Final Report

Photo Courtesy: Castlebrook Development Group

Flats on Fifth

1655 Fifth Avenue
Pittsburgh, Pennsylvania

Derek Gombos | 5th Year | Structural
DR. THOMAS BOOTHBY, P.E., R.A.

FLATS on FIFTH

Courtesy: Castlebrook Development Group

Project Team:
Owner:
David Laffey
    Castlebrook Development Group
Structural Engineer:
Mark Sipos
    Keystome Structural Solutions
Geotechnical Engineer:
Dr. Javaid Alvi
    Geo-Mechanics
Remaining project team identities are
   being withheld.

Building Statistics:

Location:	Pittsburgh, PA
Height:	82'-8"
Stories:	7
Size:	89,975 SF
Cost:	$11,958,505

Architecture:

- Lower façade pays tribute to local building culture.
- Multilevel garage with two entrances making use of uneven land surrounding site.

Mechanical/Electrical:

- Separate HVAC units in each apartment.
- Climate of public spaces controlled by individual units.
- Power by 208/120 single phase or 208Y/120 three phase power.

Courtesy: Castlebrook Development Group

Structure:

- Steel podium with wood framing above.
- Masonry towers provide lateral force resistance.
- Grade beams and caissons at foundation.

Construction:

- Design-Build project delivery method.
- Constructed May 2015-September 2016

Derek Gombos | Structural
Dr. Thomas Boothby, P.E., R.A.   https://dmg5589.wixsite.com/aethesis

Flats on Fifth
Pittsburgh, PA

Executive Summary

Flats on Fifth is a seven story residential building in Pittsburgh, Pennsylvania. The building is located in the Uptown District just off the parkway, only minutes from downtown. 74 apartment units make up the upper five floors with a few on the second floor. Parking is located on the first and second floors with additional common spaces for residents on these floors.

The structure is a podium type structure, utilizing type 1A at the first two levels and type 3A for the remaining floors. The top five floors utilize wood framing. 16" wood joists span the long direction of the building and bear on 6" stud walls located at party walls. The first two levels are framed in steel. Bearing walls end at the third floor, so the second floor framing locates beams directly under all bearing walls. Reinforced masonry shear walls are the main lateral force resisting system. Shear walls are located around stairs and elevators forming three shafts.

The proposed alternative structure changes the wood framing to steel. 14" bar joists are used spanning the long direction bearing on 4"-6" metal stud walls. Additional rows of columns were added to the lower two levels of the building to shorten the spans of more substantially loaded beams. This helped reduce beam sizes. The lateral system remains to be reinforced masonry shear walls. They have been redesigned since the load distribution changed. Floor diaphragms in the existing structure are flexible at residential levels. The proposed structure designs the diaphragms to be rigid. Most walls are 12" thick with varying reinforcement.

An economics breadth has been done to determine the benefit of a few architectural alterations to the building. All parking was assumed to be moved to a sub grade level with all remaining non-dwelling spaces moved to the first floor. The second floor would then be replaced with a floor of only dwelling units, similar to levels three through seven. Comparing the present value of the additional rent for 20 years to the construction cost of the parking level, it is determined that this change would result in a deficit of $552963.05.

An acoustics breadth was done to ensure that the proposed system would provide adequate sound transmission loss for party walls, exterior walls, and floors. This study was performed using the masses of the existing and proposed assemblies. Results from this study show that the proposed assemblies will provide equal, or better, sound transmission loss.

TABLE OF CONTENTS

Introduction

The intent of this report is to provide a brief description of the existing structural systems of Flats on Fifth in Pittsburgh, Pennsylvania. In addition, an explanation of the proposed alternate structural system will be given.

The contents of this report will be separated into the sections as follows: general building information, existing systems, proposed alternative, extended research, and concluding remarks. The "General Building Information" section will review information such as location, architecture, and other details relating to the building as a whole. "Existing Systems" will review the structural systems of the building according to the structural drawings. Both the existing gravity and lateral systems will be discussed in this section. Structural redesign will be the focus of the "Proposed Alternative" section. Here, the analysis and results from this thesis will be described and explained. Finally, the "Extended Research" section will cover non-structural system related items. More specifically, this section will cover the "Economics Breadth" and "Acoustics Breadth." A more in depth introduction to these topics is given later in the report.

General Building Information

Flats on Fifth is a seven story residential building completed in September of 2016. This building is located in the Uptown District of Pittsburgh, Pennsylvania and is part of a plan to revitalize the area. The site on Fifth Avenue, just off of the Parkway, is a prime location for residents. PPG Paints Arena is within a few blocks from the site and with quick access to the Parkway, the other major sporting venues, as well as Downtown, are not lengthy commutes. Near the site also, within a few blocks, is a major hospital.
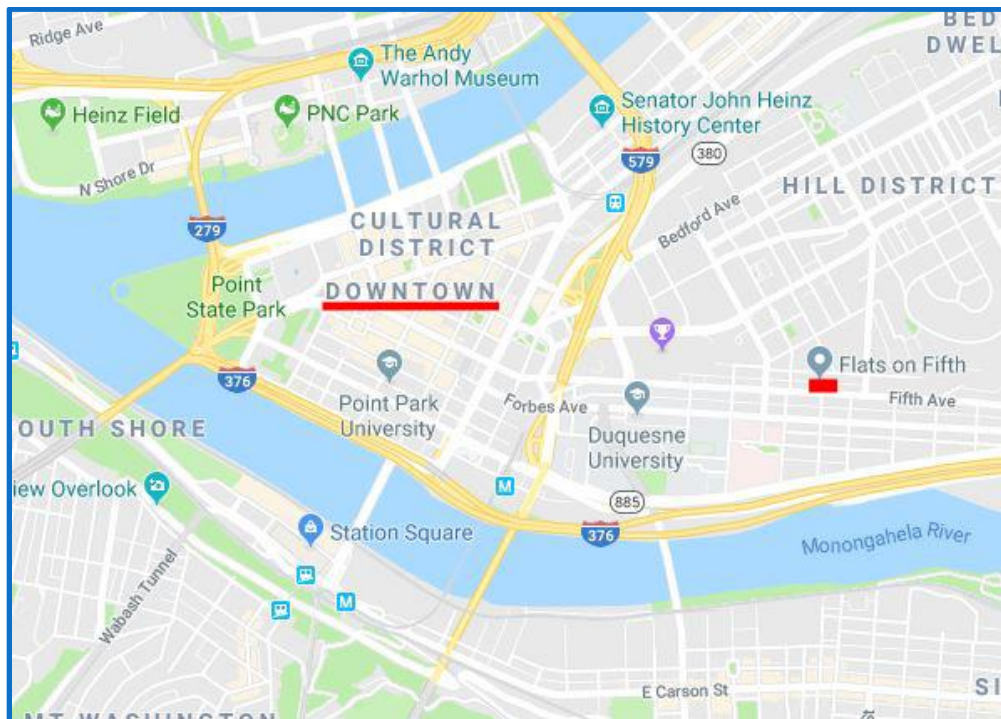
Figure 00: General Site Location

74 apartment units make up this approximately 90,000 square foot building. Dwelling units make up floors three-seven with a few additional units on floor two. The first two floors enclose a parking garage with a bicycle storage room. Due to a sloping site, low in the front and high in the rear, the garage has no ramps. Taking advantage of the elevated street to the rear of the building, two entrances are used. Also within the first two floors are additional common spaces for resident use.

The exterior of Flats on Fifth recognizes the architectural history of the Uptown District. Historically, most buildings in the area have been one or two story brick buildings. This is honored as the first two levels of the building make use of brick veneer.

Existing Systems

Gravity

Foundations

Following the recommendation of the geotechnical engineer, the structure of Flats on Fifth bears on a system of grade beams spanning drilled, cast-in-place caissons. All concrete used for this design is 3000 psi normal weight concrete. Grade beams range in size from 24-30 inches wide and 32-60 inches deep. The most common reinforcement includes #8 bars at the bottom and #5 or #8 bars at the top with #4 stirrups. Figure 01 shows conditions with and without a concrete pier. Per the detail, dowel connections change for this condition. When no pier is needed, 4 - #6 dowels are used to make this connection. When a pier is specified, dowels extending into the caisson match the vertical reinforcement of the pier.
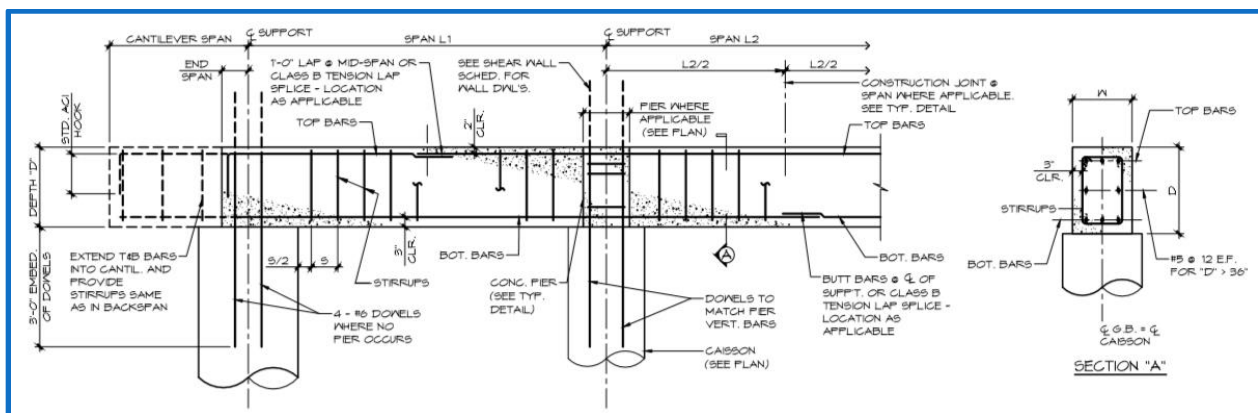

Figure 01: Grade Beam Reinforcement (Keystone Structural Solutions (KSS))

The geotechnical report recommends that caissons be designed to bear directly on solid bedrock, drilling into the rock by at least one foot. Further drilling for skin friction socketing is permitted by the report to allow caisson diameters to be reduced, but a minimum of 30 inches is given. Caissons in the existing design range from 30-42 inches in diameter. Vertical reinforcing changes with diameter but is generally #7, #8, or #9 bars with #3 ties. Depth of caissons are typically 25 or 45 feet to end bearing with an average 4.5 foot skin friction socket in rock. Caissons are designed to transfer most of their load by bearing directly on rock. Sockets are added to aid load transfer by allowing it to pass through the sides or the caisson in addition to the end. This also helps resist uplift forces. Figure 02 shows a typical reinforcement detail for caissons. In some areas, concrete piers are required above the caisson as shown in Figure 03. Concrete Piers are square of 24 or 26 inch sides with #8 vertical bars and #4 ties.
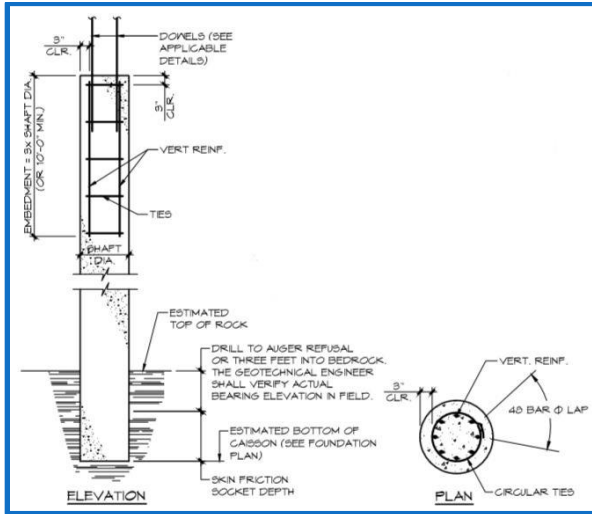
Figure 02: Caisson Reinforcement and Socket (KSS)
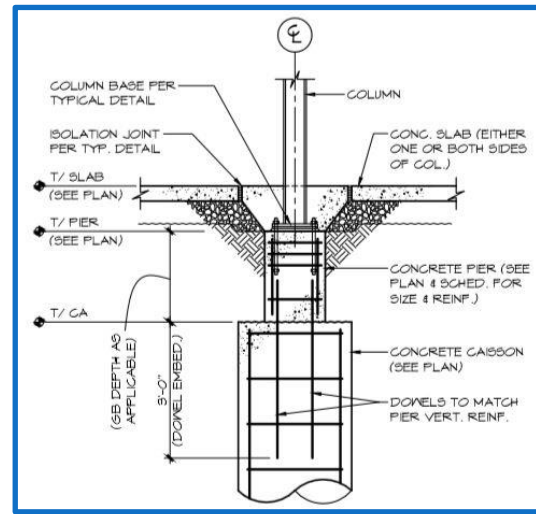
Figure 03: Concrete Pier over Caisson (KSS)

The ground floor of the building is slab-on-grade. This is also designed with 3000 psi normal weight concrete. The slab is typically 5 inches thick with fiber mesh reinforcement. Underneath the slab is a 6 inch bed of compacted, well graded granular fill. Figure 04 illustrates this design.
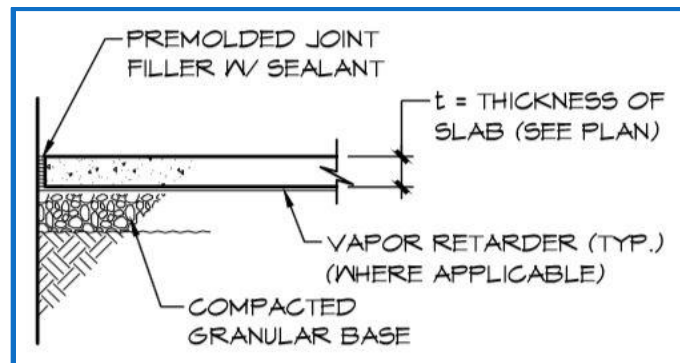
Figure 04: Typical Slab-on-Grade (KSS)

Typical Bay

This section will focus on the gravity load design of Flats on Fifth. Since there are two prominent construction types, both will be described. Continuing in the fashion of moving from the bottom of the building to the top, the steel systems will be discussed first followed by the wood systems.

Steel

The building is divided into three distinct column lines which divide the building longitudinally. This creates two major spans for infill beams of 40 and 43 feet. Laterally, the building is divided into seven distinct column lines. Girders span from line to line at most 28'-6". Figure 05 shows an example of one of the steel framed floors in the building. Figure 06 is a closer image of a typical bay of 28.5 feet by 40 feet. Some of the more common infill sizes include W24x55 and W21x44. Of the more common girders include W21x44 and W36x135. As shown in Figure 07, most of the beams and girders in this design are composite acting with the concrete slab it carries. Most members use an average of 20-30 shear studs.
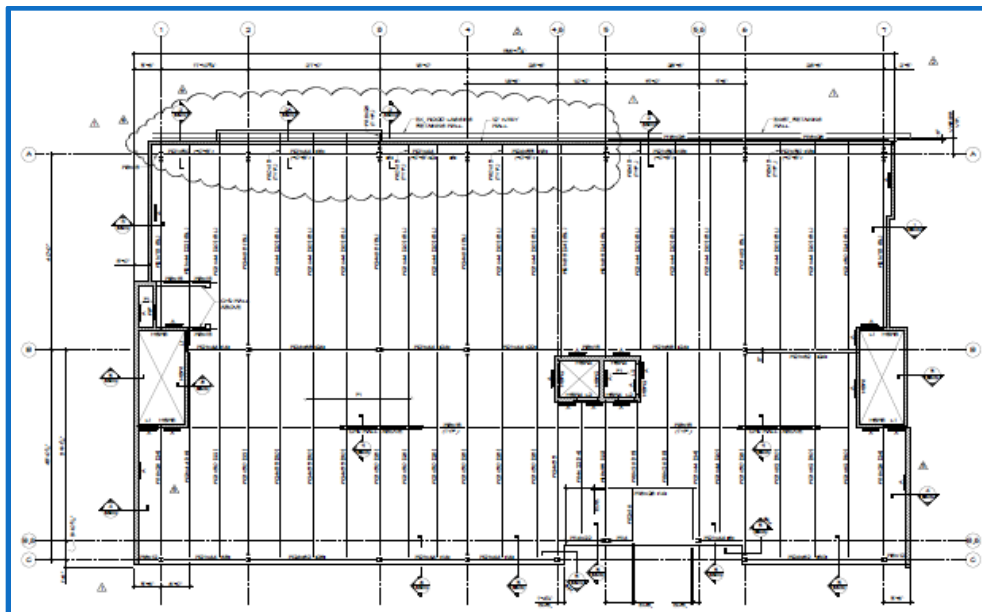
Figure 05: Level 1 Steel Framing Plan
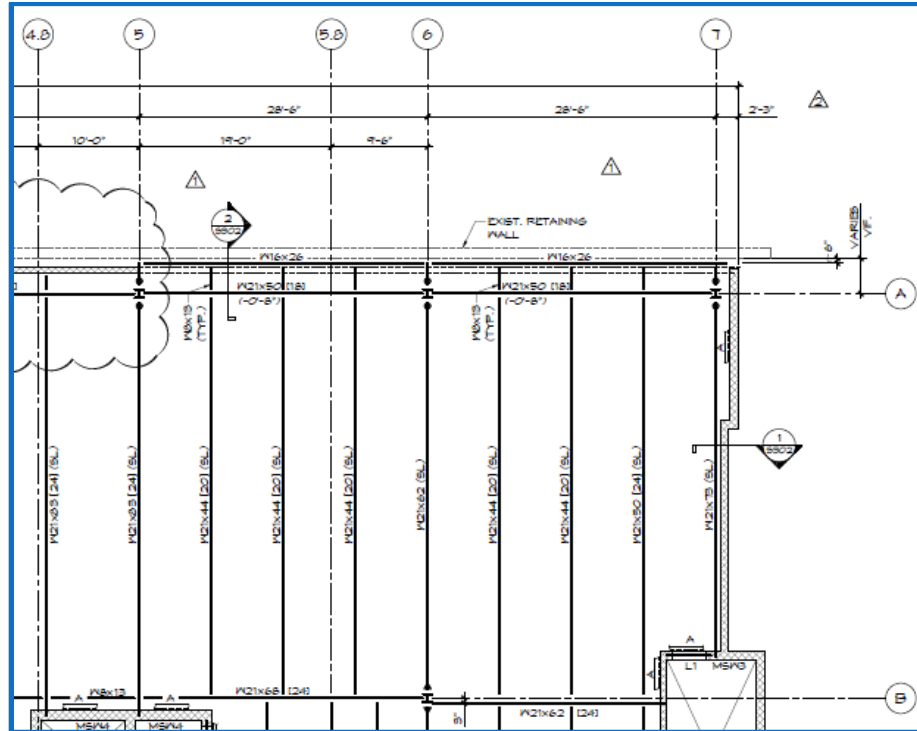
Figure 06: Close Up of North-East Corner of Steel Framing Plan

The floor structure is a 2 inch, 18 gage composite deck with normal weight concrete. Table 01 lists thickness and reinforcement of concrete topping per floor. In addition to the welded wire fabric, fiber mesh is added to the concrete mixture for crack resistance.
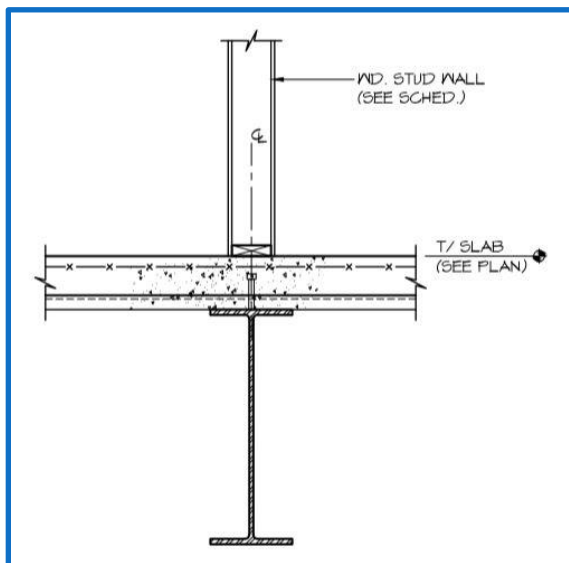
Figure 07: Composite Beam (KSS)

Level	Topping	Reinforcement
1	4½"	4x4 – W8xW8 WWF
2	5¼"	6x6 – W2.9xW2.9 WWF

Table 01: Slab Topping and Reinforcement

Wood

The upper five floors of Flats on Fifth are of wood construction. Typical infills span from wall to wall. Open web joists 16 inches deep and spaced 16 inches maximum are used to support the floor structure. Other members throughout the plan include a 1¾ x 9¼ LVL and a series of 2x10's grouped in threes.
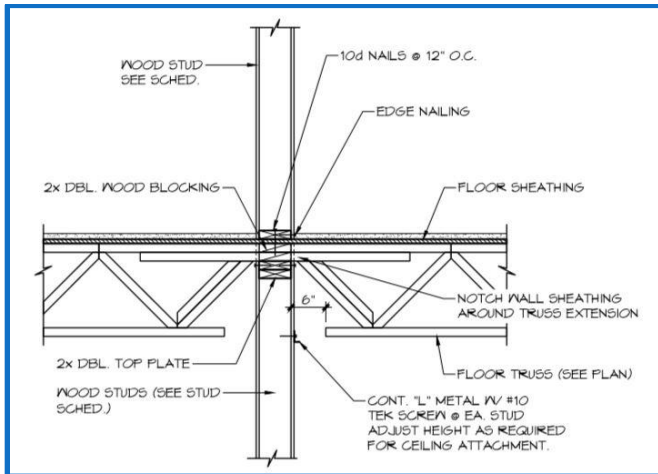
Figure 08: Wood Joist at Stud Wall (KSS)

Image 01: Wood Joists (KSS)

Typical floor diaphragms consists of 1 inch of gypcrete with a ¼ inch sound control mat over wood sheathing. Sheathing is either ¾ inches thick for floors or 5/8 inches thick for roofs with 2x4 wood blocking at the edges of all panels.
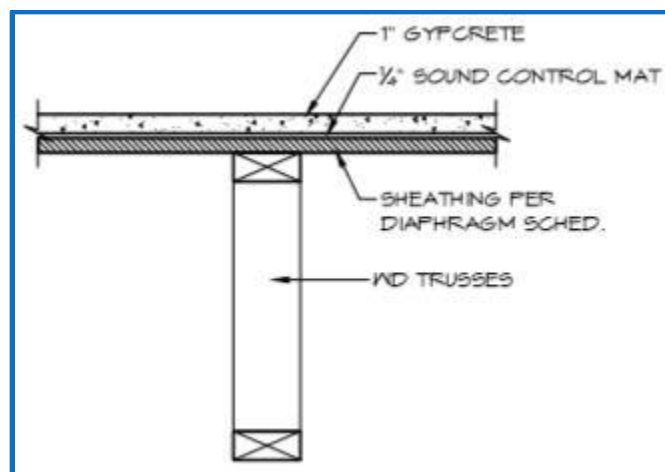
Figure 09: Wood Diaphragm Structure (KSS)

Columns

Similar to the last section, this section will discuss first steel members followed by wood members.

