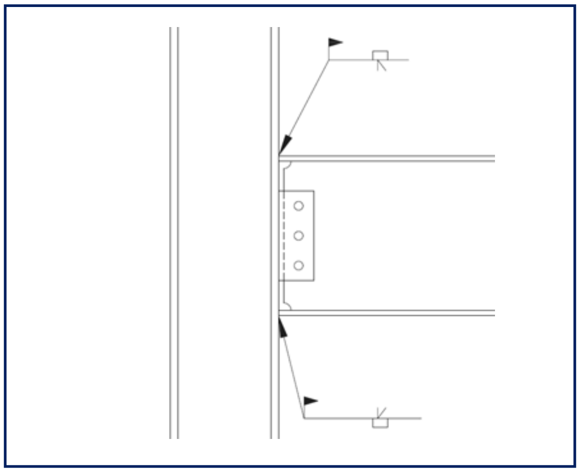
	X-Direction		**Y-Direction**	
	Controlled by Seismic		**Controlled by Wind**	
STORY	**Story Drift**	**Displacement**	**Story Drift**	**Displacement**
Penthouse	0.288	1.563	0.263	1.349
5	0.298	1.275	0.295	1.086
4	0.325	0.977	0.256	0.791
3	0.514	0.652	0.288	0.535
2	0.138	0.138	0.247	0.247

Connection Design

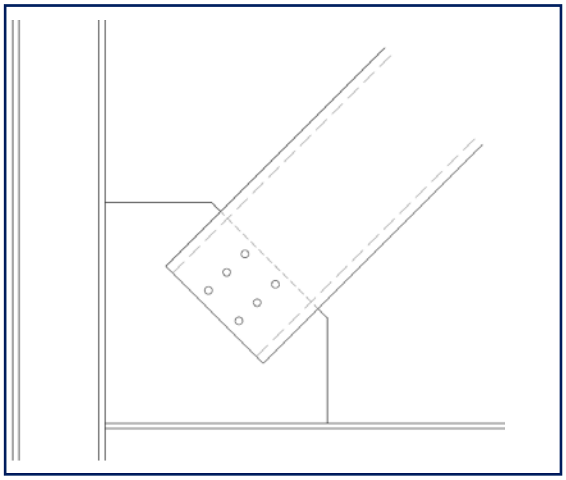
An important part of a steel structure design is the design of its connections. This redesign of The Forensic Medical Center involved three typical connection types: shear, moment, and bracing. Shear connections are used for most beam-to-girder and girder-to-column connections. Moment connections are implemented at the horizontal-to-vertical member joints within the lateral frames. The third connection type involves the joining of the braces to these frames. Typical examples of these connection types are shown below, and full calculations are available in Appendix F at the end of this report.



Typical Shear Connection



Typical Moment Connection



Typical Bracing Connection

Figure 7 – Typical Connection Details

CONSTRUCTION MANAGEMENT BREADTH STUDY

Overview

Cost and schedule are crucial to any building project. Any changes to the design of a building need to be analyzed for the impact that they will have on construction before it can be decided whether the changes should be made. For this thesis breadth study, the cost and schedule implications of the structural system changes made in the structural depth study are analyzed for the difference in direct costs, such as materials, labor, and time on the jobsite. Other differences, such as overhead, profit, and earlier rent payments, are not part of the scope of this study.

For the study, the materials takeoffs from the original concrete design were compared to the takeoffs from the RAM Structural System model for the composite steel redesign. Cost data for materials and labor crews, as well as the daily output of the labor crews were taken from R.S. Means Building Construction Cost Data 2008, as well as input from industry practitioners on the Penn State Architectural Engineering Technical Discussion Board. The data was entered into a spreadsheet to calculate the difference in cost between the two systems, as well as the construction time required for each item. This construction time was entered into Microsoft Project to create a schedule for each system. These schedules were compared, and the time saved was converted to a general requirements cost.

Material Takeoffs

A detailed structural takeoff of the existing concrete system was obtained for use in this study. The takeoff values were combined into three categories: Columns, Shearwalls, and Slabs. Each category included values for formwork, reinforcement, placement, and finishing of concrete, where applicable. The “Takeoff” feature of RAM Structural System provided the weight of steel in the composite redesign, which was broken down into Columns, Braced Frames, and Floors. The full details of the takeoffs are included in Appendix G at the end of this report.

Results

Using this estimation method on both the existing system and the proposed redesign yielded more consistent results for comparison between the two systems. The existing concrete structural system was estimated at approximately $3.1 million, while the composite steel system was estimated at $1.9 million, a savings of $1.2 million.

After a scheduling study, it was found that the concrete system would take 135 days to complete, while the steel system would only take 69 days, a savings of about 3.3 months, assuming four five-day work weeks per month. Using a contractor supplied figure of approximately $1.4 million dollars for 24 months on the jobsite, the cost per month was calculated as $60,000. This amounts to a savings of approximately $198,000 in direct jobsite costs.

C-I-P CONCRETE - EXISTING CONDITIONS	
COLUMNS	**COST**
Formwork	190,278
Concrete	79,022
Reinf.	124,442
SLABS	**COST**
Formwork	783,676
Concrete	612,762
Slab Finish	191,632
Reinf.	866,472
SHEARWALLS	**COST**
Formwork	106,515
Concrete	50,710
Reinf.	47,367
CRANE	40,500
	$ 3,093,377
	135 Days

COMPOSITE STEEL SYSTEM - REDESIGN	
COLUMNS	**COST**
Steel	140,792
Baseplates	7,521
Fireproofing	35,580
FLOORS	**COST**
Framing	603,398
Steel Deck	327,454
Shear Studs	9,436
Fireproofing	186,119
Concrete	230,520
WWF	63,883
Slab Finish	193,284
BRACES	**COST**
HSS Steel	36,968
Fireproofing	6,200
CRANE	20,700
	$ 1,861,855
	69 Days

CONCRETE		
Materials:		1,536,749
Labor:		1,507,128
Equipment:		49,500
TOTAL:	**$**	**3,093,377**

STEEL		
Materials:		1,171,959
Labor:		669,196
Equipment:		20,700
TOTAL:	**$**	**1,861,855**

Steel Savings:	**$**	**1,231,522**	
		66	**Days**
		3.3	months
Jobsite Direct Costs:	$	60000	/month
Time Savings:	**$**	**198,000**	
TOTAL SAVINGS:	**$**	**1,429,522**	

Conclusions

The results of this breadth study show that considerable savings could be attained by using a steel structural system instead of the existing concrete system. A difference of three months and $1.4 million dollars are a considerable amount on any size project. However, there are some other advantages, as well as disadvantages to each system that were not within the scope of this study.

The foundations of The Forensic Medical Center were not included in this study. According to the geotechnical report for the building, 48-inch diameter drilled piers socketed into bedrock are recommended for the foundation system, given column loads of 1500 kips. Comparing the weight of the concrete structure from previous seismic calculations to that of the steel structure, it is found that the steel structure weight is roughly half that of the concrete structure. With this large reduction in dead load, it may be possible to reduce the size of the drilled pier foundations, or even use a much less expensive spread footing foundation system, which would further increase the savings associated with a steel system.

A major disadvantage of a steel framed building is the long lead time required to obtain the materials. The steel members must be designed and fabricated weeks before they are needed, and then shipped to the site. This could affect the schedule of the building if construction were to begin right away. It also leaves little room for design changes late in the project, as the pieces will have already been fabricated.

Another disadvantage of the steel system is the increase in the flooring system thickness. This increase makes it necessary to either reduce the finished floor-to-ceiling-height of each level, or to increase the total building height. In this study, the total height of The Forensic Medical Center was increased from 105 feet to 111 feet above grade. This causes an increase in the area of the exterior façade. An estimate of this cost was made by taking a total cost of $2.1 million for the exterior skin of the building from the original design and dividing it by 105 feet above grade to obtain a cost of $20,000 per foot of height. The additional six feet of height would equate to an increase of roughly $120,000, which would be subtracted from the total savings due to the steel system switch.

The engineer must take in to consideration all of these factors when designing the structural system for a building. The results of this study lead to the conclusion that a composite steel system with braced frames is indeed a viable option for The Forensic Medical Center. It is the recommendation of this thesis that further investigation into the system be considered.

ALTERNATIVE CARE FACILITY BREADTH STUDY

Overview

An original idea for The Forensic Medical Center was to include a temporary triage area in the ground floor parking lot, for use in the case of a catastrophic event. Theoretically, the medical personnel employed at the building could be called upon to staff such a triage unit in the event of a large-scale biological or chemical attack. The idea was shelved due to budget concerns.

Such triage units, also known as “Alternative Care Facilities,” or ACFs, have been established in the past when large-scale accidents, natural disasters, or terrorist attacks have occurred. Instead of overburdening area hospitals with the large number of emergency patients, these facilities serve as intermediate care facilities. Their purpose is to care for patients who may need some medical attention, but not invasive treatment, and to “sort out” more critical patients, sending them to more advanced treatment facilities.

A key requirement of an ACF is a quick set-up time. Optimally, the facility should be set up and ready to accept patients within an hour of notification. Having a permanent system in place and ready for an emergency situation would greatly decrease the required set-up time, possibly saving lives in the process.

This breadth study briefly investigated some of the architectural changes that would be needed on the ground floor of The Forensic Medical Center to accommodate an emergency Alternative Care Facility. In addition, the mechanical, lighting, and electrical upgrades that would be required for the functions of an ACF are explored. A rough cost estimate of these items was also prepared.

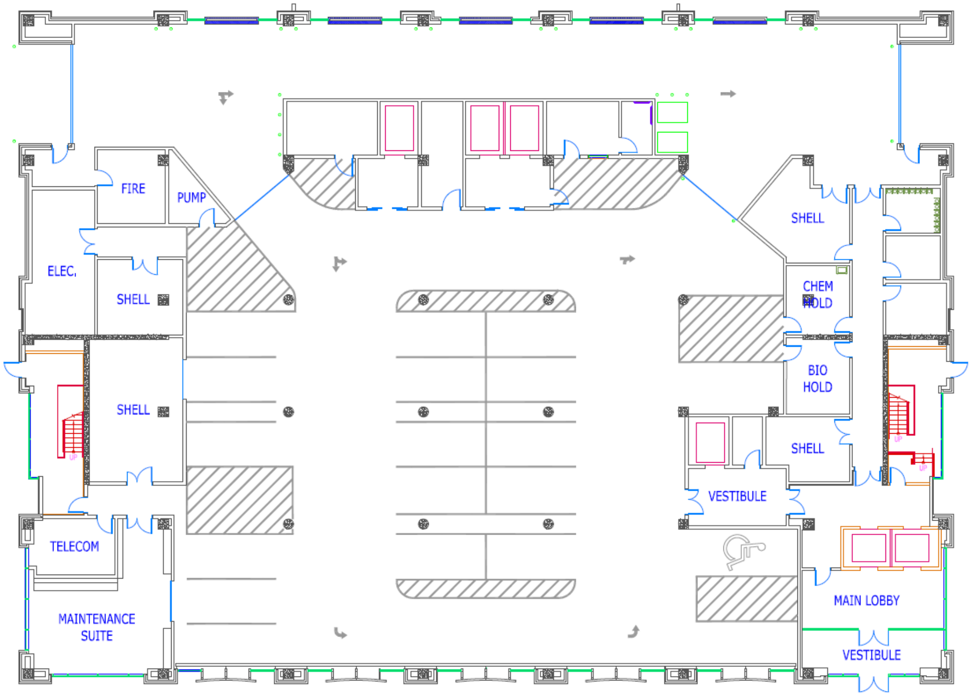


Figure 8 – Ground Floor Plan As Designed without ACF

Architecture

In the case of a biological or chemical attack, the first and most important treatment is decontamination. To do this, warm showers must be made available, along with soap and shampoo. A flow must be established for patients that arrive at the ACF which involves the decontamination procedure before contact is made with any non-contaminated patients or staff members. This arrival and decontamination area is known as the "Warm Zone," where contamination is likely, and protective equipment is required of personnel. Once decontaminated, the patients may enter the "Cold Zone," the non-contaminated portion of the facility. This is where they will be treated for any symptoms or injuries, and transferred to a more advanced care facility or released. The two zones must be separated so that there can be controlled access to the Cold Zone to avoid contamination.

The ambulance drive-through area of the parking garage under The Forensic Medical Center would serve well as a drop-off point for the ACF. This point would be within the Warm Zone, where patients would be directed to shower stations for decontamination. For this study, the shell area on the west side of the building would be sacrificed for the installation of these shower stations. The Cold Zone would be a section of the parking area of the floor, and would be separated from the outside by large overhead doors located between the columns that form its perimeter. These doors would be installed within the ceiling, and left open and out of the way during normal operation of the garage. Once released, patients would be able to leave through the main lobby and entrance on the south-east corner of the building.

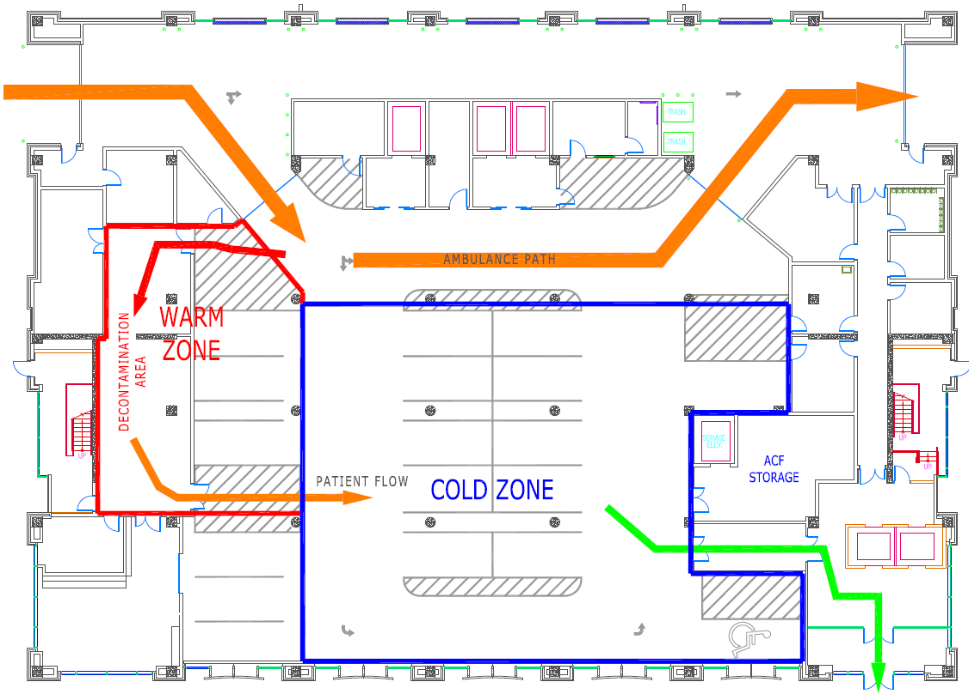


Figure 9 – Ground Floor Plan with ACF

Another architectural consideration is the need for storage area. Equipment such as cots, divider curtains, and medical supplies need to be available for quick access in the event of an emergency, but out of the way during normal operation of the building. To create this space, the shell area near the building's main lobby on the south-east corner of the building would be sacrificed for storage. Removing one of the parking spaces in this corner allows the parking lot entrance vestibule to be moved down, creating more storage area.

Since the ACF would still be used as a parking garage during non-emergency situations, it is probable that vehicles would be located in the garage at any time an emergency could occur. Since there are only 19 parking spaces in the small garage, another garage, located across the street, should have enough capacity for the relocation of these vehicles. All of the vehicles would be driven by employees of The Forensic Medical Center, so notification of the owner of each vehicle would not be a concern.

The main direct cost of making the architectural changes would be installing the overhead door system to separate the Warm and Cold Zones. The price per door was estimated at $8000. With seven doors required, this amounts to approximately $56,000. This cost does not include any lost revenue from the shell spaces that were removed to accommodate the ACF.

Mechanical

Generally, the design temperatures for an indoor parking garage are not the same as what one would hope for in a medical treatment facility. In this case, however, the space in question would be used for parking for the vast majority of the time, so keeping it at a comfortable room temperature would be uneconomical. In the case of an emergency, however, the heating or cooling systems of the building would be required to keep the ACF space at a reasonable temperature. The goal of this part of the study is to show that the existing mechanical system is adequate for this requirement, without added equipment.

An estimate of the heating and cooling loads for the ground floor parking garage area was made, assuming a hospital-type occupancy and activity level, using Trane Trace 700. The space dimensions and properties were entered into the program, and the summary of the system loads for the space was obtained.

The ACF space was designed for an outdoor temperature of $91^{\circ}F_{DB}/77^{\circ}F_{WB}$ in the summer, and $13^{\circ}F_{DB}/8^{\circ}F_{WB}$ in the winter. Because of the possibility of chemical or biological contamination in the Warm Zone of the building, it is necessary to supply 100% outdoor air for heating or cooling the space rather than recirculating any air. All five of the building's air-handling units are capable of supplying this requirement.

Using a spreadsheet for calculations, it was found that the peak cooling load in the summer would be 42 tons. The existing mechanical system includes two 365 ton chillers, for a total capacity of 730 tons, while the existing design cooling load is only 457 tons. The system is designed such that at peak conditions, the chillers are each working at two-thirds capacity. Adding an additional 42 tons to the load will not have a large effect on the system, as this is still well within its capacity.

The peak winter heating load for the ACF was found to be 819 MBH. Two existing boilers each supply 8300 MBH, for a total capacity of 16600 MBH. The ACF loads constitute less than 5% of the total capacity of the system. Therefore, it is concluded that the ACF would have an almost negligible effect on the heating system of the building.

While the ACF would not require an increase in capacity to the mechanical system of The Forensic Medical Center, there still would need to be modifications to the ductwork. To determine the cost of installing the necessary ductwork in the ground floor, the total cost of the ductwork from a building estimate was taken and divided by four, the number of floors with existing ductwork. This gives an approximate cost for ductwork of $175,000 per floor.

Lighting and Electrical

The parking garage area of The Forensic Medical Center on the ground floor is illuminated by twelve High-Intensity-Discharge (HID) metal halide lamps. This is adequate for a typical parking garage, which generally requires an illuminance of 1 foot-candle. An emergency room situation, however, requires a significantly larger quantity of light. Replacing the HID system would not be an economical solution, since the parking garage will be used as a garage for almost all of its functional life. Instead, this study investigated supplementing the parking garage system with suspended fluorescent fixtures that would only be utilized in the event of an emergency that required use of the ACF.

This study focused on the Cold Zone of the ACF (see Figure 10), as the Warm Zone is located mainly in an area that is not part of the parking garage. The Cold Zone was approximated by a rectangular area 104 feet by 75 feet, with a ceiling height of 14 feet, 6 inches. The floor of the garage is cement, with a reflectance of 27%; the walls are mainly concrete, with a reflectance of 55%; and the ceiling is gypsum board, with a reflectance of 70%. For the workplane height, three feet was used. High-output suspended semi-direct (70% down-light) luminaires with four T8 fluorescent lamps were selected to be suspended 18 inches from the ceiling, along with high-output F48T8/HO lamps and two-lamp ballasts. Calculations determined that 45 of these luminaries would be required to supply 50 foot-candles at the workplane. It was also determined that four #12 copper wires would be needed to supply the feeder to a 20 amp circuit breaker.

In addition to the lighting, the ACF would also need access to standard duplex receptacles. It was determined that approximately 50 receptacles could be located throughout the Cold Zone, along walls and columns. Allowing for five receptacles per circuit, this would add ten circuits to the 208/120 V panelboard serving the ground floor. Assuming 180 VA per receptacle and allowing for growth, this is an increase of 11250 VA to the load on this panelboard.

