Point Pleasant Apartments
Point Pleasant, NJ

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Structural Option
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Final Report
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POINT PLEASANT APARTMENTS

Point Pleasant, NJ

Building Information

Occupancy: Residential

Square Footage: 64,000

Number of Stories: 4 over parking

Building Height: 65 Feet

Construction: Aug. 2006-Fall 2007

Structural:

- Shallow foundation with spread footings, a 12" thick concrete foundation wall, and 5" thick slab on grade
- Floor system is 16" deep Vescom Composite Joist w/ 3.5" thick concrete on 22 GA. metal deck
- First floor is 12" thick reinforced concrete slab
- Parking garage has 5" slab on grade over 6" of stone
- Frame is steel beam and column, mostly HSS
- Walls are steel stud
- Metal trusses frame the roof

Architecture:

- Building 1 of 5 waterfront, luxury apartment complexes
- Each apartment has front and rear balcony, rear balconies overlook the water
- 3 different veneer types (stone, hardshingle, stucco) create unique façade
- Hip roof with multiple dormers, a dome feature on one side and a steeple at the center

Mechanical:

- Each unit has 5 ton air-conditioner located on concrete pads outdoors along with two 2 ton ac's for corridors
- Two 1.5 ton, 710 cfm heat pumps located in machine room at garage level
- Common areas have two 5 kW, 250-500 cfm unit heaters
- The attic houses two 800 cfm, 39,000 btu air handling units/ warm air furnaces
- Heating system is gas powered
- Air distributed through ceiling diffusers

Lighting/Electrical:

- 120/208V, 3-phase, 4-wire system
- 1600A main switchboard
- Unit lighting consists of surface mounted, wall mounted, recessed at wet areas, and pendant mounted chandeliers
- Recessed fluorescents in common areas
- Parking garage lighting is 2 x 4 troffers

Ryan Flynn **Structural Option**

http://www.engr.psu.edu/ae/thesis/portfolios/2008/RPF129/

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Acknowledgments

I would like to acknowledge and express my sincere gratitude to the following individuals, design professionals, and faculty members for assisting in the completion of this educational study.

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- Chris Scharff for his assistance in the building selection process

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- My consultant, Dr. Hanagan, and the rest of the Penn State Architectural Engineering Staff for providing the engineering background necessary to complete a study of this nature

- And last but not least, my family and friends for their constant support not only in senior thesis, but throughout my collegiate career

Executive Summary

The purpose of this report is to explore the feasibility of a wood structural system to replace the existing composite steel joist system for floors 2-4. Based on previous research, it has been determined that the current structural system of open-web steel joists with metal deck and concrete slab may not be the most economical or efficient choice for Point Pleasant Apartments. Throughout this semester, an alternate system using wood floor trusses was designed and compared to the existing structure. The wood trusses are supported by PSL's, wood bearing walls and built-up or PSL posts, replacing the current W and HSS shapes and metal stud bearing walls. In addition to the redesign of floors 2-4, alternative options for the 12" thick concrete slab on the first floor were explored. A RAM Structural System Model was created and the first floor was redesigned as a composite steel system.

A wood system drastically changes the weight of the building, therefore, the seismic loads were recalculated and the lateral forces redistributed to ensure that wind was still the controlling design load. With the switch to a wood truss floor system, wood shear walls were utilized to resist lateral load as opposed to the braced frames of the existing system. The shear walls were designed based on the code provisions outlined in IBC 2006 and the 2005 NDS.

After the loads had been recalculated and shear walls designed, the members were rechecked to ensure adequacy and the results compared to those of the existing structural system. The members were checked for strength, deflection, and vibration.

In addition to the structural changes made to Point Pleasant Apartments, two breadth topics were explored. The first of these breadths was construction management. Changing from steel to wood creates drastic changes in both scheduling and cost of construction. A detailed schedule of the construction of the structure was created for the new structural system and then compared to the schedule of the existing building. An in depth cost analysis was also performed and compared to the existing cost to ensure that switching from steel to wood would be economically beneficial.

The second breadth option explored was acoustical performance. With the new structural system, the noise barrier created by the 3.5" concrete slab is lost and replaced with a subfloor. Over the course of the semester, a vibration analysis was performed and research was done to provide an adequate sound barrier from apartment to apartment. This included comparisons of the new and old floor systems and new and old common walls.

After performing all of the previously mentioned analyses, the proposed changes to the structural system of Point Pleasant Apartments resulted in significant cost savings and a decrease in construction time. All systems designed are adequate to support the loads of the building and only very slight changes had to be made to the floor plan. An effective sound barrier for both the common walls and floor system was designed to negate the consequences of switching to a wood system. Therefore, it is the recommendation of this educational study that the changes proposed in this report be implemented in place of the existing structural conditions.

Introduction

Point Pleasant is a 5-building apartment complex located at the New Jersey Shore. This report will focus on building 1, which is 64,000 square feet and has four stories over a partially exposed parking garage. There are sixteen luxury apartments in the building, four on each floor. The apartments are approximately 2,500 square feet and each has a front balcony facing the central courtyard and a rear balcony overlooking the Manasquan River. The exterior of the building is a combination of stone, stucco, and hardshingle siding. This change in material along with the bump out balconies creates an interesting façade and effectively masks its basic box shape. The roof is a simple hip accented with multiple dormers, a dome feature on one side, and steeple at the center.

For the most part, the five buildings are being built one at a time. Building 1 is the first building to begin construction. As the construction on Building 1 moves toward the finishes stage, superstructure erection for Building 2 begins. Construction began in August of 2006 for Building 1, and when the author of this report visited the site in August of 2007, it was completely enclosed and the structure for Building 2 was approximately halfway complete.

Existing Structural System

Foundation

For Point Pleasant Apartments, a traditional shallow foundation with spread footings was used. The building was designed based on a 3,000 PSF soil bearing capacity. The exterior foundation walls are 12" thick concrete over either a 2'-6"x12" thick footing with #5 @ 24" o.c. S.W.B. and (3) #4 L.W.B. or a 3'-0"x12" thick footing with #5 @ 16" o.c. S.W.B. and (3) # 5 L.W.B. There is a 5" concrete slab on grade with 6.0x6.0 – W2.0x2.0 welded wire fabric over 4" of crushed stone and a 6 Mil vapor barrier. The main columns at this level are 16"x24", 18"x26", or 24"x24" reinforced concrete columns. Beneath these columns are 11'-0"x11'-0"x26" deep concrete spread footings which are reinforced with (12) #7 bars each way.

Floor System

The framing for floors 2, 3, and 4 is all basically the same. These stories are supported by 16" deep Vescom composite joists with a 3 1/2"reinforced concrete slab. The slab is supported by a 1 5/16", 22 gage UFX 36 metal form deck. The joists are spaced at 48" o.c. and are designed to carry a total load of about 380 plf. The typical span for these joists is approximately 20', with a maximum span of about 24'. Spans run front to back. This composite system is supported by a series of steel girder trusses, wide flange beams, and HSS columns.

Each of the apartments throughout the building features front and rear balconies. The balconies are supported by a shallower composite joist of 12". HSS shapes are used as both edge beams and columns for the balconies.

The first floor is framed very differently from the floors above. Instead of a composite joist system, the first floor is a 12" thick, reinforced two-way slab. In addition to the 12" thick slab, there are slab beams in the outer apartments for additional support. Above the concrete columns below, are 12'-0"x12'-0"x20" deep (20"-12"=8" below slab depth) drop panels.

Roof Sytem

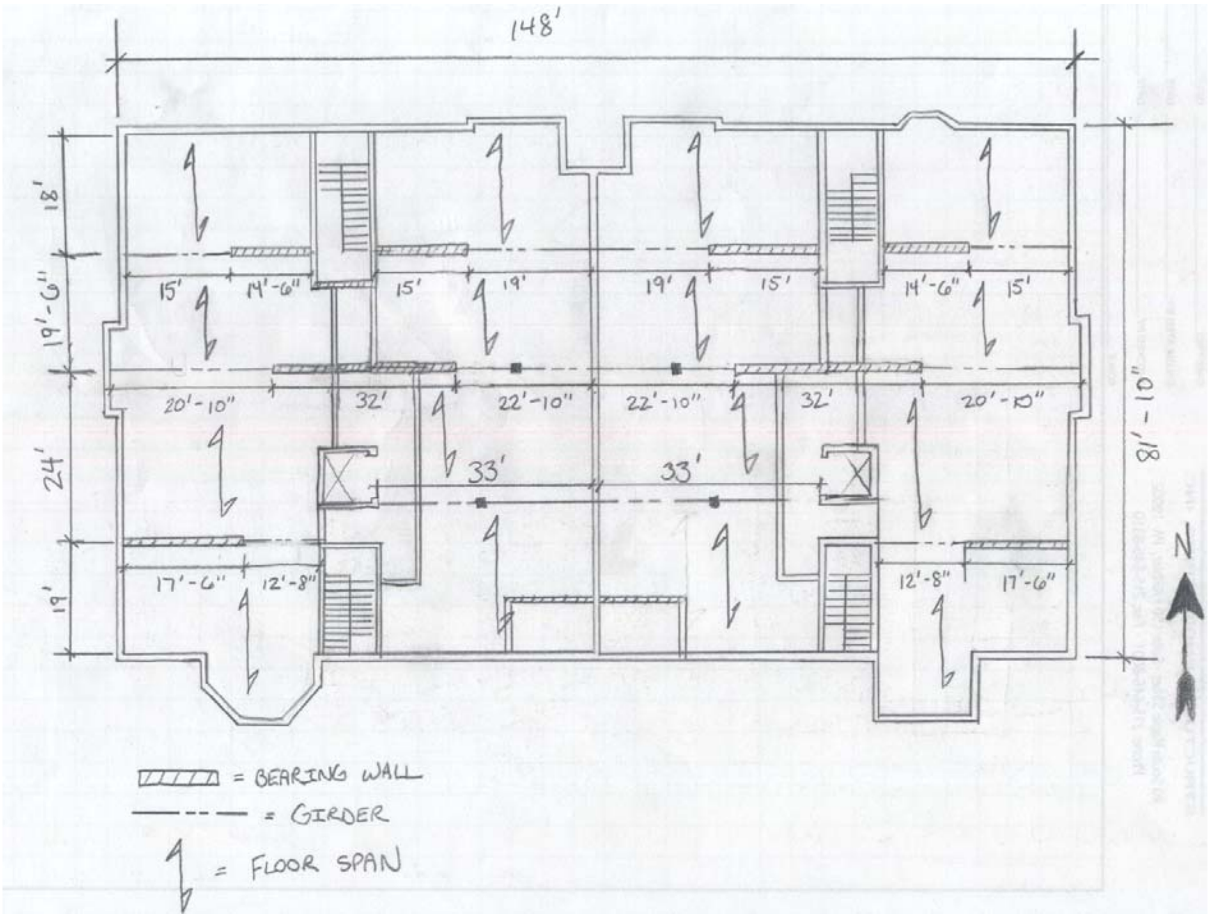
The roof system is a simple hip with two large dormers in the rear and two smaller dormers, a tower, and a dome feature in the front. The roof is made up of light gage metal roof trusses spaced at 48" o.c.