Steel

Steel columns extend from the foundation of the building to just below the second floor. Columns are a range of W12 shapes. The maximum load delivered to the foundation is 565 kips. Base plates are most commonly 18 inches square and on average 1½ inches thick. Columns extend full height. Beams connect directly to the sides at floor 1 and lay on top at floor 2 as shown in Figures 10 and 11 respectively.
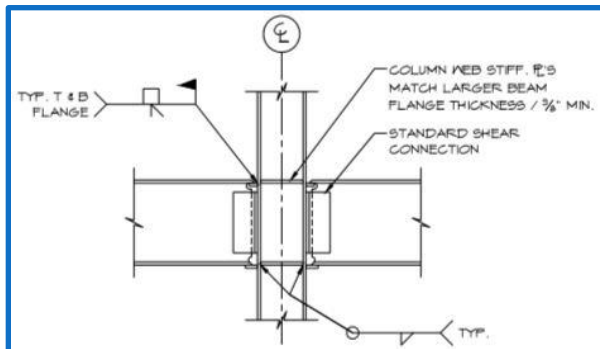
Figure 10: Beam to Column Side (KSS)
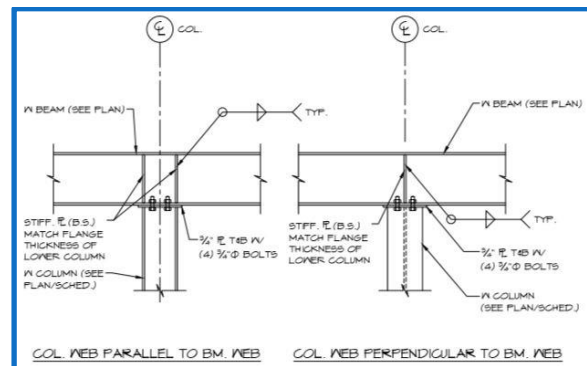
Figure 11: Beam over Column (KSS)

Wood

Stud walls make up most of the vertical members in the upper five floors. Typical walls are 2x6 studs spaced either 12 inches or 16 inches on center. These stud walls frame into wood posts which run along the main corridor. Wood posts are either (3) 2x8 dimensioned lumber or one 5¼"x5¼" engineered lumber. Engineered lumber is produced to provide higher strength capacities than traditional sawn lumber. These posts seem to be used only in places where excessive load is expected, such as bearing walls with several long headers.
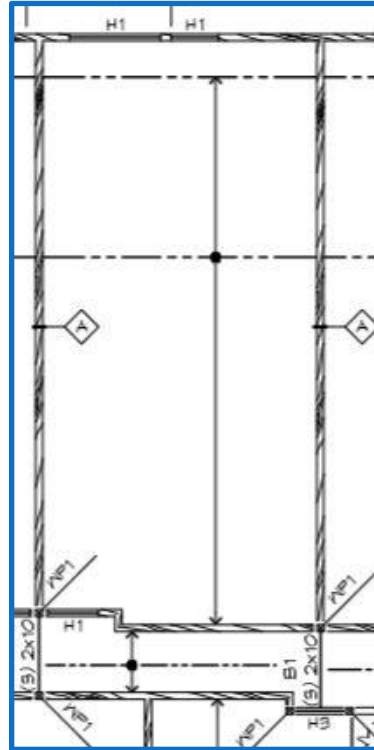
Figure 12: Excerpt From Level 3-6 Structural Plan (KSS)

Lateral

Reinforced masonry shear walls are used as the main lateral force resisting system.

Masonry Shafts

There are three main masonry shafts that surround elevators and stairs. These can be seen outlined in red in Figure 13. These shafts provide stiffness for the entire building to resist lateral loads. Reinforced masonry shear walls are constructed of 8 inch to 12 inch ivany block. Typical reinforcement includes #5 bars every 48 inches with #8 bars at each end vertically with #4 bars every 16 inches horizontally at each face of the wall.
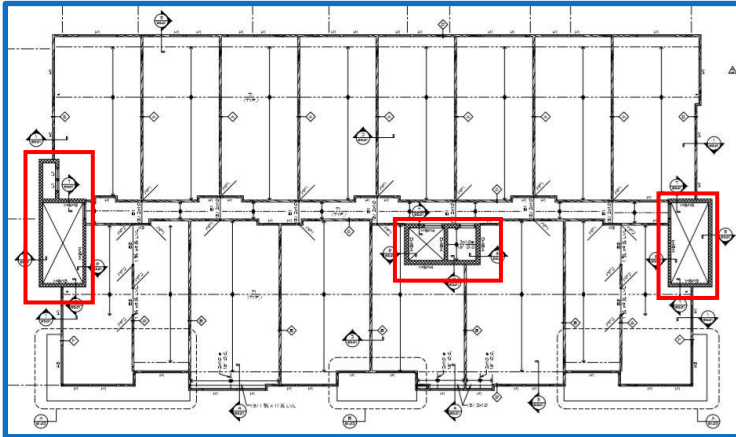
Figure 13: Apartment Level Floor Plan, Masonry Shaft Callout (KSS)   *Image 02: Masonry Shafts (KSS)*

Other Lateral Elements

While the masonry shafts are the main lateral force resisting system. Other supplementary systems are used for extra measure.

Moment Connections

As mentioned in a previous section, the gravity system for the first two floors is steel. This system includes moment frames and connections to supplement the reinforced masonry shear walls.
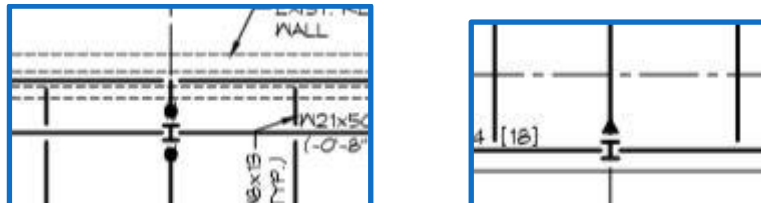
Figure 14: Plan Marked Moment Connections (KSS)

Floor Blocking

Apartment level floors are constructed with 2x4 blocking. Due to high shear in these floors, this blocking was added to aid in transferring load to the vertical lateral lead resisting elements such as the masonry shear walls.
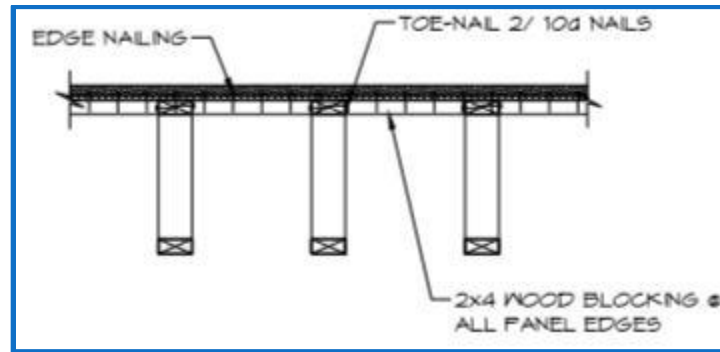
Figure 15: Floor Diaphragm for Shear Transfer (KSS)

Other Structural Elements

Flats on Fifth features balconies for its residents. Unlike the rest of the structure of the apartment level floors, the balconies are steel construction. Balconies are constructed of mostly 8 inch channels. 8 inch wide flange members are used typically where moment connections are required. Edge members, as well as members extending into the building, are 12x4 rectangular HSS.
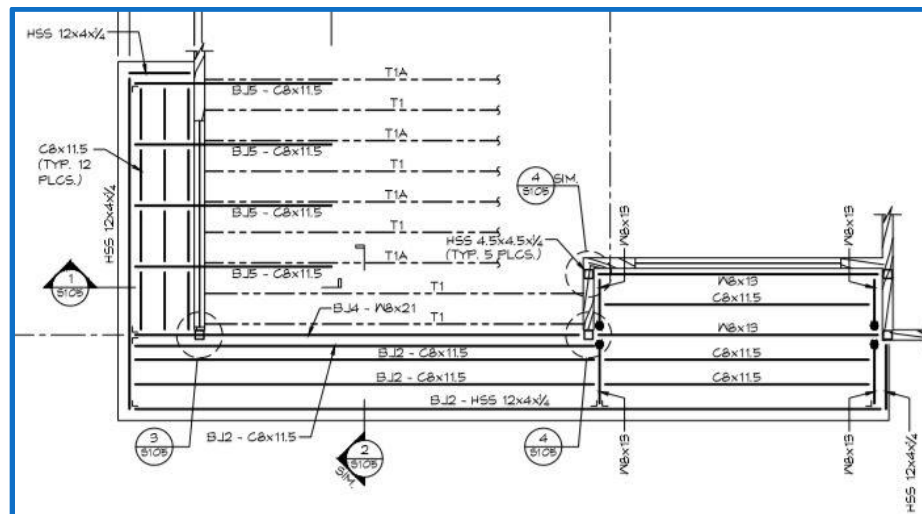
Figure 16: Balcony Structural Plan (KSS)

Image 03: Balcony Structure

Crowning the front of the building is a decorative overhang. The extent of this overhang can be seen in Figure 17 with the gray hatching.
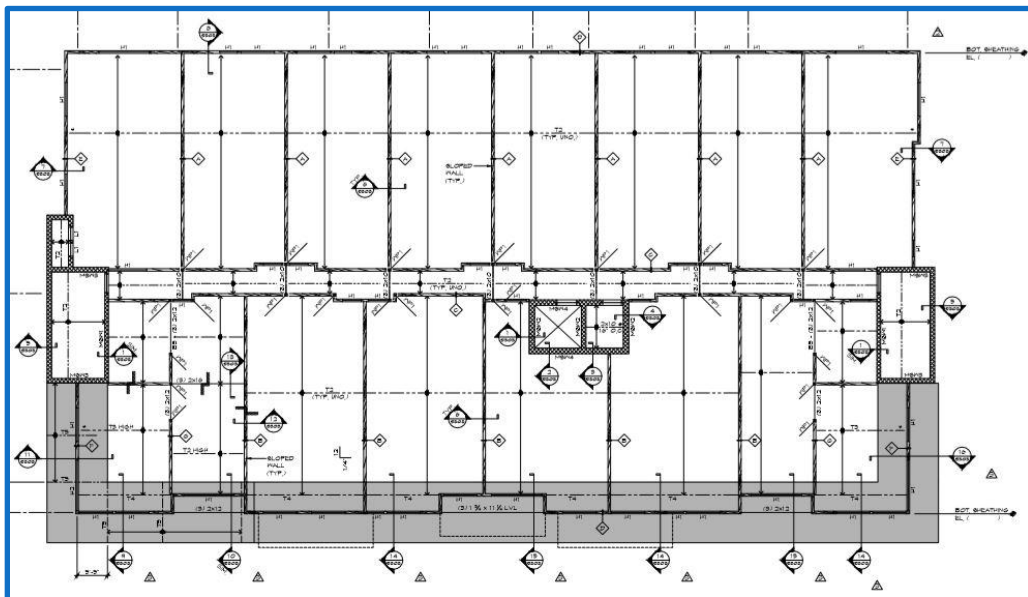
Figure 17: Roof Framing Plan (KSS)

The crown has two styles. Towards the left-front corner of the building, the crown is larger and more outward reaching. Along the rest of the building front, it is shorter and more vertical. Two different wood structures were implemented for these pieces. The first, as shown in Figure 18, uses a step down truss to cantilever off the edge of the building. Figure 19 shows the second type, a more block and stud type truss to create the shorter cantilever.
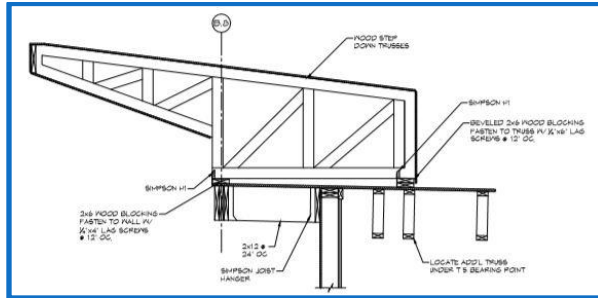
Figure 18: Larger Crown Truss (KSS)
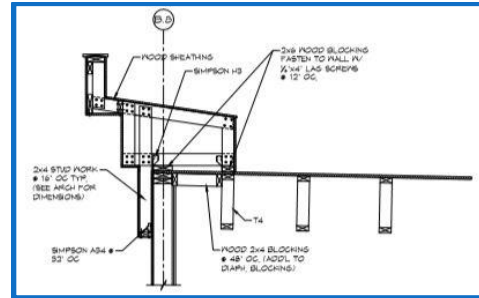
Figure 19: Smaller Crown Truss (KSS)

The floor plan of Flats on Fifth becomes irregular between the second and third level of the building. As shown in Figure 20, the bearing wall of the residential floor has no wall to continue the same load path. To mend this, a larger steel beam is used to carry the load.
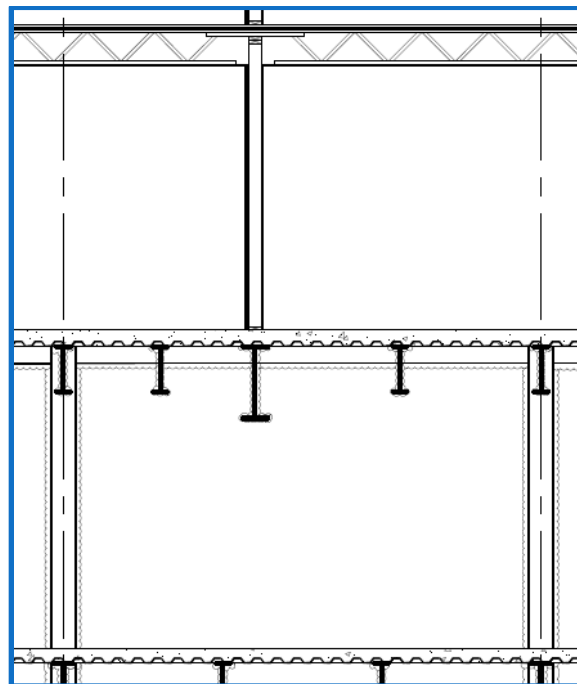
Figure 20: Alignment of Bearing Wall and Steel Beam (Architect)

Joint Details

Moment Connections

There are two different types of moment connections used in the steel framing. Standard moment connections, like the ones shown in Figures 21 and 22, are welded connections. Shear and moment are resisted by the entire connection. Plates are added to the column to increase stiffness of the joint. The wind moment connection, shown in

Figure 23, is bolted at the flanges and welded along the web. Here, shear is resisted completely by the web connection and the bolted flanges resist moment.
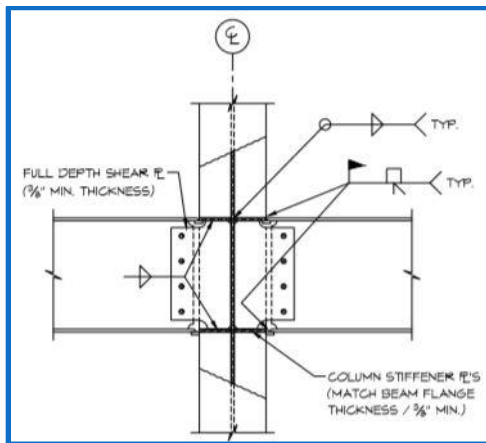
Figure 21: Moment Connection to Web (KSS)
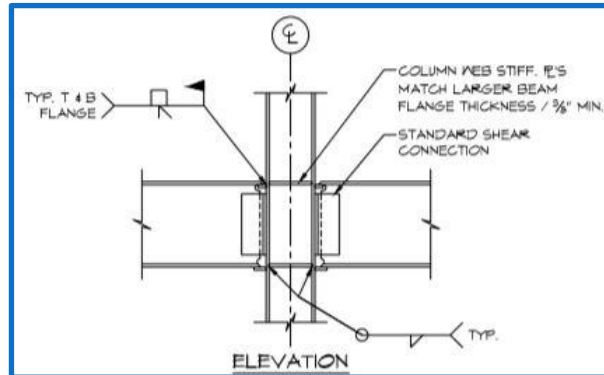
Figure 22: Moment Connection to Flange (KSS)
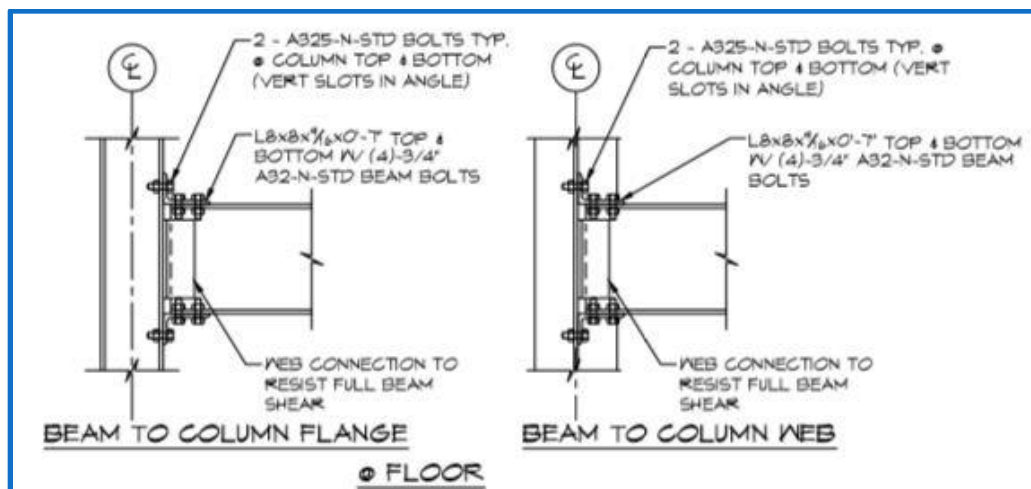
Figure 23: Wind Moment Connection (KSS)

Truss to Bearing Wall

Wood trusses are made continuous at stud walls. The top chord of the truss is extended through the partition to adjacent trusses. In addition to being continuous, the top chord is also double layered to better resist moment transfer through the chord. Being a continuous member, the stud wall must carry twice the load at a single spot. The double 2x top plate helps distribute the load over the length of the wall.
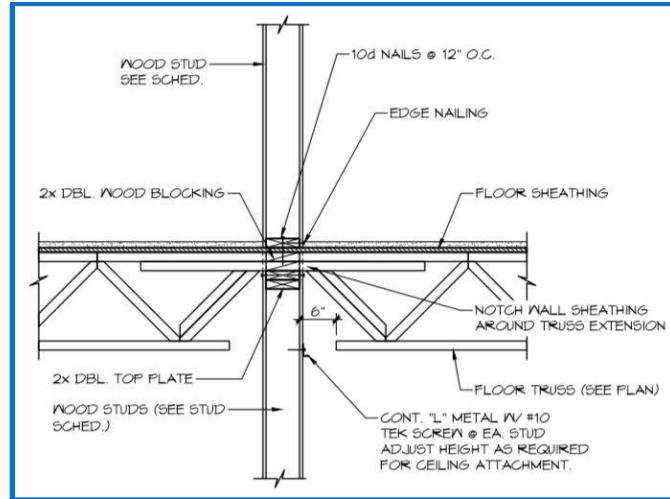
Figure 24: Wood Truss End Bearing (KSS)

Proposed Alternative

Overview

The existing structural system of Flats on Fifth uses wood floor trusses bearing on wood stud walls. At the third floor, the structure changes to steel framing. Lateral forces are resisted by reinforced masonry shear walls. This thesis proposes altering the wood framing as described in the sections above to steel. Vulcraft bar joists bearing on metal stud walls will be designed for the residential floors. Steel framing will be used for the first two levels of the building. Framing will be designed in attempt to use lighter or shallower members when possible. When necessary, partial composite beam design will be used. Floor diaphragms on most levels will be altered from flexible wood to rigid concrete slab on deck. Thus, reinforced masonry shear walls will remain as the lateral force resisting system, but will be redesigned for a load distribution based on relative stiffness. The following sections cover each part of the design in more detail.

The following codes, standards, and design manuals were used for this design:

- IBC 2015
- ASCE 7-10
- ASCE Steel Manual 15th Edition
- TMS 402/602-16
- Vulcraft Steel Joist and Deck Design Manuals
- Clark-Dietrich Metal Stud Design Manual

Typical Loads	
Dead Loads	
Roof	28.5 psf
Floor Type 1	65.5 psf
Floor Type 2	75 psf
Live Loads	
Residential Floor	40 psf
Garage Floor	40 psf
Corridors Above 1st Floor	Same as Occupancy
Classrooms	40 psf
Gymnasiums	100 psf
Partitions	15 psf
Roof Live	20 psf
Snow Loads	
Flat Snow	21 psf
Drift Snow	43 psf

Table 02: Typical Loads

Gravity

Light Gauge Framing

Two structural layouts were considered for the residential levels of the building. The first option, like the existing wood framed plan, placed bearing walls at party walls with joists spanning in the long direction of the building. The second utilized the longitudinal exterior walls and corridor walls for bearing walls. Joists would thus span in the shorter direction of the building. Both options are represented in Figures 25 and 26.