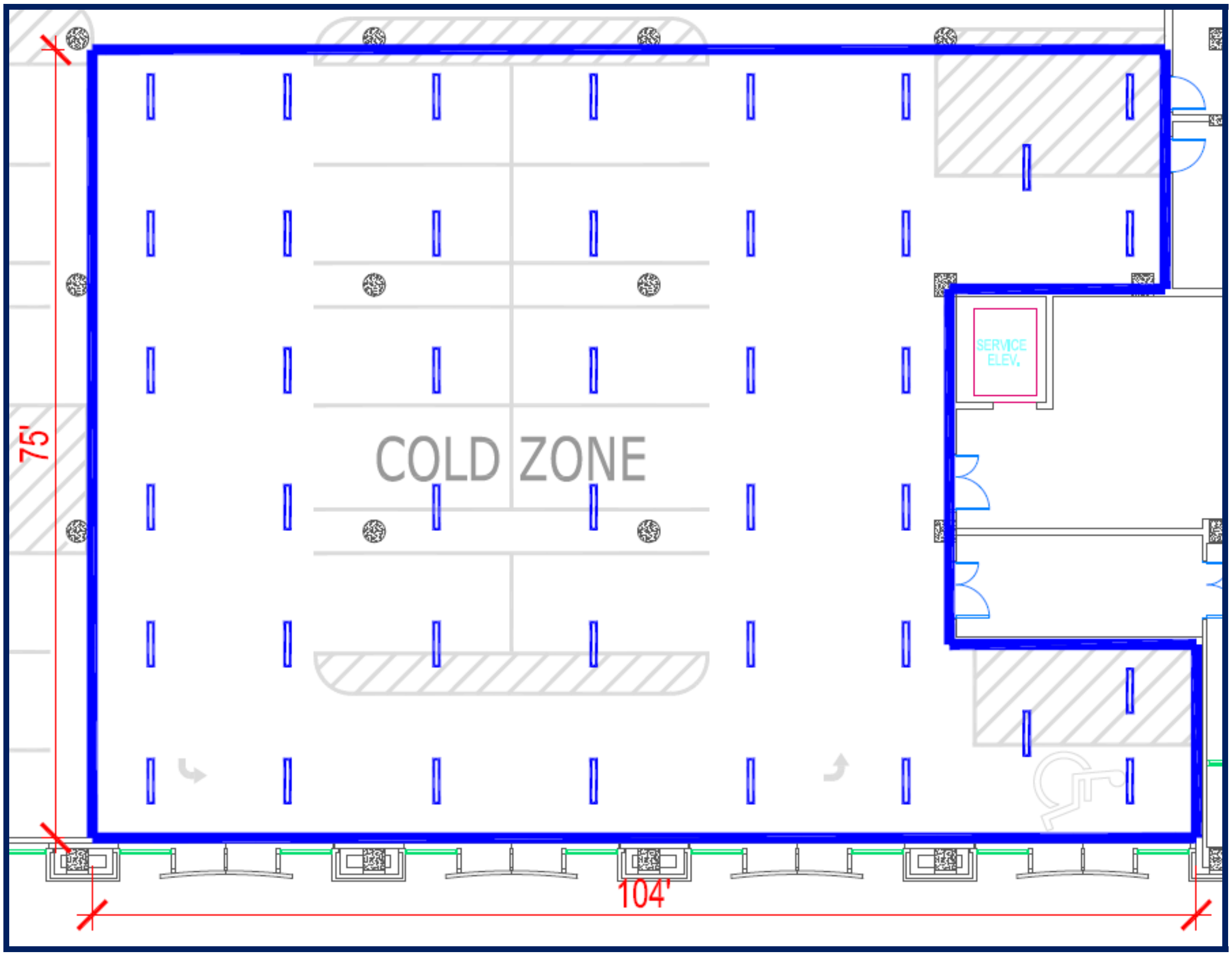


Figure 10 – ACF Lighting Layout

The cost of the lighting system was estimated by pricing the luminaires, lamps, and ballasts required. The result is a material cost of approximately $16,500. Labor costs were also estimated, based on the estimate of $80 per lighting fixture for pendant mounted fluorescent lights for the existing design. This gives a total lighting cost of $25,500. The wiring and electrical system costs are slightly more difficult to estimate. A method similar to the one used to estimate the mechanical system cost was used, using the square footage of the ACF compared to the total square footage of the building, rather than breaking down the costs per floor. Direct costs for wiring and distribution for the existing design were approximately $1.5 million, which equates to roughly $15 per square foot. The 104-by-75 foot Cold Zone is 7,800 square feet, adding $117,000 to the cost of the ACF.

Conclusions

With the ever-growing concerns about large-scale terrorist attacks, as well as the always-present possibility of accidents and natural disasters, Alternative Care Facility considerations are starting to become more common. Usually, it is in the form of an airplane hangar, fire hall, or gymnasium that can be set up to serve this purpose. The advantage of designing an ACF for The Forensic Medical Center is that the requirements can be built into the building to begin with, instead of being added later. In addition, being a medical facility, much of the needed supplies will be readily available, and much of the personnel needed to provide care in an emergency would already be located on-site.

The main disadvantage of this plan is the cost. While the direct material and construction costs are estimated at approximately $400,000 for this study, this number does not include the cost of supplies and equipment for the facility, nor does it include running water and other plumbing that would undoubtedly be required in a facility such as this. Also not included is the lost revenue from eliminating shell spaces that could have otherwise been rented for research or office space. All of these items will contribute a significant amount to the total cost of the ACF.

It is the conclusion of this breadth study that further research into the installation of an Alternative Care Facility in The Forensic Medical Center is warranted by the apparent feasibility and relatively low cost of the required architectural, mechanical, and electrical changes. It would be the owner's decision as to whether the facility, which hopefully never would be needed, was worth the added expense, including the cost of supplies, equipment, and plumbing.

ACF COST ESTIMATE

Arch:	Barriers:	$	10,000	per overhead door				
		x	7	required		=	**$70,000**	
HVAC:	Ductwork:	$	700,000	for existing 4 floors		=	**$175,000**	per floor
Lighting:	Luminaires:		45	@	$100	=	$4,500	
	Lamps:		180	@	$17	=	$3,060	
	Ballasts:		90	@	$100	=	$9,000	
	Installation:					=	$4,000	
						=	**$20,560**	
Electrical:	Wire, etc.	$	1,500,000	for 101,000 SF		=	$15	per SF
		x	104' x 75'	= 7800 SF		=	**$117,000**	
					TOTAL:		**$382,560**	

Full calculations for this study are available in Appendix H at the end of this report.

SUMMARY

Structural Depth

The goal of this depth study was to determine the feasibility of a change in structural design of The Forensic Medical Center, from two-way concrete slabs with shearwalls and moment frames to a composite steel system with braced frames. This was to be accomplished without any major effects to the architectural layout, or any of the building systems.

After the study was completed, it was clear that a structural design in steel could be developed to carry the loads required by code, without a large impact on other aspects of the building. Where many assumptions had to be made to make the concrete system work with the sensitive equipment vibration calculations, the steel system was designed according to a published guide. In addition, the concrete system was only designed for slow to moderate walking; however, the situation in the building may very well require the more stringent fast walking criteria. This design did require some very large steel members to meet these vibration requirements, greatly increasing the floor depth over the existing 11” thick slab, but this increase might be necessary.

Construction Management Breadth

Following the redesign of the structural system, the goal of the construction management breadth study was to analyze the costs of materials and labor of the existing system versus the new system and determine the financial feasibility of such a redesign.

The results of this study showed that the redesigned system not only was a possibility, but could yield substantial savings over the existing concrete system. In addition, the construction time of the steel system was found to be several months shorter than that of the concrete system, meaning an earlier move-in date, and earlier ability to rent space within the building.

Alternative Care Facility Breadth

An Alternative Care Facility was in the initial plans for The Forensic Medical Center, but was left out in later designs, due to the cost. The goal of this breadth study was to examine the requirements of such a facility and roughly determine the necessary costs to include these requirements in the design of the building.

At the conclusion of this study, it was found that an ACF is definitely feasible within the ground floor of the building, but not without a somewhat substantial cost to the owner. The pros and cons of having such a facility must be weighed to determine whether to include it in the design of the building.

CONCLUSIONS

A state-of-the-art laboratory building equipped with the latest high-tech equipment would not be effective if the sensitive equipment could not function properly due to excessive floor vibration. The existing concrete structure of The Forensic Medical Center was designed to avoid such an issue, but many assumptions had to be made, as there is no established method of concrete design for sensitive equipment vibration. Also, the floor as designed was not guaranteed to meet the criteria for fast walking excitation.

This thesis study investigated the use of AISC Design Guide 11 in the design of a composite steel structure for the building. The guide is an industry-accepted method of designing a building to avoid vibrations due to human activity. In this case it resulted in a lighter structure that will still be effective in limiting vibration to a level acceptable for the use of sensitive microscopes on the fifth floor of The Forensic Medical Center.

There are also several additional advantages to using a steel structure. The structure is much lighter than the existing concrete design, leading to smaller foundation sizes, and possibly even a change from drilled piers to a much less expensive spread footing system. Smaller columns are used in this design, W10s and W12s instead of 24-inch square columns used in the concrete design. Also, this study found that a steel system would be less expensive overall than the existing concrete design, and would be completed several months earlier.

As with any structural system, there are disadvantages as well. The steel system causes an increase in the thickness of each floor system, which leads to a taller building. This leads to an increase in the size of the exterior surface of the building, adding to the cost of the façade. Steel members also require longer lead times which could impact the schedule of the building if construction were to begin soon. This longer lead time, due to the need to prefabricate each member before shipping it to the site, also means there is less flexibility in the design or layout of the building, as far as making late changes. In this specific case, the steel design varied slightly on each floor, especially on the vibration-critical fifth floor. The concrete system, by contrast, was virtually the same throughout, with 11-inch-thick, two-way, flat-plate slabs on every floor, regardless of vibration requirements. This consistency greatly influences the ease of construction, and limits the possibility of mistakes being made in the field. Steel construction also requires a large staging area on the construction site, something that may be difficult to provide in an urban setting.

Weighing these advantages and disadvantages, it is the conclusion of this thesis study that the composite steel system is a viable alternative to the existing concrete design, and it is recommended that this system be further investigated.

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APPENDIX A: LATERAL LOAD CALCULATIONS

Seismic Load Calculations

Level 2

Slab:				48	psf	*	25368	sq ft			=	**1218**	k
Framing:											=	**115**	k
Ext. Wall:	44	psf	*	644	ft perimeter	*	19.5	ft height			=	**553**	k
Partition:	20	psf				*	25368	sq ft			=	**507**	k
Columns:				70	lb/ft	*	19.5	ft height	*	44	=	**60**	k
								TOTAL			**=**	**2453**	**k**

Level 3

Slab:				48	psf	*	18547	sq ft			=	**890**	k
Framing:											=	**112**	k
Ext. Wall:	44	psf	*	644	ft perimeter	*	17.33	ft height			=	**491**	k
Partition:	20	psf				*	18547	sq ft			=	**371**	k
Columns:				70	lb/ft	*	17.33	ft height	*	42	=	**51**	k
Storage:	250	psf	*	800	sq ft	*	25	%			=	**50**	k
Roof:				48	psf	*	3500	sq ft			=	**168**	k
								TOTAL			**=**	**2133**	**k**

Level 4

Slab:				48	psf	*	21700	sq ft			=	**1042**	k
Framing:											=	**97**	k
Ext. Wall:	44	psf	*	644	ft perimeter	*	16.17	ft height			=	**458**	k
Partition:	20	psf				*	21700	sq ft			=	**434**	k
Columns:				60	lb/ft	*	16.17	ft height	*	42	=	**41**	k
								TOTAL			**=**	**2072**	**k**

Level 5

Slab:				48	psf	*	21810	sq ft			=	**1047**	k
Framing:											=	**200**	k
Ext. Wall:	44	psf	*	644	ft perimeter	*	16.17	ft height			=	**458**	k
Partition:	20	psf				*	21810	sq ft			=	**436**	k
Columns:				60	lb/ft	*	16.17	ft height	*	42	=	**41**	k
Storage:	250	psf	*	600	sq ft	*	25	%			=	**38**	k
								TOTAL			**=**	**2220**	**k**

Penthouse

Slab:				48	psf	*	8400	sq ft			=	**403**	k
Framing:											=	**91**	k
Ext. Wall:	44	psf	*	644	ft perimeter	*	7.84	ft height			=	**222**	k
Columns:	150	pcf	*	4	sq ft	*	7.84	ft height	*	42	=	**198**	k
Equip:							318	k			=	**318**	k
Roof:				48	psf	*	13600	sq ft			=	**653**	k
								TOTAL			**=**	**1885**	**k**

Roof

Framing:	10	psf	*	10000	sq ft						=	**100**	**k**
Roofing:	17	psf	*	10000	sq ft						=	**170**	**k**
								TOTAL			**=**	**270**	**k**

W = 11032 k

$$C_{vx} = \frac{w_x h_x^k}{\Sigma\, w_i h_i^k} \qquad k = 1.1$$

S_S =	0.169	S_1 =	0.051
Fa =	1.2	Fv =	1.7
S_{DS} =	0.135	S_{D1} =	0.059

Ordinary Concentric Steel Braced Frames

R = 3.25

Occupancy Category IV - I = 1.5

$T_a = C_t h_n^x$ $= 0.02(110)^{0.75} =$ 0.679

$T_L = 6$

$C_u = 1.7$

CuTa = 1.15

Cs = MIN

$S_{DS}/(R/I)$	0.062308
$S_{D1}/[T(R/I)]$	0.023679
$(S_{D1}T_L)/[T^2(R/I)]$	0.123542

$V = C_s * W$ $\qquad C_s =$ 0.023679

$F_x = C_{vx} * V$

V = 261.22 k

	h_x	$w_x h_x^k$
Level 2	21	69835
Level 3	40	123396
Level 4	55.67	172376
Level 5	72.33	246326
Penthouse	88	259524
Roof	111	47998
	Σ =	919454

	Cvx	Fx	
Level 2	0.0760	19.84	k
Level 3	0.1342	35.06	k
Level 4	0.1875	48.97	k
Level 5	0.2679	69.98	k
Penthouse	0.2823	73.73	k
Roof	0.0522	13.64	k
Σ =	1.0000	261.22	k

Wind Load Calculations

V =	90	mph
K_{zt} =	1	

I =	1.15
K_d =	0.85

$g_a = g_v = 3.4$

$Q = \sqrt{(1/(1+0.63((B+h)/Lz)^{0.63}))}$

$$G=0.925\frac{(1+1.7g_aI_zQ)}{(1+1.7g_vI_z)}$$

$I_z = c*(33/z)^{1/6} = 0.18$

$L_z = l*(z/33)^{\varepsilon} = 569$

$c = 0.2 \quad z = 63 \quad \varepsilon = 0.2$

$Q_{N\text{-}S}$=	0.841
$Q_{E\text{-}W}$=	0.856

$G_{N\text{-}S}$ =	0.85
$G_{E\text{-}W}$ =	0.86

$q = 0.00256*K_zK_dV^2I$

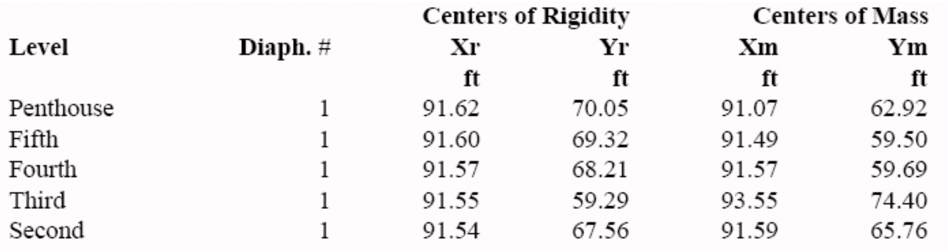
$p = qGC_p$

(Table 6.3)

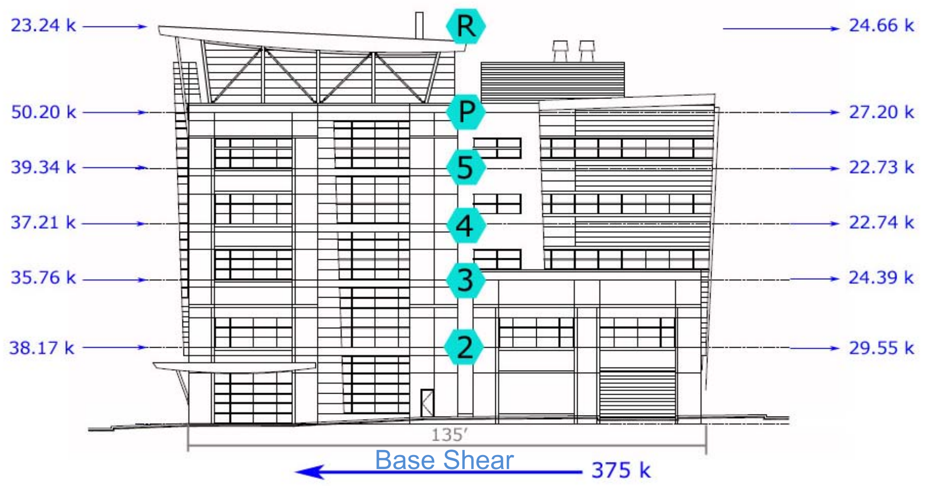
STORY	Start Height (ft.)	End Height (ft.)	Kz	q	Wind Pressures (psf) N-S WW	N-S LW	E-W WW	E-W LW
				Cp	0.8	-0.42	0.8	-0.5
Pent.	88	111	1.04	21.08	14.33	-7.53	14.50	-9.06
5	72.33	88	0.96	19.46	13.23	-7.53	13.39	-9.06
4	55.67	72.33	0.93	18.85	12.82	-7.53	12.97	-9.06
3	40	55.67	0.85	17.23	11.72	-7.53	11.85	-9.06
2	21	40	0.76	15.40	10.48	-7.53	10.60	-9.06
1	0	21	0.66	13.38	9.10	-7.53	9.20	-9.06

LEVEL	Trib. Height (ft.)	Wind Forces (k) N-S Width (ft.)	N-S WW	N-S LW	E-W Width (ft.)	E-W WW	E-W LW
Roof	11.5	141	23.24	-24.66	122	20.35	-12.72
Pent.	11.5 7.83	187	50.20	-27.20	135	36.67	-23.65
5	7.83 8.33	187	39.34	-22.74	135	28.74	-19.78
4	8.33 7.83	187	37.12	-22.74	135	27.11	-19.78
3	7.83 9.5	187	35.76	-24.39	135	26.12	-21.21
2	9.5 11.5	187	38.17	-29.55	135	27.88	-25.70
1	0	187	0.00	0.00	135	0.00	0.00