Lateral Framing

The walls of the building are comprised of metal studs, therefore, light gage shearpanels and are utilized to resist lateral load. The shear walls, which actually act as braced frames, typically consist of 4"x14 gage flat strap bracing with 3 1/2"x3 1/2"x1/2" HSS shapes. The flat straps can either be screwed or welded to the HSS's. All of the panels are 9' 6" in length.

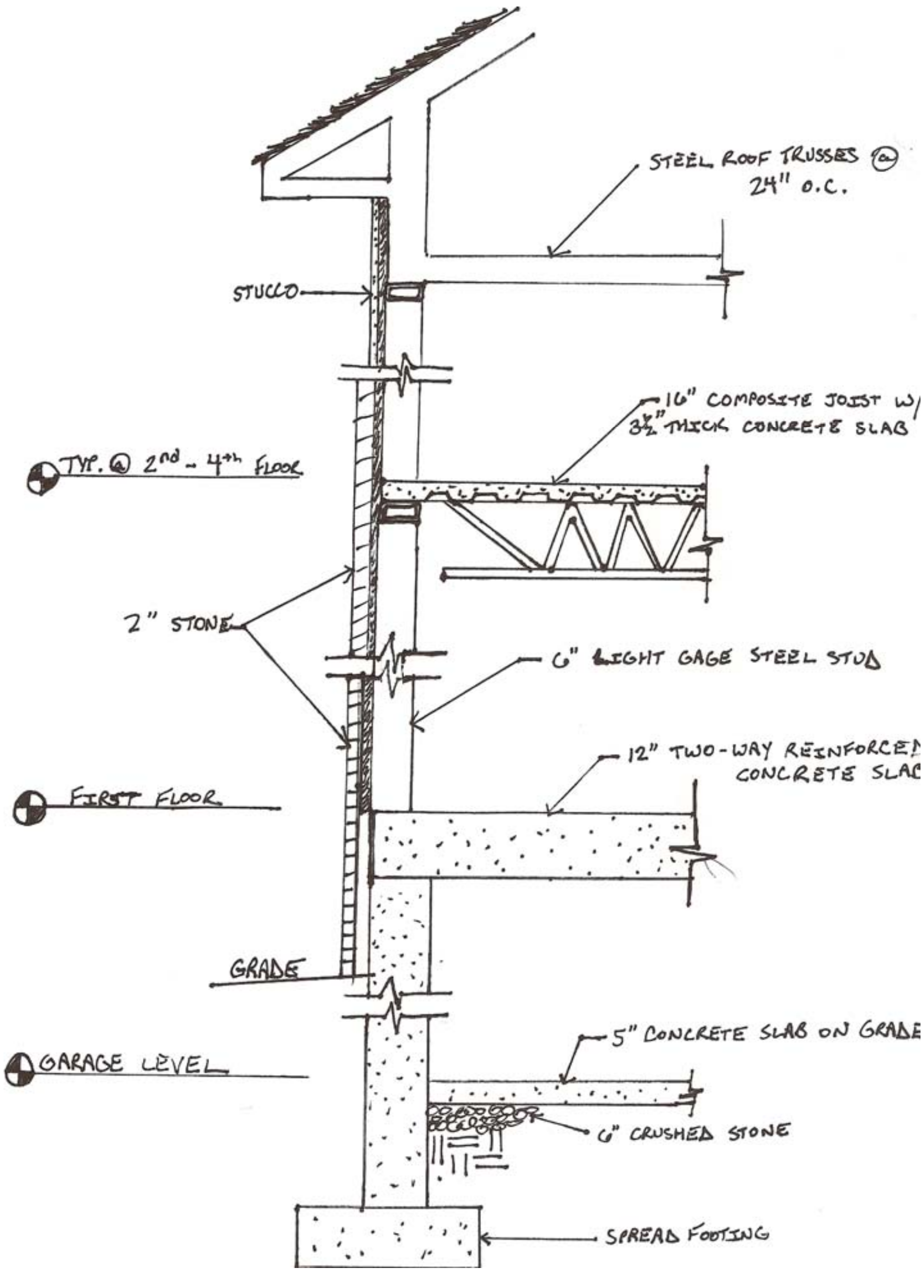
Typical Floor Plan (Structural Layout)

The floor plan below illustrates the typical framing for floors 2-4. The span arrows represent the composite joist system used for these floors. The outline of the building is the same for first floor and parking garage level as well.



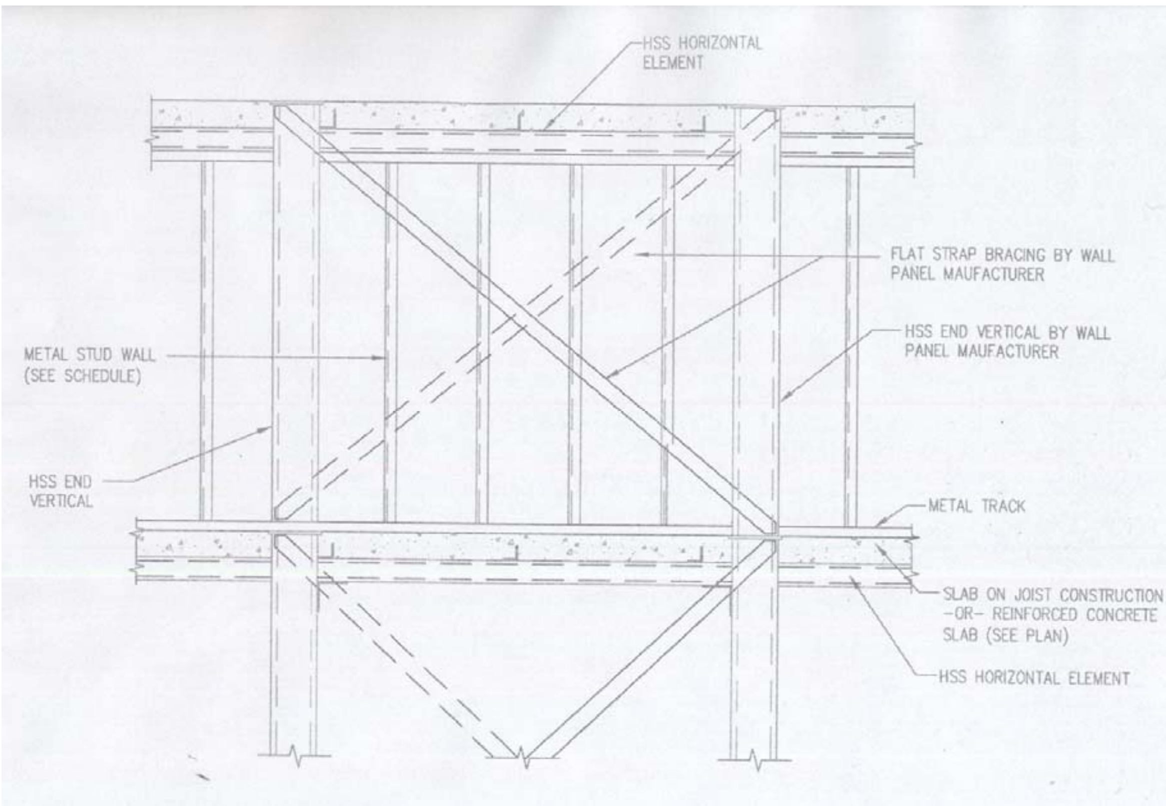
Typical Exterior Wall Section

The section below shows the basic structural framing from the foundation up to the roof. Floors 2-4 were generalized with one section because they use the same composite joist system. At different areas of the building the façade material may change to include hardshingle siding but this image gives a typical snapshot of the framing. How much of the garage that is above grade also changes around the building. For example, at the rear of the building, the full height of the garage is exposed so that cars can enter and exit.