Since span lengths for the first option would be shorter, smaller joists will be required. Smaller tributary width will also decrease the required stud sizes.
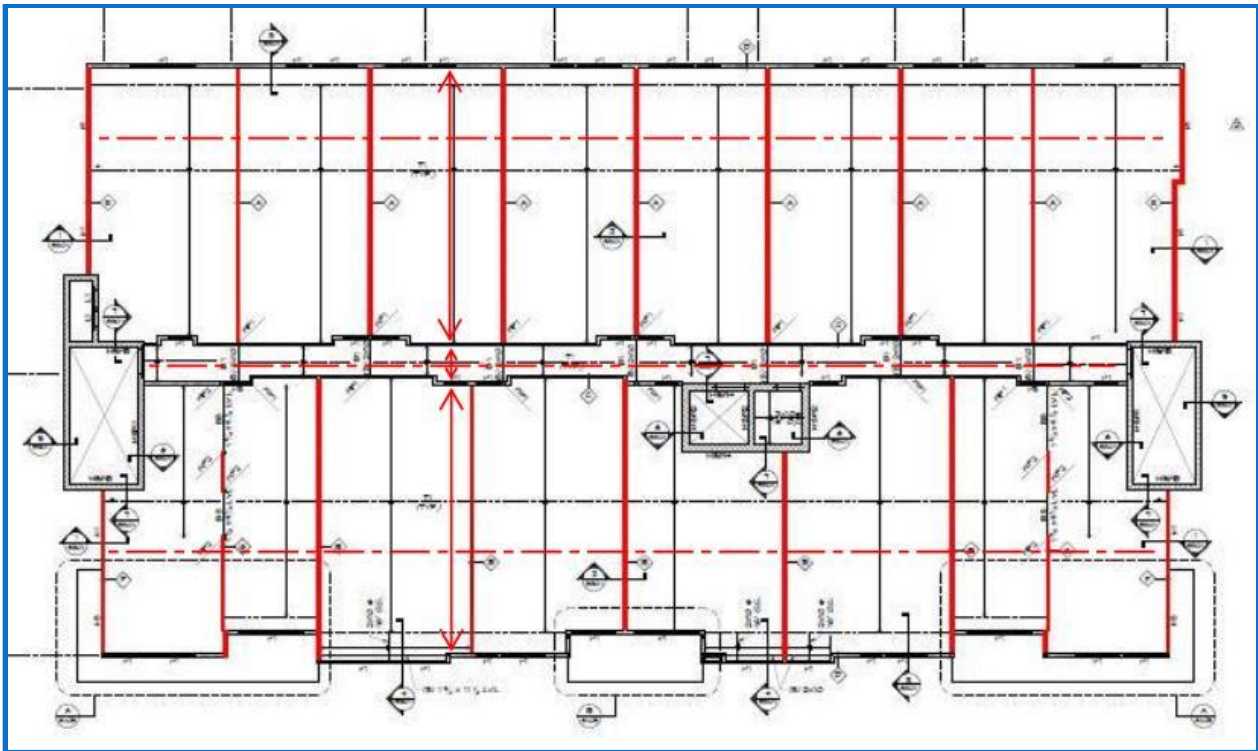
Figure 25: Residential Framing Consideration – Option One
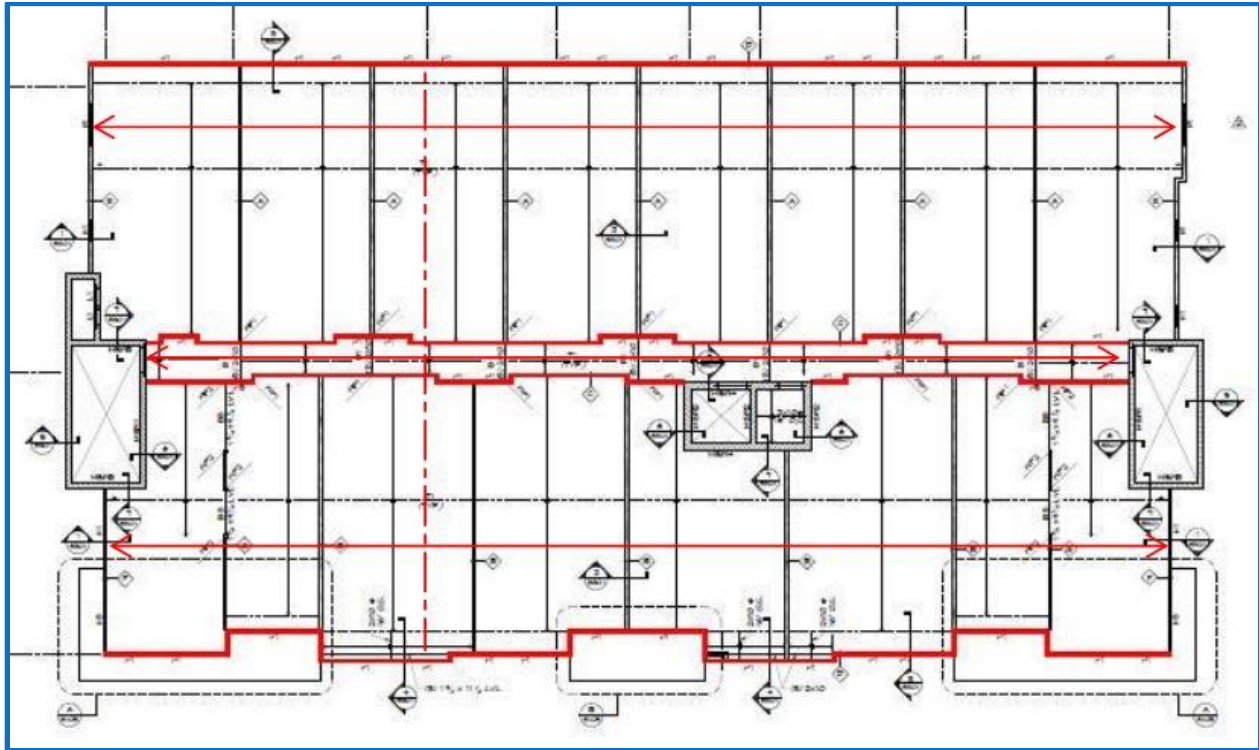
Figure 26: Residential Framing Consideration – Option 2

Joists under residential floors span a maximum of 23'-4$\frac{3}{16}$" and carry a typical superimposed dead load of 65.5 psf, which includes an estimated self-weight, and a live load of 40 psf with an additional 15 psf for partitions. These loads were used in combination with Vulcraft's steel joist design manual. Results have been listed in Table 05.

Bearing walls are designed using data from Clark-Dietrich's light gauge design manual. Load from the floor was converted from an area load to a line load using the tributary area. Assuming a 12" stud spacing, the line load was converted to an axial load per stud. This process was repeated for each floor, making sure to also include the load from floors above. Both 6" and 4" stud walls can be used, allowing walls to become thinner on upper levels of the building. More details are listed in Table 03.

Concrete slab on deck was designed using Vulcraft's steel deck design manual. A three-span condition was assumed for all floors. While this was not an issue with the residential levels due to only 16" spacing of joists, this allowed for wider spacing of members on the lower two levels. Deck information is listed in Table 06.
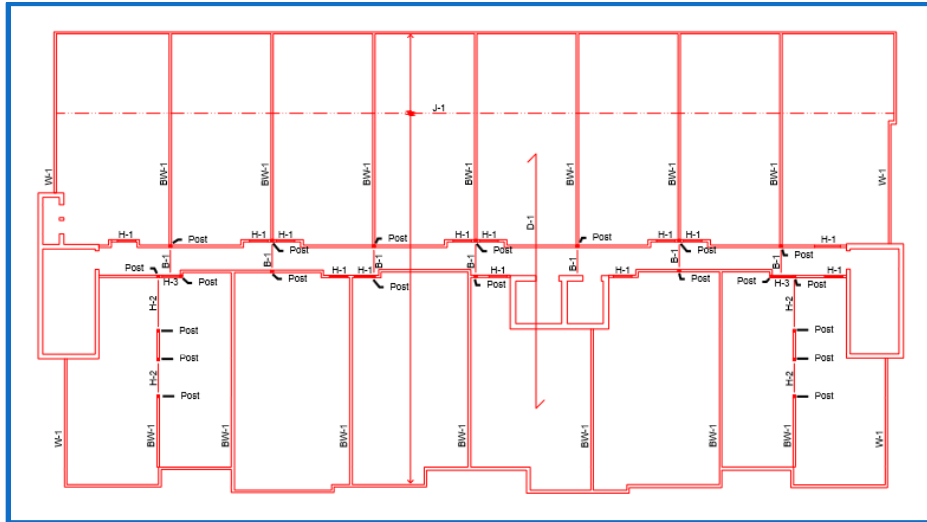
Figure 27: 7th Floor Framing Plan
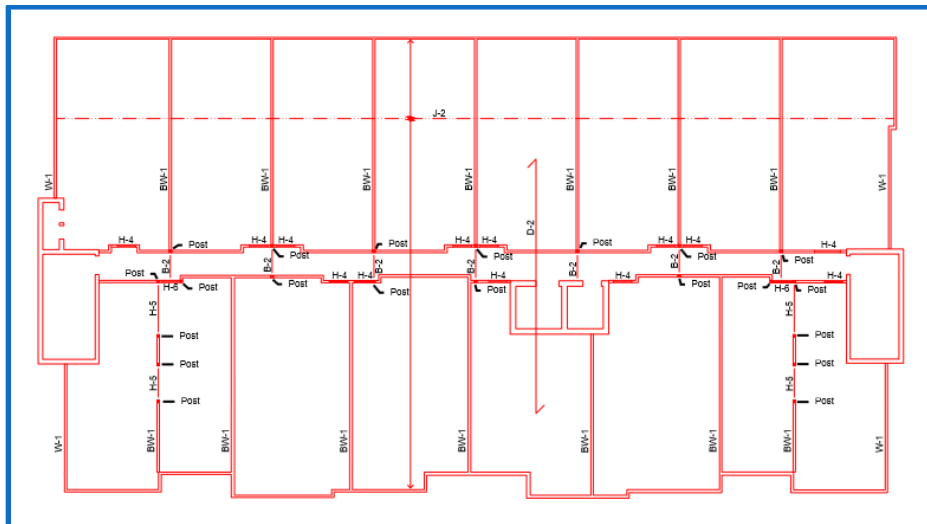
Figure 28: 6th Floor Framing Plan
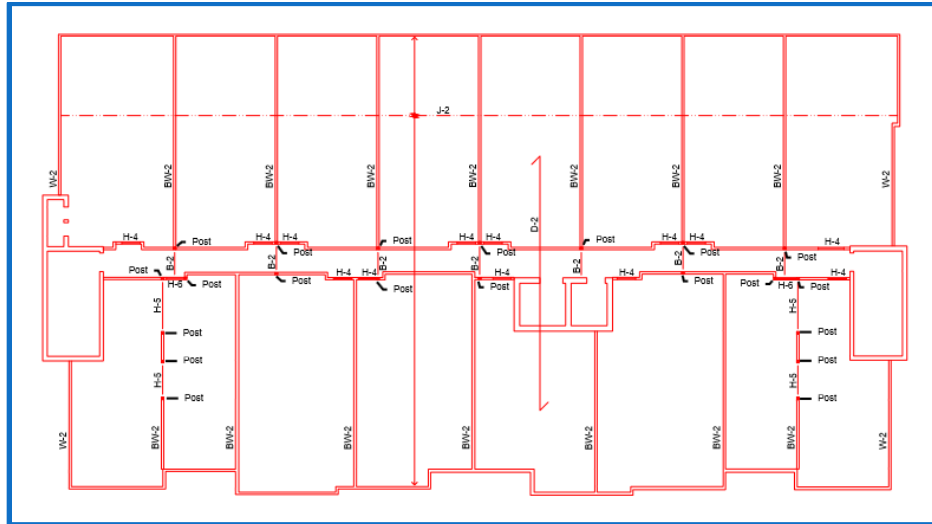
Figure 29: 4th-5th Floor Framing Plan
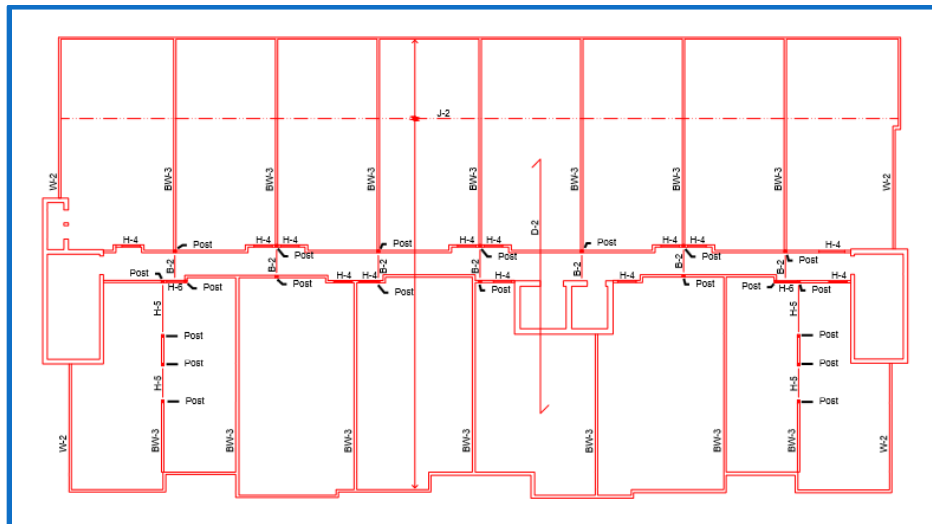
Figure 30: 3rd Floor Framing Plan

Interior Bearing Wall Schedule		
Name	Stud Type	Stud Spacing
BW-1	400S250-97	12"
BW-2	600S300-97	12"
BW-3	(2) 600S250-97	12"

Table 03: Interior Bearing Wall Schedule

Exterior Wall Schedule		
Name	Stud Type	Stud Spacing
W-1	400S162-54	12"
W-2	400S162-97	12"
W-3	600S162-97	12"

Table 04: Exterior Bearing Wall Schedule

Joist Schedule		
Name	Type	Spacing
J-1	12K5	16"
J-2	14K4	16"

Table 05: Joist Schedule

Diaphragm Schedule		
Name	Deck Type	Topping
D-1	1.5B24	--
D-2	1.5VLI22	2"
D-3	1.5VLR16	4"

Table 06: Diaphragm Schedule

Residential Level Beam and Header Schedule		
Name	Type	Notes
B-1	HSS 4.5x4.5x.1875	
B-2	HsSS 4.5x4.5x.3125	
H-1	HSS 4x2x.125	Oriented for Wask Axis Bending
H-2	HSS 5x4x.625	
H-3	HSS 4x4x.125	
H-4	HSS 4x2x.125	Oriented for Wask Axis Bending
H-5	HSS 6x4x.5	
H-6	HSS 5x4x.125	

Table 07: Residential Level Beam and Header Schedule

Residential Post Schedule		
Name	Type	Notes
Post	HSS 4x4x.3125	Typ. All Residential Levels

Table 08: Residential Post Schedule

Joist Bearing

The top of the stud walls are capped with a track. This piece would not be adequate for carrying the loads from the joists. Thus, a double angle section has been designed to assist in distributing this load. Assuming the joists from both sides of the wall are located at the midspan between two joists produces the maximum moment for design. Each joist applies approximately 1.4 kips to the wall resulting in a total moment of 8.6 in-kips. This load had been calculated in ASD. To use the member specification values in the AISC Steel Manual, this load was multiplied by a factor of 1.5 to convert the load to an approximate LRFD equivalent. 2x2 angles were used so the thickness of the 4" stud wall would not be exceeded. A 2L2x2x1/4 is adequate to carry this load.

Steel Framing

Transitioning from the third floor to the second floor, the structure changes from light gauge bearing walls to beam and column framing. Infil beams will span in the short direction of the building with girders spanning the long direction. This will create shorter spans for the girders and keep member sizes to a minimum. Since the bearing walls do not continue at the second floor, transfer beams were located directly under all bearing walls. These beams were designed to frame directly into columns. This also helps reduce girder size by reducing the amount of high mid-span point loads. The entrance to the garage at the second level is a special case. Here, a column could not be placed in line with the transfer beam. To keep member sizes small, the column line was shifted and shorter infils were added between two beams to transfer the load to the girders.

Partial composite beam design was used to keep member sizes smaller under more substantial loading conditions. Data from the AISC Steel Manual Table 3-19 was used to determine adequate member sizes for moment and shear as well as the required number of shear studs. Composite beams meet requirements for both composite and construction deflection.

Partial composite beam design is not necessary for all beams. Where loading and span conditions are minimal enough such that a shallow beam is adequate without the use of composite action, non-composite design is used.
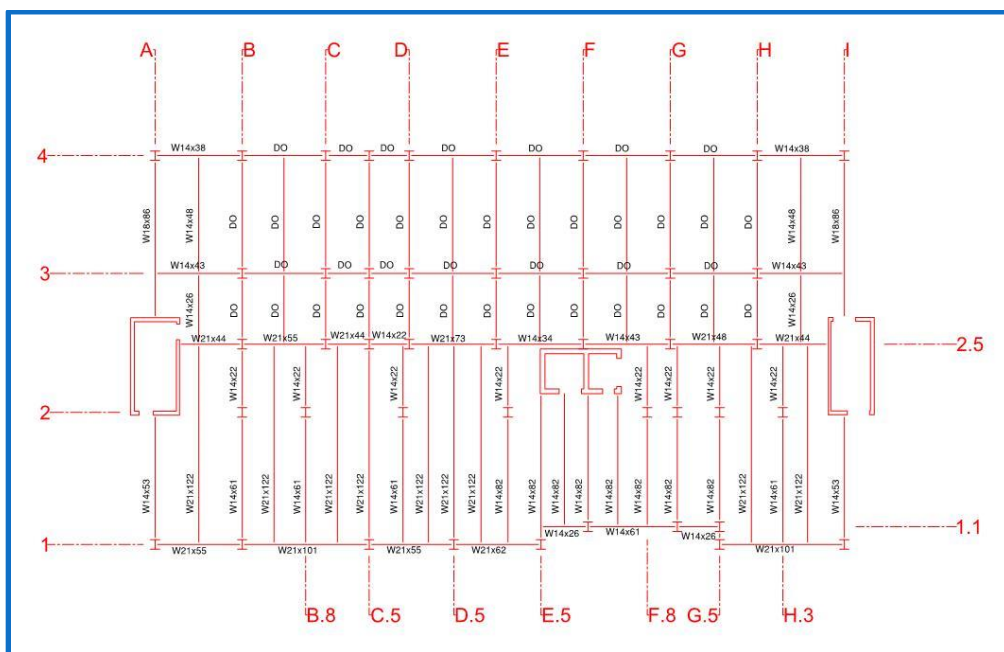
Figure 30: 2nd Floor Framing Plan
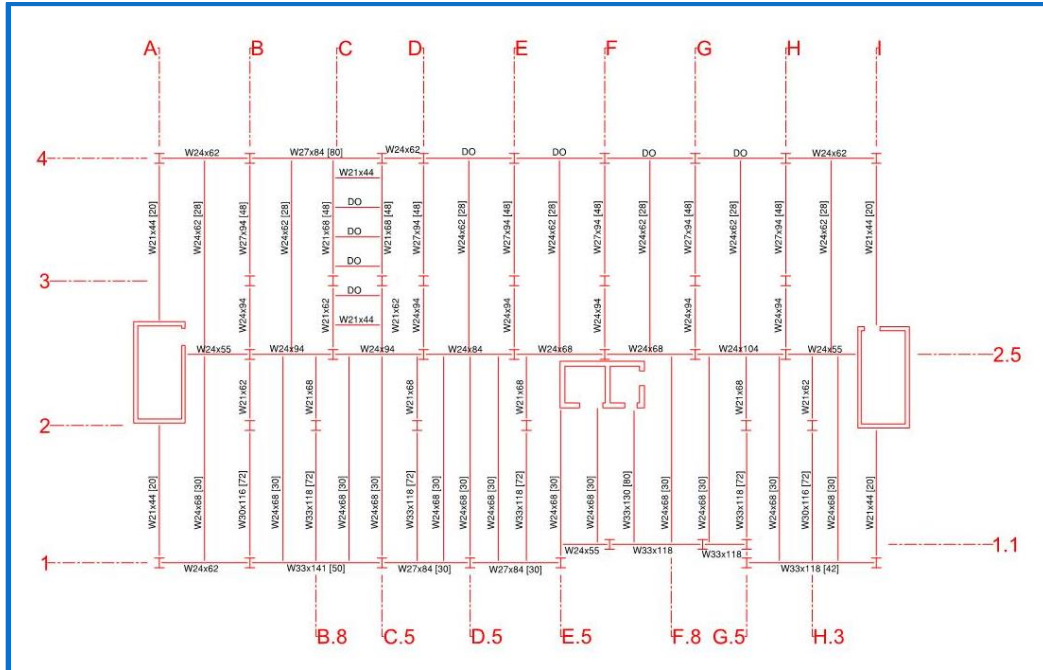
Figure 32: 1st Floor Framing Plan

Table 09a: Column Schedule

	1-A	1-B	1-C.5	1-D.5	1-E.5	1-G.5	1-I	1.1-F	1.1-G	1.1-G.5	2-B
Third Floor											
Second Floor											
First Floor	W12x26	W12x50	W12x50	W12x45	W12x40	W12x30	W12x30	W12x40	W12x30	W12x40	W12x45
Load to Base Plate (kips)	60	303.9	306	270	181.7	131.1	148.4	229.7	145.7	188.7	254

Table 09a: Column Schedule

	2-B.8	2-D	2-E	2-F.8	2-G	2-G.5	2-H.3	2.5-B	2.5-C	2.5-C.5	2.5-D
Third Floor											
Second Floor											
First Floor	W12x45	W12x45	W12x45	W12x19	W12x19	W12x45	W12x45	W12x45	W12x40	W12x26	W12x53
Load to Base Plate (kips)	254	254	261	31.3	31.3	261	254	267.5	242.5	45.9	339

Table 09b: Column Schedule (Continued)

	2.5-E	2.5-F	2.5-G	2.5-H	3-B	3-C	3-C.5	3-D	3-E	3-F	3-G
Third Floor											
Second Floor											
First Floor	W12x53	W12x40	W12x50	W12x50	W12x50	W12x50	W12x50	W12x50	W12x50	W12x50	W12x50
Load to Base Plate (kips)	323.7	188.9	297.3	290.8	290.7	290.7	290.7	290.7	290.7	290.7	290.7

Table 09c: Column Schedule (Continued)

	3-H	4-A	4-B	4-C	4-C.5	4-D	4-E	4-F	4-G	4-H	4-I
Third Floor											
Second Floor											
First Floor	W12x50	W12x26	W12x40	W12x22	W12x40	W12x40	W12x40	W12x40	W12x40	W12x40	W12x26
Load to Base Plate (kips)	290.7	57.9	229.7	33.7	229.7	229.7	229.7	229.7	229.7	229.7	57.9

Table 09d: Column Schedule (Continued)
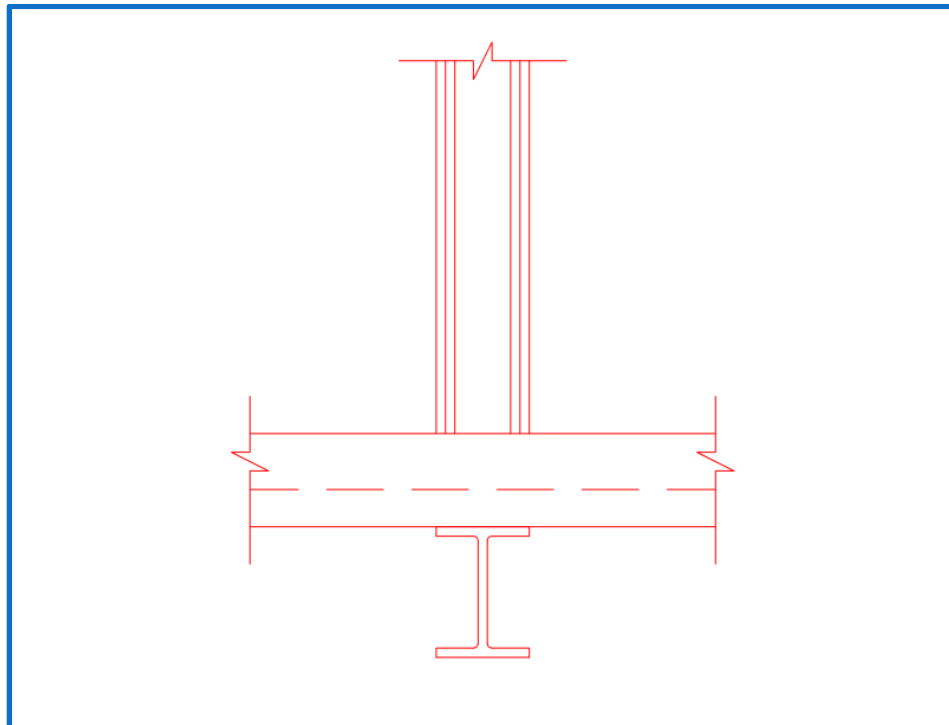
Figure 33: Bearing Wall over Beam Detail
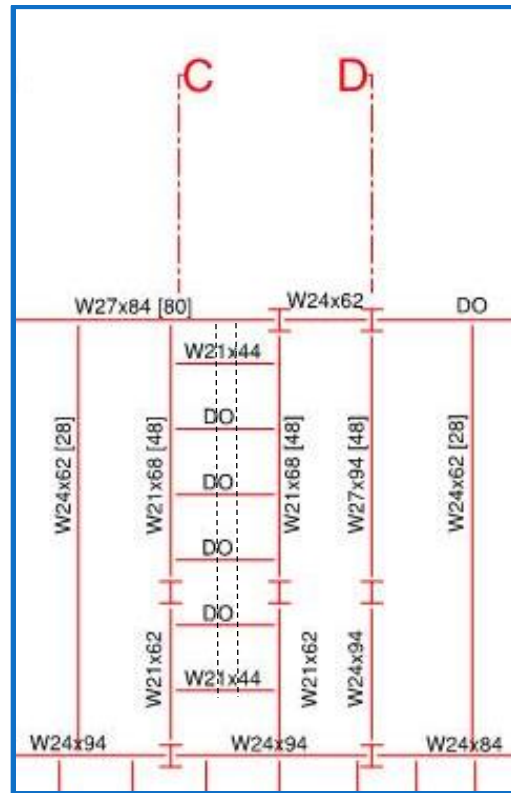
Figure 34: Enlarged View of 2nd Floor Framing at Garage Entrance

Lateral

Since the diaphragms of levels four through seven are changing from flexible wood to rigid concrete slab on deck, load distribution is based on the stiffness of each lateral element. Thus, masonry shear walls will remain to be the lateral force resisting system, but have been redesigned for updated load distribution.