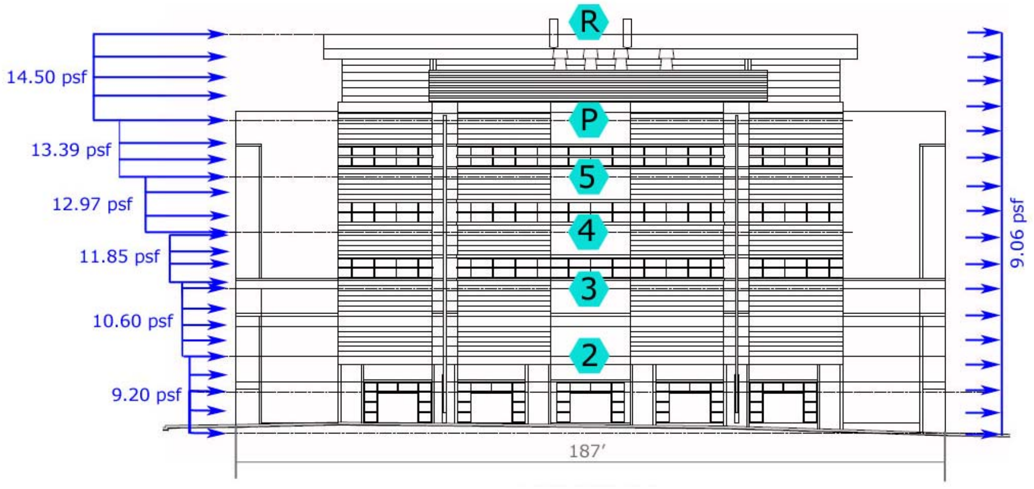
Base Shear: **375.14** **289.70**



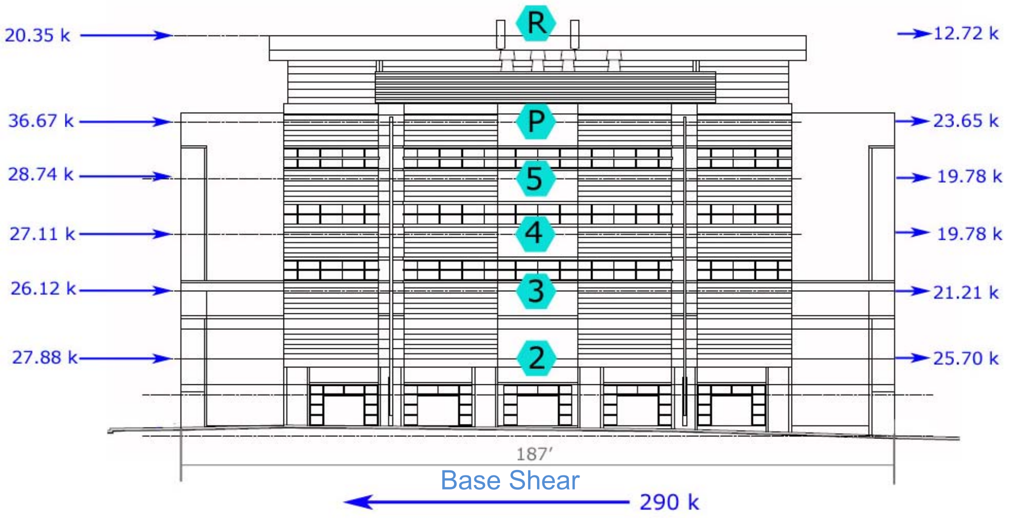
Level	Diaph. #	Centers of Rigidity Xr ft	Yr ft	Centers of Mass Xm ft	Ym ft
Penthouse	1	91.62	70.05	91.07	62.92
Fifth	1	91.60	69.32	91.49	59.50
Fourth	1	91.57	68.21	91.57	59.69
Third	1	91.55	59.29	93.55	74.40
Second	1	91.54	67.56	91.59	65.76



North-South Wind Story Forces

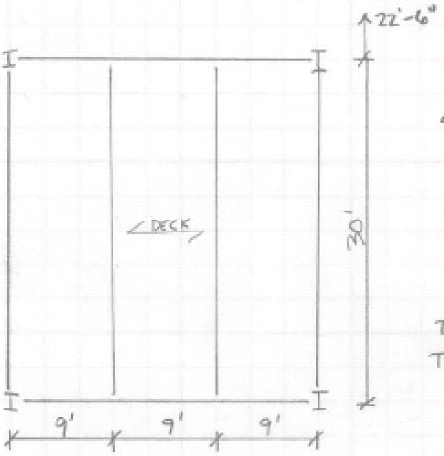


East-West Wind Pressures



East-West Wind Story Forces

APPENDIX B: FLOOR FRAMING CALCULATIONS



LIGHTWEIGHT CONCRETE
110 pcf, $f'_c = 5$ ksi

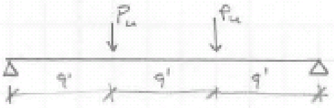
2" LOK-FLOOR 19 gage DECK w/ 4" SLAB
48 psf, MAX. UNSHORED SPAN: 9.64'

TOTAL DL: 60 psf
TOTAL LL: 80 psf

GIRDER DESIGN: TRIB AREA: $\left(\frac{30' + 22.5'}{2}\right) \times 27' = 709 \text{ ft}^2$

INFLUENCE AREA: $2A_T = 1418 \text{ ft}^2$

$$LL = L_o\left(0.25 + \frac{15}{\sqrt{1418}}\right) = 0.65L_o \Rightarrow LL = 52 \text{ psf}$$



P_u: DEAD: $60 \text{ psf} \times 9' \times \left(\frac{30+22.5}{2}\right) = 14.2 \text{ k}$

LIVE: $52 \text{ psf} \times 9' \times \left(\frac{30 \times 22.5}{2}\right) = 12.3 \text{ k}$

STRENGTH: $1.2D + 1.6L = 36.7 \text{ k} = P_u$

$$M_u = P_u \times 9' = 331 \text{ ft} \cdot \text{k}$$

DEFLECTION: $\Delta_{LL} \leq \frac{27 \times 12}{360} = 0.9'' = \frac{12.3 \times (27 \times 12)^3}{28(29000) I_{req}} \Rightarrow I_{REQ} = 573 \text{ in}^4$ (LB)

$\Delta_T \leq \frac{27 \times 12}{240} = 1.35'' = \frac{26.5 \times (27 \times 12)^3}{28(29000) I_{REQ}} \Rightarrow I_{REQ} = 822 \text{ in}^4$ (LB.)

PRE-COMPOSITE DL
$48(9')\left(\frac{30+22.5}{2}\right) = 11.3^k$

$\Delta_{PC} \leq \frac{27 \times 12}{360} = 0.9'' = \frac{11.3 \times (27 \times 12)^3}{28(29000) I_{REQ}} \Rightarrow I_{REQ} = 526 \text{ in}^4$ (I_x)

TRY W18×40

$Y2 = 6'' - 2''/2 = 5'' \Rightarrow$ USE PNA ⑦

$\phi M_n = 422 \text{ ft} \cdot \text{k}$ $I_{LB} = 1070 \text{ in}^2$ $I_x = 612 \text{ in}^2$

$\Sigma Q_n = 147 \text{ k}$ $a = \frac{147}{0.85 \times 5 \times 81''} = 0.427'' < 2''$ OK

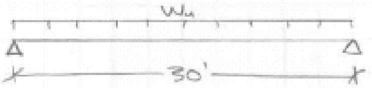
$Q_n = 18.3 \text{ k}$ FOR $3/4''\ \phi$ STUDS, DECK PARALLEL

$147/18.3 \Rightarrow 9$ STUDS/SIDE $\Rightarrow$ 18 STUDS

BEAM DESIGN: TRIB AREA: $9' \times 30' = 270 \text{ ft}^2$

INFLUENCE AREA: $2A_T = 540 \text{ ft}^2$

$$LL = L_o\left(0.25 + \frac{15}{\sqrt{540}}\right) = 0.90\,L_o \Rightarrow LL = 72 \text{ psf}$$



$w_u =$ DEAD: $60 \text{ psf} \times 9' = 0.54 \text{ k/ft}$

LIVE: $72 \text{ psf} \times 9' = 0.65 \text{ k/ft}$

STRENGTH: $1.2D + 1.6L = 1.69 \text{ k/ft} = w_u$

$$M_u = \frac{1.69 \times (30)^2}{8} = 190 \text{ ft}\cdot\text{k}$$

DEFLECTION: $\Delta_{LL} \le \frac{(30\times12)}{360} = 1'' = \frac{5(0.65/12)(30\times12)^4}{384(29000)(I_{REQ})} \Rightarrow I_{REQ} = 409 \text{ in}^4 \quad (I_{LB})$

$\Delta_T \le \frac{(30\times12)}{240} = 1.5'' = \frac{5(1.19/12)(30\times12)^4}{384(29000)(I_{REQ})} \Rightarrow I_{REQ} = 499 \text{ in}^4 \quad (I_{LB})$

PRE-COMPOSITE DL:

$48 \text{ psf} \times 9' = 0.43 \frac{k}{ft}$ $\Delta_{PC} \le \frac{(30\times12)}{360} = 1'' = \frac{5(0.43/12)(30\times12)^4}{384(29000)(I_{REQ})} \Rightarrow I_{REQ} = 270 \text{ in}^4 \quad (I_x)$

TRY W16×26

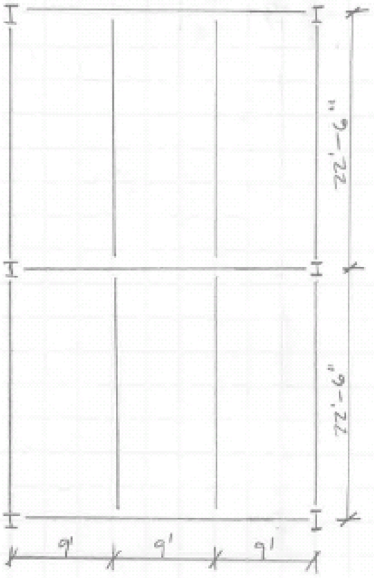
$Y2 = 6'' - 2''/2 = 5''$ $\Rightarrow$ USE PNA ⑦

$\phi M_n = 245 \text{ ft}\cdot\text{k}$ $\quad I_{LB} = 554 \text{ in}^4$ $\quad I_x = 301 \text{ in}^4$

$\Sigma Q_n = 96.0 \text{ k}$ $\quad a = \frac{96}{0.85\times5\times90} = 0.25'' < 2''$ <u>OK</u>

$Q_n = 17.2 \text{ k}$ FOR 3/4" ⌀ STUDS, DECK PERPENDICULAR, WEAK

$96.0/17.2 \Rightarrow 6 \text{ STUDS/SIDE} \Rightarrow 12 \text{ STUDS}$



LIGHTWEIGHT CONCRETE
110 pcF, $f'_c = 5$ ksi

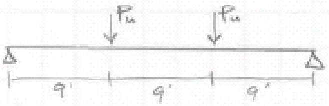
2" LOK-FLOOR, 19 gage DECK w/ 4" SLAB
48 psF, MAX. UNSHORED SPAN: 9.64'

TOTAL DL: 60 psF

TOTAL LL: 80 psF

GIRDER DESIGN: TRIB. AREA: 22'-6" × 27' = 608 ft²
INFLUENCE AREA: $2A_T$ = 1216 ft²

$$LL = L_o\left(0.25 + \frac{15}{\sqrt{1216}}\right) = 0.68\,L_o \Rightarrow LL = 55 \text{ psF}$$



P_u: DEAD: 60 psF × 22.5' × 9' = 12.2 k
LIVE: 55 psf × 22.5' × 9' = 11.1 k.

STRENGTH: $1.2D + 1.6L = 32.4\text{ k} = P_u$

$$M_u = 32.4 \times 9 = 292 \text{ ft}\cdot\text{k}$$

DEFLECTION: $\Delta_{LL} \le \frac{27\times12}{360} = 0.9" = \frac{12.2\times(27\times12)^3}{28(29000)I_{REQ}} \Rightarrow I_{REQ} = 568 \text{ in}^4 \; (I_{LB})$

$\Delta_T \le \frac{27\times12}{240} = 1.35" = \frac{23.3\times(27\times12)^3}{28(29000)I_{REQ}} \Rightarrow I_{REQ} = 723 \text{ in}^4 \; (I_{LB})$

PRE-COMPOSITE DL:
$48(9)(22.5) = 9.72^k$ $\Delta_{PC} \le \frac{27\times12}{360} = 0.9" = \frac{9.72\times(27\times12)^3}{28(29000)I_{REQ}} \Rightarrow I_{REQ} = 452 \text{ in}^4 \; (I_x)$

W18×35 OR W18×40

- USE W18×40 FOR CONSISTENCY w/ OTHER BAYS

$Y2 = 5"$ ⇒ USE PNA ⑦

$\phi M_n = 422$ ft·k $\quad I_{LB} = 1070 \text{ in}^4 \quad I_x = 612 \text{ in}^4$

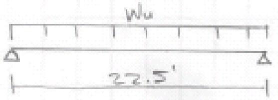
$\Sigma Q_n = 147$ k $\quad a = \frac{147}{0.85\times5\times81} = 0.427" < 2"$ OK

$Q_n = 18.3$ k ⇒ $147/18.3$ = 9 STUDS/SIDE ⇒ 18 STUDS

BEAM DESIGN: TRIB AREA: $9' \times 22.5' = 203 \text{ ft}^2$

INFLUENCE AREA: $2A_T = 406 \text{ ft}^2$

$$LL = L_o\left(0.25 + \frac{15}{\sqrt{406}}\right) = 0.99L_o \Rightarrow LL = 80 \text{ psf}$$



W_u: DEAD: $60 \text{ psf} \times 9' = 0.54 \text{ k/ft}$

LIVE: $80 \text{ psf} \times 9' = 0.72 \text{ k/ft}$

STRENGTH: $1.2D + 1.6L = 1.8 \text{ k/ft} = w_u$

$$M_u = \frac{1.8(22.5)^2}{8} = 114 \text{ ft}\cdot\text{k}$$

DEFLECTION: $\Delta_{LL} \le \frac{22.5\times12}{360} = 0.75'' = \frac{5(0.72/12)(22.5\times12)^4}{384(29000)I_{REQ}} \Rightarrow I_{REQ} = 191 \text{ in}^4 \ (I_{LB})$

$\Delta_T \le \frac{22.5\times12}{240} = 1.13'' = \frac{5(1.26/12)(22.5\times12)^4}{384(29000)I_{REQ}} \Rightarrow I_{REQ} = 222 \text{ in}^4 \ (I_{LB})$

PRE-COMPOSITE DL:
$48 \times 9 = 0.43 \text{ k/ft}$ $\Delta_{PC} \le \frac{22.5\times12}{360} = 0.75'' = \frac{5(0.43/12)(22.5\times12)^4}{384(29000)I_{REQ}} \Rightarrow I_{REQ} = 114 \text{ in}^4 \ (I_x)$

LIGHTEST SIZE FOR PRE-COMPOSITE DEFL: W12×19

W12×19: $Y2 = 5'' \Rightarrow$ USE PNA ⑦

$\phi M_n = 143 \text{ ft}\cdot\text{k}$ $I_{LB} = 267 \text{ in}^4$ $I_x = 130 \text{ in}^4$

$\Sigma Q_n = 69.7 \text{ k}$ $a = \frac{69.7}{0.85 \times 5 \times 67.5} = 0.243'' < 2''$ OK

$Q_n = 17.2 \text{ k} \Rightarrow 69.7/17.2 \Rightarrow 5$ STUDS/SIDE $\Rightarrow$ 10 STUDS

Gridlines A-B Vibration Calculations

VIBRATION CALCULATIONS

LOADS:	Dead:	52	psf	Beam Spacing:				
	Live:	11	psf		6	ft.	9	in.
				Beam Span:				
					30	ft.	0	in.
				Girder Span:				
					27	ft.	0	in.

Slab	wc =	110	pcf			
	f'c =	5	ksi	Ec =	2580	ksi
	tslab=	4	in			
	trib=	2	in	n =	8.33	
	wt=	48	psf			

Beam	**W27X129**		Girder	**W30X191**	
A=	**37.8**	in2	A=	**56.3**	in2
I=	**4760**	in4	I=	**9200**	in4
d=	**27.6**	in	d=	**30.7**	in
beff=	81	in	beff=	129	in

BEAM MODE PROPERTIES:			GIRDER MODE PROPERTIES:		
ybar=	10.77128	in.	ybar=	10.49202	in.
Ij=	10886.76	in4	Ig =	20861.28	in4
wj =	554.25	plf	wg =	2463.333	plf
Δj =	0.032	in.	Δg =	0.049	in.
fj =	19.77	Hz	fg =	16.03	Hz
Ds =	15.01	in^4/ft			
Dj =	1612.85	in^4/ft	Dg =	695.38	in^4/ft
Bj =	18.6	ft	Bg =	60.0	ft.
Wj =	68.9	k	Wg =	133.0	k

COMBINED MODE PROPERTIES:					
Δg' =	0.07	in	W =	113.0	k
β =	0.03		P_0=	65	lb
fn =	11.04	Hz	a_p/g =	**0.04%**	g

Δoj = 1.54E-06 in/lb

ΔgP = 5.86E-07 in/lb

Neff = 2.6033

ΔP = 8.84E-07 in/lb

RESULTS		
a_p/g =	0.04%	g
FAST	2001	μin/sec
MODERATE	440	μin/sec
SLOW	120	μin/sec

Gridlines E-F Vibration Calculations

VIBRATION CALCULATIONS

LOADS:	Dead:	52	psf	Beam Spacing:			
	Live:	11	psf	9	ft.	0	in.
				Beam Span:			
				28	ft.	0	in.
				Girder Span:			
				27	ft.	0	in.

Slab	wc =	110	pcf			
	f'c =	5	ksi	Ec =	2580	ksi
	tslab=	4	in			
	trib=	2	in	n =	8.33	
	wt=	48	psf			

Beam		W27X114		Girder		W30X191	
	A=	**33.5**	in2		A=	**56.3**	in2
	I=	**4080**	in4		I=	**9200**	in4
	d=	**27.3**	in		d=	**30.7**	in
beff=	108	in		beff=	129	in	

BEAM MODE PROPERTIES:			GIRDER MODE PROPERTIES:		
ybar=	8.925279	in.	ybar=	10.49202	in.
Ij=	10490.43	in4	Ig =	20861.28	in4
wj =	681	plf	wg =	2118.667	plf
Δj =	0.031	in.	Δg =	0.042	in.
fj =	20.10	Hz	fg =	17.28	Hz
Ds =	15.01	in^4/ft			
Dj =	1165.60	in^4/ft	Dg =	745.05	in^4/ft
Bj =	18.9	ft	Bg =	54.4	ft.
Wj =	60.0	k	Wg =	111.0	k

COMBINED MODE PROPERTIES:

Δg' =	0.06	in	W =	93.6	k
β =	0.03		P_0=	65	lb
fn =	11.73	Hz	a_p/g =	**0.04%**	g

Δoj =	1.30E-06	in/lb	ΔgP =	5.86E-07	in/lb
		Neff = 2.0786			

ΔP = 9.18E-07 in/lb

RESULTS

a_p/g =	0.04%	g
FAST	1956	μin/sec
MODERATE	430	μin/sec
SLOW	117	μin/sec

Gridlines B-E Vibration Calculations

VIBRATION CALCULATIONS

LOADS:	Dead:	52	psf	Beam Spacing:				
	Live:	11	psf		9	ft.	0	in.
				Beam Span:				
					22	ft.	6	in.
				Girder Span:				
					27	ft.	0	in.