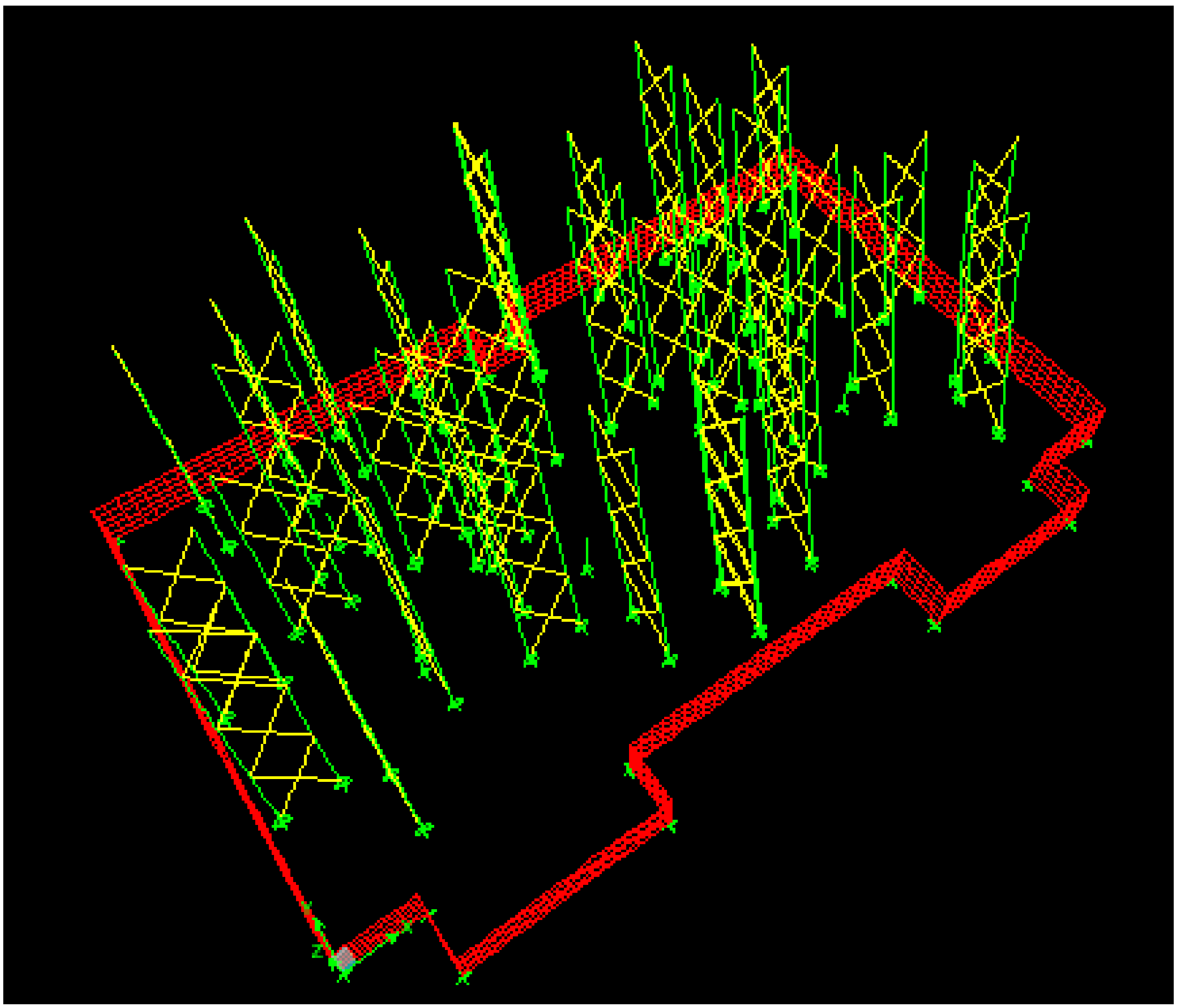
Braced Frame Details

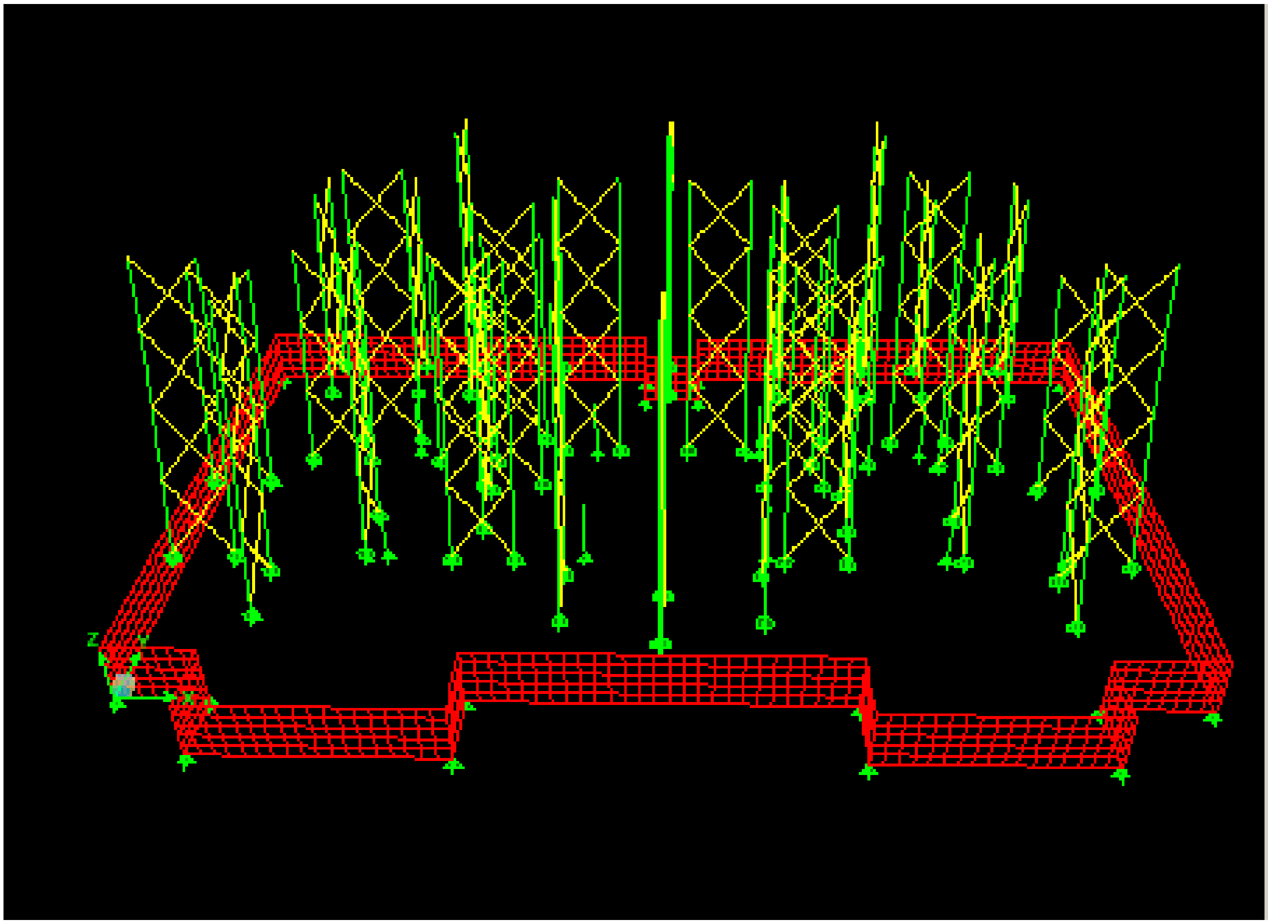
The image below illustrates the braced frames used for lateral resistance in the building. The HSS shapes at each end of the panel act as restraining points for the 4"x14 gage metal cross-braced straps. The story force is distributed among the braced frames, with the forces being transferred into tension in the straps. The manufacturer of the straps is Marinoware. Their design manual was consulted during the spot checks of the straps.



ETABS 3-D View of Lateral System

The images below show the ETABS layout of the lateral system. At the first floor, the lateral resisting element is the 12" thick concrete wall. The concrete columns of the first floor that support the two-way slab above are also modeled. The main lateral resistance is provided by the braced frames throughout the building. Floors 1 thru 3 have the same frame layout while only some of the frames are carried up to the 4th floor. For the purpose of this analysis, the slab on grade for the parking garage is considered to be at ground level. The level of grade actually varies around the perimeter of the building, but for simplification the walls of the parking garage are considered to be completely above grade.





Problem Statement

The results from all the analyses performed in the first three Technical Reports show the current structural system is sufficiently designed to support forces due to gravity, wind, and seismic loading. However, because Point Pleasant Apartments is only four stories above grade and typical spans are not especially long, the building lends itself to wood structural system.

An advantage of the existing open-web steel joists is that the mechanical equipment can be run through them as opposed to having to be dropped below. However, the use of wood floor trusses is a possible alternative that could achieve this same goal and may in fact reduce the overall depth of the floor system. In this report, a wood truss floor system will be analyzed for strength, deflection, and vibration to ensure it is a viable alternative to the existing structure.

With the use of a wood floor system, existing steel studs would be replaced with wood as well, and the braced frames will be replaced with shear walls. Lateral loads due to wind and seismic will be reassessed and a combination of plywood and gypsum sheathed walls will resist these loads. In addition, the existing first floor which is a 12” thick two-way slab, will be analyzed and redesigned in a more economical manner. The structure proposed for the first floor in this report is a composite system with steel beams and girders and a metal deck and concrete slab.

Once the proposed structure has been designed and checked, a detailed cost comparison will be completed to determine the economic benefits of the proposal. In addition to a cost analysis, a construction schedule for the structural elements of the building will be developed for the existing and proposed structures to compare timelines.

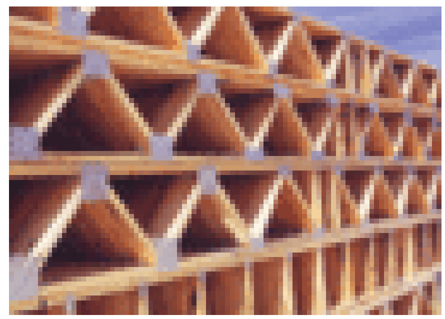
Changing from steel and concrete to a wood structure impacts many other systems in the building. One major area of concern is acoustic performance. In this report, an effective sound barrier will be developed for both the common walls between units and the floor assembly.

Depth Analysis: Structural Re-design

Floors 2-4

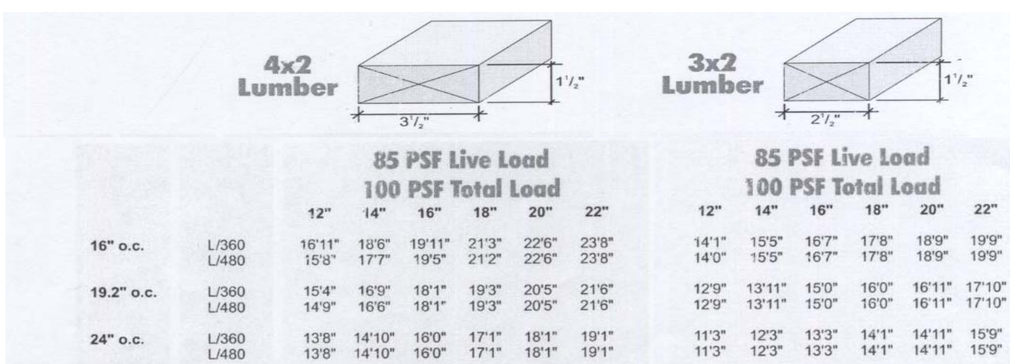
The majority of this project involved replacing the existing steel and concrete system with a wood based system. Two wood alternative flooring solutions were explored during the fall semester. The first alternative was to use I-level floor joists by Weyerhaeuser. These joists consist of a top and bottom 2x3 chord with a plywood web. The second option explored was wood floor trusses manufactured by Alpine. The trusses are made up of a 2x3 or 2x4 top and bottom chords and web members.

Both of these systems have their advantages. I-joists are less expensive and easier to construct than the existing structural system. Based on calculations from Technical Assignment 2 of last semester, I-joists could reduce the floor depth by approximately four to six inches. However, because most of the mechanical equipment was run through the web of the steel joists, a number of soffits would have to be built in, or the ceiling would have to be dropped all together.



The use of wood floor trusses would allow for the same method of duct work placement as the existing structure does. Wood floor trusses may be slightly more expensive than I-joists, but no increase in floor depth would be required. In fact after sizing the floor trusses for the largest span, the depth required was 18”. When added to the ¾” of subfloor and ¾” of gypsum topping, the total depth of the floor structure is 19.5”, ½” less than the existing structure.