Masonry Shear Walls

All reinforced masonry shear walls have been redesigned based on updated load distributions. The existing floor structure consisted of a flexible wood diaphragm for most levels of the building. The proposed diaphragm is considered to be rigid. Therefore, load distribution is no longer based on tributary area, but relative stiffness of the shear walls.

The shear walls were designed based on a balanced failure assumption. The ratio of steel to masonry was not allowed to pass the balance point. This means the steel will yield before the masonry fails, resulting in a ductile failure. To ensure adequate flexural strength, the resulting stresses in the steel and concrete are not larger than the maximum values as specified in the TMS code. The shear capacity of the masonry of

each wall was determined to be grater then the applied stresses, meaning no steel reinforcement is necessary. Reinforcement bars have been specified regardless satisfying the TMS provision for minimum reinforcement in an ordinary reinforced masonry shear wall.
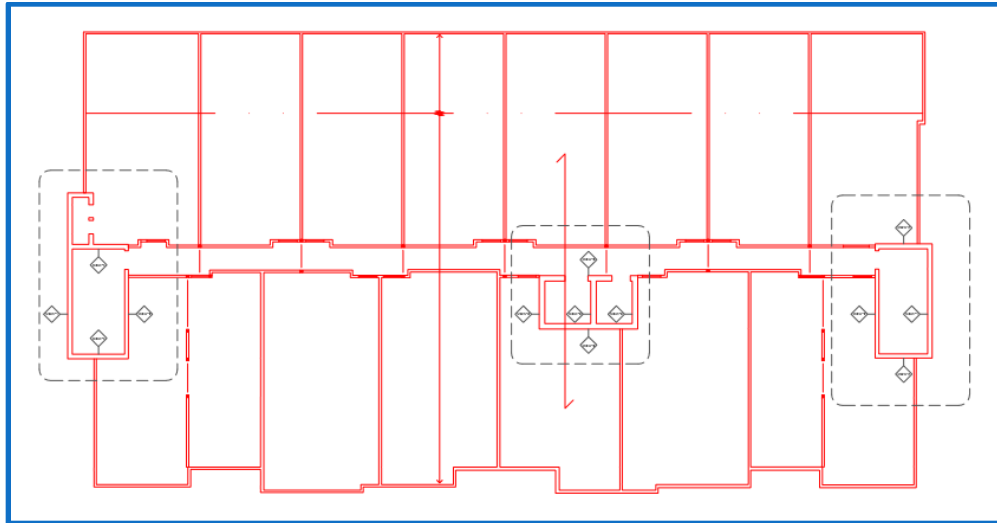
Figure 35: Masonry Shear Wall Callouts
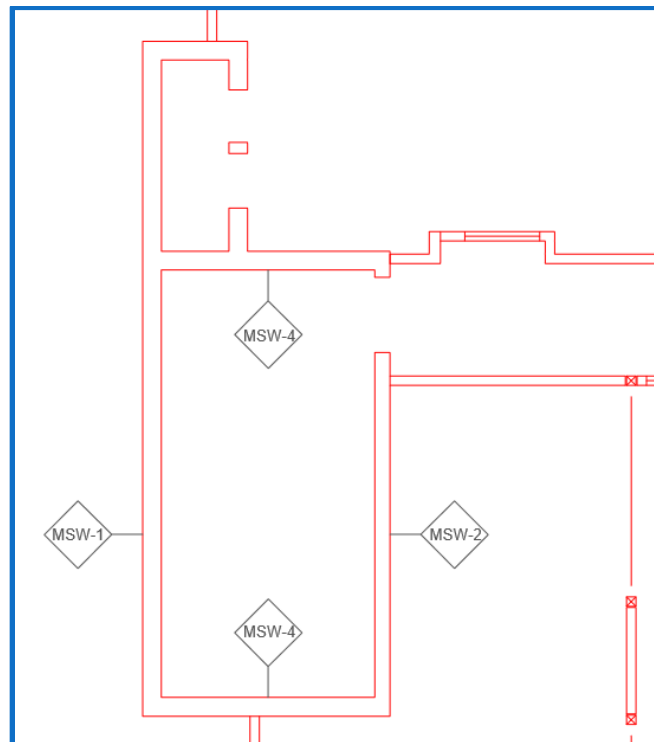
Figure 56a: Enlarged View of Masonry Shear Walls
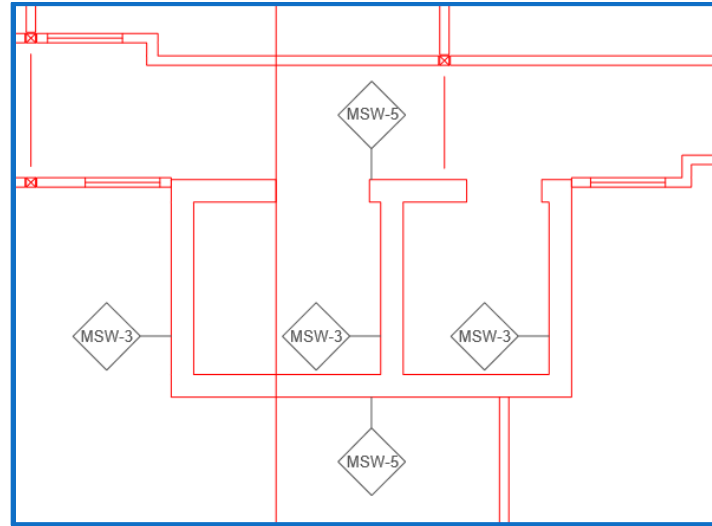
Figure 36b: Enlarged View of Masonry Shear Walls
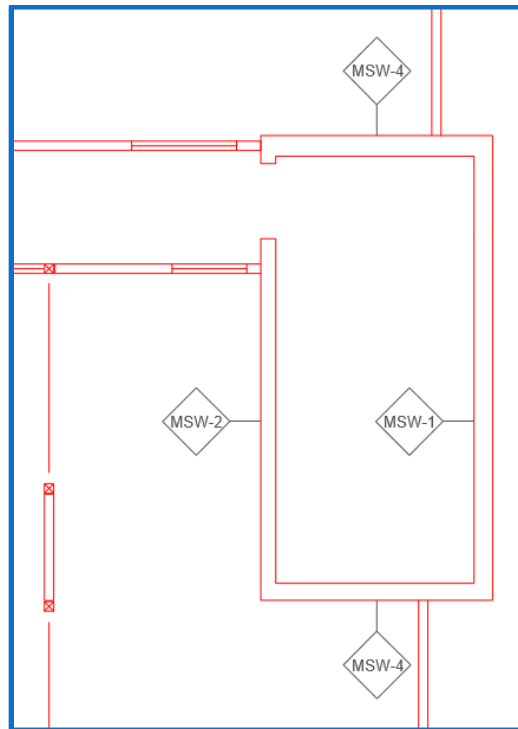
Figure 36c: Enlarged View of Masonry Shear Walls

Masonry Shear Wall Schedule								
Type	Thickness	f'm	Jamb Steel	Vert. Bars	Spacing	Horiz. Bars	Spacing	Notes
MSW-1	10"	1900 psi	(12) #8	#5	48"	#5	48"	Place Jamb Steel in 2 Rows.
MSW-2	12"	2500 psi	(14) #8	#5	48"	#5	48"	"
MSW-3	12"	1900 psi	(4) #8	#5	48"	#5	48"	"
MSW-4	12"	3500 psi	(6) #8	#5	48"	#5	48"	"
MSW-5	12"	2500 psi	(16) #8	#5	48"	#5	48"	"

Table 10: Masonry Shear Wall Schedule

Extended Research

Economics Breadth

Goal

This study proposes a few alterations to the architecture of the building. First, all parking from both levels can be relocated to a sub-grade level. Also, any non-apartment unit space will be moved from the second level to the ground level. With the second level now vacant, aside from dwelling units, the empty space can be filled with more apartments.

These alterations increase the available rentable property and provide more income for the owner. However, to accomplish this, an additional floor must be constructed. To determine if this proposed alteration would be economically beneficial, an estimate of the additional floor construction will be compared to the present value of the estimated income from 20 years of rent.

Analysis

Income gained will be based on the square foot cost of rentable property. After some research, the average rent per square foot in Pennsylvania is $1.20. The existing second and third floor plans are used to determine the increase in rentable space. The existing plan includes 2712 square feet of apartments. The proposed plan will include 10238 square feet, increasing the total rentable space by 7526 square feet. Using the average rent mentioned above, the owner will be paid an extra $9031.20 per year. To better compare this to the construction estimate, the present value must be calculated. Assuming 5% interest over a 20 year period, the present value of the rent paid comes to $112548.71.
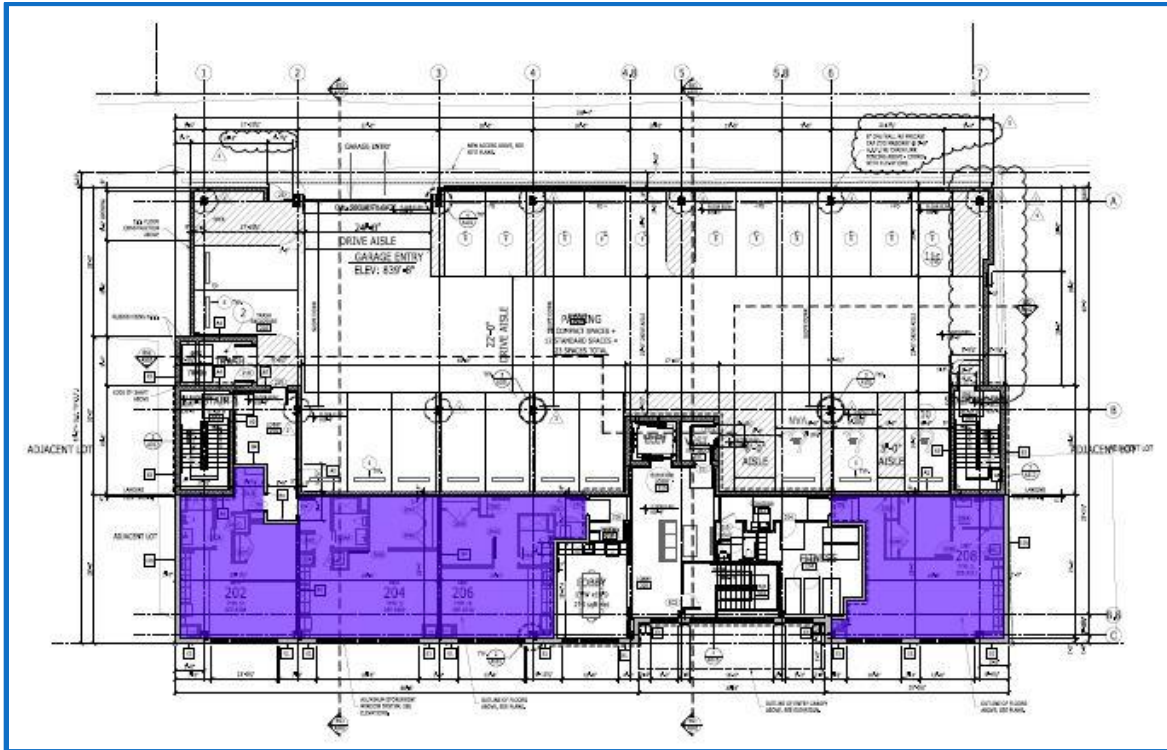
Figure 37: Existing Rentable Space at 2ⁿᵈ Floor

Figure 38: Proposed Rentable Space at 2ⁿᵈ Floor

The estimated cost of construction will include excavation, concrete, formwork, reinforcement, and structural steel. A more in depth breakdown of the estimate can be found in Table 11. Data from the RS Means Building Construction Cost manual was used to estimate costs for materials, labor, and equipment. The final estimated cost to construct this additional level comes to $665511.76.

RS Means Code	Item	Units	Quantity	Mat'l Unit Cost	Mat'l Cost	Labor Unit Cost	Labor Cost	Equip Unit Cost	Equip Cost	Total
					$ -		$ -		$ -	
	Formwork				$ -		$ -		$ -	
03 11 13.85 4200	Forms in Place, Walls, Below Grade, Job-Built Plywood, 1 Use	SFCA	4860	$ 2.48	$ 12,052.80	$ 9.55	$ 46,413.00		$ -	
					$ -		$ -		$ -	
					$ -		$ -		$ -	
	Concrete				$ -		$ -		$ -	
03 31 13.35 0150	Heavyweight Concrete, Ready Mix, 3000 psi	C.Y.	512.4	$ 99.00	$ 50,727.60		$ -		$ -	
03 31 13.70 4300	Placing Concrete, Slab on Grade, Up to 6' Thick, Direct Chute	C.Y.	251.3		$ -	$ 16.70	$ 4,196.71	$ 0.60	$ 150.78	
13 31 13.70 5100	Placing Concrete, Walls, 12" thick, Pumped	C.Y.	150		$ -	$ 23.00	$ 3,450.00	$ 7.05	$ 1,057.50	
					$ -		$ -		$ -	
					$ -		$ -		$ -	
	Reinforcement				$ -		$ -		$ -	
03 21 11.60 0700	Reinforcing in Place, Walls, #3 to #7	Tons	9	$ 1,000.00	$ 9,000.00	$ 540.00	$ 4,860.00		$ -	
03 22 11.10 0700	Plain Welded Wire Fabric, 4x4 - W4xW4	C.S.F	135.7	$ 50.50	$ 6,852.85	$ 32.50	$ 4,410.25		$ -	
					$ -		$ -		$ -	
					$ -		$ -		$ -	
	Steel				$ -		$ -		$ -	
05 12 23.17 7200	Columns, Structural, W12x87	L.F.	240	$ 127.00	$ 30,480.00	$ 2.86	$ 686.40	$ 1.55	$ 372.00	
05 12 23.75 2380	Structural Steel Members, W14x90	L.F.	1592	$ 131.00	$ 208,552.00	$ 3.80	$ 6,049.60	$ 2.07	$ 3,295.44	
05 12 23.75 4780	Structural Steel Members, W21x122	L.F.	458	$ 178.00	$ 81,524.00	$ 4.05	$ 1,854.90	$ 1.67	$ 764.86	
					$ -		$ -		$ -	
					$ -		$ -		$ -	
	Excavation				$ -		$ -		$ -	
31 23 16.42 0250	Excavating, Excavator, Hydraulic, Crawler, 1-1/2 C.Y. cap.	B.C.Y	6032		$ -	$ 0.70	$ 4,222.40	$ 1.03	$ 6,212.96	
31 23 23.20 0054	Hauling, 30 MPH ave, Cycle 8 Miles	L.C.Y.	7761		$ -	$ 2.09	$ 16,220.49	$ 2.90	$ 22,506.90	
					$ -		$ -		$ -	
					$ -		$ -		$ -	
	Subtotals				$ 399,189.25		$ 92,363.75		$ 34,360.44	$ 525,913.44
	Sales Tax		7%		$ 27,943.25		$ -		$ 2,405.23	$ 30,348.48
	Overhead & Profit		20%		$ 85,426.50		$ 18,472.75		$ 7,353.13	$ 111,252.38
	Subtotals with OH&P				$ 512,559.00		$ 110,836.50		$ 44,118.80	$ 667,514.30
	Contingency		0%		$ -		$ -		$ -	$ -
	Adjustments		0.997	1	0.997		0.997		0.997	
	Total Bid				$ 511,021.32		$ 110,503.99		$ 43,986.45	$ 665,511.76

Table 11: Cost Estimation for Sub-Grade Parking Level

Outcome

After estimating the present value of the additional income from rent ($112548.71) and the cost of constructing the sub-grade parking level ($665511.76), a decision can be determined on the economic benefit of this proposed alteration. Considering the above data, the cost of construction is $552963.05 more than the income from rent. Therefore, the proposed alteration to the buildings architecture is not recommended.

Acoustics Breadth

Goal

This study is intended to ensure that the sound transmission levels of the proposed steel stud walls are equivalent to or better than the existing wood stud walls. Consulting Architectural Acoustics: Principles and Design, doubling the mass of a system results in a roughly 5-6 dB increase in transmission loss. Following this rule, the masses of the proposed wall and floor systems will be compared to the masses of the existing systems to determine the adequacy of the proposed system.

Analysis

Three assemblies will be reviewed in this study. The first will be a party wall between apartment units. Party walls are required to have a Sound Transmission Class (STC) of at least 50. Exterior walls will also be tested for adequacy assuming a required STC of 30. Finally, floor assemblies will be reviewed. They will be tested for conformance to both STC and Impact Insulation Class (IIC). Floor assemblies must have an STC and IIC of at least 50. Refer to Table 12 for a breakdown of analysis results.

Assembly	Required STC	Existing Mass	Existing STC	Proposed Mass	Proposed STC
Party Wall	50	.36	50	.48	51.7
Exterior Wall	30	.36	--*	.57	--*
Floor	50	.60	64	1.28	69.3

Table 12: Comparison of Existing and Proposed Assembly STC and IIC Values

The architectural drawings did not specify the STC of the exterior walls. Thus, these values could not be accurately represented. However, assuming that the existing wall is adequate, the proposed wall will be adequate as well based on mass.

IIC values for the floor have been estimated based on sound rated assemblies of floors that match the proposed system. The assembly of concrete slab-on-deck, steel bar joists, batt insulation, and gypsum board is rated an IIC of roughly 35. To meet the required 50, floor underlayment is needed. A sample from a flooring supplier is rated an IIC of 67 which brings the assembly over the requirement.

Outcome

The results above show that each of the proposed assemblies are equivalent, or better than, the existing assemblies for STC and IIC. This means less sound will travel through the proposed assemblies. Thus, the proposed system can still be considered since it meets sound transmission requirements.

Concluding Remarks

Flats on Fifth is a seven story podium building consisting of two levels of steel framing and five levels of wood joists and bearing walls. The lateral force resisting system utilizes reinforced masonry shear walls at three locations in the building. This system has been altered to steel bar joists and metal stud bearing walls at residential levels with an altered steel framing layout at the first two levels. Masonry shear walls have been redesigned for updated lateral loading since floor diaphragms have changed from flexible to rigid.

To determine if the proposed design should be recommended, a cost estimate will be compared to the cost of the existing structure. Based on an estimate from Castlebrook Development Group, the existing structure costs roughly $4.7 million. The proposed structure comes to about $3.2 million. This is a difference of $1.5 million. However, this may not be an accurate comparison as the specific details of the existing structural cost estimate are unknown. So, to help make a decision relative construction times will be considered.

Most of the building consists of residential dwelling units framed with joists and bearing walls. Both the existing system and the proposed system are able to be prefabricated, so the length of construction should not be affected much. The floor diaphragms, however, change from wood sheathing to concrete slab on deck. Walls can be erected immediately above the wood sheathed floor. To build on top of the concrete slab on deck, the concrete must be allowed to cure for at least seven days. This will likely add time to the construction schedule. The lower two floors make use of additional rows of columns to reduce column sizes. Installing the additional columns and beams will likely add time to the schedule.

Based on the observations made above, it does not seem like the proposed alternative structure can be recommended.

PSU AE – ABET 2.3

A goal from the start of this thesis was to complete the structural redesign without altering the architecture of the building. Aside from a few minor alterations, this goal has been accomplished. Of these alterations, ceilings of most residential levels must be lowered by less than 2". However, party walls from the sixth floor up and exterior walls from the third floor up can be reduced from 6" wood studs to 4" metal studs, reducing the thickness of the walls.

PSU AE – ABET 2.4

Structural elements were designed individually to result in more accurate load cases. This prevents the use of oversized beams, columns, and other elements. The variation in bearing wall sizes, as mentioned above, is an example of the results produced by this type of design.

Acknowledgements

- Thank you to the AE faculty, especially Dr. Boothby for being my advisor for this thesis.

- Thank you to David Laffey of Castlebrook Development Group for giving me permission to study Flats on Fifth for my thesis.

- Special thanks to Keystone Structural Solutions for giving me the opportunity to learn with them through internship and providing me with the necessary information to complete my thesis.

- Thanks to the architect of record for helping me learn more about Flats on Fifth.

Appendices

Appendix A – Sample Calculations

Roof Deck:

Max Clear Span: 16"

Load:
$D = 28.5$ psf
$L_r = 20$ psf
$S = 21$ psf
$S_d = 43$ psf

$V_{max} = 92.5$ psf

Per Vulcraft Deck Manual:

| 1.5 B 24 |

3-Span Condition

Max Const. Span: 5'-10"

Allowable Load: 154 psf
120 psf (1/240)

Floor Deck 1:

Max Clear Span: 16"

Load:
$D = 65.5$ psf
$L = 55$ psf

$W_{max} = 120.5$ psf

Per Vulcraft Deck Manual:

| 1.5 VLI 22 $t = 2''$ |

3-Span Condition

Max Const. Span: 7'-10"

Allowable load: 314 psf

Floor Deck 2:

Max Clear Span: 8'-7"

Load:
$D = 75$ psf
$L = 100$ psf

$W_{max} = 175$ psf

Per Vulcraft Deck Manual:

| 1.5 VLR 16 $t = 4''$ |

3-Span Condition

Max Const. Span: 9'-1"

Allowable Load: 276 psf

Figure AP01: Vulcraft Deck Calculations

Typical Roof Joist:

Span: 23'-4 3/16"
Spacing: 16" o.c.

Loading: $D = 28.5$ psf $(19/12) = 37.9$ plf
$L_r = 20$ psf $(16/12) = 26.6$ plf
$S = 21$ psf $(16/12) = 27.9$ plf
$S_d = 43$ psf $(16/12) = 57.2$ plf

$W_{max} = 37.9 + [27.9 + 57.2] = 123$ plf

Per Vulcraft Joist Manual:

> 12 K 5
>
> $W_{max} = 282$ plf
> $= 132$ plf for $\Delta = l/360$

Typical Floor Truss:

Span: 23'-4 3/16"
Spacing: 16" o.c.

Loading: $D = 65.5$ psf $(16/12) = 87.1$ plf
$L = 55$ psf $(16/12) = 73.2$ plf

LL Red. $A_T = 23.35' \times 1.33' = 31.1$ ft²
$K_{LL} = 2$
$K_{LL} A_T = 2(31.1) = 62.2$ ft² < 400 ft² ∴ No Reduction

$W_{max} = 87.1 + 73.2 = 160.3$ plf

Per Vulcraft Joist Manual:

> 14 K 4
>
> $W_{max} = 295$ plf
> $= 165$ plf for $\Delta = l/360$

*Can use 12 K 5 if spacing is reduced to 12" o.c.

Figure AP02: Vulcraft Joist Calculations

5th Floor Interior Bearing Walls:

Trib. Width of Floor: 20.9'
Wall Length: 38.5'
Stud Spacing: 12" o.c.