Slab	wc =	110	pcf			
	f'c =	5	ksi	Ec =	2580	ksi
	tslab=	4	in			
	trib=	2	in	n =	8.33	
	wt=	48	psf			

Beam	W21X44		Girder	W24X55	
A=	13	in2	A=	16.3	in2
I=	843	in4	I=	1360	in4
d=	20.7	in	d=	23.6	in
beff=	108	in	beff=	129	in

BEAM MODE PROPERTIES:			GIRDER MODE PROPERTIES:		
ybar=	4.875342	in.	ybar=	5.242532	in.
Ij=	3052.77	in4	Ig =	4670.565	in4
wj =	611	plf	wg =	1527.5	plf
Δj =	0.040	in.	Δg =	0.135	in.
fj =	17.73	Hz	fg =	9.63	Hz
Ds =	15.01	in^4/ft			
Dj =	339.20	in^4/ft	Dg =	207.58	in^4/ft
Bj =	20.6	ft	Bg =	54.9	ft.
Wj =	47.3	k	Wg =	100.7	k

COMBINED MODE PROPERTIES:					
Δg' =	0.18	in	W =	90.9	k
β =	0.03		P_0=	65	lb
fn =	7.61	Hz	a_p/g =	0.17%	g

RESULTS		
a_p/g =	0.17%	g
FAST	7950	μin/sec
MODERATE	1749	μin/sec
SLOW	477	μin/sec

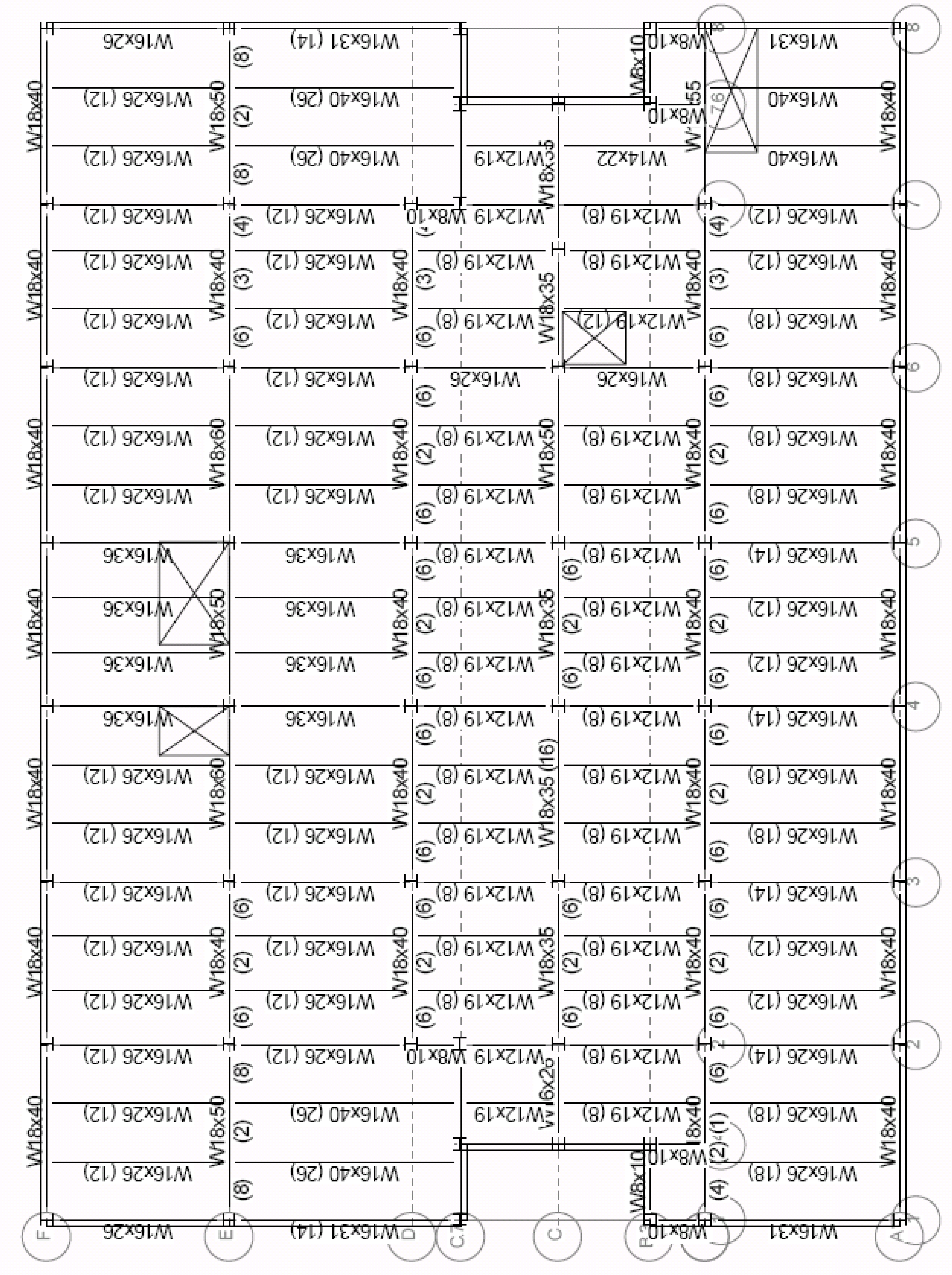
Δoj = 2.32E-06 in/lb

ΔgP = 2.62E-06 in/lb

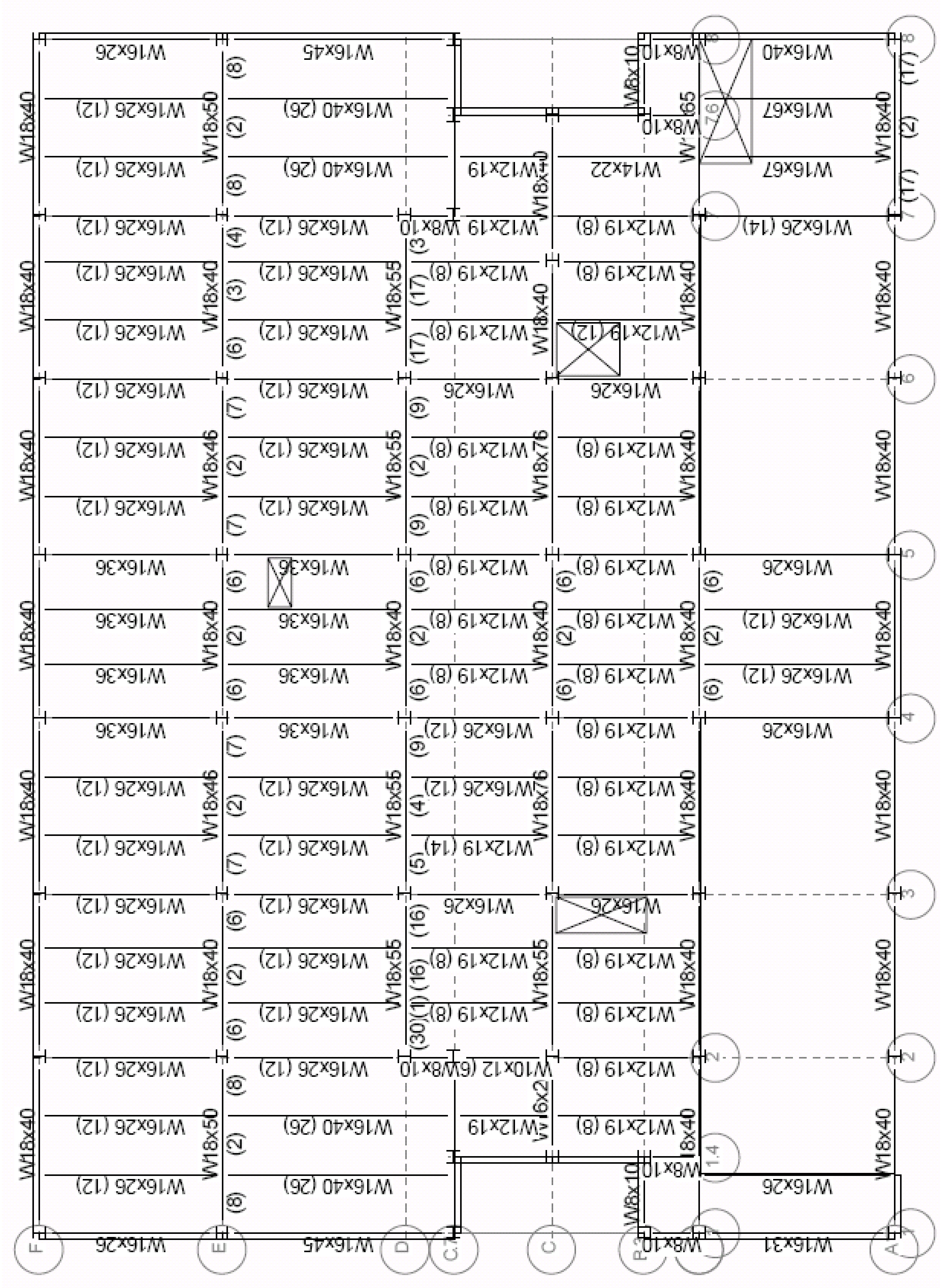
Neff = 2.0853

ΔP = 2.42E-06 in/lb

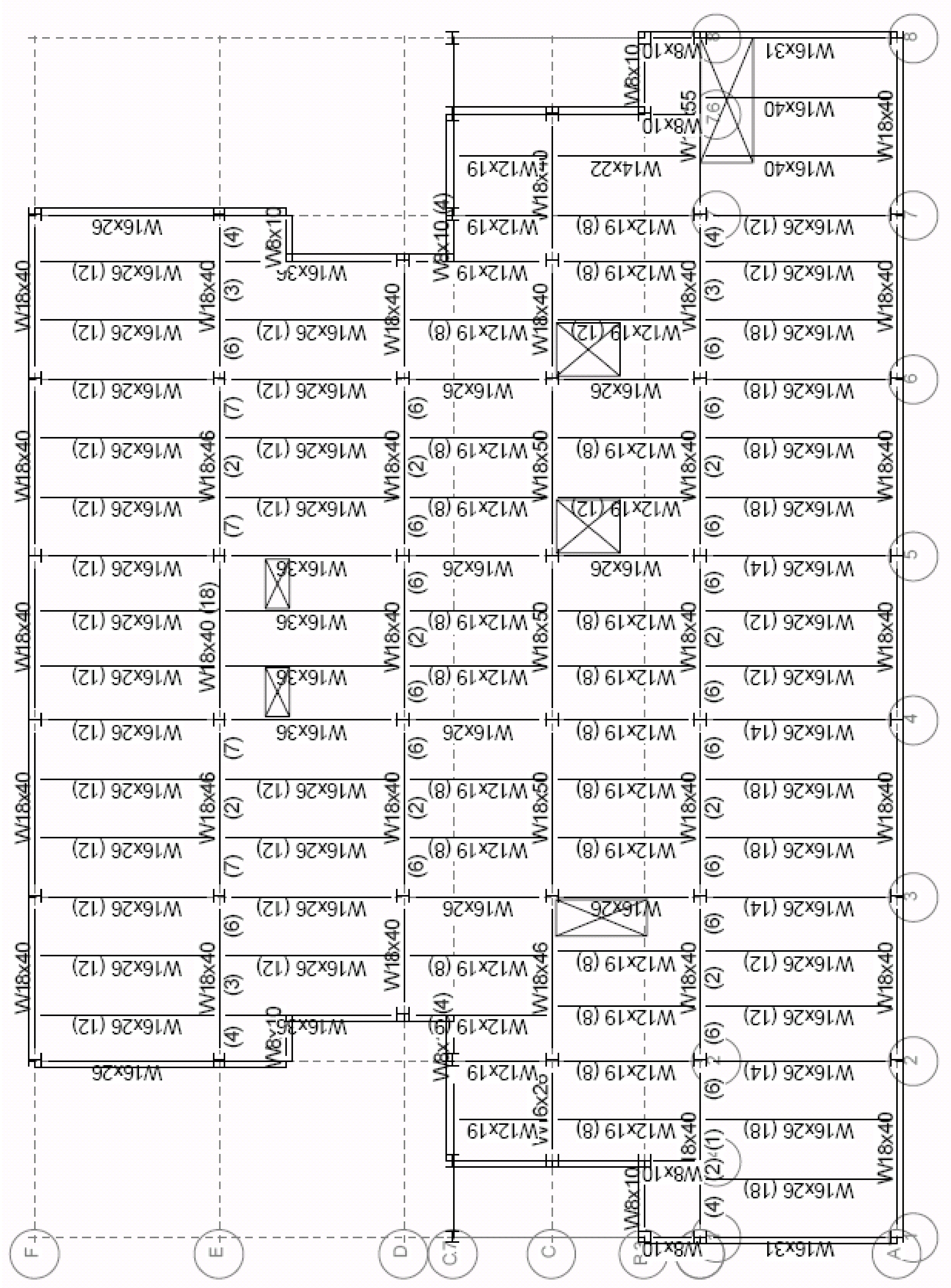
APPENDIX C: FLOOR FRAMING PLANS



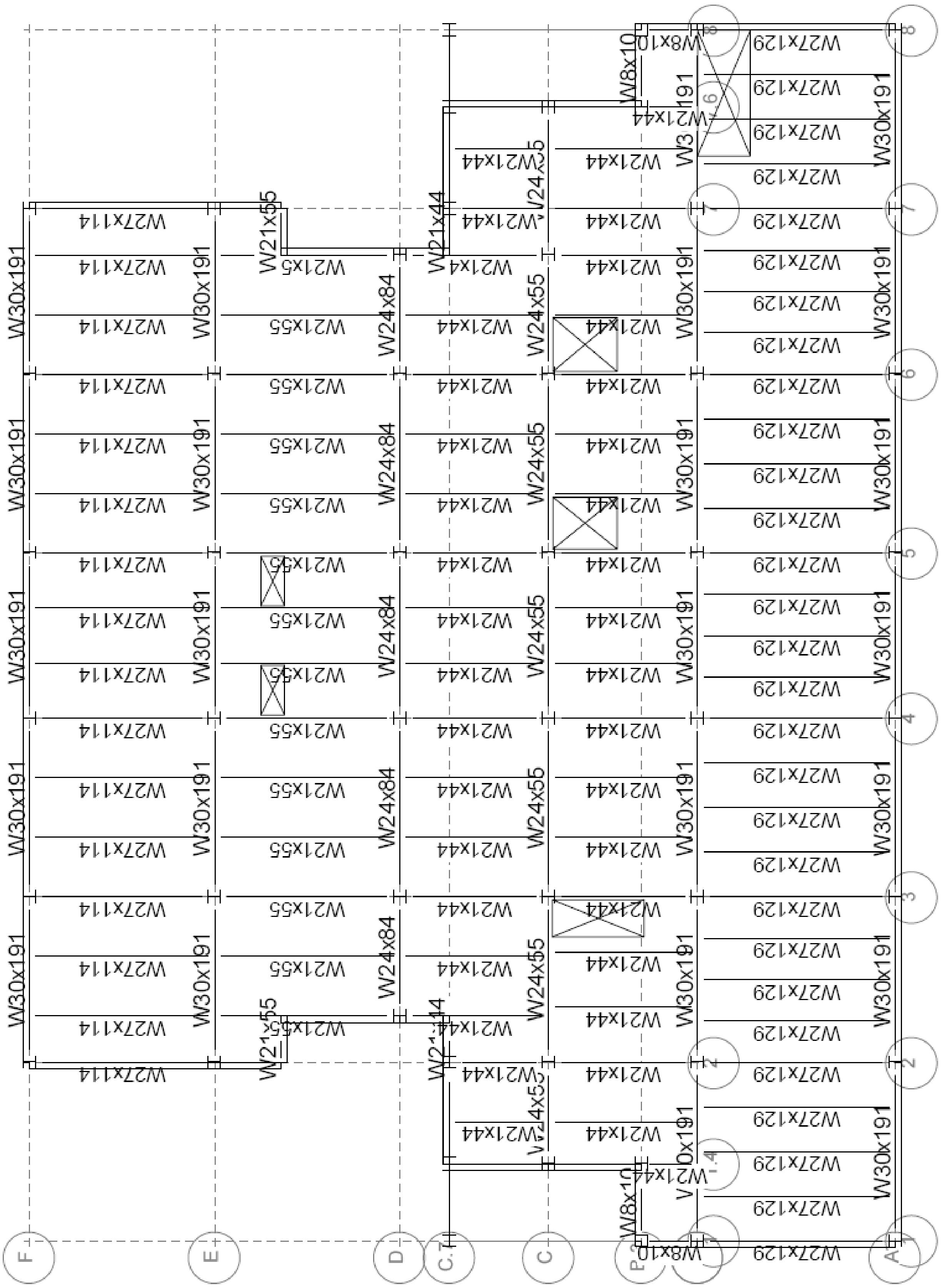
2nd Floor Framing Plan



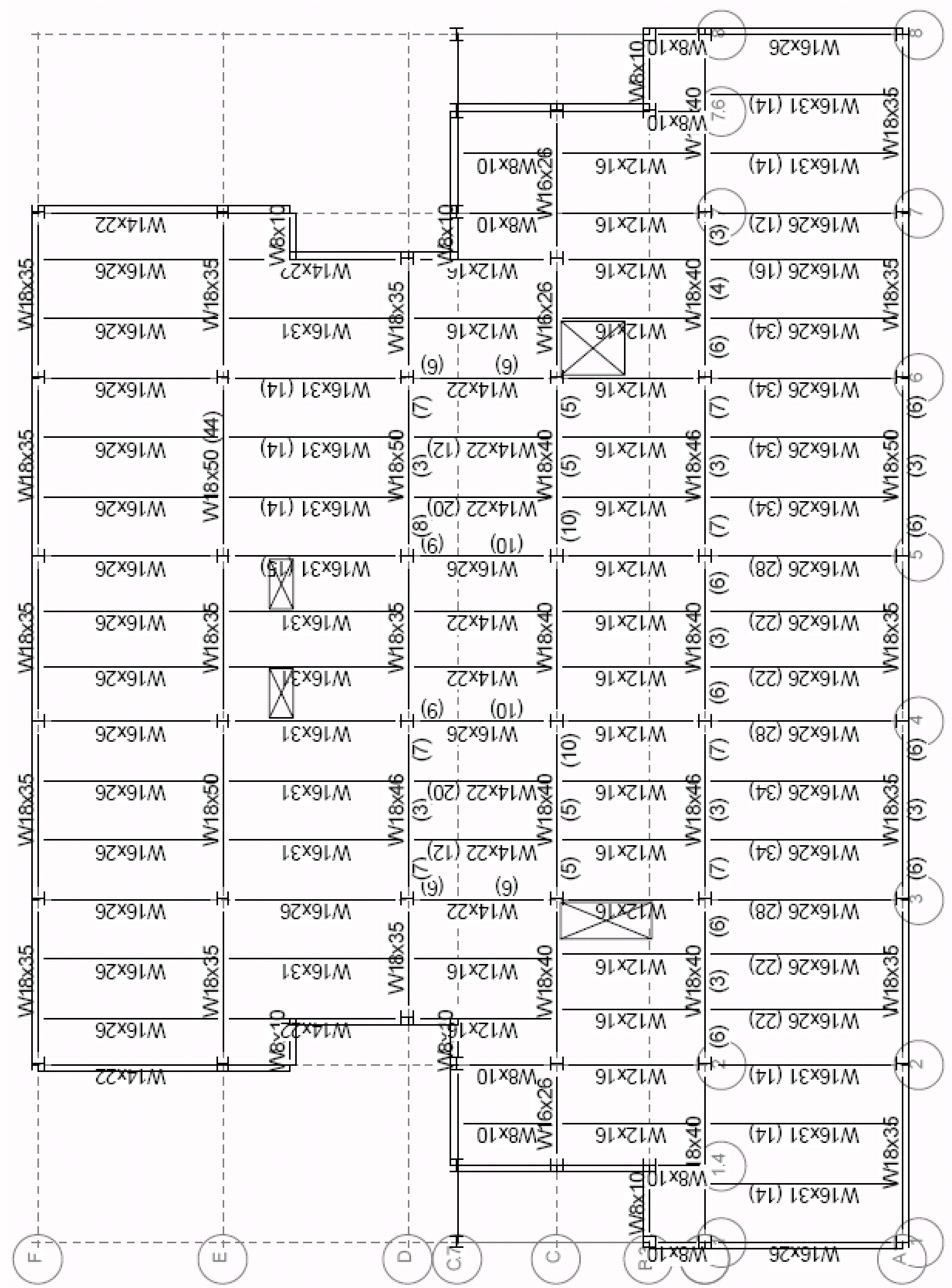
3rd Floor Framing Plan



4th Floor Framing Plan



5th Floor Framing Plan – CLASS A - VIBRATION CRITICAL



Penthouse Floor Framing Plan

APPENDIX D: COLUMN CALCULATIONS AND COLUMN PLANS

COLUMN: E-5 **K_{LL} =** 4

	LOAD (psf)					
STORY	**D**	**L**	**S**	**Trib Area**	**Total Area**	**LL Red.**
Penthouse	60	30	21	585	585	--
5	60	80		585	1170	0.47
4	60	80		585	1755	0.43
3	60	80		585	2340	0.41
2	60	80		585	2925	0.40

Total Area: 2925 ft^2

	TOTAL LOAD (k)				FACTORED LOAD (k)	KL (ft)
STORY	**D**	**L**	**S**	**Equip**		
Penthouse	35.1	17.6	12.3	45.9	**144.94**	15.67
5	35.1	22.0			**222.19**	16.67
4	35.1	20.1			**296.44**	15.67
3	35.1	19.0			**368.89**	19
2	35.1	18.7			**440.96**	21

Hand Calculation:	4-5-P:	W12X50 @ KL=16:	ΦP_n =	326 k
	2-3:	W12X65 @ KL=22:	ΦP_n =	491 k
RAM Struct. Sys.:	4-5-P:	W12X53		
	2-3:	W12X72		