The Alpine span tables from the manufacturer’s website were used to size the floor trusses. The dead load calculated for a wood truss floor was 23.25psf excluding the self weight of the floor truss (3psf for plywood, 5psf for floor finish, 6.25psf for Gyp-crete, 5psf for MEP, and 3psf for ceiling). This new dead load is less than 50% of the dead load of 53psf for the existing structure. The live load for floors 2-4 remains at 40psf plus a 20psf allowance for partitions. In order to maintain the same ceiling height throughout each apartment, the floor trusses were sized based on the largest span of 20’-4”. The values used in the chart were for 85psf live load and 100psf total load. The total load below this was 75psf which was not large enough.



4x2 Lumber — 85 PSF Live Load, 100 PSF Total Load

		12"	14"	16"	18"	20"	22"
16" o.c.	L/360	16'11"	18'6"	19'11"	21'3"	22'6"	23'8"
	L/480	15'8"	17'7"	19'5"	21'2"	22'6"	23'8"
19.2" o.c.	L/360	15'4"	16'9"	18'1"	19'3"	20'5"	21'6"
	L/480	14'9"	16'6"	18'1"	19'3"	20'5"	21'6"
24" o.c.	L/360	13'8"	14'10"	16'0"	17'1"	18'1"	19'1"
	L/480	13'8"	14'10"	16'0"	17'1"	18'1"	19'1"

3x2 Lumber — 85 PSF Live Load, 100 PSF Total Load

		12"	14"	16"	18"	20"	22"
16" o.c.	L/360	14'1"	15'5"	16'7"	17'8"	18'9"	19'9"
	L/480	14'0"	15'5"	16'7"	17'8"	18'9"	19'9"
19.2" o.c.	L/360	12'9"	13'11"	15'0"	16'0"	16'11"	17'10"
	L/480	12'9"	13'11"	15'0"	16'0"	16'11"	17'10"
24" o.c.	L/360	11'3"	12'3"	13'3"	14'1"	14'11"	15'9"
	L/480	11'3"	12'3"	13'3"	14'1"	14'11"	15'9"

The floor trusses in this system are supported by a combination of PSL beams, dimension lumber built up headers, wood bearing walls, 2x6 built up posts, and PSL posts. The member length, tributary width, and loading information was entered into Excel spreadsheets. The PSL beams were designed based on the Allowable Design Properties Tables in the iLevel by Weyerhaeuser floor design literature. All headers, bearing walls, and built up posts were designed in accordance with the 2005 National Design Specification for Wood Construction.

Beam Design for Floors 2-4									
Beam	Length (ft)	Trib (ft)	Live Load (klf)	Total Load (klf)	Moment (ft-k)	I for L/480 (in^4)	I for TL/360 (in^4)	Design	End Reactions (k)
1	15.25	11	0.66	0.95	27.58	1,053.3	1,135.6	3 1/2" x 16" PSL	7.23
2	19	14	0.84	1.21	54.49	2,592.7	2,795.3	7" x 18" PSL	11.47
3	13.167	15.5	0.93	1.34	28.97	955.3	1,030.0	3 1/2" x 16" PSL	8.80
4	8	15.7	0.942	1.35	10.83	217.0	234.0	3 1/2" x 9 1/2" PSL	5.42
5	9	15.7	0.942	1.35	13.71	309.0	333.2	3 1/2" x 11 7/8" PSL	6.09
6	17.5	15.67	0.9402	1.35	51.74	2,267.5	2,444.6	5 1/4" x 18 PSL	11.83
7	9.25	19.9	1.194	1.72	18.36	425.2	458.5	3 1/2" x 11 7/8" PSL	7.94
8	13.5	19.9	1.194	1.72	39.10	1,322.0	1,425.2	3 1/2" x 18" PSL	11.59
9	9.5	15.6	0.936	1.35	15.18	361.1	389.3	3 1/2" x 11 7/8" PSL	6.39
10	9.5	15.6	0.936	1.35	15.18	361.1	389.3	3 1/2" x 11 7/8" PSL	6.39
11	13.75	9.25	0.555	0.80	18.85	649.3	700.0	3 1/2" x 14" PSL	5.48

Post Capacity	
Built Up Post Size	**Load Range (k)**
(2)2x6	**3.3 - 6.5**
(3)2x6	**6.6 - 9.8**
(4)2x6	**9.9 - 13.1**
(5)2x6	**13.2 - 16.4**

Post Capacity	
PSL Post Size	**Load Range (k)**
5 1/4" x 5 1/4"	**Up to 26.655**
5 1/4" x 7"	**Up to 35.5**

All bearing walls in the building are designed as 2x6 Spruce Pine Fir, Stud Grade, spaced at 16" o.c. At the largest span below the second floor, a couple of centrally located bearing walls were designed with 12" o.c. spacing because they are also carrying the load supported by the bearing walls two floors above. In an effort to shorten some of the larger spans found throughout the building, several partition walls were converted from 2x4 to 2x6, but there were no alterations to the floor plan in order to accommodate the wood structural system with the exception of one post.

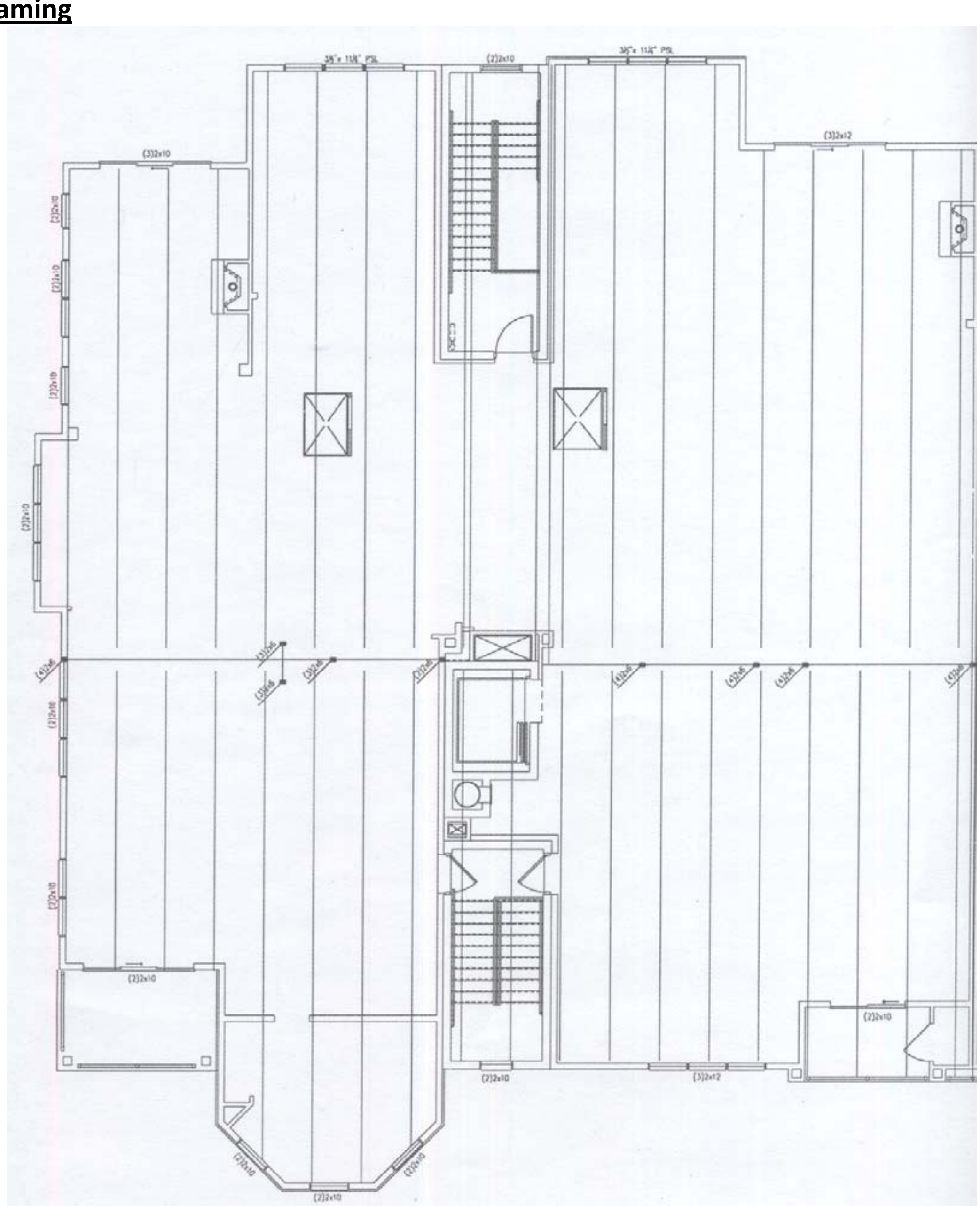
Built up headers were used around the exterior of the building to take the load over the windows. They were also used over doors in bearing walls. For the most part, these headers were double or triple 2x10's or 2x12's. In some instances, a PSL beam had to be used for larger spans. The table on the following page is the spreadsheet used to calculate all the headers throughout the building.