LL Redi: $A_T = 20.9' \times 38.5' = 804.7$ ft²
$k_{LL} = 4$
$k_{LL} A_T = 4(804.7) = 3218.8$ ft² > 400 ft²

$$L = 40\left(.25 + \frac{15}{\sqrt{3218.8}}\right) = 20.6 \text{ psf} > .4(40) \checkmark$$

Load from Roof: $D = 28.5$ psf $(20.9) = 595.7$ plf
$L_r = 12$ psf $(20.9) = 250.8$ plf
$S = 21$ psf $(20.9) = 438.9$ plf
$S_i = 43$ psf $(20.9) = 898.7$ plf

Load from Floor: $D = 65.5$ psf $(20.9) = 1367$ plf
$L = 35.6$ psf $(20.9) = 744$ plf

Wall SW: $D = 58.5$ plf $(2) = 117$ plf

$W_{max} = \left[595.7 + 1367 + 117\right] + .75(744) + .75(438.9 + 898.7)$

$= 3640.9$ plf

Load per Stud: $P = \dfrac{3640.9}{12/12} = 3640.9$ lb

Per Clark-Dietrich: 400S250-97

$P_{max} = 3.98$ K for 11' unbraced
4" Stud

600S200-97
$P_{max} = 3.70$ K for 11' unbraced

Figure AP03: Interior Bearing Wall at 6th Story

2nd Floor Interior Bearing Wall:

Roof

Level 6 ─ 11'
Level 5 ─ 11'
Level 4 ─ 11'
Level 3 ─ 11'
─ 11.5'

Trib. Width: 20.9'
Wall Length: 38.5'
Stud Spacing: 12" o.c.

Load from Roof: $D = 595.7$ plf
$L_r = 250.8$ plf
$S = 438.9$ plf
$S_H = 898.7$ plf

Load from Floor: $D = 1367$ plf (4) $= 5468$ plf
$L = 744$ plf (4) $= 2976$ plf

Wall SW: $D = 58.5$ plf (4) $= 234$ plf   11' Wall

$D = 60.75$ plf   11.5' Wall

$W_{max} = [595.7 + 5468 + 234 + 60.75] + .75(2976) + .75(438.9 + 898.7)$

$= 9593.7$ plf

Load per Stud: $P = \dfrac{9593.7}{12/12} = 9593.7$ lb

Per Clark-Dietrich:

(2) 600S250-97

$P_{max} = 10.98$ K for 11' unbraced 6" Stud

Figure AP04: Interior Bearing Wall at 3rd Story

4th Floor Exterior Bearing Wall:

Trib Width: 10.6'   Wind: 8.2 psf
Wall Length: 38.5
Stud Spacing: 12" OC.

Load from Roof:
$D = 302.1$ plf
$L_r = 167.5$ plf
$S = 222.6$ plf
$S_d = 455.8$ plf

Load from Floor:
$D = 694.3$ plf   (2) $= 1388.6$ plf
$L = 422.9$ plf   (2) $= 845.8$ plf

Wall SW:
$D = 60$ plf   11.28' Wall
$D = 58.5$ plf   (3) $= 175.5$ plf   11' Wall

$W_{max} = [302.1 + 1388.6 + 60 + 175.5] + .75(845.8) + .75[222.6 + 455.8] = 3069.4$ plf

Load Per Stud: $P = \dfrac{3069.4}{12/12} = 3069.4$ lb

Per Clark-Dietrich: $400 S162-68$

$P_{axial} = 3.43$ k   unbraced 12'
$P_{wind} = 20$ psf
4" Stud

$600 S162-54$

$P_{axial} = 4.48$ k   unbraced 12'
$P_{wind} = 20$ psf
6" Stud

Figure AP05: Exterior Bearing Wall at 5th Story

B2 :

Span : 6'
Trib. Width : 18.5'

LL Red.: $A_T = 6' \times 18.5' = 111 \; ft^2$
$K_{LL} = 2$
$K_{LL}A_T = 2(111) = 222 \; ft^2 < 400 \; ft^2$ ∴ No Reduction

Loading : $D = 65.5 \; psf \; (18.5) = 1211.8 \; plf$
$L = 55 \; psf \; (18.5) = 1017.5 \; plf$

Steel SW: $D = 25 \; plf$

$W_{max} = [1211.8 + 25] + 1017.5 = 2254.3 \; plf$

$V_{max} = \dfrac{2254.3 (6)}{2} = 6762.9 \; lb$

$M_{max} = \dfrac{2254.3 (6)^2}{8} = 10144.4 \; ft \cdot lb$

Try: HSS $4\frac{1}{2} \times 4\frac{1}{2} \times \frac{5}{16}$

$SW = 16.96 \; plf < 25 \; plf$ ✓

$M_n/\Omega = 18.1 \; ft \cdot k > 10.1 \; ft \cdot k$ ✓

$V_n/\Omega = .6 (50) [2(3.64)(.291)] / 1.67 = 38.1 \; k > 6.8 \; k$ ✓

$h/t = 12.5$

$1.1 \sqrt{k_v E / F_y} = 59.2 > 12.5$ ∴ $C_{v2} = 1.0$

$\Delta_{limit} = \ell/360 = .2''$

$\Delta = \dfrac{5(2.25)(6)^4(1728)}{384(29000)(13.4)} = .17'' < .2''$ ✓

Use : $\boxed{HSS \; 4\frac{1}{2} \times 4\frac{1}{2} \times \frac{5}{16}}$

Figure AP06: Residential Level Beam

H4:

Span: 4.5'
Trib. Width: 16"

LL Red: $A_T = 5.99 \, ft^2$
         $k_{LL} = 2$
         $k_{LL} A_T = 2(5.99) = 11.98 \, ft^2 < 400 \, ft^2$ ∴ No Reduction

Loading: $D = 65.5 \, psf \, (^{16}/_{12}) = 87.1 \, plf$
          $L = 55 \, psf \, (^{16}/_{12}) = 73.2 \, plf$

Wall SW: $D = 20 \, plf$

Steel SW: $D = 15 \, plf$

$W_{max} = \left[87.1 + 20 + 15 \right] + 73.2 = 195.3 \, plf$

$V_{max} = \dfrac{.1953 \, (4.5)}{2} = .44 \, K$

$M_{max} = \dfrac{.1953 (4.5)^2}{8} = .49 \, ft \cdot K$

Try: HSS $4 \times 2 \times \frac{1}{8}$ (Weak Axis Orientation)

      $SW = 4.75 \, plf < 15 \, plf$ ✓

      $M_n/\Omega = 2.34 \, ft \cdot K > .49 \, ft \cdot K$ ✓

      $V_n/\Omega = .6 (50) \left[2(1.65)(.116) \right] / 1.67 = 6.88 \, K > .44 \, K$ ✓

          $b/t = 14.2$

          $1.1 \sqrt{k_v E / F_y} = 57.2 > 14.2$ ∴ $C_{v2} = 1.0$

      $\Delta_{limit} = \ell/360 = .15''$

      $\Delta = \dfrac{5(.1953)(4.5)^4 (1728)}{384 (29000)(.898)} = .069'' < .15''$ ✓

Use: | HSS $4 \times 2 \times \frac{1}{8}$ (Weak Axis Oriented) |

Figure AP07: Residential Level Header

<u>Post</u> : Residential Levels

Max. Height : 11.5'

Load from Roof : P = 5.16   K

Load from Floor : P = 12.15   K

Steel SW :   D = 25   plf

$$P_{max} = 5.16 + 4(12.15) + \frac{25[11.5 + 4(11)]}{1000} = 55.1 \ K$$

Try :   HSS 4x4 x 5/16

$P_n/\Omega = 62 \ K \ > 55.1 \ K$ ✓

$SW = 14.83 \ plf < 25 \ plf$ ✓

Use : | HSS 4x4 x 5/16 |
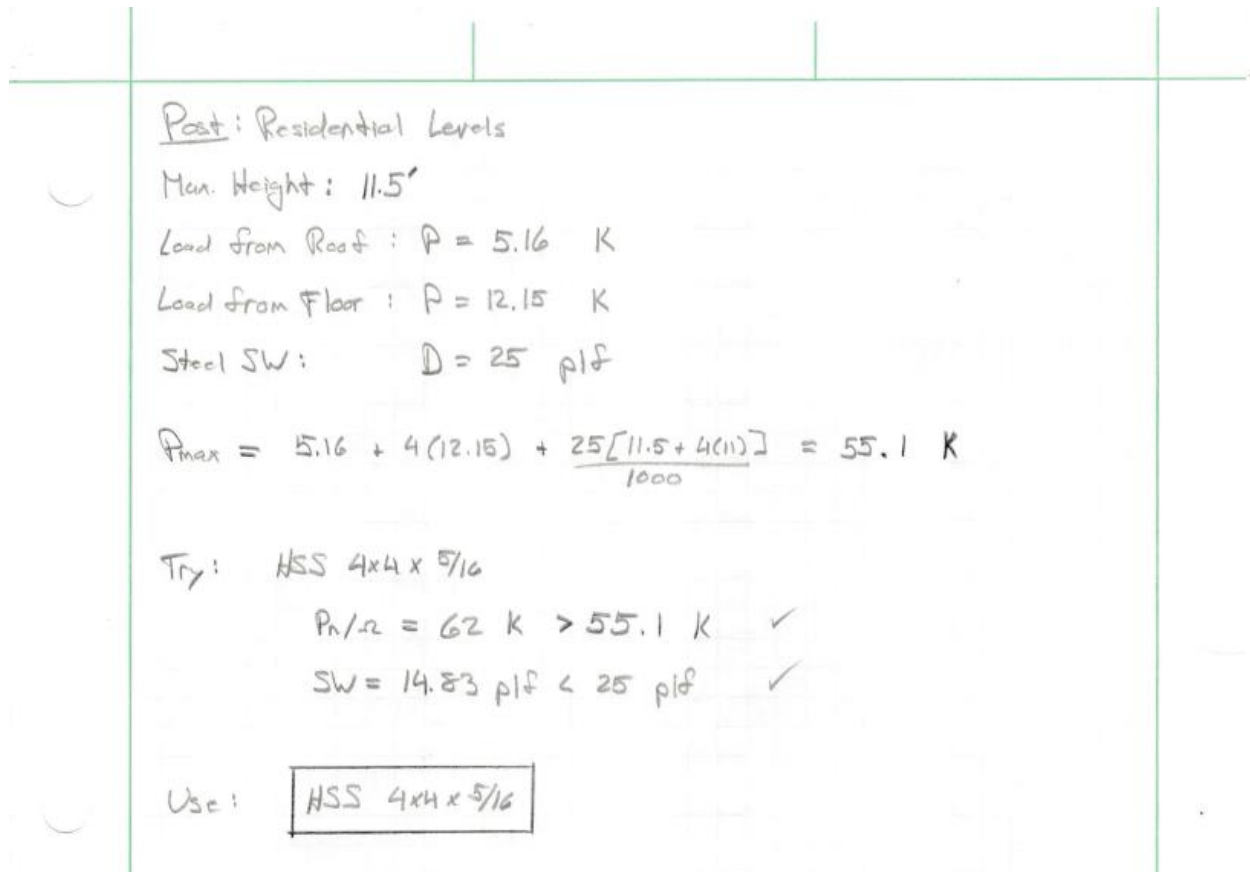
Figure AP08: Residential Level Post

Beam B:

Span: 25' $t = 4"$
Trib. Width: 9.25' $f'_c = 5^*$

LL Red.! $A_T = 25' \times 9.25' = 231.25 \, ft^2$
           $k_{LL} = 2$
           $k_{LL} A_T = 2(231.25) = 462.5 \, ft^2 > 400 \, ft^2$

           $L = 40 \left(.25 + \dfrac{15}{\sqrt{462.5}} \right) = 37.9 \, psf \qquad > .4(40) \; \checkmark$

Load from Wall: $W = 9593.7 \, plf$

Load from Floor: $D = 65.5 \, psf \; (9.25) = 605.88 \, plf$
                  $L = 52.9 \, psf \; (9.25) = 489.3 \, plf$

Steel SW: $D = 150 \, plf$

$W_{max} = 9593.7 + 605.88 + 150 + 489.3 = 10\,838.9 \, plf$

$V_{max} = \dfrac{10.8(25)}{2} = 135 \; K$

$M_{max} = \dfrac{10.8(25)^2}{8} = 843.75 \; ft \cdot k$

Assume 48 Studs ($^3/_4"$) ($^2/rib$)   Studs Required = 48

$\sum Q_n = 24(14.6) = 350.4$ $a = \dfrac{345}{.85(5)(75)} = 1.08"$

$b' = \begin{cases} 25(12)/8 = 37.5" \\ 9.25(12)/2 = 55.5" \end{cases}$

$b_{eff} = 2(37.5) = 75"$ $y_2 = 4 - \dfrac{1.08}{2} = 3.46" \qquad \therefore$ Conservative

$a = \dfrac{350.4}{.85(5)(75)} = 1.1"$ $I_{LB} = 4760 \, in^4 \qquad \Delta_{limit} = \dfrac{25(12)}{360} = .83"$
                                                        $I = 3270 \, in^4$

$y_2 = 4 - \dfrac{1.1}{2} = 3.45"$ $\Delta = \dfrac{5(10.8)(25)^4(1728)}{384(29000)(4760)} = .69" < .83" \; \checkmark$

Table 3-19: W27×94 $W_{constr} = \left[605.88 + 150 \right] + 20(9.25) = 940.88 \, plf$

   PNA: 7 $\Delta_{constr.} = \dfrac{5(.94)(25)^4(1728)}{384(29000)(3270)} = .087" < .83" \; \checkmark$
   $\sum Q_n = 345 \; K$
   $M_{n/a} = 914 \, ft \cdot k$ Use: $\boxed{\text{W27×94 [48]}}$
   $y_2 = 3"$

Figure AP09: 2nd Floor Framing – Partial Composite Beam Under Bearing Wall

Beam A4:

Span: 25'   t = 4"
Trib. Width :   9.25' $f'_c = 5$ ksi

Load from Floor : $D = 62$ psf $(9.25) = 573.5$ plf
                     $L = 40$ psf $(9.25) = 370$ plf

Steel SW: $D = 150$ plf

$W_{max} = [573.5 + 150] + 370 = 1093.5$ plf

$V_{max} = \dfrac{1.1 (25)}{2} = 13.75$ K

$M_{max} = \dfrac{1.1 (25)^2}{8} = 85.9$ ft·K

Table 6-2 :   W14 × 48

  $SW = 48$ plf < 150 plf   ✓
  $M_n/\Omega = 92.7$ ft·k > 85.9 ft·k   ✓
  $V_n/\Omega = 93.8$ k > 13.75 K   ✓
  $\Delta_{limit} = \dfrac{25(12)}{360} = .83"$

  $\Delta = \dfrac{5(1.1)(25)^4(1728)}{384(29000)(484)} = .69" < .83"$ ✓

Use: | W14 × 48 |

Figure AP10: 1st Floor Framing – Non-Composite Beam

Column 30 :

Height: 10.2'

Load: $P_1 =$ 8.25 k

$P_2 =$ 7.0 k

$P_3 =$ 9.3 k

$P_4 =$ 24.0 k

$P_5 =$ 217.4 k

$P_{sw} =$ 1.5 k

$P_{max} =$ 267.5 k

Table 6-2 | W12 x 45
$P_n/a = 281$ k

Column 31:

Height: 10.2'

Load: $P_1 =$ 8.25 k

$P_2 =$ 21.5 k

$P_3 =$ 20.0 k

$P_4 =$ 191.2 k

$P_{sw} =$ 1.5 k

$P_{max} =$ 242.5 k

Table 6-2 | W12 x 40
$P_n/a = 250$ k

Column 32 :

Height: 10.2'

Load: $P_1 =$ 8.25 k

$P_2 =$ 25.8 k

$P_3 =$ 8.1 k

$P_4 =$ 2.2 k

$P_{sw} =$ 1.5 k

$P_{max} =$ 45.9 k

Table 6-2 : | W12 x 26
$P_n/a = 131$ k

Column 33:

Height: 10.2'

Load: $P_1 =$ 8.25 k

$P_2 =$ 7.0 k

$P_3 =$ 42.9 k

$P_4 =$ 279.3 k

$P_{sw} =$ 1.5 k

$P_{max} =$ 339 k

Table 6-2 : | W12 x 53
$P_n/a = 380$ k

Figure AP11: Column Design

CMU Wall:

$P = 1 K$

$h = 79.25 \, ft$
$l = 20.58 \, ft$

$\dfrac{h}{l} = \dfrac{79.25}{11} = 7.2 > 4$

$\Delta P = \dfrac{Ph^3}{3EI}$

$E = 900(1900) = 1.71 \times 10^6 \, psi = 1710 \, Ksi$

$f'_m = 1900 \, psi$

$I = \dfrac{10(246.96)^3}{12} = 12551585.9 \, in^4$

$\Delta P = \dfrac{1(79.25)^3(1728)}{3(1710)(12551585.1)} = 0.013 \, in$

$K = \dfrac{1}{.013} = \boxed{76.9 \, K/in}$

Figure AP12: Shear Wall Stiffness Calculation

MSW-1:

$V = 87.6$ K $b = 9.625"$ SDC B
$M = 4669$ ft·K $d_v = 247"$ ∴ Ordinary Reinforced MSW
$P = 175.5$ K

Flexure:

$E_s = 29000$ Ksi
$E_m = 900(1900) = 1710000$ psi
$n = 16.96$
$F_b = .45(1900) = 855$ psi
$F_s = 32000$ psi

$A_{s,req} = \dfrac{247 - \sqrt{247^2 - \dfrac{4(4669)}{1.6(1.9)(9.625)}}}{\dfrac{2(60)}{1.6(1.9)(9.625)}} = .315$ in²

$\rho_b = \dfrac{16.96(855)}{2(32000)(16.96 + \frac{32000}{855})} = .00417$

$A_s = .00417(9.625)(247) = 9.91$ in²

Try (12) #8 bars, 2 rows : $A_s = 9.48$ in²

$\rho = \dfrac{9.48}{9.625(247)} = .004$ $f_s = \dfrac{4669(12)}{9.625(.847)(247)} = 27.8$ ksi ✓

$\rho n = .068$

$K = \sqrt{2(.068) + .068^2} - .068 = .307$ $f_b = \dfrac{2(4669)(12)}{9.625(.847)(.307)(247^2)} = .734$ ksi ✓

$j = 1 - \dfrac{.307}{3} = .847$

Shear:

$f_v = \dfrac{87.6(1000)}{9.625(247)} = 36.8$ psi $F_{vm} = \dfrac{(4 - 1.75)\sqrt{1900}}{2} + .25\left(\dfrac{175.5(1000)}{9.625(247)}\right)$

$\dfrac{M}{Vd_v} = \dfrac{4669(12)}{87.6(247)} = 2.57 > 1.0$ $= 67.5$ psi > 36.8 psi

∴ $F_v \le 2\sqrt{1900} = 87.2$ psi   ∴ No Shear Reinf. Required

Figure AP13: Shear Wall Design

Joist Bearing: Double-Angle Header

Typical Floor Joist Load: $W = 123$ plf
Span: $23' - 4\,^{3}/_{16}"$

End Reaction: $R = \dfrac{123\,(23.35)}{2} = 1436$ lb per joist
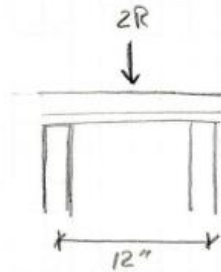
Maximum Moment: $M = \dfrac{2(1436)(12)}{4} = 8616$ in·lb

ASD → LRFD: $M_u = 8616 \times 1.5 = 12924$ in·lb

$Z_{req} = \dfrac{12\,942}{36\,000} = .360$ in³

Per AISC Table 1-7:

L2×2×¼ $Z_x = 0.44$ in³

∴ $\boxed{\text{Use } 2L\,2×2×¼}$ $Z_x = 0.88$ in³ $> Z_{req} = .36$ in³ ✓

Figure AP14: Joist Bearing Calculation

Appendix B – RS Means Data

03 11 13.85 Forms In Place, Walls

Line	Description	Ref	Crew	Daily Output	Labor-Hours	Unit	Material	Labor		Total	Total Incl O&P
0010	FORMS IN PLACE, WALLS	R031113-10									
0100	Box out for wall openings, to 16" thick, to 10 S.F.		C-2	24	2	Ea.	25	89.50		114.50	166
0150	Over 10 S.F. (use perimeter)	R031113-40	"	280	.171	L.F.	2.13	7.65		9.78	14.15
0250	Brick shelf, 4" w, add to wall forms, use wall area above shelf										
0260	1 use	R031113-60	C-2	240	.200	SFCA	2.28	8.95		11.23	16.30
0300	2 use			275	.175		1.26	7.80		9.06	13.45
0350	4 use			300	.160	▼	.91	7.15		8.06	12
0500	Bulkhead, wood with keyway, 1 use, 2 piece		▼	265	.181	L.F.	1.90	8.10		10	14.60
0600	Bulkhead forms with keyway, 1 piece expanded metal, 8" wall	G	C-1	1000	.032		1.25	1.39		2.64	3.53
0610	10" wall	G		800	.040		1.36	1.74		3.10	4.19
0620	12" wall	G	▼	525	.061	▼	1.63	2.65		4.28	5.90
0700	Buttress, to 8' high, 1 use		C-2	350	.137	SFCA	4.19	6.10		10.29	14.05
0750	2 use			430	.112		2.31	4.98		7.29	10.25
0800	3 use			460	.104		1.68	4.66		6.34	9.05
0850	4 use			480	.100	▼	1.38	4.47		5.85	8.40
1000	Corbel or haunch, to 12" wide, add to wall forms, 1 use			150	.320	L.F.	2.28	14.30		16.58	24.50
1050	2 use			170	.282		1.26	12.60		13.86	21
1100	3 use			175	.274		.91	12.25		13.16	19.90
1150	4 use			180	.267	▼	.74	11.90		12.64	19.15
2000	Wall, job-built plywood, to 8' high, 1 use			370	.130	SFCA	2.64	5.80		8.44	11.85
2050	2 use			435	.110		1.67	4.93		6.60	9.45
2100	3 use			495	.097		1.21	4.33		5.54	8.05
2150	4 use			505	.095		.99	4.24		5.23	7.65
2400	8' to 16' high, 1 use			280	.171		2.91	7.65		10.56	15
2450	2 use			345	.139		1.24	6.20		7.44	10.95
2500	3 use			375	.128		.89	5.70		6.59	9.75
2550	4 use			395	.122		.73	5.45		6.18	9.15
2700	Over 16' high, 1 use			235	.204		2.51	9.10		11.61	16.80
2750	2 use			290	.166		1.38	7.40		8.78	12.90
2800	3 use			315	.152		1	6.80		7.80	11.60
2850	4 use			330	.145		.82	6.50		7.32	10.90
4000	Radial, smooth curved, job-built plywood, 1 use			245	.196		2.41	8.75		11.16	16.15
4050	2 use			300	.160		1.33	7.15		8.48	12.45
4100	3 use			325	.148		.96	6.60		7.56	11.25
4150	4 use			335	.143		.78	6.40		7.18	10.70
4200	Below grade, job-built plywood, 1 use			225	.213		2.48	9.55		12.03	17.40
4210	2 use		▼	225	.213	▼	1.36	9.55		10.91	16.20

57

Image AP01: RS Means Cost Estimation Data

Image AP02: RS Means Cost Estimation Data

Image AP03: RS Means Cost Estimation Data

03 31 13.35 Heavyweight Concrete, Ready Mix

0010	**HEAVYWEIGHT CONCRETE, READY MIX,** delivered	R033105-10						
0012	Includes local aggregate, sand, Portland cement (Type I) and water							
0015	Excludes all additives and treatments	R033105-20						
0020	2000 psi		C.Y.	93			93	102
0100	2500 psi	R033105-30		95.50			95.50	105
0150	3000 psi			99			99	109
0200	3500 psi	R033105-40		101			101	111
0300	4000 psi			104			104	114
0350	4500 psi	R033105-50		107			107	117
0400	5000 psi			110			110	121
0411	6000 psi			113			113	124
0412	8000 psi			119			119	130
0413	10,000 psi			125			125	137
0414	12,000 psi			131			131	144
1000	For high early strength (Portland cement Type III), add			10%				
1010	For structural lightweight with regular sand, add			25%				
1300	For winter concrete (hot water), add			4.50			4.50	4.95
1400	For hot weather concrete (ice), add			7.65			7.65	8.40
1410	For mid-range water reducer, add			3.69			3.69	4.06
1420	For high-range water reducer/superplasticizer, add			5.70			5.70	6.30
1430	For retarder, add			3.06			3.06	3.37
1440	For non-Chloride accelerator, add			5.65			5.65	6.20
1450	For Chloride accelerator, per 1%, add			3.32			3.32	3.65
1460	For fiber reinforcing, synthetic (1 lb./C.Y.), add			6.95			6.95	7.60
1500	For Saturday delivery, add			4.93			4.93	5.40
1510	For truck holding/waiting time past 1st hour per load, add		Hr.	97			97	107
1520	For short load (less than 4 C.Y.), add per load		Ea.	77.50			77.50	85
2000	For all lightweight aggregate, add		C.Y.	45%				