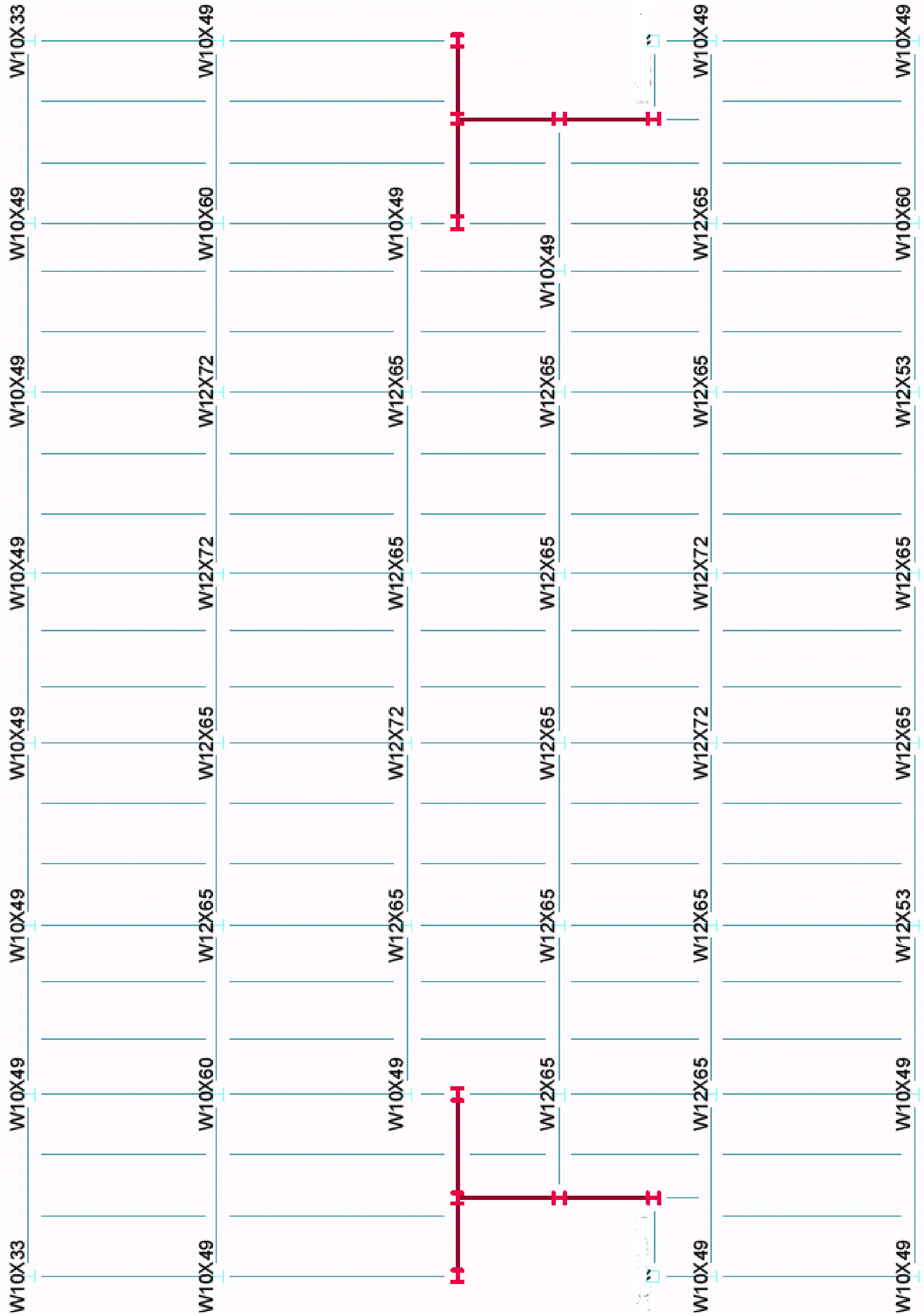
COLUMN: A-1 **K_{LL} =** 4

	LOAD (psf)					
STORY	**D**	**L**	**S**	**Trib Area**	**Total Area**	**LL Red.**
Penthouse	60	30	21	203	203	--
5	60	80		203	406	0.62
4	60	80		203	609	0.55
3	60	80		203	812	0.51
2	60	80		203	1015	0.49

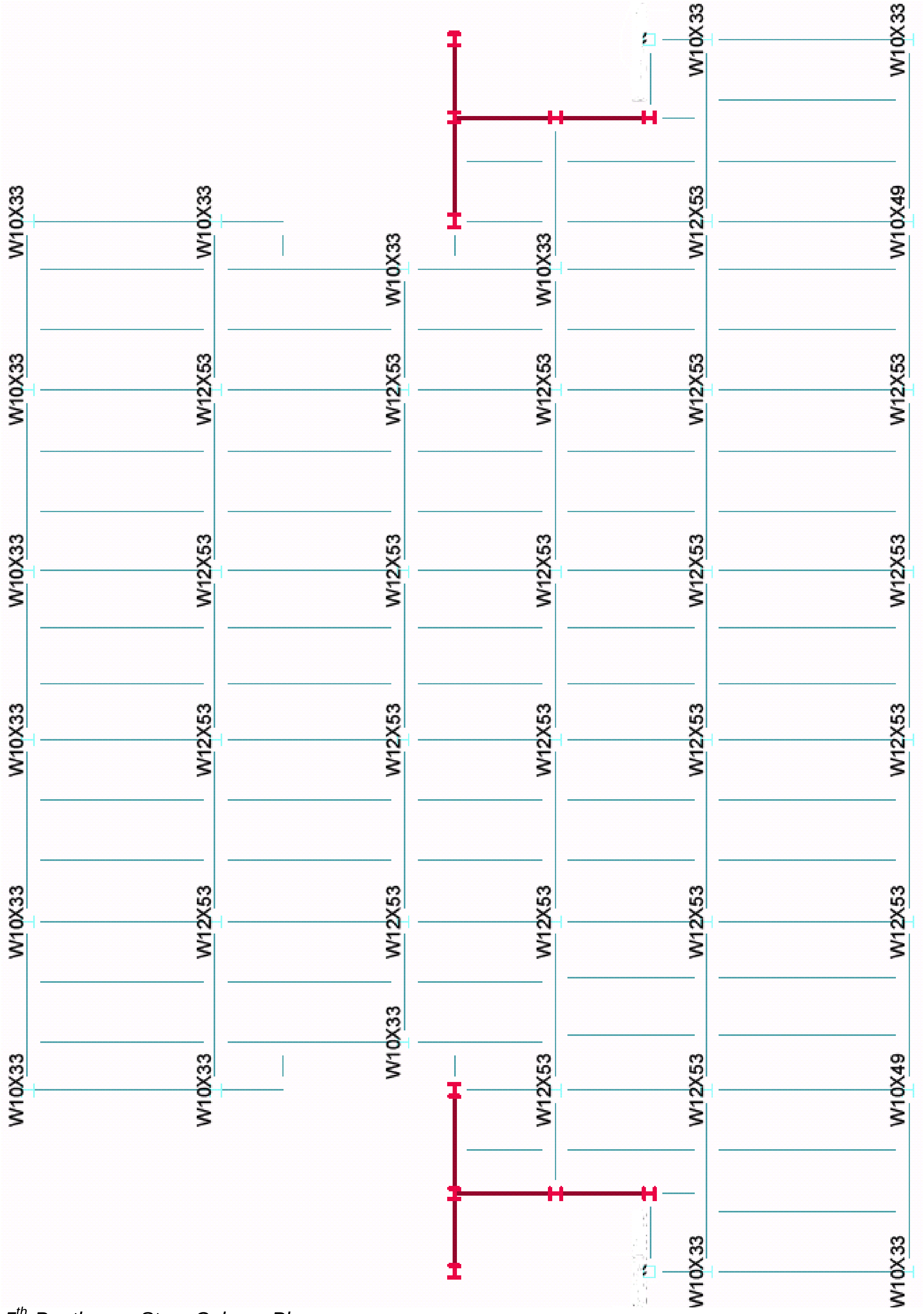
Total Area: 1015 ft^2

	TOTAL LOAD (k)				FACTORED LOAD (k)	KL (ft)
STORY	**D**	**L**	**S**	**Equip**		
Penthouse	12.2	6.1	4.3		**31.18**	15.67
5	12.2	10.1			**61.96**	16.67
4	12.2	9.0			**90.97**	15.67
3	12.2	8.3			**118.92**	19
2	12.2	7.9			**146.15**	21

Hand Calculation:	4-5-P:	W10X33 @ KL=16:	ΦP_n =	213 k
	2-3:	W10X45 @ KL=22:	ΦP_n =	174 k
RAM Struct. Sys.:	4-5-P:	W10X33		
	2-3:	W10X49		

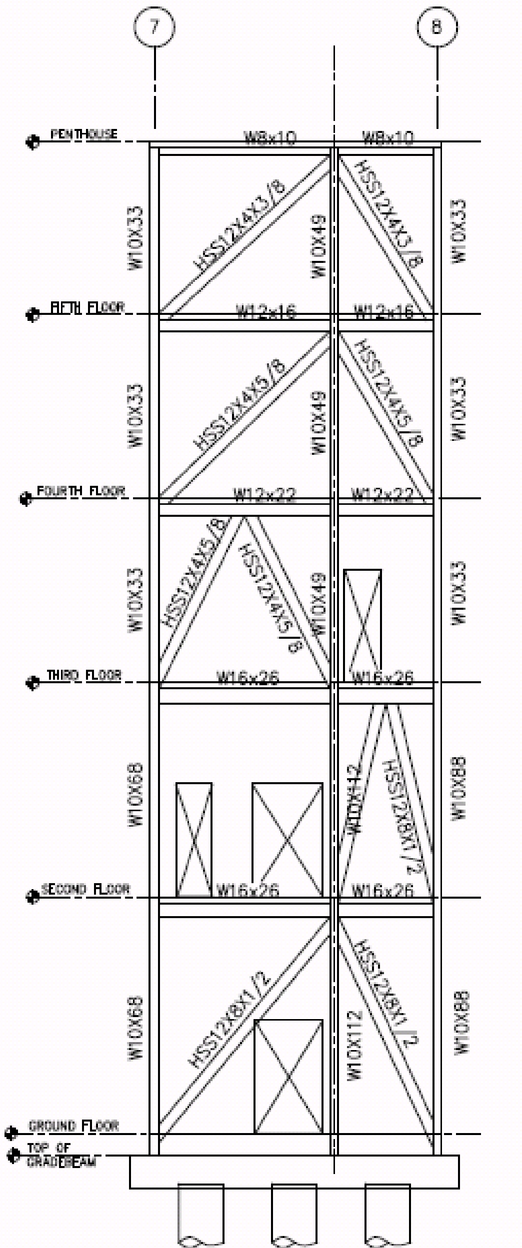


2nd-3rd Story Column Plan

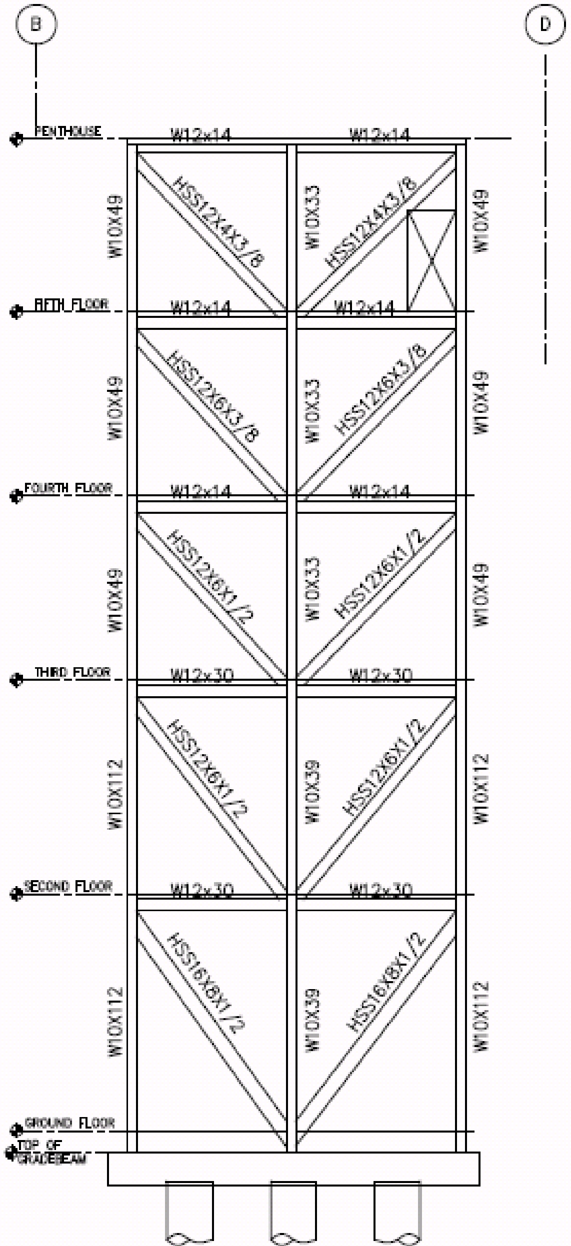


4th-5th-Penthouse Story Column Plan

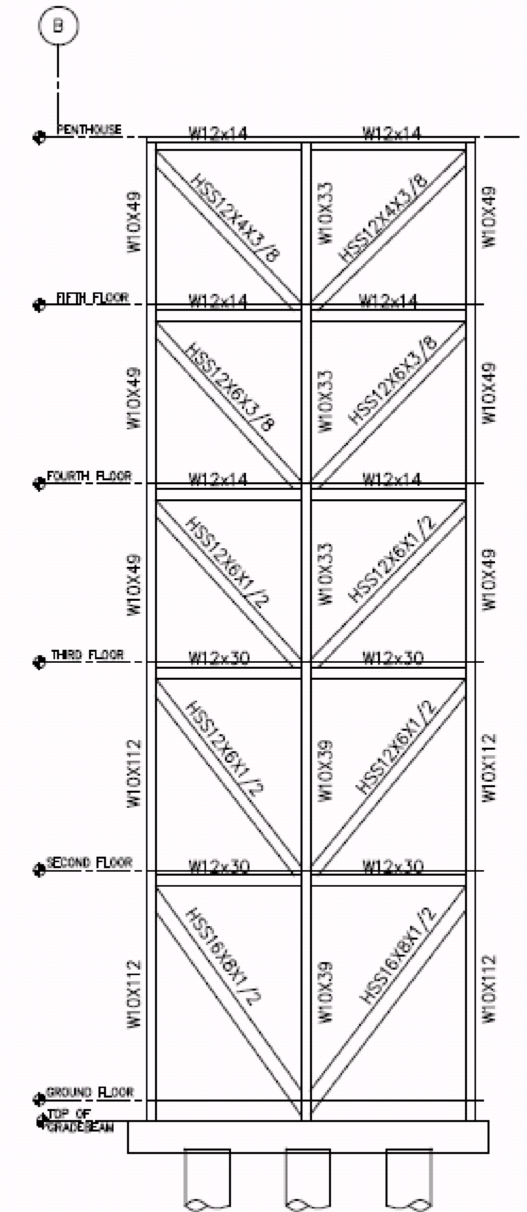
APPENDIX E: BRACED FRAME ELEVATIONS



1 BRACED FRAME #1
NO SCALE



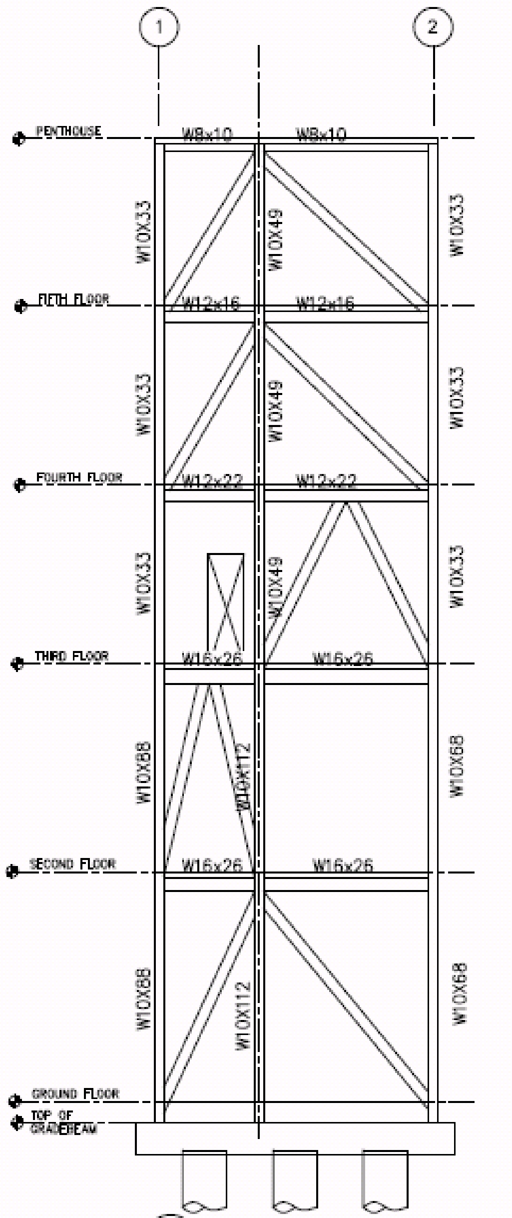
2 BRACED FRAME #2
NO SCALE
(NEAR STAIR A)



3 BRACED FRAME #3

NO SCALE

(NEAR STAIR B)

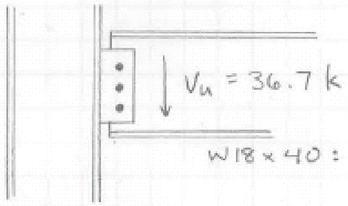


4 BRACED FRAME #4

NO SCALE

APPENDIX F: CONNECTION DESIGN

SHEAR CONNECTION – TYPICAL (GIRDER – TO – COLUMN)



W18 × 40 : $t_w = 0.315''$
$T = 15.5''$

USE 7/8" ⌀ A325-N BOLTS : $\varnothing r_n = 21.6$ k

$n = 36.7/21.6 = 1.7 \Rightarrow$ USE 3 BOLTS (MIN.)
$n \leq 9$: NO ECCENTRICITY

– PLATE THICKNESS:
- MAXIMUM: $t_{PLATE} \leq \frac{d_b}{2} + 1/16'' = 0.5''$

TRY 1/4" PLATE

– BOLT BEARING:
- PLATE $\varnothing r_n = 0.75 \times 2.4 \times (58)(0.875)(0.25) = 22.8 \text{ k} > 21.6 \text{ k}$

∴ BOLTS CONTROL

– BLOCK SHEAR:
- BEAM NOT COPED – NO BLOCK SHEAR

- PLATE: TABLE 9-3:

SHEAR YIELD: $121 \text{ k/in} \times 1/4'' = 30.3 \text{ k} \leftarrow$
SHEAR RUPTURE: $131 \text{ k/in} \times 1/4'' = 32.8 \text{ k}$
TENSION RUPTURE: $43.5 \text{ k/in} \times 1/4'' = 10.9 \text{ k} \leftarrow$