Headers		EI (3)2x10	EI (3)2x12									
Floors 2-4		356,148,000	640,800,000									
Length (ft)	Trib (ft)	Live Load (klf)	Dead Load (klf)	Fb' (psi) 2x10	Fb' (psi) 2x12	fb (psi) 2x10	fb (psi) 2x12	EI for L/480 LL defl.	EI for L/360 TL defl.	PSL I Needed	End Reaction	Design
9.5	9.25	0.56	0.24	742.5	675	1683.09	1137.84	428,258,812.50	531,977,743.65	265.99	3.79	(3)2x12
9.5	9.33	0.56	0.24	742.5	675	1697.65	1147.68	431,962,672.50	536,578,632.25	268.29	3.82	(3)2x12
6.5	7.67	0.46	0.20	742.5	675	653.34	441.69	113,744,182.50	141,291,601.70	70.65	2.15	(2)2x10
9	5.625	0.34	0.15	742.5	675	918.60	621.01	221,433,750.00	275,062,236.33	137.53	2.18	(2)2x12
3	10.67	0.64	0.28	742.5	675	193.61	130.89	15,556,860.00	19,324,537.03	9.66	1.38	(2)2x10
3	12.09	0.73	0.32	742.5	675	219.38	148.31	17,627,220.00	21,896,312.34	10.95	1.56	(2)2x10
3	19.08	1.14	0.50	742.5	675	346.21	234.05	27,818,640.00	34,555,966.88	17.28	2.47	(2)2x10
9	9.25	0.56	0.24	742.5	675	1510.58	1021.22	364,135,500.00	452,324,566.41	226.16	3.59	(2)2x12
9.5	6.25	0.38	0.16	742.5	675	1137.22	768.81	289,364,062.50	359,444,421.39	179.72	2.56	(2)2x12
6.5	3.75	0.23	0.10	742.5	675	319.43	215.95	55,611,562.50	69,079,987.79	34.54	1.05	(2)2x10
9	5.75	0.35	0.15	742.5	675	939.01	634.81	226,354,500.00	281,174,730.47	140.59	2.23	(3)2x10
3	15	0.9	0.39	742.5	675	272.18	184.00	21,870,000.00	27,166,640.63	13.58	1.94	(2)2x10
3	19	1.14	0.50	742.5	675	344.76	233.07	27,702,000.00	34,411,078.13	17.21	2.46	(2)2x10
3	12	0.72	0.32	742.5	675	217.74	147.20	17,496,000.00	21,733,312.50	10.87	1.55	(2)2x10
3	12	0.72	0.32	742.5	675	217.74	147.20	17,496,000.00	21,733,312.50	10.87	1.55	(2)2x10
3	14.4	0.864	0.38	742.5	675	261.29	176.64	20,995,200.00	26,079,975.00	13.04	1.86	(2)2x10
3	14.4	0.864	0.38	742.5	675	261.29	176.64	20,995,200.00	26,079,975.00	13.04	1.86	(2)2x10
3	19.1	1.146	0.50	742.5	675	346.57	234.30	27,847,800.00	34,592,189.06	17.30	2.47	(2)2x10
3	19.1	1.146	0.50	742.5	675	346.57	234.30	27,847,800.00	34,592,189.06	17.30	2.47	(2)2x10
5	11	0.66	0.29	742.5	675	554.44	374.82	74,250,000.00	92,232,421.88	46.12	2.37	(2)2x10
3	11.8	0.708	0.31	742.5	675	214.11	144.75	17,204,400.00	21,371,090.63	10.69	1.53	(2)2x10
3	11.8	0.708	0.31	742.5	675	214.11	144.75	17,204,400.00	21,371,090.63	10.69	1.53	(2)2x10
3	15.9	0.954	0.42	742.5	675	288.51	195.04	23,182,200.00	28,796,639.06	14.40	2.06	(2)2x10
3	6.75	0.41	0.18	742.5	675	122.48	82.80	9,841,500.00	12,224,988.28	6.11	0.87	(2)2x10
3		2.68	1.15	742.5	675	805.75	544.72	65,124,000.00	80,281,125.00	40.14	5.75	(2)2x10

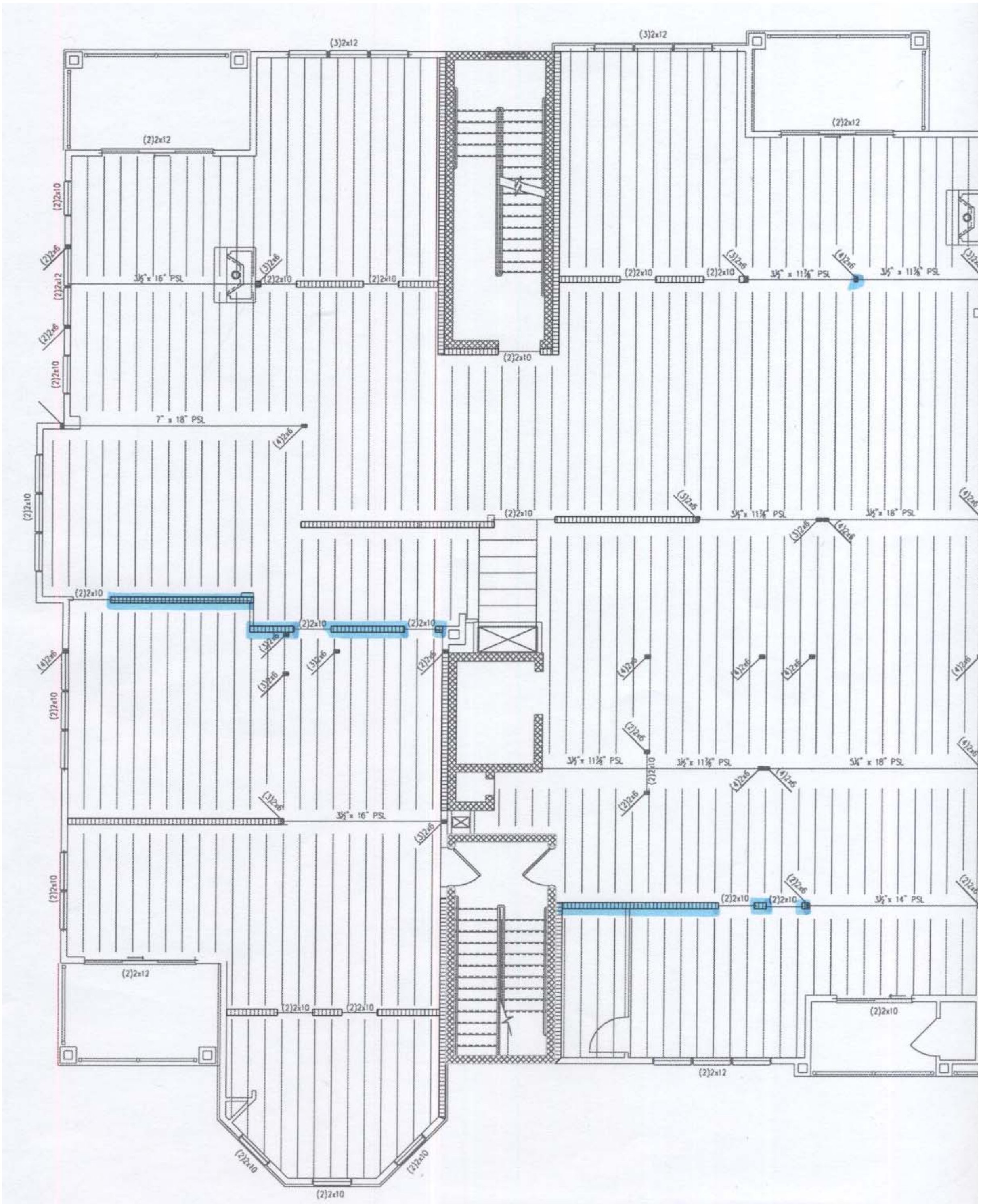
Headers		EI (3)2x10	EI (3)2x12									
Roof		356,148,000	640,800,000									
Length (ft)	Trib (ft)	Live Load (klf)	Dead Load (klf)	Fb' (psi) 2x10	Fb' (psi) 2x12	fb (psi) 2x10	fb (psi) 2x12	EI for L/480 LL defl.	EI for L/360 TL defl.	PSL I Needed	End Reaction	Design
9.5	24	0.5	0.48	853.88	776.25	2067.44	1397.68	385,818,750.00	706,048,312.50	353.02	4.66	3 1/2" x 11 1/4" PSL
9	20	0.42	0.4	853.88	776.25	1552.59	1049.62	275,562,000.00	501,916,500.00	250.96	3.69	(3)2x12
9	12.375	0.26	0.25	853.88	776.25	965.64	652.81	170,586,000.00	312,467,625.00	156.23	2.30	(3)2x10
9.5	16	0.336	0.32	853.88	776.25	1383.92	935.59	259,270,200.00	472,242,150.00	236.12	3.12	(3)2x12
6	13.75	0.29	0.275	853.88	776.25	475.46	321.43	56,376,000.00	102,424,500.00	51.21	1.70	(2)2x10
3	21.25	0.45	0.425	853.88	776.25	184.08	124.45	10,935,000.00	19,819,687.50	9.91	1.31	(2)2x10

The images below are the structural floor plans for floors 2-4 and the roof. The roof design was not addressed in this report. The structure remains pre-fabricated metal roof trusses at 48" o.c. The partition walls have been removed from the plan. All posts shown are buried within bearing or partition walls. The one post that was added which is not within a wall is highlighted, as are the partition walls that were converted to bearing walls. The plans show the West side of the building only since it is symmetric about the center line.