Image AP04: RS Means Cost Estimation Data

03 31 Structural Concrete

03 31 13 – Heavyweight Structural Concrete

03 31 13.70 Placing Concrete		Crew	Daily Output	Labor-Hours	Unit	Material	2014 Bare Costs Labor	Equipment	Total	Total Incl O&P
0800	24" thick, pumped	C-20	92	.696	C.Y.		27.50	8.45	35.95	51.50
0850	With crane and bucket	C-7	70	1.029			41	17.50	58.50	82
1000	36" thick, pumped	C-20	140	.457			18	5.55	23.55	33.50
1050	With crane and bucket	C-7	100	.720			28.50	12.25	40.75	57.50
1400	Elevated slabs, less than 6" thick, pumped	C-20	140	.457			18	5.55	23.55	33.50
1450	With crane and bucket	C-7	95	.758			30	12.90	42.90	60
1500	6" to 10" thick, pumped	C-20	160	.400			15.75	4.85	20.60	29.50
1550	With crane and bucket	C-7	110	.655			26	11.15	37.15	52.50
1600	Slabs over 10" thick, pumped	C-20	180	.356			14	4.31	18.31	26
1650	With crane and bucket	C-7	130	.554			22	9.45	31.45	44
1900	Footings, continuous, shallow, direct chute	C-6	120	.400			15.30	.55	15.85	24
1950	Pumped	C-20	150	.427			16.80	5.20	22	31
2000	With crane and bucket	C-7	90	.800			32	13.60	45.60	63.50
2100	Footings, continuous, deep, direct chute	C-6	140	.343			13.10	.47	13.57	20.50
2150	Pumped	C-20	160	.400			15.75	4.85	20.60	29.50
2200	With crane and bucket	C-7	110	.655			26	11.15	37.15	52.50
2400	Footings, spread, under 1 C.Y., direct chute	C-6	55	.873			33.50	1.20	34.70	52.50
2450	Pumped	C-20	65	.985			39	11.95	50.95	72.50
2500	With crane and bucket	C-7	45	1.600			63.50	27.50	91	128
2600	Over 5 C.Y., direct chute	C-6	120	.400			15.30	.55	15.85	24
2650	Pumped	C-20	150	.427			16.80	5.20	22	31
2700	With crane and bucket	C-7	100	.720			28.50	12.25	40.75	57.50
2900	Foundation mats, over 20 C.Y., direct chute	C-6	350	.137			5.25	.19	5.44	8.20
2950	Pumped	C-20	400	.160			6.30	1.94	8.24	11.80
3000	With crane and bucket	C-7	300	.240			9.55	4.09	13.64	19.10
3200	Grade beams, direct chute	C-6	150	.320			12.25	.44	12.69	19.20
3250	Pumped	C-20	180	.356			14	4.31	18.31	26
3300	With crane and bucket	C-7	120	.600			24	10.20	34.20	48
3500	High rise, for more than 5 stories, pumped, add per story	C-20	2100	.030			1.20	.37	1.57	2.25
3510	With crane and bucket, add per story	C-7	2100	.034			1.37	.58	1.95	2.73
3700	Pile caps, under 5 C.Y., direct chute	C-6	90	.533			20.50	.74	21.24	32
3750	Pumped	C-20	110	.582			23	7.05	30.05	43
3800	With crane and bucket	C-7	80	.900			36	15.35	51.35	72
3850	Pile cap, 5 C.Y. to 10 C.Y., direct chute	C-6	175	.274			10.50	.38	10.88	16.45
3900	Pumped	C-20	200	.320			12.60	3.88	16.48	23.50
3950	With crane and bucket	C-7	150	.480			19.10	8.15	27.25	38
4000	Over 10 C.Y., direct chute	C-6	215	.223			8.55	.31	8.86	13.40
4050	Pumped	C-20	240	.267			10.50	3.23	13.73	19.60
4100	With crane and bucket	C-7	185	.389			15.50	6.65	22.15	31
4300	Slab on grade, up to 6" thick, direct chute	C-6	110	.436			16.70	.60	17.30	26
4350	Pumped	C-20	130	.492			19.40	5.95	25.35	36
4400	With crane and bucket	C-7	110	.655			26	11.15	37.15	52.50
4600	Over 6" thick, direct chute	C-6	165	.291			11.10	.40	11.50	17.45
4650	Pumped	C-20	185	.346			13.60	4.20	17.80	25.50
4700	With crane and bucket	C-7	145	.497			19.75	8.45	28.20	39.50
4900	Walls, 8" thick, direct chute	C-6	90	.533			20.50	.74	21.24	32
4950	Pumped	C-20	100	.640			25	7.75	32.75	47
5000	With crane and bucket	C-7	80	.900			36	15.35	51.35	72
5050	12" thick, direct chute	C-6	100	.480			18.35	.66	19.01	28.50
5100	Pumped	C-20	110	.582			23	7.05	30.05	43
5200	With crane and bucket	C-7	90	.800			32	13.60	45.60	63.50
5300	15" thick, direct chute	C-6	105	.457			17.45	.63	18.08	27
5350	Pumped	C-20	120	.533			21	6.45	27.45	39

79

Image AP05: RS Means Cost Estimation Data

31 23 16.42 Excavating, Bulk Bank Measure

Line	Description	Ref	Crew	Daily Output	Labor-Hours	Unit					
0010	EXCAVATING, BULK BANK MEASURE	R312316-40									
0011	Common earth piled										
0020	For loading onto trucks, add									15%	15%
0050	For mobilization and demobilization, see Section 01 54 36.50	R312316-45									
0100	For hauling, see Section 31 23 23.20										
0200	Excavator, hydraulic, crawler mtd., 1 C.Y. cap. = 100 C.Y./hr.		B-12A	800	.020	B.C.Y.		.87	1.02	1.89	2.45
0250	1-1/2 C.Y. cap. = 125 C.Y./hr.		B-12B	1000	.016			.70	1.03	1.73	2.19
0260	2 C.Y. cap. = 165 C.Y./hr.		B-12C	1320	.012			.53	.89	1.42	1.78
0300	3 C.Y. cap. = 260 C.Y./hr.		B-12D	2080	.008			.33	1.17	1.50	1.80
0305	3-1/2 C.Y. cap. = 300 C.Y./hr.		"	2400	.007			.29	1.02	1.31	1.56
0310	Wheel mounted, 1/2 C.Y. cap. = 40 C.Y./hr.		B-12E	320	.050			2.17	1.40	3.57	4.86
0360	3/4 C.Y. cap. = 60 C.Y./hr.		B-12F	480	.033			1.45	1.38	2.83	3.73
0500	Clamshell, 1/2 C.Y. cap. = 20 C.Y./hr.		B-12G	160	.100			4.35	4.51	8.86	11.60
0550	1 C.Y. cap. = 35 C.Y./hr.		B-12H	280	.057			2.48	4.36	6.84	8.60
0950	Dragline, 1/2 C.Y. cap. = 30 C.Y./hr.		B-12I	240	.067			2.90	3.75	6.65	8.55
1000	3/4 C.Y. cap. = 35 C.Y./hr.		"	280	.057			2.48	3.22	5.70	7.35
1050	1-1/2 C.Y. cap. = 65 C.Y./hr.		B-12P	520	.031			1.34	2.33	3.67	4.61
1200	Front end loader, track mtd., 1-1/2 C.Y. cap. = 70 C.Y./hr.		B-10N	560	.021			.96	.93	1.89	2.49
1250	2-1/2 C.Y. cap. = 95 C.Y./hr.		B-10O	760	.016			.71	1.26	1.97	2.47
1300	3 C.Y. cap. = 130 C.Y./hr.		B-10P	1040	.012			.52	1.15	1.67	2.05
1350	5 C.Y. cap. = 160 C.Y./hr.		B-10Q	1280	.009			.42	1.20	1.62	1.96
1500	Wheel mounted, 3/4 C.Y. cap. = 45 C.Y./hr.		B-10R	360	.033			1.49	.82	2.31	3.18
1550	1-1/2 C.Y. cap. = 80 C.Y./hr.		B-10S	640	.019			.84	.58	1.42	1.92
1600	2-1/4 C.Y. cap. = 100 C.Y./hr.		B-10T	800	.015			.67	.65	1.32	1.74
1650	5 C.Y. cap. = 185 C.Y./hr.		B-10U	1480	.008			.36	.71	1.07	1.33
1800	Hydraulic excavator, truck mtd. 1/2 C.Y. = 30 C.Y./hr.		B-12J	240	.067			2.90	3.67	6.57	8.45
1850	48 inch bucket, 1 C.Y. = 45 C.Y./hr.		B-12K	360	.044			1.93	2.79	4.72	6
3700	Shovel, 1/2 C.Y. capacity = 55 C.Y./hr.		B-12L	440	.036			1.58	1.69	3.27	4.27
3750	3/4 C.Y. capacity = 85 C.Y./hr.		B-12M	680	.024			1.02	1.39	2.41	3.09
3800	1 C.Y. capacity = 120 C.Y./hr.		B-12N	960	.017			.72	1.30	2.02	2.54
3850	1-1/2 C.Y. capacity = 160 C.Y./hr.		B-12O	1280	.013			.54	.98	1.52	1.91
3900	3 C.Y. cap. = 250 C.Y./hr.		B-12T	2000	.008			.35	.80	1.15	1.41
4000	For soft soil or sand, deduct									15%	15%
4100	For heavy soil or stiff clay, add									60%	60%

603

Image AP06: RS Means Cost Estimation Data

Image AP07: RS Means Cost Estimation Data

Image AP08: RS Means Cost Estimation Data

05 12 Structural Steel Framing

05 12 23 – Structural Steel for Buildings

05 12 23.75 Structural Steel Members		Crew	Daily Output	Labor-Hours	Unit	Material	2014 Bare Costs Labor	Equipment	Total	Total Incl O&P
1900	W 14 x 26	G	E-2	990	.057	L.F.	38	2.84	1.54	42.38	48
2100	x 30	G		900	.062		43.50	3.12	1.70	48.32	55
2300	x 34	G		810	.069		49.50	3.47	1.89	54.86	62.50
2320	x 43	G		810	.069		62.50	3.47	1.89	67.86	77
2340	x 53	G		800	.070		77.50	3.51	1.91	82.92	93
2360	x 74	G		760	.074		108	3.70	2.01	113.71	128
2380	x 90	G		740	.076		131	3.80	2.07	136.87	153
2500	x 120	G		720	.078		175	3.90	2.12	181.02	201
2700	W 16 x 26	G		1000	.056		38	2.81	1.53	42.34	48
2900	x 31	G		900	.062		45	3.12	1.70	49.82	56.50
3100	x 40	G		800	.070		58.50	3.51	1.91	63.92	72
3120	x 50	G		800	.070		73	3.51	1.91	78.42	88
3140	x 67	G		760	.074		97.50	3.70	2.01	103.21	116
3300	W 18 x 35	G	E-5	960	.083		51	4.22	1.74	56.96	65
3500	x 40	G		960	.083		58.50	4.22	1.74	64.46	73
3520	x 46	G		960	.083		67	4.22	1.74	72.96	83
3700	x 50	G		912	.088		73	4.44	1.83	79.27	89.50
3900	x 55	G		912	.088		80	4.44	1.83	86.27	97.50
3920	x 65	G		900	.089		94.50	4.50	1.86	100.86	114
3940	x 76	G		900	.089		111	4.50	1.86	117.36	132
3960	x 86	G		900	.089		125	4.50	1.86	131.36	148
3980	x 106	G		900	.089		155	4.50	1.86	161.36	180
4100	W 21 x 44	G		1064	.075		64	3.81	1.57	69.38	79
4300	x 50	G		1064	.075		73	3.81	1.57	78.38	88.50
4500	x 62	G		1036	.077		90.50	3.91	1.61	96.02	108
4700	x 68	G		1036	.077		99	3.91	1.61	104.52	117
4720	x 83	G		1000	.080		121	4.05	1.67	126.72	142
4740	x 93	G		1000	.080		136	4.05	1.67	141.72	158
4760	x 101	G		1000	.080		147	4.05	1.67	152.72	171
4780	x 122	G		1000	.080		178	4.05	1.67	183.72	205
4900	W 24 x 55	G		1110	.072		80	3.65	1.51	85.16	96
5100	x 62	G		1110	.072		90.50	3.65	1.51	95.66	107
5300	x 68	G		1110	.072		99	3.65	1.51	104.16	117
5500	x 76	G		1110	.072		111	3.65	1.51	116.16	130
5700	x 84	G		1080	.074		122	3.75	1.55	127.30	143
5720	x 94	G		1080	.074		137	3.75	1.55	142.30	159
5740	x 104	G		1050	.076		152	3.86	1.59	157.45	175
5760	x 117	G		1050	.076		171	3.86	1.59	176.45	196
5780	x 146	G		1050	.076		213	3.86	1.59	218.45	242
5800	W 27 x 84	G		1190	.067		122	3.41	1.40	126.81	142
5900	x 94	G		1190	.067		137	3.41	1.40	141.81	158
5920	x 114	G		1150	.070		166	3.52	1.45	170.97	191
5940	x 146	G		1150	.070		213	3.52	1.45	217.97	242
5960	x 161	G		1150	.070		235	3.52	1.45	239.97	266
6100	W 30 x 99	G		1200	.067		144	3.38	1.39	148.77	166
6300	x 108	G		1200	.067		157	3.38	1.39	161.77	180
6500	x 116	G		1160	.069		169	3.49	1.44	173.93	194
6520	x 132	G		1160	.069		192	3.49	1.44	196.93	220
6540	x 148	G		1160	.069		216	3.49	1.44	220.93	245
6560	x 173	G		1120	.071		252	3.62	1.49	257.11	285
6580	x 191	G		1120	.071		278	3.62	1.49	283.11	315
6700	W 33 x 118	G		1176	.068		172	3.45	1.42	176.87	196
6900	x 130	G		1134	.071		189	3.57	1.47	194.04	216

Image AP09: RS Means Cost Estimation Data

Image AP10: RS Means Cost Estimation Data

Image AP11: RS Means Cost Estimation Data

05 41 Structural Metal Stud Framing
05 41 13 – Load-Bearing Metal Stud Framing

05 41 13.30 Framing, Stud Walls		Crew	Daily Output	Labor-Hours	Unit	Material	2014 Bare Costs Labor	Equipment	Total	Total Incl O&P
7570	16" O.C.	G 2 Carp	45	.356	L.F.	22.50	16.30		38.80	49.50
7580	24" O.C.	G	61	.262		15.90	12.05		27.95	36
7590	6" wide, studs 12" O.C.	G	30	.533		36.50	24.50		61	77.50
7600	16" O.C.	G	44	.364		28.50	16.65		45.15	56.50
7610	24" O.C.	G	60	.267		20	12.25		32.25	41
7760	12 ga. x 4" wide, studs 12" O.C.	G	29	.552		41	25.50		66.50	84
7770	16" O.C.	G	40	.400		31.50	18.35		49.85	63
7780	24" O.C.	G	55	.291		22	13.35		35.35	44.50
7790	6" wide, studs 12" O.C.	G	28	.571		51.50	26		77.50	97.50
7800	16" O.C.	G	39	.410		39.50	18.80		58.30	72.50
7810	24" O.C.	G	54	.296		27.50	13.60		41.10	51.50
8590	20' high walls, 14 ga. x 6" wide, studs 12" O.C.	G	29	.552		45	25.50		70.50	88
8600	16" O.C.	G	42	.381		34.50	17.45		51.95	65
8610	24" O.C.	G	57	.281		24	12.85		36.85	46.50
8620	8" wide, studs 12" O.C.	G	28	.571		48.50	26		74.50	94
8630	16" O.C.	G	41	.390		37.50	17.90		55.40	68.50
8640	24" O.C.	G	56	.286		26.50	13.10		39.60	49
8790	12 ga. x 6" wide, studs 12" O.C.	G	27	.593		64	27		91	112
8800	16" O.C.	G	37	.432		48.50	19.85		68.35	84
8810	24" O.C.	G	51	.314		33.50	14.40		47.90	59
8820	8" wide, studs 12" O.C.	G	26	.615		77.50	28		105.50	129
8830	16" O.C.	G	36	.444		59	20.50		79.50	96.50
8840	24" O.C.	G	50	.320		41	14.65		55.65	67.50

Image AP12: RS Means Cost Estimation Data

Appendix C – Cut Sheets

ALLOWABLE COMBINED AXIAL & LATERAL LOADS (Kips/Stud)

Wind = 20psf

		S162 (1-5/8" Flange)					S200 (2" Flange)					S250 (2-1/2" Flange)			
Stud length (ft)	Spacing (in) o.c.	-33 (20ga) 33ksi	-43 (18ga) 33ksi	-54 (16ga) 50ksi	-68 (14ga) 50ksi	-97 (12ga) 50ksi	-33 (20ga) 33ksi	-43 (18ga) 33ksi	-54 (16ga) 50ksi	-68 (14ga) 50ksi	-97 (12ga) 50ksi	-43 (18ga) 33ksi	-54 (16ga) 50ksi	-68 (14ga) 50ksi	-97 (12ga) 50ksi
3-5/8" Stud															
8	12	1.25 a	2.02 a	3.56 a	4.78 a	7.19 a	1.58 a	2.59 a	4.52 a	6.03 a	8.84 a	2.98 a	5.12 a	7.04 a	10.36 a
	16	1.00 a	1.76 a	3.32 a	4.53 a	6.90 a	1.31 a	2.30 a	4.24 a	5.75 a	8.54 a	2.68 a	4.82 a	6.73 a	10.07 a
	24	0.53 b	1.27 a	2.85 a	4.05 a	6.35 a	0.80 b	1.76 a	3.71 a	5.22 a	7.97 a	2.09 a	4.26 a	6.14 a	9.51 a
9	12	0.99 a	1.71 a	3.14 a	4.25 a	6.43 a	1.29 a	2.23 a	3.98 a	5.37 a	7.94 a	2.61 a	4.59 a	6.28 a	9.38 a
	16	0.70 b	1.40 a	2.85 a	3.95 a	6.09 a	0.97 a	1.89 a	3.65 a	5.04 a	7.58 a	2.24 a	4.23 a	5.91 a	9.02 a
	24	0.17 d	0.84 c	2.31 b	3.39 a	5.44 a	0.39 c	1.27 a	3.04 a	4.42 a	6.91 a	1.56 a	3.57 a	5.22 a	8.35 a
10	12	0.73 b	1.40 a	2.69 a	3.69 a	5.64 a	1.00 a	1.85 a	3.43 a	4.68 a	7.00 a	2.22 a	4.04 a	5.50 a	8.34 a
	16	0.41 d	1.05 c	2.37 a	3.35 a	5.25 a	0.64 c	1.48 b	3.06 a	4.31 a	6.59 a	1.80 a	3.63 a	5.08 a	7.93 a
	24	—	0.44 d	1.78 c	2.74 b	4.53 a	0.01 d	0.80 d	2.40 c	3.63 b	5.84 a	1.05 c	2.89 b	4.32 a	7.17 a
12	12	0.27 e	0.81 d	1.83 c	2.61 b	4.08 a	0.46 d	1.15 c	2.37 b	3.36 a	5.16 a	1.43 b	2.85 a	3.99 a	6.29 a
	16	—	0.43 e	1.48 c	2.24 c	3.66 b	0.07 e	0.74 d	1.98 c	2.95 b	4.71 a	0.96 d	2.40 c	3.53 a	5.82 a
	24	—	—	0.88 e	1.60 e	2.90 d	—	0.01 e	1.29 e	2.24 d	3.90 c	0.15 e	1.62 d	2.72 c	4.99 b
14	12	—	0.33 e	1.16 e	1.76 d	2.85 c	0.03 e	0.58 e	1.54 d	2.31 c	3.68 b	0.77 d	1.88 c	2.77 b	4.59 a
	16	—	—	0.82 e	1.40 e	2.43 d	—	0.17 e	1.16 e	1.92 d	3.23 c	0.30 e	1.44 d	2.32 d	4.12 b
	24	—	—	0.24 f	0.78 f	1.71 e	—	—	0.51 f	1.23 e	2.45 e	—	0.70 e	1.54 e	3.30 d
16	12	—	—	0.68 f	1.15 e	1.96 d	—	0.16 f	0.95 e	1.56 e	2.61 d	0.27 e	1.19 e	1.90 d	3.34 c
	16	—	—	0.37 f	0.81 f	1.57 e	—	—	0.60 f	1.19 e	2.19 e	—	0.78 e	1.47 e	2.89 d
	24	—	—	—	0.23 f	0.90 f	—	—	—	0.55 f	1.46 f	—	0.08 f	0.73 f	2.11 e
4" Stud															
8	12	1.44 a	2.28 a	4.05 a	5.60 a	8.42 a	1.79 a	2.90 a	5.14 a	6.99 a	10.34 a	3.29 a	5.63 a	7.98 a	12.10 a
	16	1.20 a	2.03 a	3.81 a	5.35 a	8.13 a	1.53 a	2.63 a	4.87 a	6.71 a	10.05 a	3.00 a	5.35 a	7.69 a	11.81 a
	24	0.73 a	1.55 a	3.35 a	4.86 a	7.58 a	1.03 a	2.10 a	4.35 a	6.18 a	9.48 a	2.45 a	4.81 a	7.11 a	11.25 a
9	12	1.19 a	1.99 a	3.66 a	5.12 a	7.71 a	1.51 a	2.56 a	4.64 a	6.38 a	9.49 a	2.95 a	5.20 a	7.40 a	11.15 a
	16	0.90 a	1.69 a	3.37 a	4.81 a	7.36 a	1.20 a	2.23 a	4.31 a	6.04 a	9.12 a	2.59 a	4.86 a	7.02 a	10.79 a
	24	0.37 c	1.13 b	2.82 a	4.22 a	6.70 a	0.62 b	1.61 a	3.69 a	5.40 a	8.43 a	1.93 a	4.20 a	6.32 a	10.10 a
10	12	0.93 a	1.68 a	3.23 a	4.58 a	6.93 a	1.23 a	2.20 a	4.10 a	5.72 a	8.55 a	2.58 a	4.70 a	6.70 a	10.13 a
	16	0.61 c	1.34 a	2.90 a	4.22 a	6.52 a	0.87 b	1.82 a	3.72 a	5.33 a	8.13 a	2.17 a	4.29 a	6.26 a	9.70 a
	24	0.02 d	0.71 c	2.28 b	3.56 a	5.76 a	0.23 d	1.13 c	3.03 a	4.60 a	7.33 a	1.41 b	3.53 a	5.44 a	8.89 a
12	12	0.44 b	1.08 c	2.36 b	3.43 a	5.30 a	0.67 c	1.48 b	3.02 a	4.34 a	6.63 a	1.81 a	3.61 a	5.13 a	7.99 a
	16	0.07 e	0.68 d	1.97 c	3.02 b	4.82 a	0.26 d	1.04 c	2.59 b	3.88 a	6.12 a	1.32 c	3.11 a	4.61 a	7.47 a
	24	—	—	1.29 e	2.28 d	3.96 c	—	0.27 e	1.82 d	3.06 c	5.21 b	0.46 d	2.24 c	3.69 b	6.53 a
14	12	0.04 e	0.55 d	1.59 d	2.40 c	3.81 a	0.20 e	0.86 d	2.08 c	3.08 b	4.86 a	1.10 c	2.51 b	3.69 a	5.99 a
	16	—	0.14 e	1.20 e	1.98 d	3.33 c	—	0.40 e	1.64 d	2.62 c	4.35 b	0.58 d	2.01 d	3.16 c	5.45 a
	24	—	—	0.52 f	1.26 e	2.49 d	—	—	0.88 e	1.82 e	3.44 d	—	1.14 e	2.24 d	4.49 c
16	12	—	0.14 e	1.00 e	1.62 d	2.70 c	—	0.36 e	1.36 e	2.14 d	3.52 c	0.52 e	1.66 d	2.58 c	4.42 b
	16	—	—	0.63 f	1.23 e	2.24 d	—	—	0.94 e	1.70 e	3.02 d	0.02 e	1.19 e	2.08 d	3.90 c
	24	—	—	—	0.55 f	1.45 e	—	—	0.23 f	0.94 f	2.17 e	—	0.37 f	1.21 e	2.98 e