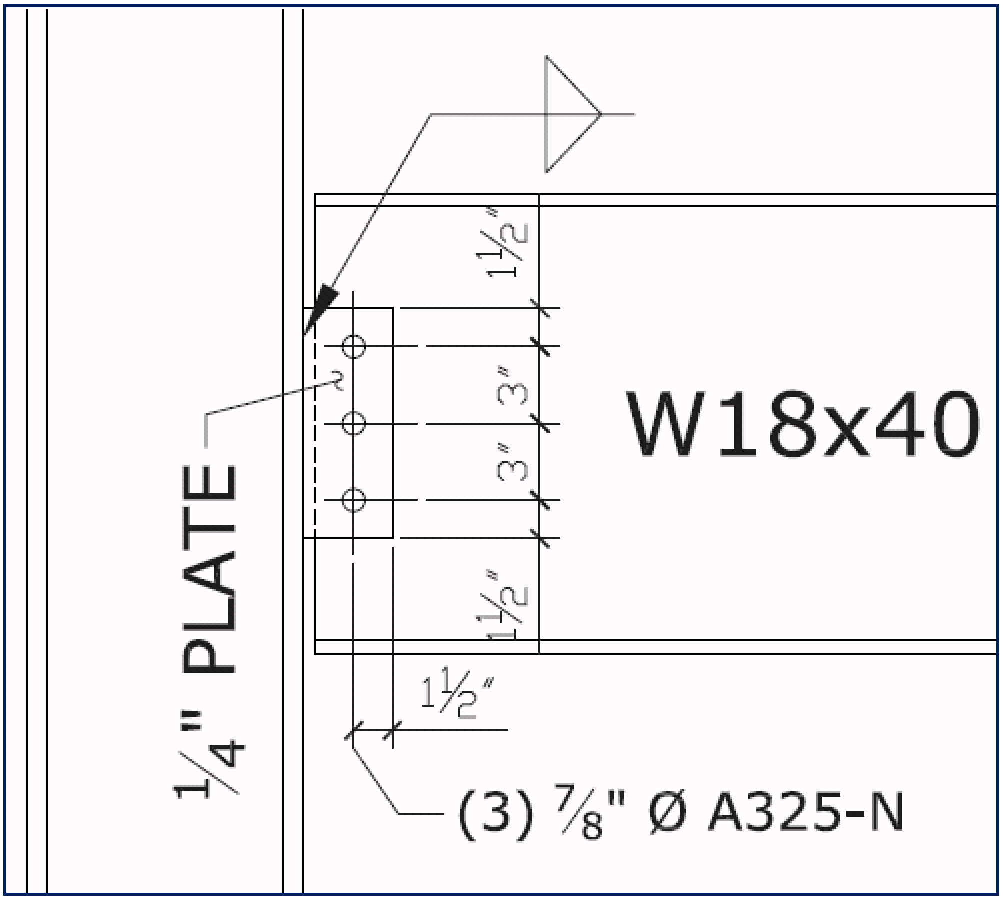
$\varnothing R_n = 41.2$ k
$41.2 \text{ k} > 36.7 \text{ k}$ OK

– SHEAR YIELD:
$$\varnothing R_n = 1.0(0.6 F_y)A_g$$
$$\varnothing R_n = 1.0(0.6 \times 36)(9 \times 1/4)$$
$$\varnothing R_n = 48.6 \text{ k} > 36.7 \text{ k} \quad \underline{\text{OK}}$$

– SHEAR RUPTURE:
$$\varnothing R_n = 0.75(0.6 \times F_u)A_n$$
$$\varnothing R_n = 0.75(0.6 \times 58)[9'' - 3(7/8 + 1/8)](1/4)$$
$$\varnothing R_n = 39.2 \text{ k} > 36.7 \text{ k} \quad \underline{\text{OK}}$$

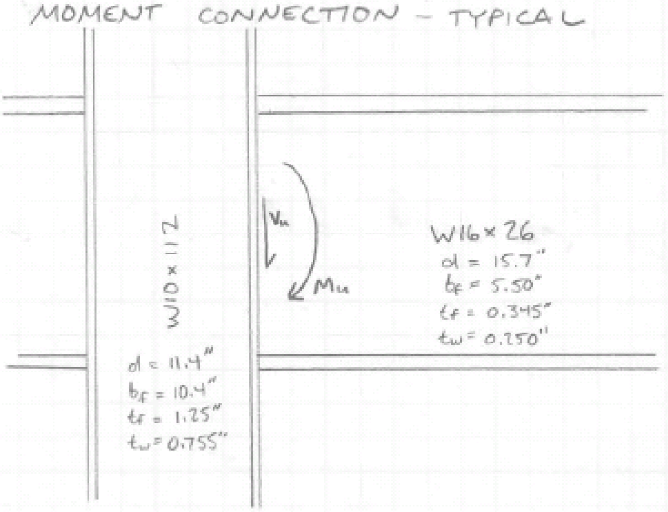
– SIZE WELD: $t_{WELD, MIN} = 1/4(5/8) = 0.16 \Rightarrow 2.5/16$

$\Rightarrow 3/16''$ WELD, EACH SIDE



Typical Shear Connection

MOMENT CONNECTION – TYPICAL



$V_u = \underline{22.7\ k}$
$M_u = 78.4\ ft \cdot k$
$= 941\ in \cdot k$
$F_u = 941/15.7 = \underline{59.9\ k}$

– FLANGE WELDED / WEB BOLTED

– SHEAR: SHEAR TAB CONNECTION – $t_{WELD} = 5/8\ t_{PLATE} \Rightarrow 3/8"$ WELD

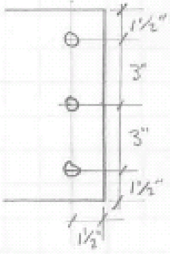
– NUMBER OF BOLTS
- USE 7/8" Ø A325-N $\Rightarrow \phi r_n = 21.6$ k

$\frac{22.7}{21.6} \Rightarrow 1.05$, MINIMUM OF 3 BOLTS – USE 3

– PLATE THICKNESS
- MAXIMUM: $t_{PLATE} \leq \frac{d_b}{2} + \frac{1}{16} = 0.5"$
TRY 1/4" PLATE

– BOLT BEARING
- PLATE: $\phi r_n = 0.75(2.4)(58)(0.875)(0.25) = 22.8\ k < 21.6 k$
  - BOLT SHEAR CONTROLS
- BEAM WEB: SAME THICKNESS, WITH STRONGER MAT'L ⇒ PLATE CONTROLS

– BLOCK SHEAR: FROM TABLE 9-3



SHEAR YIELD: $121\ k/in \times 1/4" = 30.3\ k$ ← CONTROLS

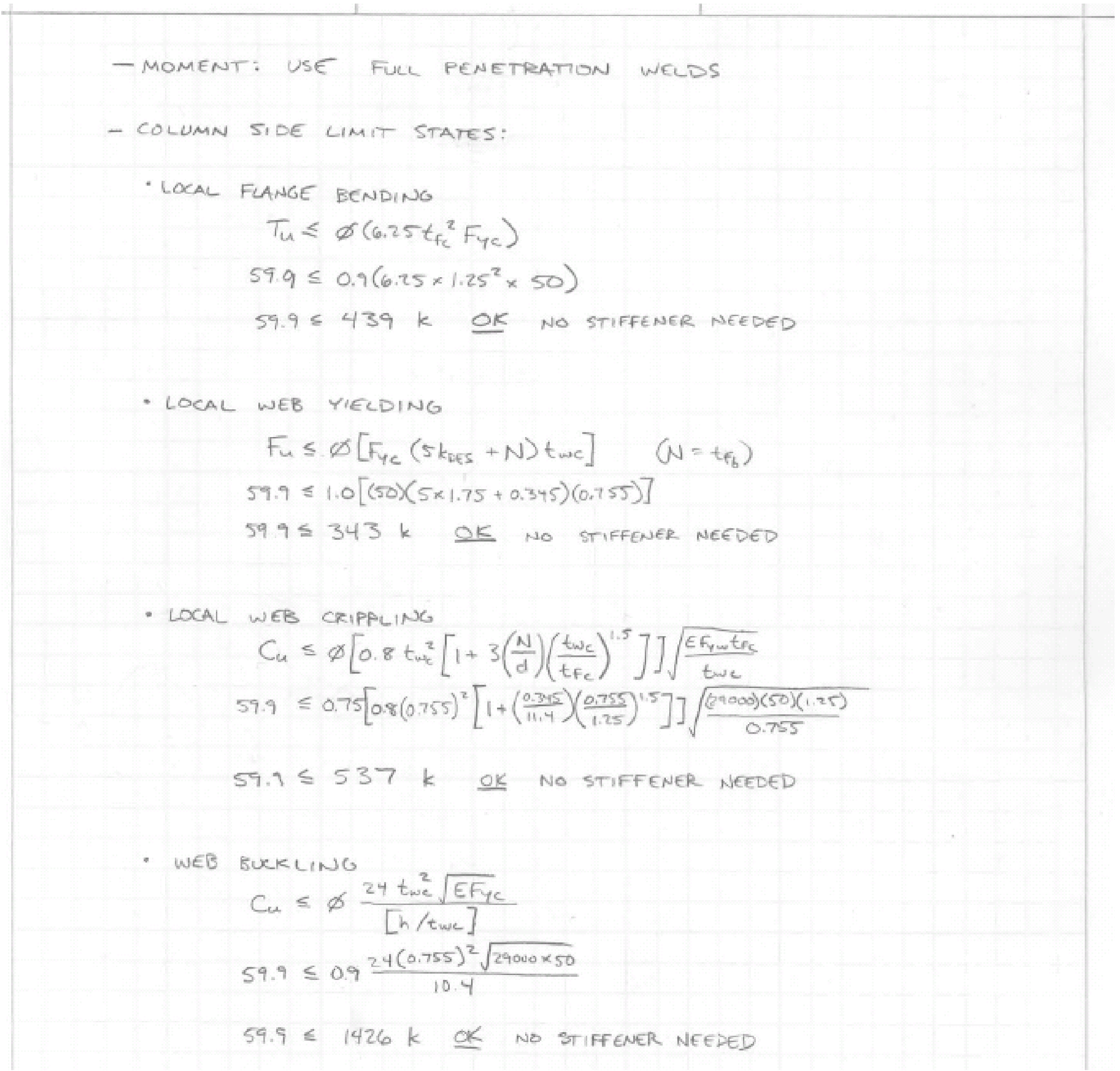
SHEAR RUPTURE: $131\ k/in \times 1/4" = 32.8\ k$

TENSION RUPTURE: $43.5\ k/in \times 1/4" = \underline{10.9\ k}$

$\phi R_n = 41.2\ k > 22.7\ k$ OK

– SHEAR YIELD: $\phi R_n = 1.0(0.6F_y)A_g$
$\phi R_n = 1.0(0.6 \times 36)(9" \times 0.25") = 48.6\ k > 22.7\ k$ OK

– SHEAR RUPTURE: $\phi R_n = 0.75(0.6F_u)A_n$, $A_n = [9 - 3(0.875 + 1/8)](0.25) = 1.5\ in^2$
$\phi R_n = 0.75(0.6 \times 58)(1.5) = 39.2\ k > 22.7\ k$ OK



— MOMENT: USE FULL PENETRATION WELDS

— COLUMN SIDE LIMIT STATES:

- LOCAL FLANGE BENDING

$$T_u \le \phi(6.25 t_{fc}^2 F_{yc})$$

$$59.9 \le 0.9(6.25 \times 1.25^2 \times 50)$$

$59.9 \le 439$ k <u>OK</u> NO STIFFENER NEEDED

- LOCAL WEB YIELDING

$$F_u \le \phi[F_{yc}(5k_{DES} + N)t_{wc}] \qquad (N = t_{fb})$$

$$59.9 \le 1.0[(50)(5 \times 1.75 + 0.345)(0.755)]$$

$59.9 \le 343$ k <u>OK</u> NO STIFFENER NEEDED

- LOCAL WEB CRIPPLING

$$C_u \le \phi\left[0.8 t_{wc}^2\left[1 + 3\left(\frac{N}{d}\right)\left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right]\right]\sqrt{\frac{EF_{yw}t_{fc}}{t_{wc}}}$$

$$59.9 \le 0.75\left[0.8(0.755)^2\left[1 + \left(\frac{0.345}{11.4}\right)\left(\frac{0.755}{1.25}\right)^{1.5}\right]\right]\sqrt{\frac{(29000)(50)(1.25)}{0.755}}$$

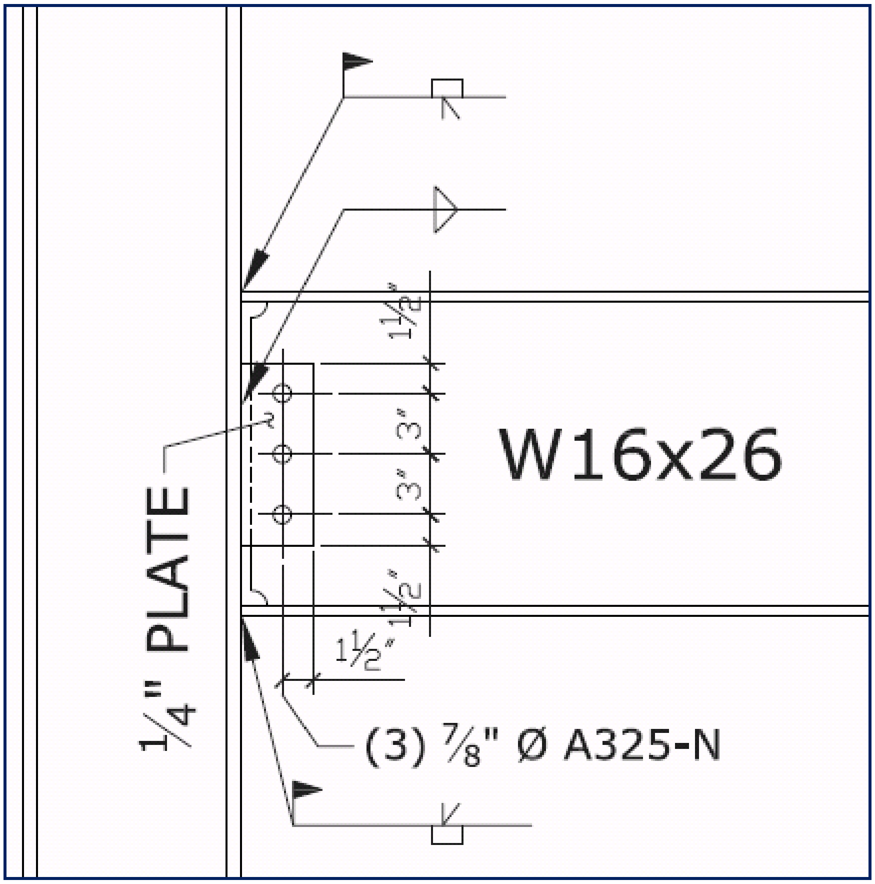
$59.9 \le 537$ k <u>OK</u> NO STIFFENER NEEDED

- WEB BUCKLING

$$C_u \le \phi\frac{24 t_{wc}^2\sqrt{EF_{yc}}}{[h/t_{wc}]}$$

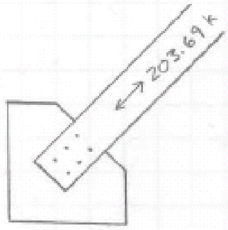
$$59.9 \le 0.9\frac{24(0.755)^2\sqrt{29000 \times 50}}{10.4}$$

$59.9 \le 1426$ k <u>OK</u> NO STIFFENER NEEDED



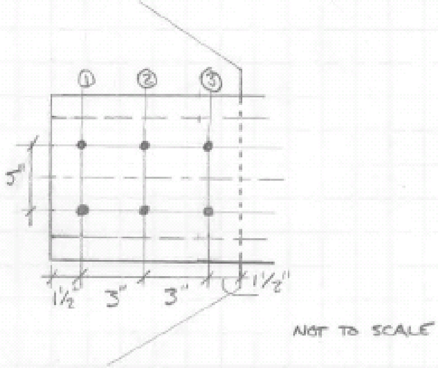
Typical Moment Connection

BRACING CONNECTION – TYPICAL



HSS 16×8×½ ($F_y = 46$ ksi, $F_u = 58$ ksi), $t = 0.465"$
→ WORKABLE FLAT: 13 ¾"
A36 STEEL GUSSET PLATE, ¾" THICK
USE ⅞" Ø A325-N BOLTS: $\phi r_n = 43.3$ k (DOUBLE SHEAR)

FOR $P_u = 203.9$ k, USE 6 BOLTS



NOT TO SCALE

BOLT SHEAR: $\phi r_n = 43.3$ k

BEARING: PLATE: $\phi 2.4 F_u t d_B = (0.75)2.4(58)(3/4)(7/8) = 68.5$ k
HSS : $2[\phi 2.4 F_u t d_B = 2(0.75)2.4(58)(0.465)(7/8) = 85.0$ k

TEAROUT: PLATE EDGE: $\phi 1.2 F_u l_e t = (0.75)1.2(58)\left(1\tfrac{1}{2} - \frac{7/8 + 1/16}{2}\right)(3/4) = 40.4$ k
HSS EDGE: $2[\phi 1.2 F_u l_e t] = 2(0.75)1.2(58)\left(1\tfrac{1}{2} - \frac{7/8 + 1/16}{2}\right)(0.465) = 50.1$ k
PLATE INT.: $\phi 1.2 F_u l_e t = (0.75)1.2(58)(3 - 7/8 - 1/16)(3/4) = 80.7$ k
HSS INT.: $2[\phi 1.2 F_u l_e t] = 2(0.75)1.2(58)(3 - 7/8 - 1/16)(0.465) = 100.1$ k

BOLT LINE ①: $\phi r_n = \min[43.3, 68.5, 50.1] = 43.3$ k

BOLT LINE ②: $\phi r_n = \min[43.3, 68.5, 80.7] = 43.3$ k

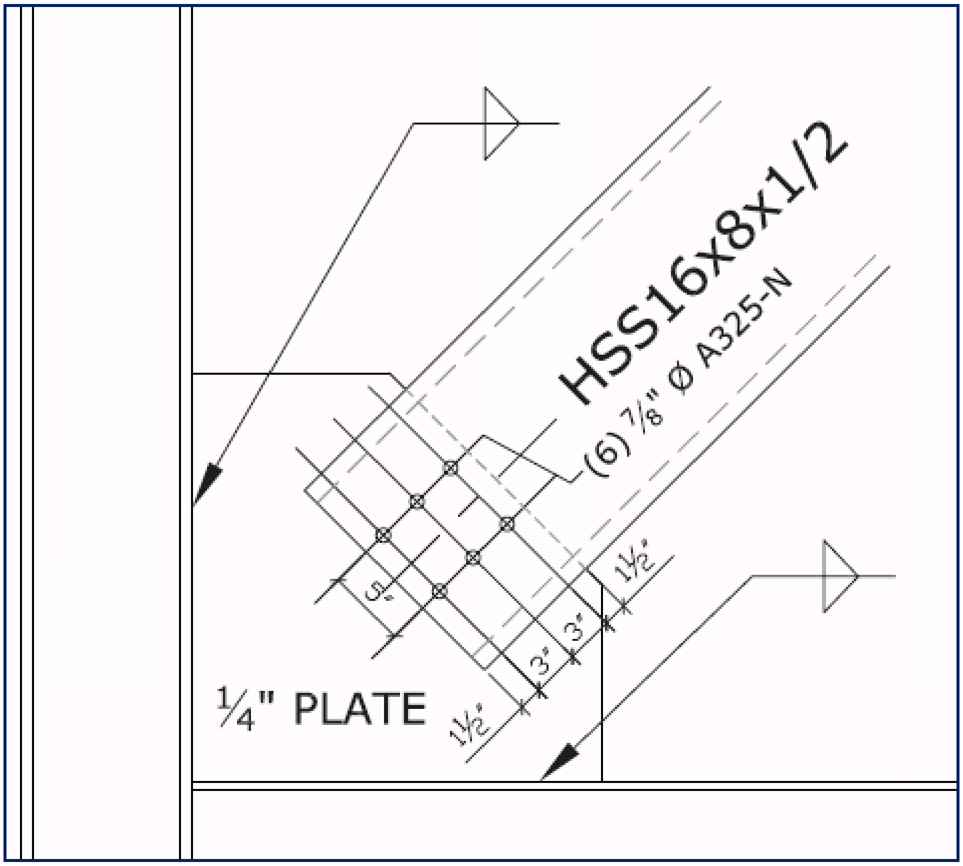
BOLT LINE ③: $\phi r_n = \min[43.3, 68.5, 40.4] = 40.4$ k

$$\phi R_n = 2[43.3 + 43.3 + 40.4] = 254 \text{ k} > 203.7 \text{ k} \quad \underline{\text{OK}}$$