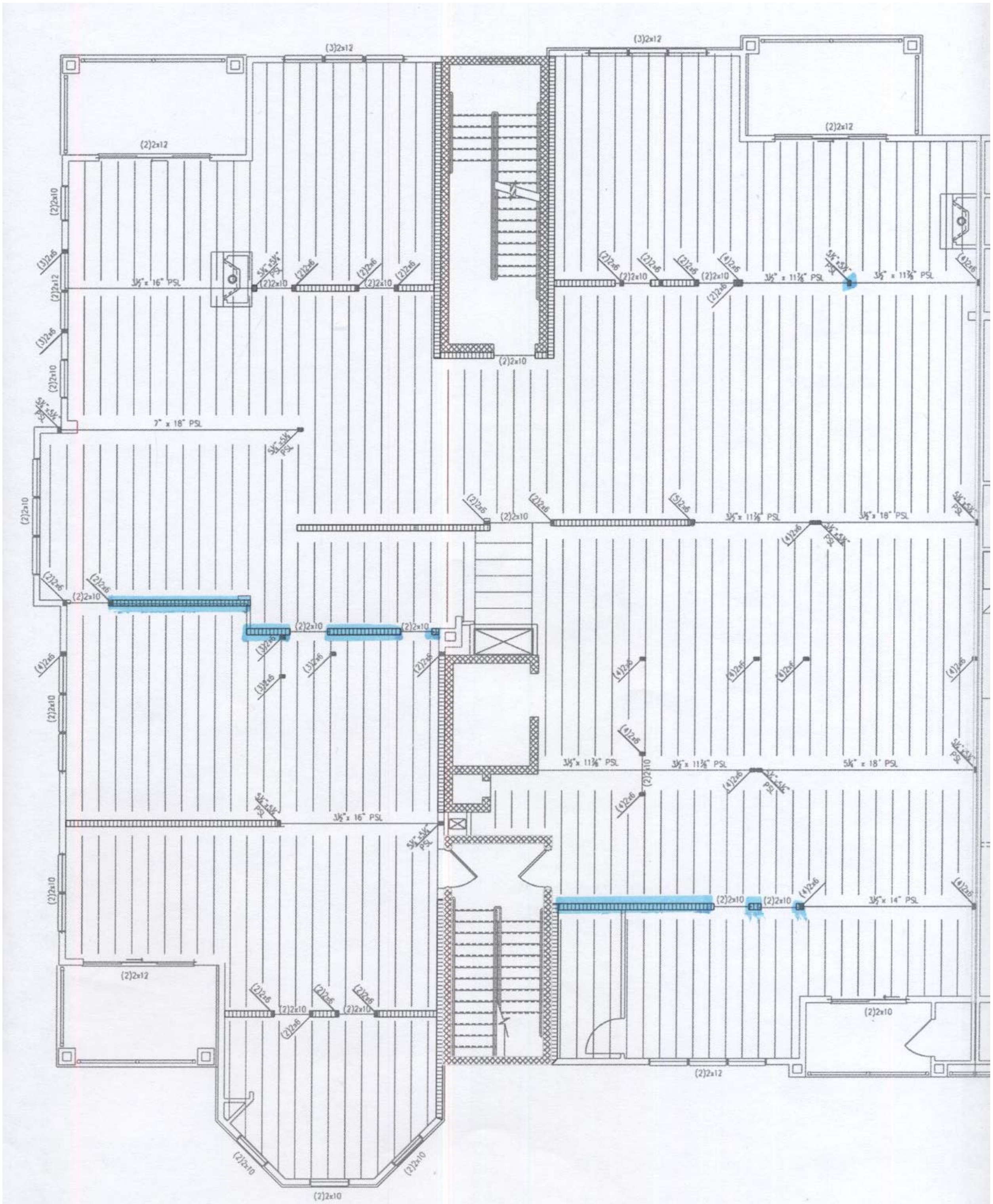
Roof Framing



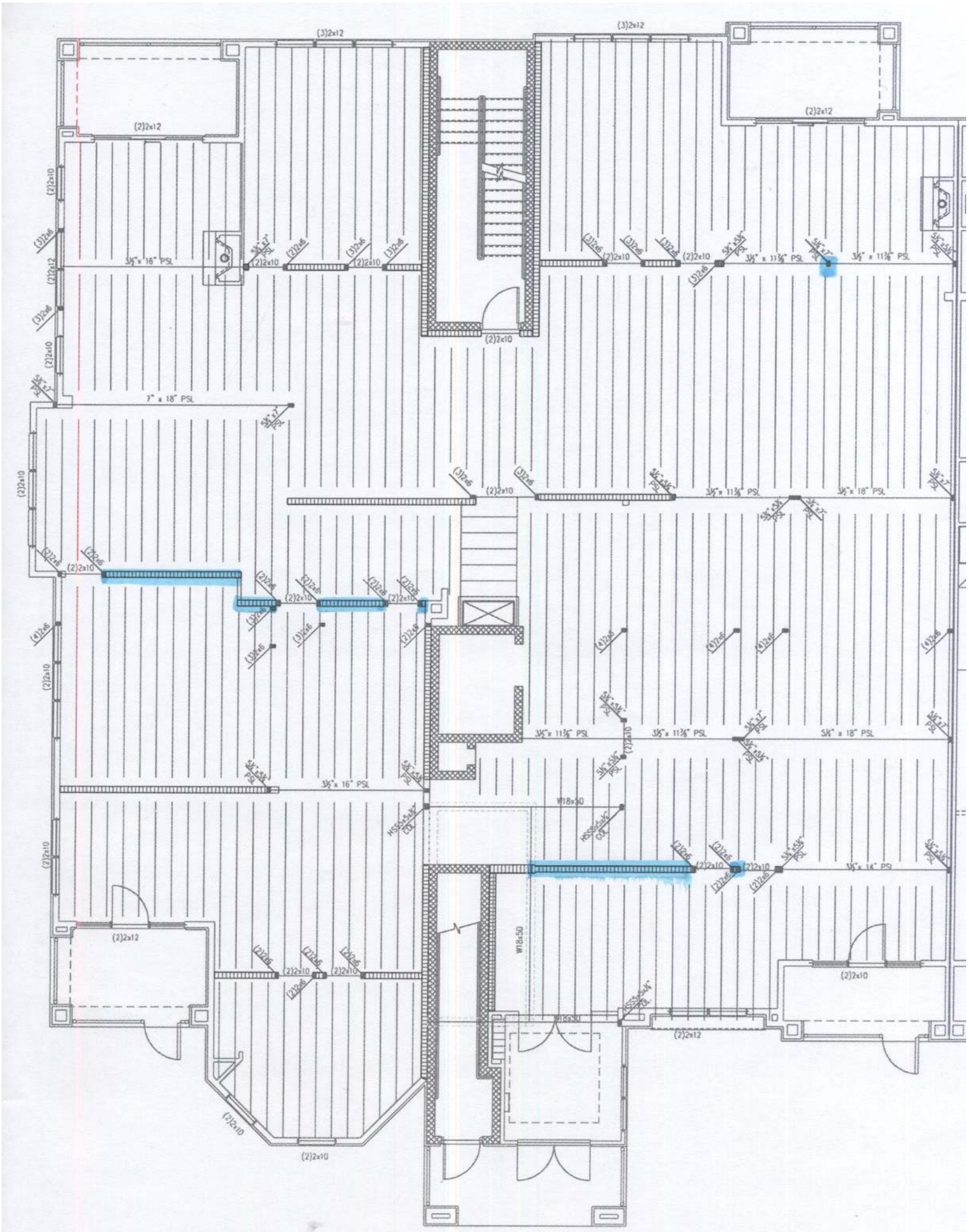
4th Floor



3rd Floor



2nd Floor

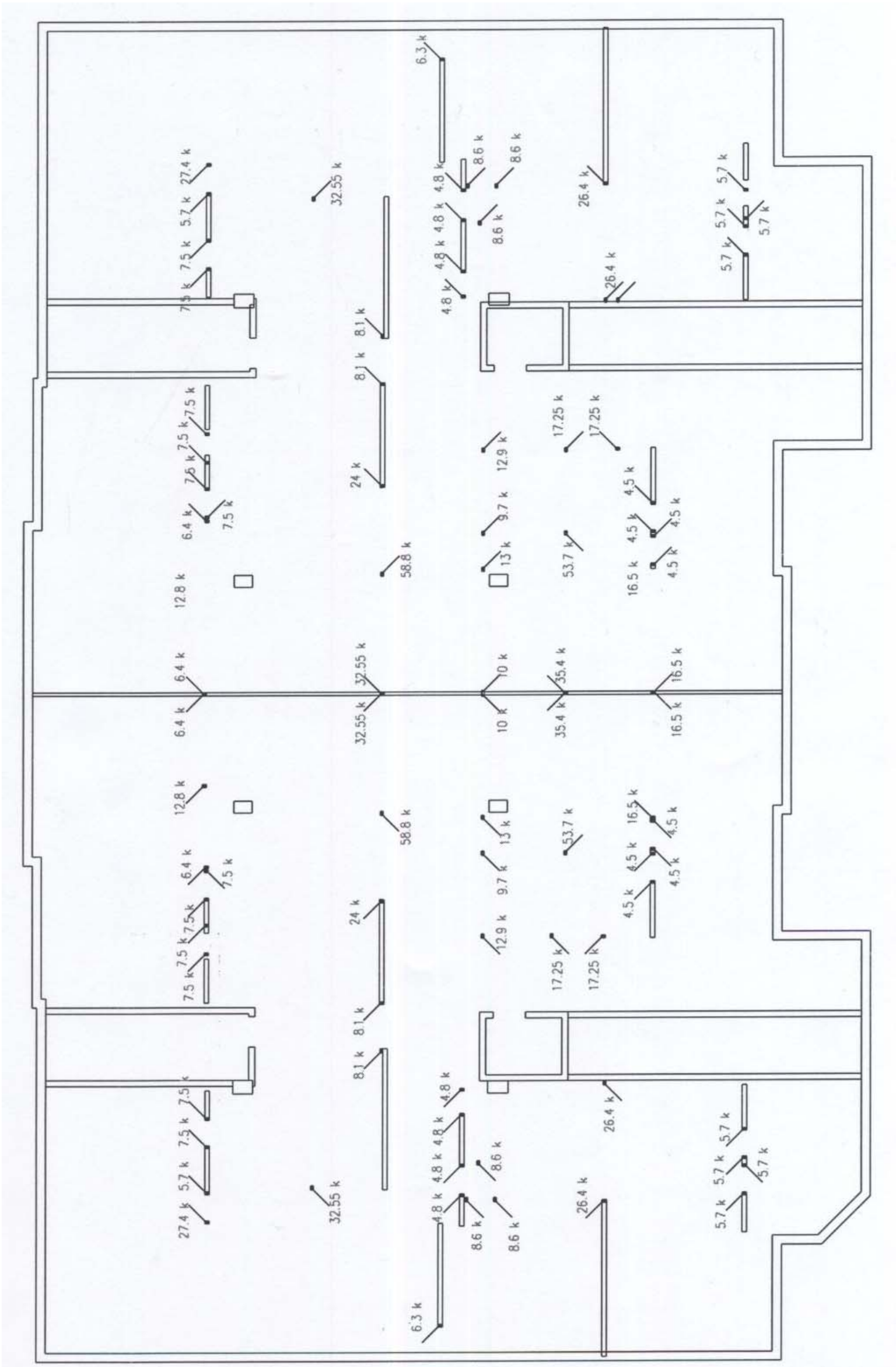


First Floor

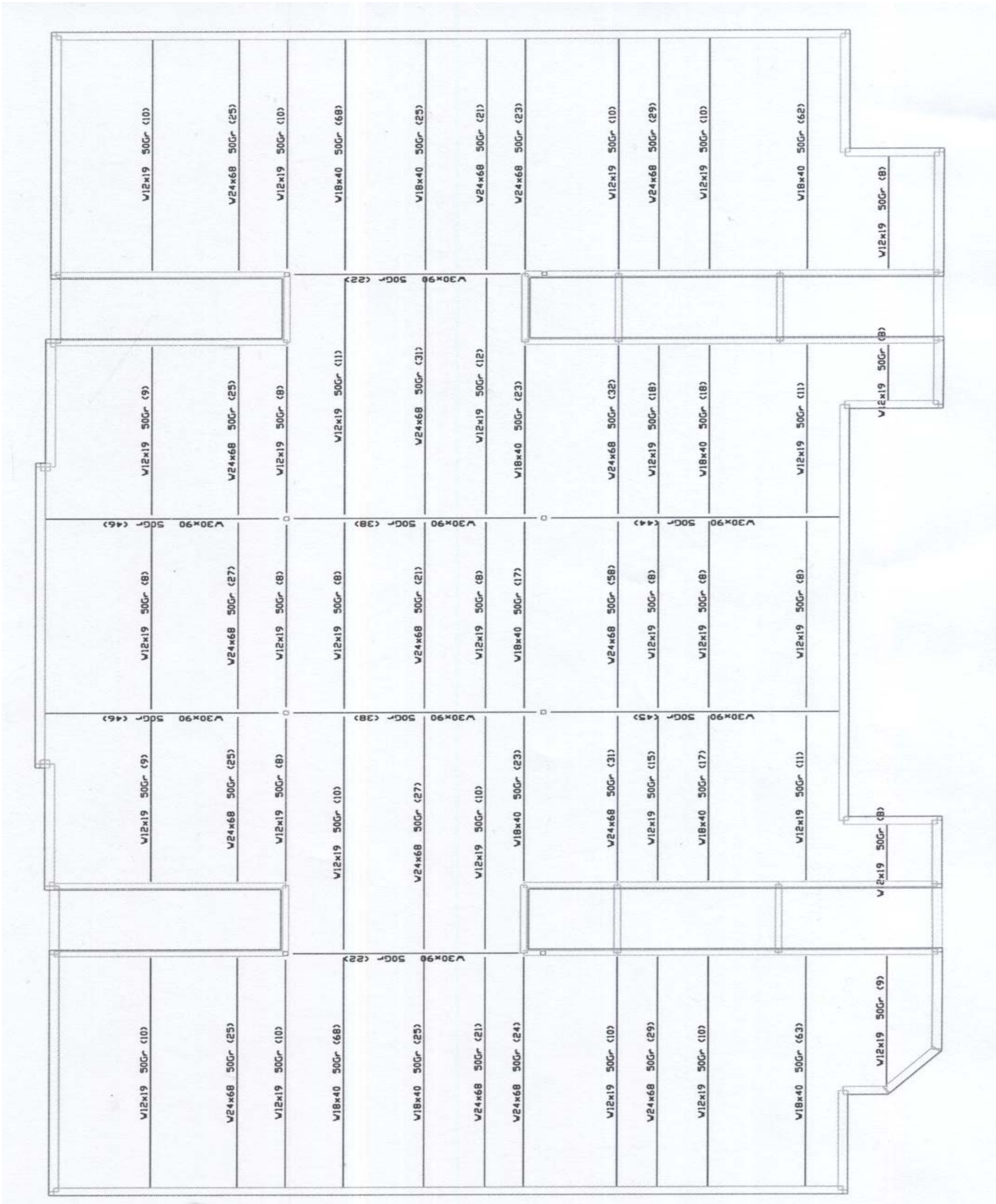
Another major structural topic explored in this report was the first floor. As previously mentioned, the existing first floor is a 12" thick two-way slab with drop panels. Because of the increased loading in the corridors for the first floor, and because of the parking garage below, wood floor trusses were not a viable solution for the first floor. Alternate flooring systems were explored before a composite steel beam and concrete slab was designed using RAM Structural System. The metal deck chosen was Vulcraft 1.5VLR21 and the concrete slab is 4.5", 3" over the top of the deck. The concrete foundation walls and columns below were left as they were in the existing structure. Girders run N-S and beams E-W.

One major design issue for the first floor is the parking garage below. The columns had to remain in their existing location so as not to disturb the parking space layout. The parking garage below also makes the floor depth an important issue. The original slab was 12" thick with 8" drop panels for a total thickness of 20". The deepest beam produced by the RAM model was a W30x90. This would make the largest depth of the proposed design 34.5", 14.5" inches thicker than the original design. However, the new system would still leave more than 8' of clearance.

Because of the parking garage below, the posts and bearing wall loads cannot be carried directly down to the foundation. Therefore, the beam grid was laid out so that a beam or girder was below each post and bearing wall from above. Each of these loads was carefully carried down from the roof to the first floor. The drafted floor plan on the following page shows each of the loads and their magnitudes.

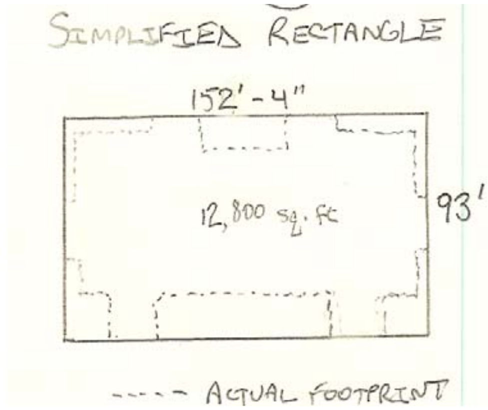

6.3 k
27.4 k
5.7 k
7.5 k
32.55 k
4.8 k
8.6 k
26.4 k
8.1 k
24 k
6.4 k
12.8 k
58.8 k
12.9 k
9.7 k
13 k
17.25 k
53.7 k
4.5 k
16.5 k
10 k
35.4 k

In order to ensure that all the loads mentioned were supported with a beam, the beam layout entered into RAM was far from uniform. Due to the varying spacing of the beams and the differing loads directly applied to each, the RAM output produced a multitude of beam sizes. In an effort to simplify the design, some beams were manually replaced with slightly larger beams. For example, all W8, W10, smaller W12 shapes were replaced with W12x19's. The first floor plan below shows the beam layout and number of shear studs for each beam.



Shear Wall Design

Point Pleasant is located right along the coast of New Jersey; therefore, the design wind speed is 120 MPH and the wind exposure category is C. This wind speed is increased from 115 MPH, which was used in the original design. For the purposes of calculating story forces and pressures, the building was simplified into a rectangle as shown in the image to the right. Below are tables showing the wind pressures and story forces for the building using Method 2 for wind analysis found in ASCE-7-05. The shorter dimension of the building runs in the North-South direction and the longer East-West.



	Wind from N-S				
Level	Height (ft.)	Total PSF	Story Force (k)	Total Shear (k)	OT Moment (ft-k)
Parking	0	0.0	0.0	**308.1**	**10541.6**
1	11	34.0	57.6	308.1	634.0
2	21.33	35.4	59.8	250.5	1275.7
3	32.67	37.1	62.3	190.7	2036.5
4	43.5	38.4	61.7	128.3	2685.8
Attic	53.5	39.4	48.3	66.6	2584.3
Roof	72.5	12.6	18.3	18.3	1325.2

	Wind from E-W				
Level	Height (ft.)	Total PSF	Story Force (k)	Total Shear (k)	OT Moment (ft-k)
Parking	0	0.0	0.0	**174.2**	**6058.0**
1	11	30.6	31.7	174.2	349.2
2	21.33	32.0	33.1	142.4	706.4
3	32.67	33.8	34.7	109.3	1133.2
4	43.5	35.1	34.5	74.6	1499.6
Attic	53.5	36.1	28.5	40.1	1523.0
Roof	72.5	12.8	11.7	11.7	846.6