Image AP13a: Clark-Dietrich Axial and Flexural Load Stud Sesign Tables

ALLOWABLE COMBINED AXIAL & LATERAL LOADS (Kips/Stud)

Wind = 20psf

		S162 (1-5/8" Flange)					S200 (2" Flange)					S250 (2-1/2" Flange)			
Stud length (ft)	Spacing (in) o.c.	-33 (20ga) 33ksi	-43 (18ga) 33ksi	-54 (16ga) 50ksi	-68 (14ga) 50ksi	-97 (12ga) 50ksi	-33 (20ga) 33ksi	-43 (18ga) 33ksi	-54 (16ga) 50ksi	-68 (14ga) 50ksi	-97 (12ga) 50ksi	-43 (18ga) 33ksi	-54 (16ga) 50ksi	-68 (14ga) 50ksi	-97 (12ga) 50ksi
6" Stud															
8	12	2.00 a	3.02 a	5.25 a	7.10 a	11.06 a	2.43 a	3.86 a	7.01 a	9.55 a	15.23 a	4.19 a	7.21 a	10.58 a	17.81 a
	16	1.82 a	2.85 a	5.10 a	6.95 a	10.92 a	2.25 a	3.66 a	6.81 a	9.36 a	15.04 a	3.99 a	7.01 a	10.37 a	17.60 a
	24	1.47 a	2.53 a	4.79 a	6.65 a	10.62 a	1.88 a	3.27 a	6.42 a	9.00 a	14.67 a	3.59 a	6.63 a	9.96 a	17.19 a
9	12	1.85 a	2.87 a	5.11 a	6.96 a	10.92 a	2.26 a	3.65 a	6.73 a	9.25 a	14.84 a	3.98 a	6.95 a	10.24 a	17.31 a
	16	1.62 a	2.66 a	4.91 a	6.77 a	10.73 a	2.02 a	3.40 a	6.48 a	9.01 a	14.60 a	3.72 a	6.70 a	9.97 a	17.04 a
	24	1.18 a	2.25 a	4.52 a	6.38 a	10.35 a	1.56 a	2.91 a	5.98 a	8.54 a	14.12 a	3.22 a	6.22 a	9.45 a	16.51 a
10	12	1.67 a	2.71 a	4.94 a	6.80 a	10.75 a	2.06 a	3.41 a	6.41 a	8.89 a	14.37 a	3.74 a	6.65 a	9.84 a	16.72 a
	16	1.40 a	2.45 a	4.69 a	6.55 a	10.50 a	1.77 a	3.11 a	6.10 a	8.59 a	14.07 a	3.43 a	6.35 a	9.51 a	16.38 a
	24	0.86 a	1.94 a	4.20 a	6.06 a	10.02 a	1.22 a	2.51 a	5.49 a	8.02 a	13.47 a	2.82 a	5.76 a	8.86 a	15.72 a
12	12	1.25 a	2.28 a	4.48 a	6.37 a	10.30 a	1.60 a	2.86 a	5.63 a	8.00 a	13.16 a	3.19 a	5.93 a	8.88 a	15.26 a
	16	0.88 a	1.92 a	4.11 a	6.00 a	9.92 a	1.22 a	2.44 a	5.19 a	7.58 a	12.72 a	2.76 a	5.50 a	8.41 a	14.77 a
	24	0.19 c	1.24 a	3.43 a	5.30 a	9.19 a	0.50 b	1.66 a	4.37 a	6.77 a	11.86 a	1.94 a	4.69 a	7.51 a	13.83 a
14	12	0.79 a	1.78 a	3.79 a	5.58 a	9.63 a	1.11 a	2.24 a	4.71 a	6.92 a	11.64 a	2.57 a	5.10 a	7.75 a	13.49 a
	16	0.35 c	1.33 b	3.33 a	5.10 a	9.09 a	0.64 b	1.73 a	4.18 a	6.38 a	11.06 a	2.02 a	4.56 a	7.15 a	12.85 a
	24	—	0.52 d	2.50 c	4.21 a	8.09 a	—	0.79 c	3.19 b	5.39 a	9.97 a	1.03 b	3.56 a	6.02 a	11.64 a
16	12	0.35 c	1.26 b	3.03 a	4.64 a	8.22 a	0.62 c	1.62 a	3.76 a	5.75 a	9.94 a	1.92 a	4.26 a	6.56 a	11.55 a
	16	—	0.75 d	2.52 c	4.08 a	7.58 a	0.10 d	1.04 c	3.16 a	5.14 a	9.25 a	1.29 b	3.62 a	5.85 a	10.79 a
	24	—	—	1.80 d	3.09 c	6.44 b	—	0.01 d	2.09 d	4.03 c	8.01 a	0.17 d	2.48 c	4.57 b	9.41 a
8" Stud															
8	12	2.10 a*	3.07 a	5.18 a	7.00 a	11.02 a	2.65 a*	4.14 a	7.42 a	9.99 a	15.70 a	4.55 a	7.85 a	11.46 a	19.44 a
	16	1.97 a*	2.95 a	5.07 a	6.89 a	10.91 a	2.51 a*	4.00 a	7.28 a	9.86 a	15.58 a	4.40 a	7.70 a	11.31 a	19.29 a
	24	1.71 a*	2.70 a	4.84 a	6.67 a	10.70 a	2.23 a*	3.71 a	6.99 a	9.60 a	15.33 a	4.10 a	7.42 a	11.00 a	18.99 a
9	12	1.99 a*	2.97 a	5.08 a	6.91 a	10.93 a	2.53 a*	4.02 a	7.30 a	9.88 a	15.59 a	4.41 a	7.69 a	11.28 a	19.22 a
	16	1.83 a*	2.81 a	4.94 a	6.77 a	10.79 a	2.36 a*	3.84 a	7.11 a	9.71 a	15.43 a	4.22 a	7.51 a	11.09 a	19.03 a
	24	1.50 a*	2.50 a	4.65 a	6.49 a	10.51 a	2.01 a*	3.47 a	6.75 a	9.38 a	15.11 a	3.84 a	7.14 a	10.70 a	18.65 a
10	12	1.87 a*	2.85 a	4.97 a	6.80 a	10.82 a	2.40 a*	3.88 a	7.15 a	9.75 a	15.46 a	4.25 a	7.51 a	11.08 a	18.96 a
	16	1.67 a*	2.65 a	4.79 a	6.62 a	10.65 a	2.18 a*	3.65 a	6.93 a	9.54 a	15.26 a	4.02 a	7.28 a	10.84 a	18.72 a
	24	1.27 a*	2.27 a	4.44 a	6.27 a	10.30 a	1.75 a*	3.20 a	6.47 a	9.12 a	14.86 a	3.55 a	6.83 a	10.35 a	18.24 a
12	12	1.59 a*	2.57 a	4.71 a	6.53 a	10.55 a	2.09 a*	3.55 a	6.81 a	9.42 a	15.14 a	3.87 a	7.06 a	10.57 a	18.30 a
	16	1.30 a*	2.29 a	4.44 a	6.27 a	10.29 a	1.78 a*	3.22 a	6.47 a	9.11 a	14.83 a	3.53 a	6.73 a	10.21 a	17.94 a
	24	0.74 a*	1.74 a	3.93 a	5.76 a	9.78 a	1.17 a*	2.57 a	5.81 a	8.49 a	14.23 a	2.87 a	6.08 a	9.51 a	17.23 a
14	12	1.25 a*	2.24 a	4.38 a	6.20 a	10.21 a	1.71 a*	3.11 a	6.28 a	8.94 a	14.71 a	3.42 a	6.48 a	9.85 a	17.31 a
	16	0.87 a*	1.86 a	4.02 a	5.84 a	9.84 a	1.30 a*	2.67 a	5.82 a	8.51 a	14.27 a	2.96 a	6.04 a	9.36 a	16.81 a
	24	0.15 b*	1.14 a	3.32 a	5.14 a	9.13 a	0.52 a*	1.83 a	4.94 a	7.66 a	13.41 a	2.10 a	5.19 a	8.42 a	15.84 a
16	12	0.88 a*	1.86 a	3.98 a	5.80 a	9.77 a	1.28 a*	2.59 a	5.55 a	8.13 a	13.78 a	2.89 a	5.81 a	8.95 a	15.96 a
	16	0.41 b*	1.38 a	3.52 a	5.32 a	9.28 a	0.78 a*	2.05 a	4.98 a	7.57 a	13.20 a	2.33 a	5.25 a	8.33 a	15.32 a
	24	—	0.49 b	2.63 a	4.42 a	8.34 a	—	1.03 a	3.91 a	6.52 a	12.09 a	1.28 a	4.19 a	7.15 a	14.08 a

Image AP13b: Clark-Dietrich Axial and Flexural Load Stud Sesign Tables (Continued)

ALLOWABLE UNBRACED AXIAL LOADS — Based on length (Kips)

3-5/8" Stud

Member	Fy (ksi)	1	1.5	2	2.5	3	3.5	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
362S137-33	33	2.66	2.59	2.49	2.38	2.21	2.02	1.82	1.44	1.09	0.86	0.70	0.56	0.46	0.38	0.32	0.27*	0.23*	0.20*	0.18*	0.16*	0.14*	0.13*	0.11*
362S137-43	33	3.81	3.67	3.49	3.27	3.03	2.78	2.52	2.02	1.57	1.18	0.90	0.71	0.58	0.48	0.40	0.34*	0.30*	0.26*	0.23*	0.20*	0.18*	0.16*	0.14*
362S137-54	50	6.88	6.62	6.22	5.66	5.06	4.46	3.89	2.79	1.93	1.42	1.09	0.86	0.70	0.58	0.48	0.41*	0.36*	0.31*	0.27*	0.24*	0.21*	0.19*	0.17*
362S137-68	50	9.28	8.78	8.14	7.43	6.67	5.83	4.93	3.31	2.30	1.69	1.29	1.02	0.83	0.68	0.57	0.49*	0.42*	0.37*	0.32*	0.29*	0.26*	0.23*	0.21*
362S137-97	50	13.07	12.32	11.32	10.14	8.87	7.57	6.31	4.15	2.88	2.12	1.62	1.28	1.04	0.86	0.72*	0.61*	0.53*	0.46*	0.40*	0.36*	0.32*	0.29*	0.26*
362S162-33	33	3.12	3.05	2.96	2.84	2.69	2.50	2.29	1.87	1.47	1.14	0.91	0.75	0.63	0.53	0.46	0.41	0.37	0.33	0.30*	0.27*	0.24*	0.22*	0.20*
362S162-43	33	4.43	4.30	4.12	3.91	3.67	3.40	3.13	2.58	2.06	1.60	1.28	1.05	0.89	0.77	0.68	0.59	0.51	0.44	0.39*	0.35*	0.31*	0.28*	0.25*
362S162-54	50	7.99	7.74	7.44	6.87	6.24	5.60	4.96	3.76	2.75	2.13	1.73	1.45	1.21	1.00	0.84	0.72	0.62	0.54	0.47*	0.42*	0.37*	0.34*	0.30*
362S162-68	50	10.79	10.31	9.68	8.95	8.16	7.31	6.46	4.92	3.70	2.94	2.28	1.80	1.46	1.20	1.01	0.86	0.74	0.65*	0.57*	0.50*	0.45*	0.40*	0.36*
362S162-97	50	15.24	14.50	13.58	12.55	11.48	10.43	9.43	7.30	5.21	3.83	2.93	2.32	1.88	1.55	1.30	1.11	0.96	0.83*	0.73*	0.65*	0.58*	0.52*	0.47*
362S200-33	33	3.41	3.35	3.26	3.15	3.02	2.88	2.72	2.35	1.96	1.53	1.21	0.99	0.82	0.69	0.59	0.52	0.46	0.41	0.37	0.33	0.30	0.28	0.26*
362S200-43	33	5.12	5.03	4.88	4.70	4.47	4.20	3.90	3.28	2.68	2.12	1.66	1.35	1.13	0.96	0.83	0.73	0.66	0.59	0.54	0.50	0.46	0.43	0.40*
362S200-54	50	8.79	8.62	8.41	8.12	7.70	7.02	6.30	4.90	3.62	2.75	2.18	1.79	1.51	1.31	1.15	1.03	0.93	0.85	0.78	0.72	0.68	0.62	0.56*
362S200-68	50	12.43	12.11	11.64	10.87	10.02	9.12	8.15	6.30	4.72	3.64	2.94	2.46	2.11	1.85	1.65	1.50	1.37	1.21	1.06	0.94	0.84	0.75*	0.68*
362S200-97	50	18.07	17.33	16.37	15.26	14.06	12.82	11.61	9.35	7.44	5.96	4.98	4.30	3.58	2.96	2.49	2.12	1.83	1.59	1.40	1.24	1.11	0.99*	0.90*
362S250-43	33	5.25	5.16	5.04	4.89	4.71	4.51	4.29	3.80	3.15	2.49	1.95	1.57	1.30	1.09	0.94	0.82	0.73	0.65	0.59	0.53	0.49	0.45	0.42
362S250-54	50	9.00	8.77	8.46	8.08	7.63	7.13	6.64	5.67	4.25	3.20	2.51	2.04	1.70	1.45	1.26	1.11	0.99	0.90	0.82	0.75	0.70	0.65	0.61
362S250-68	50	12.44	12.16	11.78	11.32	10.80	10.00	9.13	7.36	5.46	4.15	3.30	2.72	2.30	1.99	1.75	1.57	1.42	1.30	1.19	1.11	1.04	0.98	0.92
362S250-97	50	19.64	18.98	18.14	17.19	16.24	14.88	13.43	10.69	8.30	6.50	5.32	4.50	3.91	3.47	3.12	2.84	2.62	2.43	2.27	2.13	1.96	1.76	1.59

4" Stud

Member	Fy (ksi)	1	1.5	2	2.5	3	3.5	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
400S137-33	33	2.69	2.62	2.53	2.42	2.27	2.09	1.90	1.52	1.18	0.91	0.72	0.58	0.48	0.39	0.33	0.28*	0.24*	0.21*	0.19*	0.17*	0.15*	0.13*	0.12*
400S137-43	33	3.86	3.73	3.56	3.36	3.13	2.88	2.63	2.13	1.62	1.23	0.95	0.75	0.61	0.50	0.42	0.36*	0.31*	0.27*	0.24*	0.21*	0.19*	0.17*	0.15*
400S137-54	50	6.99	6.74	6.39	5.85	5.28	4.68	4.04	2.85	2.03	1.49	1.14	0.90	0.73	0.60	0.51	0.43*	0.37*	0.32*	0.28*	0.25*	0.23*	0.20*	0.18*
400S137-68	50	9.51	9.04	8.44	7.70	6.89	6.04	5.18	3.47	2.41	1.77	1.35	1.07	0.87	0.72	0.60*	0.51*	0.44*	0.39*	0.34*	0.30*	0.27*	0.24*	0.22*
400S137-97	50	14.09	13.24	12.13	10.84	9.45	8.03	6.66	4.35	3.02	2.22	1.70	1.34	1.09	0.90	0.76*	0.64*	0.56*	0.48*	0.42*	0.38*	0.34*	0.30*	0.27*
400S162-33	33	3.15	3.08	3.00	2.89	2.75	2.58	2.39	1.99	1.60	1.25	1.01	0.83	0.70	0.61	0.53	0.46	0.41	0.36	0.32*	0.28*	0.25*	0.23*	0.21*
400S162-43	33	4.49	4.37	4.20	4.01	3.78	3.54	3.28	2.75	2.24	1.78	1.45	1.20	1.01	0.86	0.73	0.62	0.53	0.47	0.41*	0.36*	0.32*	0.29*	0.26*
400S162-54	50	8.10	7.88	7.59	7.10	6.51	5.90	5.28	4.10	3.10	2.43	1.96	1.57	1.27	1.05	0.88	0.75	0.65	0.56*	0.50*	0.44*	0.39*	0.35*	0.32*
400S162-68	50	11.03	10.58	10.00	9.32	8.58	7.80	7.03	5.56	4.21	3.11	2.38	1.88	1.53	1.26	1.06	0.90	0.78	0.68*	0.60*	0.53*	0.47*	0.42*	0.38*
400S162-97	50	16.31	15.59	14.68	13.64	12.55	11.45	10.21	7.69	5.47	4.02	3.07	2.43	1.97	1.63	1.37	1.16	1.00	0.87*	0.77*	0.68*	0.61*	0.55*	0.49*
400S200-33	33	3.44	3.38	3.30	3.20	3.09	2.96	2.81	2.48	2.12	1.71	1.36	1.11	0.93	0.80	0.69	0.60	0.53	0.47	0.42	0.38	0.35	0.32	0.30*
400S200-43	33	5.17	5.09	4.96	4.80	4.60	4.35	4.08	3.50	2.92	2.38	1.91	1.57	1.31	1.11	0.96	0.84	0.75	0.68	0.62	0.56	0.52	0.48	0.45*
400S200-54	50	8.89	8.75	8.55	8.32	7.93	7.40	6.72	5.37	4.13	3.20	2.53	2.07	1.75	1.50	1.32	1.17	1.06	0.96	0.88	0.81	0.72	0.65*	0.50*
400S200-68	50	12.66	12.37	12.00	11.30	10.52	9.68	8.82	7.12	5.50	4.22	3.39	2.83	2.42	2.11	1.88	1.69	1.45	1.27	1.11	0.99	0.88	0.79*	0.71*
400S200-97	50	19.17	18.46	17.55	16.47	15.29	14.07	12.84	10.51	8.49	6.83	5.68	4.63	3.75	3.10	2.61	2.22	1.91	1.67	1.47	1.30	1.16	1.04*	0.94*
400S250-43	33	5.30	5.22	5.12	4.99	4.83	4.66	4.46	4.01	3.47	2.84	2.27	1.85	1.54	1.29	1.11	0.97	0.85	0.76	0.69	0.62	0.57	0.53	0.49
400S250-54	50	9.12	8.92	8.65	8.31	7.91	7.47	6.98	6.15	4.94	3.78	2.98	2.41	2.01	1.71	1.48	1.30	1.16	1.04	0.95	0.87	0.80	0.75	0.70
400S250-68	50	12.67	12.42	12.09	11.69	11.22	10.59	9.82	8.37	6.49	4.92	3.90	3.20	2.69	2.32	2.03	1.81	1.63	1.49	1.37	1.27	1.19	1.11	1.05
400S250-97	50	20.74	20.13	19.33	18.41	17.45	16.34	14.92	12.15	9.68	7.61	6.20	5.22	4.51	3.98	3.58	3.25	2.99	2.77	2.59	2.30	2.05	1.84	1.66

Image AP14a: Clark-Dietrich Axial Load Stud Sesign Tables

ALLOWABLE UNBRACED AXIAL LOADS — Based on length (Kips)

5-1/2" Stud

Member	Fy (ksi)	1	1.5	2	2.5	3	3.5	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
550S162-33	33	3.20	3.15	3.07	2.99	2.87	2.74	2.57	2.20	1.81	1.45	1.15	0.94	0.78	0.67	0.58	0.50	0.44	0.39*	0.35*	0.32*	0.29*	0.26*	0.23*
550S162-43	33	4.60	4.50	4.36	4.19	3.99	3.77	3.53	3.02	2.50	1.99	1.59	1.30	1.09	0.92	0.80	0.69	0.61	0.53*	0.47*	0.41*	0.37*	0.33*	0.30*
550S162-54	50	8.32	8.13	7.87	7.50	6.96	6.38	5.76	4.53	3.39	2.61	2.08	1.70	1.42	1.20	1.01	0.86	0.74	0.65*	0.57*	0.50*	0.45*	0.40*	0.36*
550S162-68	50	11.47	11.08	10.56	9.92	9.20	8.41	7.59	5.93	4.43	3.40	2.70	2.16	1.75	1.45	1.22	1.04	0.89	0.78*	0.68*	0.61*	0.54*	0.49*	0.44*
550S162-97	50	17.79	17.15	16.29	15.26	14.07	12.80	11.46	8.78	6.30	4.63	3.54	2.80	2.27	1.87	1.57	1.34	1.16*	1.01*	0.89*	0.78*	0.70*	0.63*	0.57*
550S200-33	33	3.49	3.45	3.39	3.32	3.23	3.13	3.02	2.76	2.46	2.15	1.80	1.48	1.24	1.06	0.92	0.81	0.72	0.65	0.59	0.54	0.49	0.45*	0.41*
550S200-43	33	5.28	5.22	5.13	5.01	4.86	4.69	4.48	4.00	3.50	3.00	2.53	2.09	1.77	1.52	1.33	1.18	1.05	0.94	0.84	0.75	0.68	0.61*	0.55*
550S200-54	50	9.11	9.00	8.85	8.67	8.46	8.12	7.67	6.50	5.34	4.27	3.45	2.87	2.45	2.09	1.80	1.56	1.37	1.20	1.05	0.93	0.83	0.75*	0.67*
550S200-68	50	13.11	12.90	12.62	12.20	11.58	10.90	10.18	8.68	7.22	5.87	4.74	3.86	3.21	2.70	2.27	1.94	1.67	1.45	1.28	1.13	1.01	0.91*	0.82*
550S200-97	50	20.73	20.24	19.57	18.77	17.85	16.86	15.82	13.54	11.12	8.78	6.75	5.33	4.32	3.57	3.00	2.56	2.20	1.92	1.69	1.49	1.33*	1.20*	1.08*
550S250-43	33	5.41	5.36	5.29	5.20	5.09	4.96	4.82	4.50	4.14	3.72	3.19	2.69	2.25	1.92	1.67	1.47	1.30	1.17	1.06	0.97	0.89	0.82	0.76
550S250-54	50	9.36	9.22	9.03	8.80	8.52	8.20	7.85	7.06	6.41	5.46	4.39	3.61	3.05	2.62	2.29	2.02	1.81	1.63	1.49	1.35	1.24	1.14	1.06
550S250-68	50	13.13	12.96	12.73	12.44	12.11	11.73	11.31	10.04	8.87	7.35	5.97	4.96	4.21	3.65	3.21	2.84	2.53	2.28	2.08	1.91	1.76	1.58	1.43
550S250-97	50	22.32	21.92	21.39	20.75	20.04	19.28	18.54	16.26	13.97	11.82	9.86	8.20	6.98	6.07	5.30	4.52	3.89	3.39	2.98	2.64	2.38	2.11	1.91