WHITMORE SECTION: $l = 2(\tan 30°)(6") + 5" = 11.9"$
TENSION RUPTURE: $\phi R_n = 0.75 F_u A_e = 0.75(58)(11.9 - 2(\tfrac{7}{8} + \tfrac{1}{8}))(3/4) = 323$ k
TENSION YIELD : $\phi R_n = 0.9 F_y A_g = 0.9(36)(11.9)(3/4) = 289$ k

BLOCK SHEAR: $\phi R_n = \min\begin{cases}(0.75)[(0.6)(58)(7.5 - 2.5(\tfrac{7}{8} + \tfrac{1}{8}))(2 \times 3/4) + (58)(5 - \tfrac{7}{8} - \tfrac{1}{8})(3/4)] = 326 \text{ k} \\ (0.75)[(0.6)(36)(7.5)(2 \times 3/4) + (58)(5 - \tfrac{7}{8} - 1/8)(3/4)] = 313 \text{ k} \leftarrow \underline{\text{OK}}\end{cases}$

TENSION RUPTURE OF HSS: $A_g = 20.9 \text{ in}^2$ $A_n = 20.9 - 4(\tfrac{7}{8} + \tfrac{1}{8})(0.465) = 19.0 \text{ in}^2$
$\phi R_n = (0.75)(58)(19.0) = 827$ k OK



Typical Bracing Connection

APPENDIX G: CONSTRUCTION MANAGEMENT CALCULATIONS

CAST-IN-PLACE CONCRETE SYSTEM - EXISTING CONDITIONS

COLUMNS	Amount		Crew	# crews	units/day	Days	Labor cost/day	Labor	Mat'l cost/unit	Mat'l	Equip. cost/day	Equip.	TOTAL COST
Formwork	26880	SFCA	C-1	4	800	34	4624	157,216	1.23	33,062		0	190,278
Concrete	598	CY	C-20	1	150	4	2860	11,440	109.00	65,182	600	2,400	79,022
Reinf.	86	Ton	4Rodm	4	11	8	5504	44,032	935.00	80,410		0	124,442

SLABS	Amount		Crew	# crews	units/day	Days	Labor cost/day	Labor	Mat'l cost/unit	Mat'l	Equip. cost/day	Equip.	TOTAL COST
Formwork	150345	SFCA	C-2	7	3150	48	12474	598,752	1.23	184,924		0	783,676
Concrete	4738	CY	C-20	4	600	8	11440	91,520	109.00	516,442	600	4,800	612,762
Slab Finish	115919	SF	CeFi	8	4000	29	6608	191,632		0		0	191,632
Reinf.	600	Ton	4Rodm	6	16.5	37	8256	305,472	935.00	561,000		0	866,472

SHEARWALLS	Amount		Crew	# crews	units/day	Days	Labor cost/day	Labor	Mat'l cost/unit	Mat'l	Equip. cost/day	Equip.	TOTAL COST
Formwork	19954	SFCA	C-2	2	900	23	3564	81,972	1.23	24,543		0	106,515
Concrete	370	CY	C-20	1	150	3	2860	8,580	109.00	40,330	600	1,800	50,710
Reinf.	33	Ton	4Rodm	2	5.5	6	2752	16,512	935.00	30,855		0	47,367
CRANE					Days:	135					300	40,500	40,500

COST OF SYSTEM: $ 3,093,377
TIME TO CONSTRUCT: 135 Days

COMPOSITE STEEL SYSTEM - REDESIGN

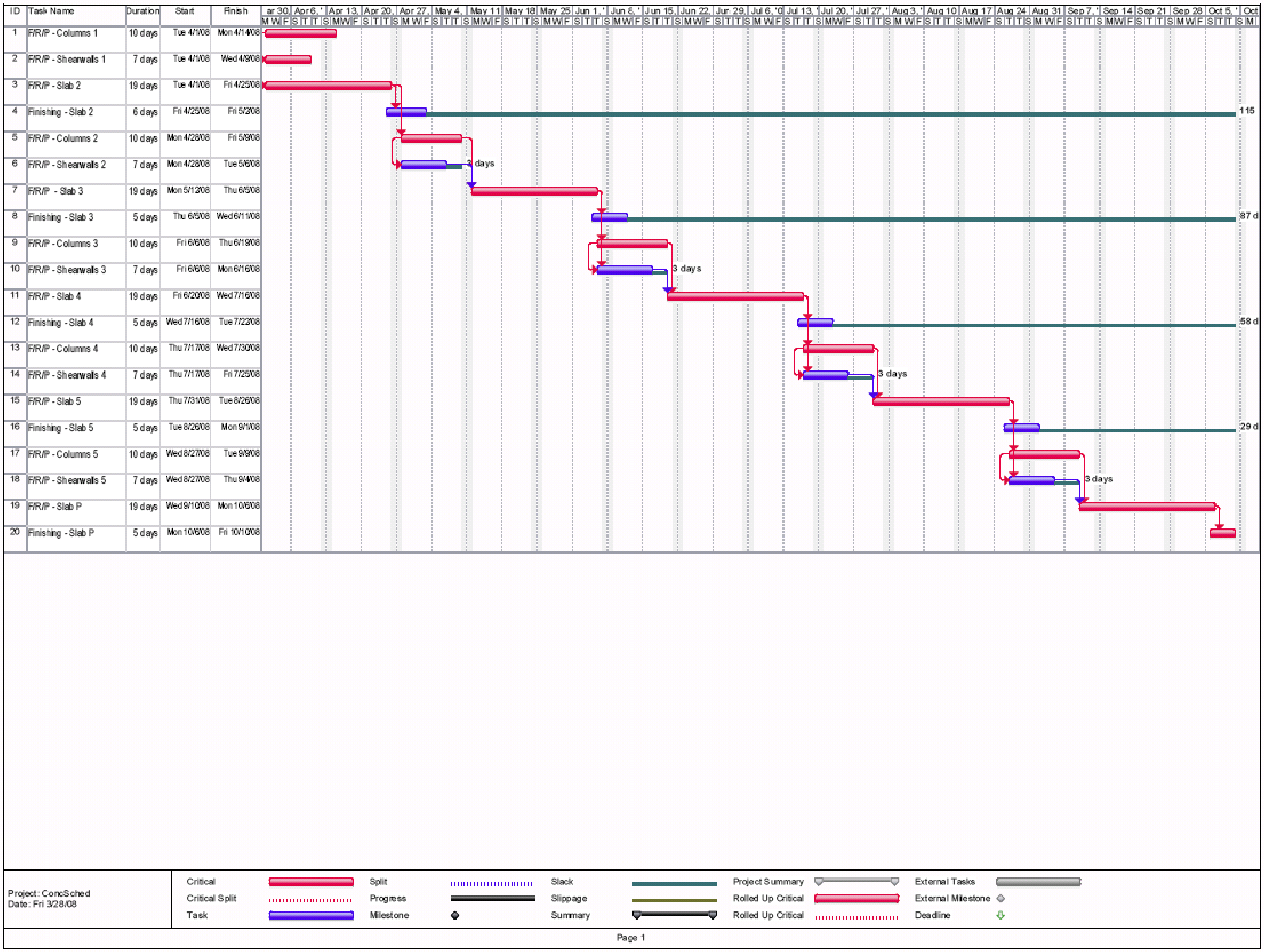
COLUMNS	Amount		Crew	# crews	units/day	Days	Labor cost/day	Labor	Mat'l cost/unit	Mat'l	Equip. cost/day	Equip.	TOTAL COST
Steel	1888	CWt	E-6	1	250	8	5091	40,728	53.00	100,064		0	140,792
Baseplates	54		E-6	1	60	1	5091	5,091	45.00	2,430		0	7,521
Fireproofing	22080	SF	G-2	1	1500	15	900	13,500	1.00	22,080		0	35,580

FLOORS	Amount		Crew	# crews	units/day	Days	Labor cost/day	Labor	Mat'l cost/unit	Mat'l	Equip. cost/day	Equip.	TOTAL COST
Framing	8215	CWt	E-6	1	250	33	5091	168,003	53.00	435,395		0	603,398
Steel Deck	115919	SF	E-4	3	10140	12	7968	95,616	2.00	231,838		0	327,454
Shear Studs	4136	Studs	E-10	1	950	5	1060	5,300	1.00	4,136		0	9,436
Fireproofing	115919	SF	G-2	2	3000	39	1800	70,200	1.00	115,919		0	186,119
Concrete	1800	CY	C-20	2	300	6	5720	34,320	109.00	196,200		0	230,520
WWF	1159	CSF	2Rodm	4	108	11	2752	30,272	29.00	33,611		0	63,883
Slab Finish	115919	SF	CeFi	6	3000	39	4956	193,284		0		0	193,284

BRACES	Amount		Crew	# crews	units/day	Days	Labor cost/day	Labor	Mat'l cost/unit	Mat'l	Equip. cost/day	Equip.	TOTAL COST
HSS Steel	454	CWt	E-6	1	250	2	5091	10,182	59.00	26,786		0	36,968
Fireproofing	3500	SF	G-2	1	1500	3	900	2,700	1.00	3,500		0	6,200
CRANE					Days:	69					300	20,700	20,700

COST OF SYSTEM: $ 1,861,855
TIME TO CONSTRUCT: 69 Days

Concrete Schedule Study

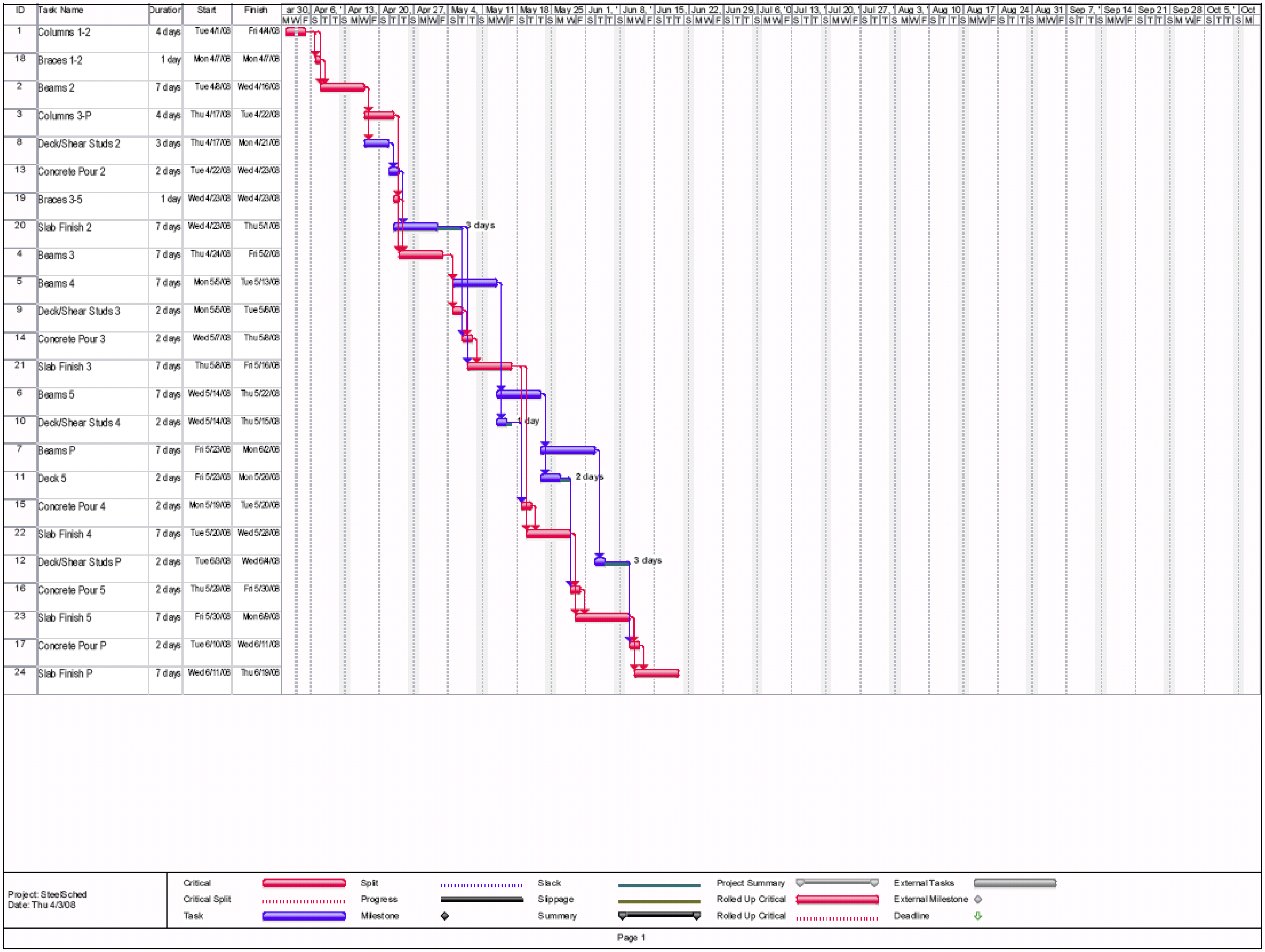


ID	Task Name	Duration	Start	Finish
1	F/R/P - Columns 1	10 days	Tue 4/1/08	Mon 4/14/08
2	F/R/P - Shearwalls 1	7 days	Tue 4/1/08	Wed 4/9/08
3	F/R/P - Slab 2	19 days	Tue 4/1/08	Fri 4/25/08
4	Finishing - Slab 2	6 days	Fri 4/25/08	Fri 5/2/08
5	F/R/P - Columns 2	10 days	Mon 4/28/08	Fri 5/9/08
6	F/R/P - Shearwalls 2	7 days	Mon 4/28/08	Tue 5/6/08
7	F/R/P - Slab 3	19 days	Mon 5/12/08	Thu 6/5/08
8	Finishing - Slab 3	5 days	Thu 6/5/08	Wed 6/11/08
9	F/R/P - Columns 3	10 days	Fri 6/6/08	Thu 6/19/08
10	F/R/P - Shearwalls 3	7 days	Fri 6/6/08	Mon 6/16/08
11	F/R/P - Slab 4	19 days	Fri 6/20/08	Wed 7/16/08
12	Finishing - Slab 4	5 days	Wed 7/16/08	Tue 7/22/08
13	F/R/P - Columns 4	10 days	Thu 7/17/08	Wed 7/30/08
14	F/R/P - Shearwalls 4	7 days	Thu 7/17/08	Fri 7/25/08
15	F/R/P - Slab 5	19 days	Thu 7/31/08	Tue 8/26/08
16	Finishing - Slab 5	5 days	Tue 8/26/08	Mon 9/1/08
17	F/R/P - Columns 5	10 days	Wed 8/27/08	Tue 9/9/08
18	F/R/P - Shearwalls 5	7 days	Wed 8/27/08	Thu 9/4/08
19	F/R/P - Slab P	19 days	Wed 9/10/08	Mon 10/6/08
20	Finishing - Slab P	5 days	Mon 10/6/08	Fri 10/10/08

Project: ConcSched
Date: Fri 3/28/08

Page 1

Steel Schedule Study



ID	Task Name	Duration	Start	Finish
1	Columns 1-2	4 days	Tue 4/1/08	Fri 4/4/08
18	Braces 1-2	1 day	Mon 4/7/08	Mon 4/7/08
2	Beams 2	7 days	Tue 4/8/08	Wed 4/16/08
3	Columns 3-P	4 days	Thu 4/17/08	Tue 4/22/08
8	Deck/Shear Studs 2	3 days	Thu 4/17/08	Mon 4/21/08
13	Concrete Pour 2	2 days	Tue 4/22/08	Wed 4/23/08
19	Braces 3-5	1 day	Wed 4/23/08	Wed 4/23/08
20	Slab Finish 2	7 days	Wed 4/23/08	Thu 5/1/08
4	Beams 3	7 days	Thu 4/24/08	Fri 5/2/08
5	Beams 4	7 days	Mon 5/5/08	Tue 5/13/08
9	Deck/Shear Studs 3	2 days	Mon 5/5/08	Tue 5/6/08
14	Concrete Pour 3	2 days	Wed 5/7/08	Thu 5/8/08
21	Slab Finish 3	7 days	Thu 5/8/08	Fri 5/16/08
6	Beams 5	7 days	Wed 5/14/08	Thu 5/22/08
10	Deck/Shear Studs 4	2 days	Wed 5/14/08	Thu 5/15/08
7	Beams P	7 days	Fri 5/23/08	Mon 6/2/08
11	Deck 5	2 days	Fri 5/23/08	Mon 5/26/08
15	Concrete Pour 4	2 days	Mon 5/19/08	Tue 5/20/08
22	Slab Finish 4	7 days	Tue 5/20/08	Wed 5/28/08
12	Deck/Shear Studs P	2 days	Tue 6/3/08	Wed 6/4/08
16	Concrete Pour 5	2 days	Thu 5/29/08	Fri 5/30/08
23	Slab Finish 5	7 days	Fri 5/30/08	Mon 6/9/08
17	Concrete Pour P	2 days	Tue 6/10/08	Wed 6/11/08
24	Slab Finish P	7 days	Wed 6/11/08	Thu 6/19/08

Project: SteelSched
Date: Thu 4/3/08

Critical
Critical Split
Task
Split
Progress
Milestone ◆
Slack
Slippage
Summary
Project Summary
Rolled Up Critical
Rolled Up Critical
External Tasks
External Milestone ◇
Deadline ⇩

Page 1

Floor Framing Takeoffs

SIZE	#	LENGTH (ft)	WEIGHT (lbs)
W8X10	46	458.75	4621
W10X12	9	195.00	2349
W12X14	2	60.00	849
W12X16	22	495.00	7933
W12X19	113	2640.00	50037
W14X22	20	504.50	11141
W16X26	198	5650.38	147663
W16X31	27	783.00	24326
W16X36	22	616.00	22219
W16X40	13	434.00	17426
W16X45	2	71.00	3213
W16X67	2	60.00	4083
W18X35	25	638.38	22374
W18X40	93	2373.75	95313
W18X50	13	347.00	17357
W18X46	8	214.00	9831
W18X55	7	183.00	10088
W18X60	2	54.00	3234
W18X76	2	54.00	4098
W18X65	1	27.00	1755
W21X44	40	810.83	35868
W21X55	16	406.00	22381
W24X55	7	159.75	8861
W24X84	5	115.00	9666
W27X114	16	468.00	53349
W27X129	29	870.00	111904
W30X191	24	624.00	119544
	-----		-------------
	764		**821482**

Total Number of Studs = **4131**

Column Takeoffs

Size	#	Length (ft)	Weight (lbs)
W10X33	17	800.0	26433
W10X49	18	736.0	36064
W12X53	25	1184.0	62851
W10X60	3	120.0	7187
W12X65	15	600.0	38996
W12X72	6	240.0	17232
	106		198217

Lateral Bracing System Takeoffs

Columns:

Wide Flange:

Steel Grade: 50

Size	**#**	**Length** ft	**Weight** lbs	**UnitWt** psf
W10X33	18	288.0	9516	
W10X39	2	40.0	1565	
W10X49	14	232.0	11368	
W10X68	4	80.0	5444	
W10X88	4	80.0	7050	
W10X112	8	160.0	17912	
	50		52855	0.47

Beams:

Wide Flange:

Steel Grade: 50

Size	**#**	**Length** ft	**Weight** lbs	**UnitWt** psf
W8X10	4	54.0	544	
W12X14	8	116.3	1647	
W12X16	4	54.0	865	
W12X19	4	58.2	1102	
W12X22	4	54.0	1191	
W12X30	8	116.3	3480	
W16X26	8	108.0	2822	
	40		11651	0.10

Braces:

Tube:

Steel Grade: 46

Size	**#**	**Length** ft	**Weight** lbs	**UnitWt** psf
HSS12X6X3/8	4	88.5	3553	
HSS12X4X3/8	8	168.4	5960	
HSS12X4X5/8	8	155.8	8694	
HSS12X6X1/2	8	181.2	9435	
HSS12X8X1/2	8	179.5	10508	
HSS16X8X1/2	4	102.2	7267	
	40		45417	0.40