In the original design, wind was the controlling force for the lateral design. This is also the case for the structure proposed in this report. The weight of the proposed structure is significantly lower than that of the original design. The dead load for floors 2-4 was decreased by approximately 50% and the weight of the first floor was decreased by approximately 60%. After completing a seismic analysis that followed the procedure in ASCE 7-05, the base shear due to earthquake loading was 140 k. This number is significantly lower than the 308 k base shear that results from wind loading. The moment of the building to resist overturning was also checked and was determined to be far greater the the overturning moment itself. Calculations for both seismic and wind loading can be found in the Appendix.

In order to resist the lateral load caused by wind, shear walls were designed replacing the existing braced frames. The 2006 International Building Code and the 2005 National Design Specifications (NDS) were used to design these shear walls. The load on and length of each wall was entered into a spreadsheet to ensure maximum unit shear force criteria were met.

The interior shear walls were designed using 5/8" Gypsum fastened with 6d cooler or wallboard nails. The maximum fastener spacing is 7" at the edges and 12" in the field and 2x horizontal blocking will be provided at the edges. The maximum unit shear for each of these walls is 290 plf for studs at 16" o.c. For ASD, the allowable unit shear must be divided by a factor of safety of 2.0. However, because the walls are sheathed with the same materials on both sides, their capacities can be doubled, maintaining the allowable 290 plf maximum. These walls are labeled G1 on the plan. The common wall at the center of the building has two layers of 5/8" gypsum on the room side of the wall. The base layer is connected with 6d cooler nails with a maximum edge spacing of 9" and the face layer is connected with 8d cooler nails with a maximum edge spacing of 7". This wall is labeled G2 on the plan

All exterior walls are sheathed with 7/16" OSB fastened with 8d nails at 6" o.c. at the edges and 12" o.c. in the field. 2x horizontal blocking will be provided between studs at panel edges per common design practice. According to the 2005 NDS, for walls with dissimilar construction on each side of the wall resisting wind load, the unit shear capacity of the two panels should be added together. This gives a unit shear capacity of 405 plf for the exterior walls.

E-W Wind Direction

4th Floor				
Location	Wall Length (ft)	Adj. Factor, Co	Force in Wall (k)	Unit Shear, v (plf)
Exterior	14.75	0.63	1.46	157.35
Exterior	15.5	0.63	1.54	157.35
Exterior	15.5	0.63	1.54	157.35
Exterior	14.5	0.63	1.44	157.35
Exterior	15.5	0.63	1.54	157.35
Exterior	14.75	0.63	1.46	157.35
Interior	17	1.00	1.69	99.13
Interior	12.5	1.00	1.24	99.13
Interior	11.5	1.00	1.14	99.13
Interior	15.5	1.00	1.54	99.13
Interior	11.5	0.77	1.14	128.74
Interior	11.5	0.77	1.14	128.74
Interior	17	1.00	1.69	99.13
Interior	12.5	1.00	1.24	99.13
Interior	11.5	1.00	1.14	99.13
Interior	15.5	1.00	1.54	99.13
Interior	11.5	0.77	1.14	128.74
Interior	11.5	0.77	1.14	128.74
Exterior	19	0.67	1.88	147.96
Exterior	19	0.67	1.88	147.96

3rd Floor				
Location	Wall Length (ft)	Adj. Factor, Co	Force in Wall (k)	Unit Shear, v (plf)
Exterior	14.75	0.63	1.77	190.48
Exterior	15.5	0.63	1.86	190.48
Exterior	15.5	0.63	1.86	190.48
Exterior	14.5	0.63	1.74	190.48
Exterior	15.5	0.63	1.86	190.48
Exterior	14.75	0.63	1.77	190.48
Interior	17	1.00	2.04	120.00
Interior	12.5	1.00	1.50	120.00
Interior	11.5	1.00	1.38	120.00
Interior	15.5	1.00	1.86	120.00
Interior	11.5	0.77	1.38	155.84
Interior	11.5	0.77	1.38	155.84
Interior	17	1.00	2.04	120.00
Interior	12.5	1.00	1.50	120.00
Interior	11.5	1.00	1.38	120.00
Interior	15.5	1.00	1.86	120.00
Interior	11.5	0.77	1.38	155.84
Interior	11.5	0.77	1.38	155.84
Exterior	19	0.67	2.28	179.10
Exterior	19	0.67	2.28	179.10