6" Stud

Member	Fy (ksi)	1	1.5	2	2.5	3	3.5	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
600S137-33	33	2.73	2.66	2.56	2.45	2.29	2.09	1.89	1.48	1.11	0.86	0.69	0.57	0.48	0.41	0.35*	0.31*	0.27*	0.24*	0.22*	0.20*	0.17*	0.16*	0.14*
600S137-43	33	3.96	3.83	3.65	3.43	3.18	2.91	2.62	2.05	1.54	1.20	0.96	0.79	0.67	0.57	0.49*	0.42*	0.37*	0.32*	0.28*	0.25*	0.22*	0.20*	0.18*
600S137-54	50	7.20	6.93	6.51	5.91	5.26	4.58	3.91	2.75	2.03	1.58	1.27	1.04	0.86	0.71	0.60*	0.51*	0.44*	0.38*	0.34*	0.30*	0.27*	0.24*	0.22*
600S137-68	50	9.92	9.39	8.69	7.87	6.98	6.06	5.15	3.60	2.66	2.06	1.61	1.27	1.03	0.85	0.71*	0.61*	0.53*	0.46*	0.40*	0.36*	0.32*	0.29*	0.26*
600S137-97	50	15.65	14.74	13.56	12.19	10.69	9.15	7.64	5.19	3.61	2.65	2.03	1.60	1.30	1.07*	0.90*	0.77*	0.66*	0.58*	0.51*	0.45*	0.40*	0.36*	0.32*
600S162-33	33	3.20	3.15	3.08	2.99	2.87	2.73	2.56	2.18	1.79	1.42	1.13	0.93	0.77	0.66	0.57	0.50	0.44	0.39*	0.35*	0.32*	0.29*	0.26*	0.24*
600S162-43	33	4.61	4.51	4.37	4.19	3.99	3.77	3.52	3.00	2.47	1.97	1.57	1.29	1.08	0.92	0.79	0.69	0.61	0.54*	0.48*	0.43*	0.38*	0.34*	0.31*
600S162-54	50	8.35	8.15	7.89	7.49	6.95	6.35	5.73	4.48	3.35	2.58	2.06	1.69	1.42	1.20	1.04	0.89	0.77	0.67*	0.59*	0.52*	0.47*	0.42*	0.38*
600S162-68	50	11.53	11.13	10.59	9.94	9.20	8.40	7.56	5.89	4.39	3.39	2.70	2.21	1.81	1.50	1.26	1.07	0.93	0.81*	0.71*	0.63*	0.56*	0.50*	0.45*
600S162-97	50	17.99	17.33	16.45	15.38	14.18	12.87	11.51	8.80	6.47	4.79	3.67	2.90	2.35	1.94	1.63	1.39	1.20*	1.04*	0.92*	0.81*	0.73*	0.65*	0.59*
600S200-33	33	3.50	3.46	3.41	3.34	3.25	3.16	3.05	2.81	2.53	2.23	1.90	1.57	1.31	1.12	0.97	0.86	0.76	0.68	0.60	0.54	0.49	0.45*	0.41*
600S200-43	33	5.30	5.24	5.16	5.04	4.90	4.75	4.55	4.09	3.61	3.12	2.65	2.21	1.87	1.59	1.37	1.20	1.05	0.94	0.84	0.75	0.68	0.62*	0.57*
600S200-54	50	9.15	9.05	8.91	8.74	8.54	8.22	7.84	6.71	5.57	4.51	3.61	2.95	2.46	2.09	1.80	1.57	1.38	1.22	1.09	0.96	0.86	0.77*	0.70*
600S200-68	50	13.19	12.99	12.72	12.35	11.76	11.11	10.42	8.96	7.44	5.95	4.73	3.86	3.22	2.73	2.34	2.01	1.73	1.51	1.32	1.17	1.05	0.94*	0.85*
600S200-97	50	20.97	20.50	19.87	19.08	18.16	17.13	16.02	13.63	11.18	8.82	6.98	5.53	4.48	3.70	3.11	2.65	2.28	1.99	1.75	1.55	1.38*	1.24*	1.12*
600S250-43	33	5.43	5.38	5.32	5.23	5.14	5.02	4.89	4.59	4.25	3.88	3.39	2.89	2.44	2.08	1.80	1.59	1.41	1.27	1.15	1.05	0.96	0.89	0.82
600S250-54	50	9.40	9.27	9.10	8.89	8.63	8.33	8.00	7.27	6.62	5.82	4.75	3.91	3.30	2.83	2.47	2.19	1.96	1.77	1.61	1.48	1.36	1.27	1.18
600S250-68	50	13.21	13.05	12.84	12.58	12.27	11.91	11.53	10.38	9.22	7.86	6.46	5.36	4.55	3.94	3.47	3.09	2.78	2.53	2.30	2.05	1.83	1.64	1.48
600S250-97	50	22.56	22.19	21.70	21.11	20.44	19.72	19.00	16.96	14.74	12.62	10.67	9.00	7.76	6.54	5.49	4.68	4.04	3.52	3.09	2.74	2.44	2.19	1.98
600S300-54	50	9.56	9.45	9.30	9.11	8.88	8.62	8.33	7.67	6.93	6.14	5.40	4.68	3.98	3.39	2.94	2.59	2.30	2.06	1.87	1.70	1.56	1.44	1.34
600S300-68	50	13.52	13.36	13.14	12.86	12.52	12.13	11.71	10.76	9.85	8.83	7.56	6.41	5.40	4.64	4.05	3.58	3.20	2.88	2.61	2.38	2.18	2.01	1.86
600S300-97	50	23.94	23.66	23.29	22.82	22.26	21.47	20.51	18.45	16.38	14.49	12.46	10.44	8.90	7.67	6.69	5.93	5.32	4.82	4.42	4.08	3.80	3.49	3.15

Image AP14b: Clark-Dietrich Axial Load Stud Sesign Tables (Continued)

ASD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown In Pounds Per Linear Foot (plf)

Joist Designation	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6	16K2	16K3	16K4	16K5	16K6	16K7	16K9
Depth (in.)	10	12	12	12	14	14	14	14	16	16	16	16	16	16	16
Approx. Wt (lbs./ft.)	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7	5.5	6.3	7.0	7.5	8.1	8.6	10.0
Span (ft.)															
10	550/550														
11	550/542														
12	550/455	550/550	550/550	550/550											
13	479/363	550/510	550/510	550/510											
14	412/289	500/425	550/463	550/463	550/550	550/550	550/550	550/550							
15	358/234	434/344	543/428	550/434	511/475	550/507	550/507	550/507							
16	313/192	380/282	476/351	550/396	448/390	550/467	550/467	550/467	550/550	550/550	550/550	550/550	550/550	550/550	550/550
17	277/159	336/234	420/291	550/366	395/324	495/404	550/443	550/443	512/488	550/526	550/526	550/526	550/526	550/526	550/526
18	246/134	299/197	374/245	507/317	352/272	441/339	530/397	550/408	456/409	508/456	550/490	550/490	550/490	550/490	550/490
19	221/113	268/167	335/207	454/269	315/230	395/287	475/336	550/383	408/347	455/386	547/452	550/455	550/455	550/455	550/455
20	199/97	241/142	302/177	409/230	284/197	356/246	428/287	525/347	368/297	410/330	493/386	550/426	550/426	550/426	550/426
21		218/123	273/153	370/198	257/170	322/212	388/248	475/299	333/255	371/285	447/333	503/373	548/405	550/406	550/406
22		199/106	249/132	337/172	234/147	293/184	353/215	432/259	303/222	337/247	406/289	458/323	498/351	550/385	550/385
23		181/93	227/116	308/150	214/128	268/160	322/188	395/226	277/194	308/216	371/252	418/282	455/307	507/339	550/363
24		166/81	208/101	282/132	196/113	245/141	295/165	362/199	254/170	283/189	340/221	384/248	418/269	465/298	550/346
25					180/100	226/124	272/145	334/175	234/150	260/167	313/195	353/219	384/238	428/263	514/311
26					166/88	209/110	251/129	308/156	216/133	240/148	289/173	326/194	355/211	395/233	474/276
27					154/79	193/98	233/115	285/139	200/119	223/132	268/155	302/173	329/188	366/208	439/246
28					143/70	180/88	216/103	265/124	186/106	207/118	249/138	281/155	306/168	340/186	408/220
29									173/95	193/106	232/124	261/139	285/151	317/167	380/198
30									161/86	180/96	216/112	244/126	266/137	296/151	355/178
31									151/78	168/87	203/101	228/114	249/124	277/137	332/161
32									142/71	158/79	190/92	214/103	233/112	259/124	311/147

Image AP15: Vulcraft ASD Load Design Table

No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (PSF) / Load Causing Deflection of L/240 or 1 inch (PSF) — Span (ft.-in.) ctr to ctr of supports										
			5-0	5-6	6-0	6-6	7-0	7-6	8-0	8-6	9-0	9-6	10-0
1	B24	4'-8	115 / 56	95 / 42	80 / 32	68 / 26	59 / 20	51 / 17	45 / 14	40 / 11	35 / 10	32 / 8	29 / 7
	B22	5'-7	98 / 81	81 / 61	68 / 47	58 / 37	50 / 30	44 / 24	38 / 20	34 / 17	30 / 14	27 / 12	25 / 10
	B20	6'-5	123 / 105	102 / 79	86 / 61	73 / 48	63 / 38	55 / 31	48 / 26	43 / 21	38 / 18	34 / 15	31 / 13
	B19	7'-1	146 / 129	121 / 97	101 / 75	86 / 59	74 / 47	65 / 38	57 / 31	51 / 26	45 / 22	40 / 19	36 / 16
	B18	7'-8	168 / 152	138 / 114	116 / 88	99 / 69	85 / 55	74 / 45	65 / 37	58 / 31	52 / 26	46 / 22	42 / 19
	B16	8'-8	215 / 196	178 / 147	149 / 113	127 / 89	110 / 71	96 / 58	84 / 48	74 / 40	66 / 34	60 / 29	54 / 24
2	B24	5'-10	124 / 153	103 / 115	86 / 88	74 / 70	64 / 56	56 / 45	49 / 37	43 / 31	39 / 26	35 / 22	31 / 19
	B22	6'-11	100 / 213	83 / 160	70 / 124	59 / 97	51 / 78	45 / 63	39 / 52	35 / 43	31 / 37	28 / 31	25 / 27
	B20	7'-9	128 / 267	106 / 201	89 / 155	76 / 122	66 / 97	57 / 79	51 / 65	45 / 54	40 / 46	36 / 39	32 / 33
	B19	8'-5	150 / 320	124 / 240	104 / 185	89 / 145	77 / 116	67 / 95	59 / 78	52 / 65	47 / 55	42 / 47	38 / 40
	B18	9'-1	169 / 369	140 / 277	118 / 213	101 / 168	87 / 134	76 / 109	67 / 90	59 / 75	53 / 63	48 / 54	43 / 46
	B16	10'-3	213 / 471	176 / 354	149 / 273	127 / 214	110 / 172	95 / 140	84 / 115	74 / 96	66 / 81	60 / 69	54 / 59
3	B24	5'-10	154 / 120	128 / 90	108 / 69	92 / 55	79 / 44	69 / 35	61 / 29	54 / 24	48 / 21	43 / 17	39 / 15
	B22	6'-11	124 / 167	103 / 126	87 / 97	74 / 76	64 / 61	56 / 50	49 / 41	43 / 34	39 / 29	35 / 24	31 / 21
	B20	7'-9	159 / 209	132 / 157	111 / 121	95 / 95	82 / 76	72 / 62	63 / 51	56 / 43	50 / 36	45 / 31	40 / 26
	B19	8'-5	186 / 250	154 / 188	130 / 145	111 / 114	96 / 91	84 / 74	74 / 61	65 / 51	58 / 43	52 / 37	47 / 31
	B18	9'-1	210 / 289	174 / 217	147 / 167	126 / 132	108 / 105	95 / 86	83 / 71	74 / 59	66 / 50	59 / 42	54 / 36
	B16	10'-3	264 / 369	219 / 277	185 / 214	158 / 168	136 / 135	119 / 109	105 / 90	93 / 75	83 / 63	74 / 54	67 / 46

Image AP16: Vulcraft Roof Deck Design Table

| TOTAL SLAB DEPTH	DECK TYPE	SDI Max. Unshored Clear Span			Superimposed Live Load, PSF — Clear Span (ft.-in.)														
		1 SPAN	2 SPAN	3 SPAN	5'-0	5'-6	6'-0	6'-6	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0
3.50 (t=2.00) 33 PSF	1.5VL22	5'-10	7'-10	7'-10	314	279	230	206	186	169	154	141	130	120	111	100	87	76	67
	1.5VL20	7'-0	9'-4	9'-6	345	306	275	249	227	187	171	157	144	133	124	108	94	82	73
	1.5VL19	7'-11	10'-3	10'-8	372	330	296	268	244	224	186	171	157	145	134	116	101	88	78
	1.5VL18	8'-8	11'-0	11'-2	395	351	315	285	260	238	220	204	168	156	142	123	107	94	82
	1.5VL16	8'-10	11'-0	11'-4	397	353	316	286	261	239	221	205	169	156	145	135	119	105	92
4.00 (t=2.50) 39 PSF	1.5VL22	5'-6	7'-5	7'-5	366	325	267	239	216	196	179	164	151	139	129	119	111	103	96
	1.5VL20	6'-7	8'-10	8'-11	400	356	319	289	239	217	198	182	167	155	143	133	124	115	108
	1.5VL19	7'-5	9'-9	10'-1	400	383	344	311	283	235	215	197	182	168	156	145	135	126	115
	1.5VL18	8'-1	10'-5	10'-7	400	400	365	330	301	276	254	211	194	180	167	156	145	136	122
	1.5VL16	8'-3	10'-5	10'-9	400	400	365	330	301	276	255	211	194	180	167	155	145	136	127
4.50 (t=3.00) 45 PSF	1.5VL22	5'-3	7'-1	7'-1	400	345	307	275	248	225	205	188	173	159	147	136	127	118	109
	1.5VL20	6'-3	8'-5	8'-6	400	400	366	303	274	249	227	208	192	177	164	152	142	132	123
	1.5VL19	7'-1	9'-3	9'-7	400	400	393	356	325	269	246	226	208	192	179	166	155	144	135
	1.5VL18	7'-8	9'-11	10'-1	400	400	400	378	344	316	262	241	222	206	191	178	166	155	145
	1.5VL16	7'-10	9'-11	10'-3	400	400	400	377	344	315	262	240	222	205	190	177	165	155	145
5.00 (t=3.50) 51 PSF	1.5VL22	5'-0	6'-9	6'-9	400	391	347	311	280	254	232	213	195	180	167	154	143	133	124
	1.5VL20	6'-0	8'-1	8'-2	400	400	400	343	310	281	257	236	217	200	186	172	160	149	139
	1.5VL19	6'-9	8'-11	9'-2	400	400	400	400	335	304	278	255	235	218	202	188	175	163	153
	1.5VL18	7'-3	9'-6	9'-8	400	400	400	400	389	324	297	272	251	233	216	201	187	175	164
	1.5VL16	7'-5	9'-6	9'-10	400	400	400	400	388	323	295	271	250	232	215	200	187	175	164
5.50 (t=4.00) 57 PSF	1.5VL22	4'-10	6'-6	6'-6	400	400	388	348	314	285	260	238	219	202	186	173	160	149	138
	1.5VL20	5'-9	7'-9	7'-10	400	400	400	383	346	314	287	263	243	224	208	193	179	167	156
	1.5VL19	6'-5	8'-6	8'-9	400	400	400	400	374	340	311	286	263	243	226	210	196	183	171
	1.5VL18	7'-0	9'-1	9'-4	400	400	400	400	400	363	331	305	281	260	241	225	210	196	183
	1.5VL16	7'-1	9'-2	9'-5	400	400	400	400	400	361	330	303	279	259	240	224	209	195	183
6.00 (t=4.50) 63 PSF	1.5VL22	4'-8	6'-4	6'-4	400	400	400	385	347	315	288	263	242	223	206	191	178	165	153
	1.5VL20	5'-6	7'-5	7'-6	400	400	400	400	383	348	318	292	269	248	230	213	199	185	173
	1.5VL19	6'-2	8'-2	8'-5	400	400	400	400	400	377	344	316	291	270	250	232	217	202	189
	1.5VL18	6'-8	8'-9	9'-0	400	400	400	400	400	400	367	337	311	288	267	249	232	217	203
	1.5VL16	6'-10	8'-10	9'-1	400	400	400	400	400	399	365	335	309	286	266	248	231	216	202

Image AP17: Vulcraft VLI Composite Deck Design Table

TOTAL SLAB DEPTH	DECK TYPE	SDI Max. Unshored Clear Span			Superimposed Live Load, PSF — Clear Span (ft.-in.)														
		1 SPAN	2 SPAN	3 SPAN	5'-0	5'-6	6'-0	6'-6	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0
3.50 (t=2.00) 38 PSF	1.5VLR22	5'-9	7'-8	7'-9	314	279	227	203	183	166	151	138	127	117	108	100	92	86	77
	1.5VLR20	6'-10	8'-9	9'-1	345	306	275	249	203	184	168	154	141	130	120	112	104	94	83
	1.5VLR19	7'-8	9'-8	9'-11	372	330	296	268	244	224	182	167	154	142	132	122	114	100	88
	1.5VLR18	8'-5	10'-3	10'-8	395	351	315	285	260	238	220	179	165	152	141	131	119	105	92
	1.5VLR16	8'-5	10'-5	10'-9	397	353	316	286	261	239	221	180	165	153	142	132	123	115	101
4.00 (t=2.50) 44 PSF	1.5VLR22	5'-6	7'-3	7'-5	366	325	264	236	213	193	176	161	147	136	125	116	107	100	93
	1.5VLR20	6'-5	8'-4	8'-8	400	356	319	261	236	214	195	179	164	151	140	130	121	112	105
	1.5VLR19	7'-3	9'-2	9'-6	400	383	344	311	283	232	212	194	179	165	153	142	132	123	115
	1.5VLR18	7'-11	9'-9	10'-1	400	400	365	330	301	276	226	207	191	177	164	152	142	132	124
	1.5VLR16	7'-11	9'-11	10'-3	400	400	365	330	301	276	226	207	191	176	164	152	142	132	124
4.50 (t=3.00) 50 PSF	1.5VLR22	5'-3	6'-11	7'-1	400	342	303	271	245	222	202	185	170	156	144	133	124	115	107
	1.5VLR20	6'-2	8'-0	8'-3	400	400	366	300	270	245	224	205	188	174	161	149	139	129	120
	1.5VLR19	6'-11	8'-9	9'-1	400	400	393	356	293	266	243	223	205	189	175	163	151	141	132
	1.5VLR18	7'-6	9'-4	9'-8	400	400	400	378	344	316	259	238	219	202	188	174	163	152	142
	1.5VLR16	7'-7	9'-6	9'-10	400	400	400	377	344	315	258	237	218	202	187	174	162	151	141
5.00 (t=3.50) 56 PSF	1.5VLR22	5'-0	6'-8	6'-10	400	387	344	308	277	251	229	209	192	177	164	151	140	130	121
	1.5VLR20	5'-10	7'-8	7'-11	400	400	379	339	306	278	254	232	214	197	182	169	157	146	136
	1.5VLR19	6'-7	8'-5	8'-8	400	400	400	400	331	301	275	252	232	214	199	184	172	160	149
	1.5VLR18	7'-2	9'-0	9'-3	400	400	400	400	389	321	293	269	248	229	213	198	184	172	161
	1.5VLR16	7'-3	9'-1	9'-5	400	400	400	400	388	320	292	268	247	228	212	197	183	171	160
5.50 (t=4.00) 62 PSF	1.5VLR22	4'-10	6'-5	6'-7	400	400	385	344	310	281	256	235	216	199	183	170	157	146	136
	1.5VLR20	5'-8	7'-4	7'-7	400	400	400	380	343	311	284	260	239	221	204	190	176	164	153
	1.5VLR19	6'-4	8'-1	8'-4	400	400	400	400	371	337	308	282	260	240	222	207	192	179	168
	1.5VLR18	6'-11	8'-8	8'-11	400	400	400	400	395	359	328	301	278	257	238	221	206	193	180
	1.5VLR16	6'-11	8'-9	9'-1	400	400	400	400	393	357	327	300	276	255	237	220	205	192	179
6.00 (t=4.50) 68 PSF	1.5VLR22	4'-8	6'-2	6'-4	400	400	400	382	344	312	284	260	239	220	204	188	175	162	151
	1.5VLR20	5'-6	7'-1	7'-4	400	400	400	400	380	345	315	289	265	245	227	210	196	182	170
	1.5VLR19	6'-2	7'-10	8'-1	400	400	400	400	400	374	341	313	288	266	247	229	213	199	186
	1.5VLR18	6'-9	8'-4	8'-7	400	400	400	400	400	398	364	334	308	285	264	245	229	214	200
	1.5VLR16	6'-9	8'-6	8'-9	400	400	400	400	400	396	362	332	306	283	262	244	228	213	199

Image AP18: Vulcraft VLR Composite Deck Design Table
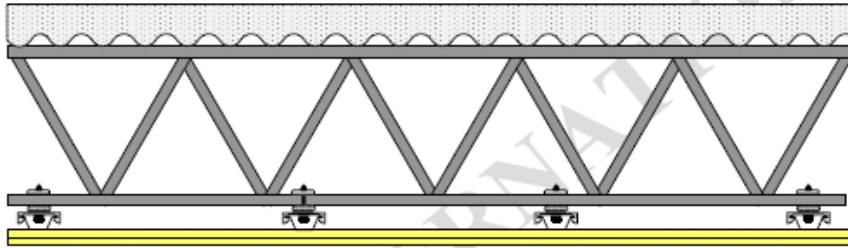
Image AP19: Concrete Slab on Deck and Bar Joist Assembly IIC Rating

3/20/2019   Roberts Super Felt Premium Underlayment

Home → Accessories → Underlayment → Felt Underlayment → Roberts Super Felt Flooring Underlayment | 3mm 100 sf

Free Shipping ◄

Roberts Super Felt Flooring Underlayment | 3mm 100 sf

$32.99 /roll
~~Was: $35.99/roll~~
Save 8%

7 Review(s) | Add Your Review

SKU: 70-190-100

Only 9457 left

Availability: In stock

FREE SHIPPING on orders above: no minimum
Free Shipping Ends: 03/26/2019
Estimated Delivery Time: 3-10 Business Days

Qty: ⑦ [   ] / roll

Add to Cart

♥ Add to Wishlist   Add to Compare   ≺ Send to friend

Customer Product Images

Upload images for this product

+ Start Uploading My Own Images

| Overview | Specification | Installation | Product Reviews |

Super Felt Premium Felt Underlayment provides a vapor barrier, insulation, and sound reducing properties. This underlayment is ideal for laminate and engineered wood flooring. It is available in 100 sq feet rolls, and is easy to install! This 3mm will reduce noise while keeping the moisture out!

Special Features:

- 100 sq. ft. per roll
- STC Rating=66
- IIC Rating=67
- Self sealing 3" overlap
- Adhesive tape strip attached for connecting multiple rows
- Green Fiber construction
- Sound dampening properties
- Insulating properties
- Made to reduce noise and help cushion flooring
- Made from recycled fibers and compressed using a high heat manufacturing process
- Pre-attached vapor barrier film protects engineered and laminate flooring from any moisture from the subfloor

https://www.bestlaminate.com/roberts-super-felt-premium-underlayment-100sf-roll/   1/2

Image AP20: Floor Underlayment IIC Rating