APPENDIX H: ALTERNATIVE CARE FACILITY CALCULATIONS

MECHANICAL

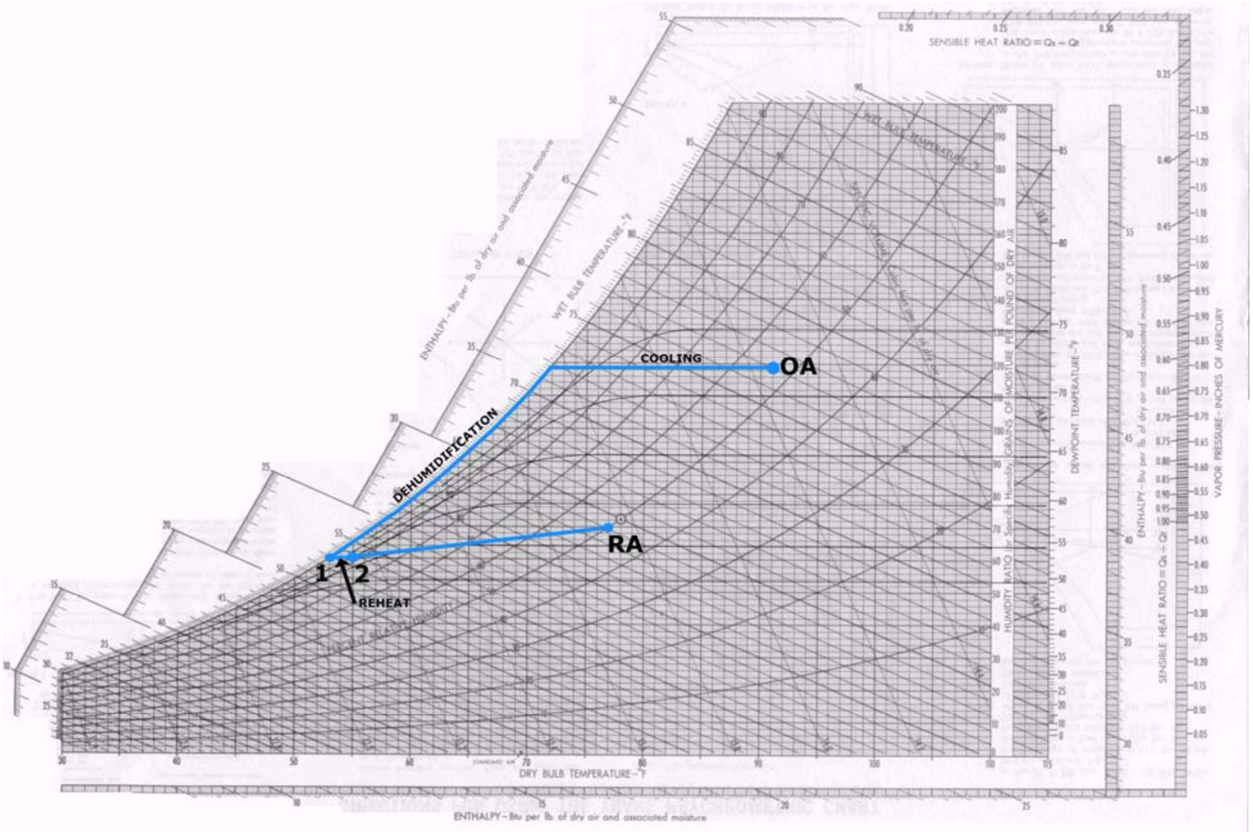
Mechanical Load Calculations

	Cooling	**Heating**
LOADS		
Sensible	61385	-221874
Latent	82760	
SHF	0.742	1
OUTDOOR DESIGN COND.		
T_{DB} [°F]	91	13
T_{WB} [°F]	77	8
RH [%]	0.54	0
W (lb_W/lb_A)	0.0168	0
Spec. Vol. [ft^3/lb_A]	14.29	11.9
Enthalpy [BTU/lb]	40.3	3.1
PREHEATING		
to T [°F]	-	55
W (lb_W/lb_A)	-	0
Enthalpy [BTU/lb]	-	13.2
Spec. Vol. [ft^3/lb_A]	-	12.99
INDOOR DESIGN CONDITIONS		
T_{DB} [°F]	77	68
RH [%]	50	50
Enthalpy [BTU/lb]	29.3	24.2
AIR SUPPLY TEMPERATURES		
MAX [°F]		140
MIN [°F]	55	
Design [°F]	55	101.9
MINIMUM OUTDOOR AIR		
Fresh Air	100%	100%
MIXING POINT		
Total Mass [lb_A/min]	455.00	455.00
Fresh Air Mass [lb_A/min]	455.00	455.00
Fresh Air Fraction	1	1
T_{DB} [°F]	91	55
Enthalpy [BTU/lb]	40.3	13.2
Spec. Vol. [ft^3/lb_A]	14.29	12.99

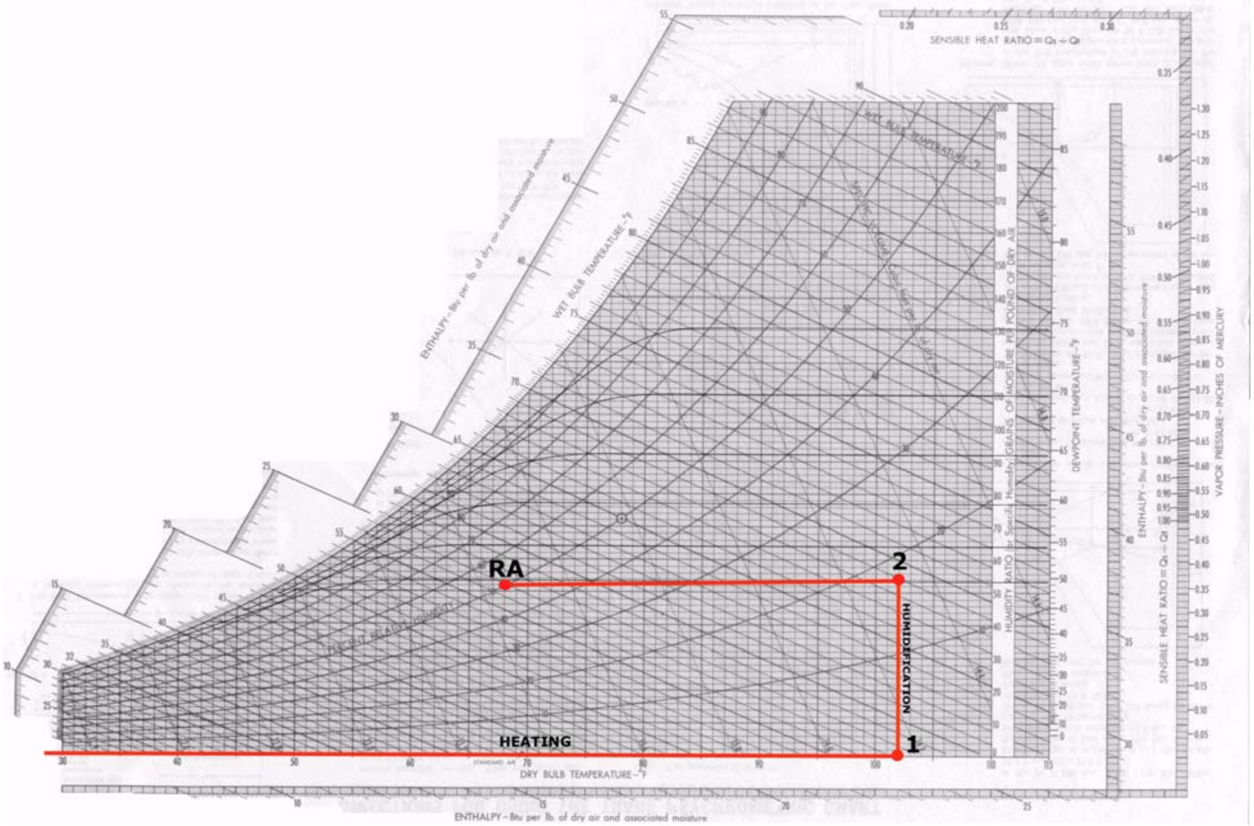
PROCESS 1:	**Cooling**	**Heating**
T Supply Air [°F]	53	102
RH Supply Air [%]	100	0
Enthalpy [BTU/lb]	22	24.5
PROCESS 2:	**Reheat**	**Humidify**
T Supply Air [°F]	55	102
RH Supply Air [%]	93	18
Enthalpy [BTU/lb]	22.5	33.1

SUMMER		
Q Cooling [Tons]	-42	
Q Reheat [BTU/hr]	13650	
Vol. Flow Rate 1 [CFM]	6501.995	
Vol. Flow Rate 2 [CFM]	0	

WINTER		
Q Preheat [BTU/hr]	275730	
Q Heating [BTU/hr]	308490	819000
Q Humidify [BTU/hr]	234780	
Vol. Flow for Fan [CFM]	5910.45	



Summer Cooling Psychrometric Chart



Winter Heating Psychrometric Chart

LIGHTING/ELECTRICAL
Electrical Calculations

45 luminaires x 4 lamps/luminaire = 180 lamps

180 lamps / 2 lamps/ballast = 90 ballasts

$$90 \text{ ballasts} \times \frac{98 \text{ W/ballast}}{0.98 \text{ PF}} = 9000 \text{ VA}$$

9000 VA x 1.25 = 11250 VA

11250 / 3 x 277 = 13.54 A 3Φ

4 CCCs: 13.54 A x 1.25 = 16.92 A

Feeder: 4 #12 Wires @ 25(0.8) = 20 A

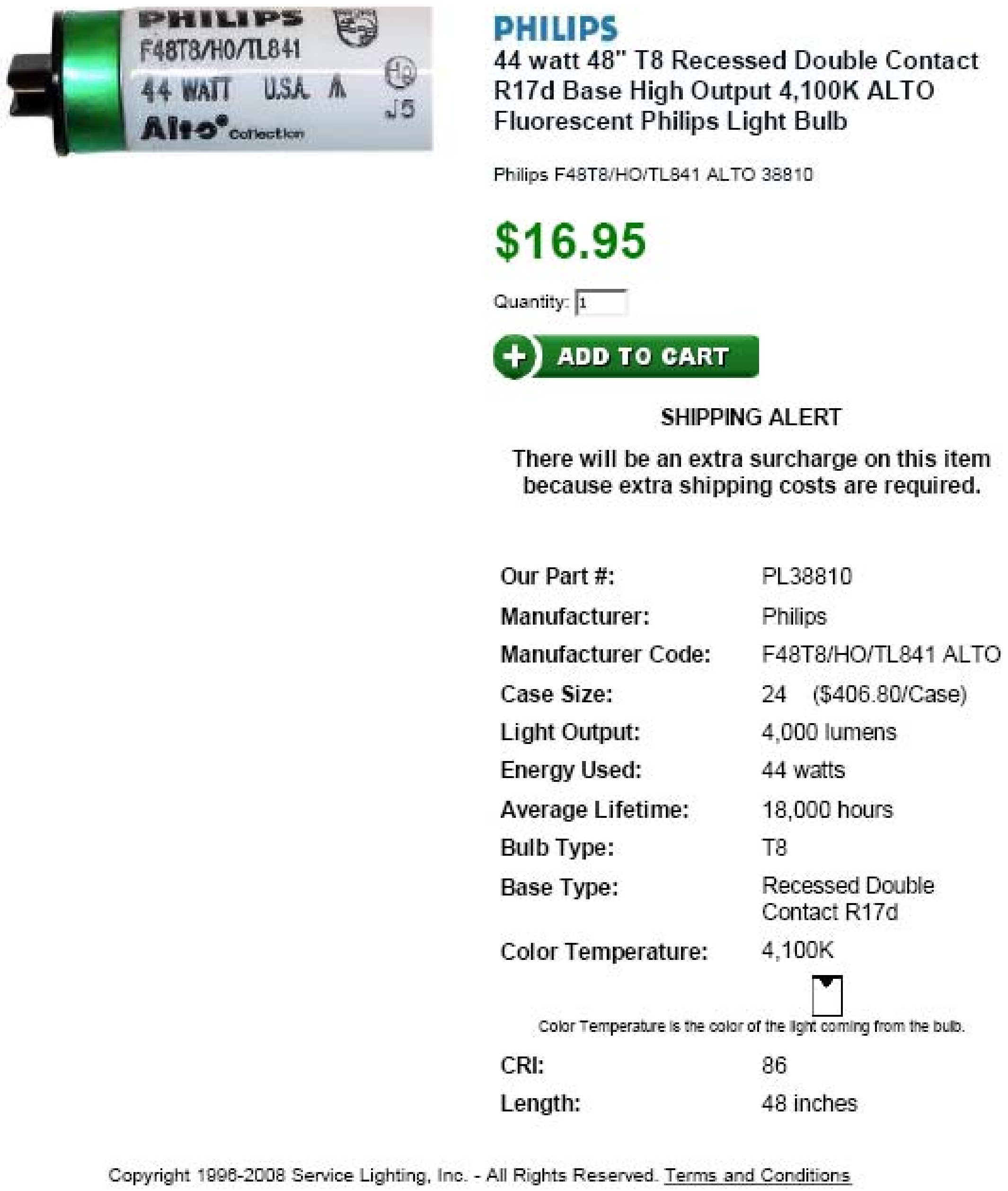
Breaker: 20 A

50 duplex receptacles x 180 VA/receptacle = 9000 VA
x 1.25 growth
11250 VA

$$I = \frac{11250}{3 \times 120} = 31.3 \text{ A (Feeder)} \dashrightarrow 40 \text{ A Breaker}$$

Use (4) #8 Wire

Lamp Information



PHILIPS
44 watt 48" T8 Recessed Double Contact R17d Base High Output 4,100K ALTO Fluorescent Philips Light Bulb

Philips F48T8/HO/TL841 ALTO 38810

$16.95

Quantity: 1

SHIPPING ALERT

There will be an extra surcharge on this item because extra shipping costs are required.

Our Part #:	PL38810
Manufacturer:	Philips
Manufacturer Code:	F48T8/HO/TL841 ALTO
Case Size:	24 ($406.80/Case)
Light Output:	4,000 lumens
Energy Used:	44 watts
Average Lifetime:	18,000 hours
Bulb Type:	T8
Base Type:	Recessed Double Contact R17d
Color Temperature:	4,100K

Color Temperature is the color of the light coming from the bulb.

CRI:	86
Length:	48 inches

Ballast Information

ADVANCE

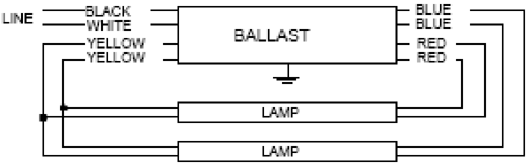
ICN-2S86@277V

Brand Name	CENTIUM
Ballast Type	Electronic
Starting Method	Programmed Start
Lamp Connection	Series
Input Voltage	277
Input Frequency	50/60HZ
Status	Active

Electrical Specifications

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (ANSI Watts)	Ballast Factor	MAX THD %	Power Factor	MAX Lamp Current Crest Factor	B.E.F.
F48T8/HO	1	44	-20/-29	0.23	59	1.02	20	0.98	1.5	1.73
* F48T8/HO	2	44	-20/-29	0.36	98	0.95	10	0.98	1.5	0.97
F60T8/HO	1	55	-20/-29	0.26	70	1.00	20	0.98	1.5	1.43
F60T8/HO	2	55	-20/-29	0.45	118	0.92	10	0.98	1.4	0.78
F72T8/HO	1	65	-20/-29	0.30	81	1.00	15	0.98	1.5	1.23
F72T8/HO	2	65	-20/-29	0.54	140	0.94	10	0.98	1.4	0.67
F96T8/HO	1	86	-20/-29	0.36	100	1.00	10	0.98	1.5	1.00
F96T8/HO	2	86	-20/-29	0.68	185	0.95	10	0.98	1.4	0.51

Wiring Diagram



Diag. 21

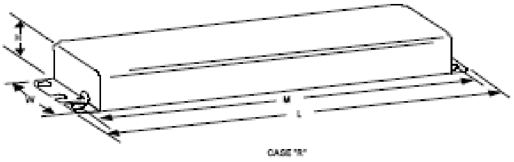
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	22	55.9
White	22	55.9
Blue	46	116.8
Red	46	116.8
Yellow	70	177.8
Gray		0
Violet		0

	in.	cm.
Yellow/Blue		0
Blue/White		0
Brown		0
Orange		0
Orange/Black		0
Black/White		0
Red/White		0

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
11.75 "	2.875 "	1.78125 "	11.14062 "
11 3/4	2 7/8	1 25/32	11 9/64
29.8 cm	7.3 cm	4.5 cm	28.3 cm

Revised 01/26/2004

ADVANCE
O'HARE INTERNATIONAL CENTER · 10275 WEST HIGGINS ROAD · ROSEMONT, IL 60018
Customer Support/Technical Service: Phone: 800-372-3331 · Fax: 630-307-3071
Corporate Offices: Phone: 800-322-2086

Average Illuminance Calculation Sheet

GENERAL INFORMATION

Project Identification: **Alternative Care Facility**
(give name of area and/or building and room number)

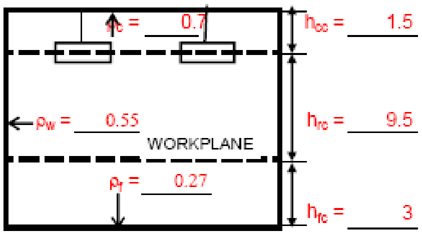
Average maintained Illuminance for design: ______ lux
50 fc

Luminaire Data:
Manufacturer: Corelite Stellar
Catalog number: SB-WB-4T8 DL70

Lamp Data:
Type and Color: F48T8/HO 4100 K
Number per luminaire: 4
Total lumens per lamp: 4000

SELECTION OF COEFFICIENT OF UTILIZATION

Step 1: Fill in sketch at right



L = 104
W = 75

Step 2: Determine Cavity Ratios

Ceiling Cavity Ratio, RCR = 0.172
Room Cavity Ratio, CCR = 1.090
Floor Cavity Ratio, FCR = 0.344

Step 3: Obtain Effective Ceiling Cavity Reflectance (ρ_{cc}) ρ_{cc} = 0.67

Step 4: Obtain Effective Floor Cavity Reflectance (ρ_{fc}) ρ_{fc} = 0.26

Step 5: Obtain Co-efficient of Utilization (CU) from Manufacturer's Data CU (67/55/20) = 0.77

Correction for ρ_{fc} = 1.022 x 0.77 0.787

SELECTION OF LIGHT LOSS FACTORS

Nonrecoverable		Recoverable	
Luminaire ambient temperature		Room surface dirt depreciation (RSDD)	0.9
Heat extraction thermal factor		Lamp lumen depreciation (LLD)	0.9
Voltage to luminaire		Lamp burnouts factor (LBO)	
Ballast factor	0.95	Luminaire dirt depreciation (LDD)	0.9
Ballast-lamp photometric factor			
Equipment operating factor			
Luminaire surface depreciation			

LLF = 0.69255

CALCULATIONS

(average maintained Illuminance)

$$\text{Number of Luminaires} = \frac{(\text{Illuminance}) \times (\text{Area})}{(\text{Lamps per Luminaire}) \times (\text{Lumens per lamp}) \times (\text{CU}) \text{ X } (\text{LLF})}$$

$$= \frac{(50) \times (104 \text{x} 75)}{(4) \times (4000) \times (.787) \times (.721)} = \boxed{45} \text{ luminaires}$$

$$\text{Illuminance} = \frac{(\text{\# luminaires}) \times (\text{Lamps per Luminaire}) \times (\text{Lumens per lamp}) \times (\text{CU}) \text{ X } (\text{LLF})}{\text{Area}}$$

$$= \frac{(45) \times (4) \times (4000) \times (.787) \times (.693)}{(104 \text{x} 75)} = \boxed{50} \text{ fc}$$