2nd Floor				
Location	Wall Length (ft)	Adj. Factor, Co	Force in Wall (k)	Unit Shear, v (plf)
Exterior	14.75	0.63	1.78	191.58
Exterior	15.5	0.63	1.87	191.58
Exterior	15.5	0.63	1.87	191.58
Exterior	14.5	0.63	1.75	191.58
Exterior	15.5	0.63	1.87	191.58
Exterior	14.75	0.63	1.78	191.58
Interior	17	1.00	2.05	120.70
Interior	12.5	1.00	1.51	120.70
Interior	11.5	1.00	1.39	120.70
Interior	15.5	1.00	1.87	120.70
Interior	11.5	0.77	1.39	156.75
Interior	11.5	0.77	1.39	156.75
Interior	17	1.00	2.05	120.70
Interior	12.5	1.00	1.51	120.70
Interior	11.5	1.00	1.39	120.70
Interior	15.5	1.00	1.87	120.70
Interior	11.5	0.77	1.39	156.75
Interior	11.5	0.77	1.39	156.75
Exterior	19	0.67	2.29	180.14
Exterior	19	0.67	2.29	180.14

1st Floor				
Location	Wall Length (ft)	Adj. Factor, Co	Force in Wall (k)	Unit Shear, v (plf)
Exterior	14.75	0.63	1.70	182.75
Exterior	15.5	0.63	1.78	182.75
Exterior	15.5	0.63	1.78	182.75
Exterior	14.5	0.63	1.67	182.75
Exterior	15.5	0.63	1.78	182.75
Exterior	14.75	0.63	1.70	182.75
Interior	17	1.00	1.96	115.13
Interior	12.5	1.00	1.44	115.13
Interior	11.5	1.00	1.32	115.13
Interior	15.5	1.00	1.78	115.13
Interior	11.5	0.77	1.32	149.52
Interior	11.5	0.77	1.32	149.52
Interior	17	1.00	1.96	115.13
Interior	12.5	1.00	1.44	115.13
Interior	11.5	1.00	1.32	115.13
Interior	15.5	1.00	1.78	115.13
Interior	11.5	0.77	1.32	149.52
Interior	11.5	0.77	1.32	149.52
Exterior	19	0.67	2.19	171.84
Exterior	19	0.67	2.19	171.84

N-S Wind Direction

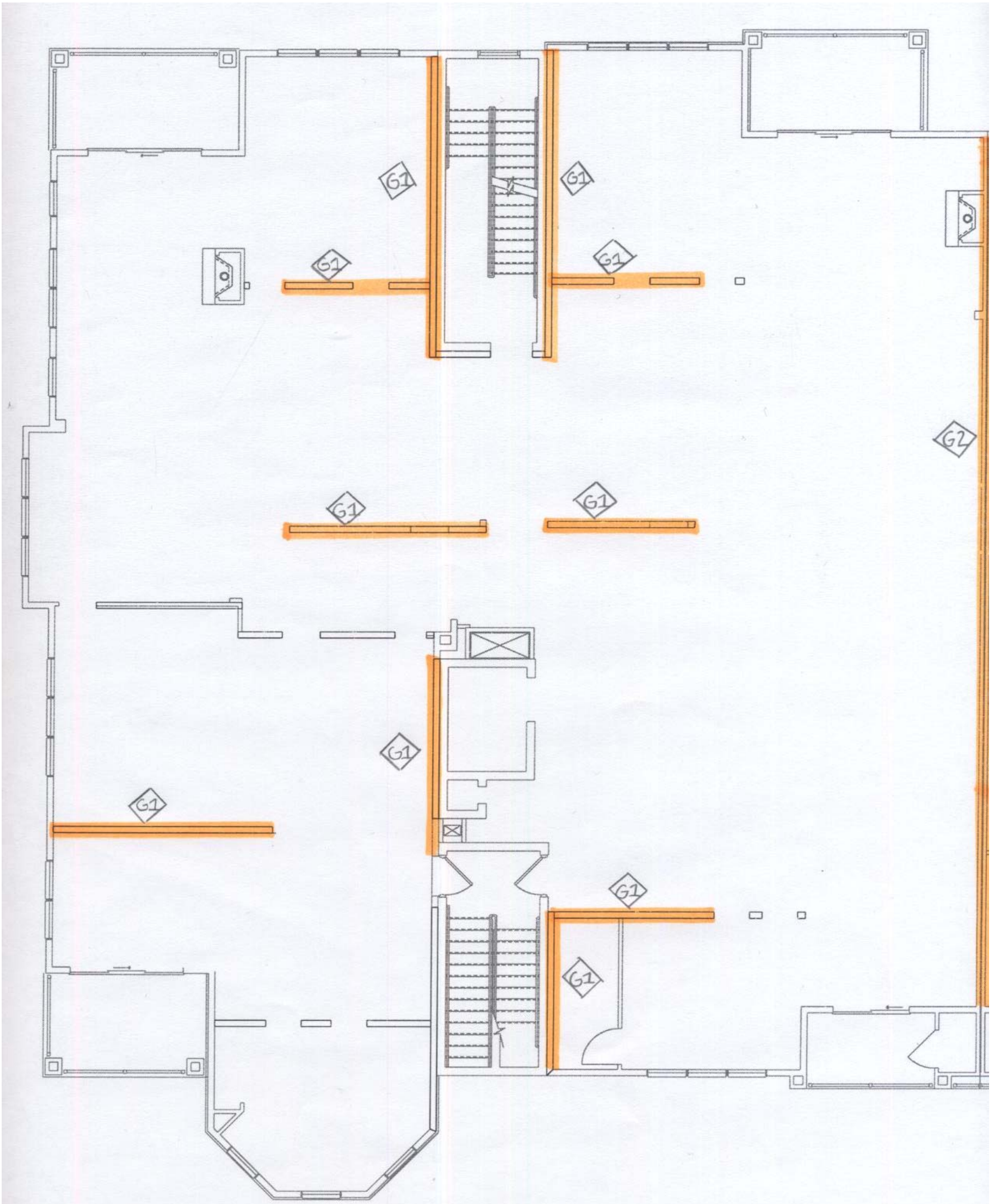
4th Floor				
Location	Wall Length (ft)	Adj. Factor, Co	Force in Wall (k)	Unit Shear, v (plf)
Exterior	66.5	0.63	7.63	182.1
Interior	24	1.00	2.75	114.7
Interior	14	1.00	1.61	114.7
Interior	24	1.00	2.75	114.7
Interior	12	1.00	1.38	114.7
Interior	70	1.00	8.03	114.7
Interior	70	1.00	8.03	114.7
Interior	12	1.00	1.38	114.7
Interior	24	1.00	2.75	114.7
Interior	14	1.00	1.61	114.7
Interior	24	1.00	2.75	114.7
Exterior	66.5	0.63	7.63	182.1

3rd Floor				
Location	Wall Length (ft)	Adj. Factor, Co	Force in Wall (k)	Unit Shear, v (plf)
Exterior	66.5	0.63	9.75	232.63
Interior	24	1.00	3.52	146.56
Interior	14	1.00	2.05	146.56
Interior	24	1.00	3.52	146.56
Interior	12	1.00	1.76	146.56
Interior	70	1.00	10.26	146.56
Interior	70	1.00	10.26	146.56
Interior	12	1.00	1.76	146.56
Interior	24	1.00	3.52	146.56
Interior	14	1.00	2.05	146.56
Interior	24	1.00	3.52	146.56
Exterior	66.5	0.63	9.75	232.63

2nd Floor				
Location	Wall Length (ft)	Adj. Factor, Co	Force in Wall (k)	Unit Shear, v (plf)
Exterior	66.5	0.63	9.84	234.89
Interior	24	1.00	3.55	147.98
Interior	14	1.00	2.07	147.98
Interior	24	1.00	3.55	147.98
Interior	12	1.00	1.78	147.98
Interior	70	1.00	10.36	147.98
Interior	70	1.00	10.36	147.98
Interior	12	1.00	1.78	147.98
Interior	24	1.00	3.55	147.98
Interior	14	1.00	2.07	147.98
Interior	24	1.00	3.55	147.98
Exterior	66.5	0.63	9.84	234.89

1st Floor				
Location	Wall Length (ft)	Adj. Factor, Co	Force in Wall (k)	Unit Shear, v (plf)
Exterior	66.5	0.63	9.45	225.46
Interior	24	1.00	3.41	142.04
Interior	14	1.00	1.99	142.04
Interior	24	1.00	3.41	142.04
Interior	12	1.00	1.70	142.04
Interior	70	1.00	9.94	142.04
Interior	70	1.00	9.94	142.04
Interior	12	1.00	1.70	142.04
Interior	24	1.00	3.41	142.04
Interior	14	1.00	1.99	142.04
Interior	24	1.00	3.41	142.04
Exterior	66.5	0.63	9.45	225.46

Typical Shear Wall Layout



Vibration Analysis

Vibration control in wood structures has been a heavily researched topic over the past few decades. Typically, structures are designed based on strength and serviceability. The major serviceability issue that is used for design is deflection criteria. However, just as apartment tenants don't want dips in their floors, damaging floor finishes, they certainly don't want the floor to shake while walking across it.

The criteria for floor vibrations in wood floors is based on the fundamental frequency of the joists, the girders and the combination of the two. Levels of acceptability have varied over the years. Initial investigations used 4 Hz as a baseline, and eventually, 8 Hz became the standard for acceptable design. Researchers, however, are currently recommending the frequency be approximately 15 Hz or greater.

For this report, a brief vibrations performance check was done for the structural redesign to ensure it meets the current standard. This analysis was highly conservative. Using the span tables on the Alpine Truss website, the moment of inertia of the truss was calculated using the allowable loads for total and live load deflection. The fundamental frequency of both the truss and girder of the critical span were calculated using the following equation:

$$f = 1.57\ ((386*E*I)/(W*L^3))^{1/2}$$

In this equation, W represents the total permanent load supported by the truss or girder. For the truss calculation, only the moment of inertia of the truss was taken into consideration, neglecting the contribution of the 3/4" inch layer of Gyp-crete topping and of the 3/4" plywood subfloor. The resulting frequency for the 18" trusses was 10.5 Hz. This is lower than the recommendation of 15 Hz, but exceeds the acceptability rating of 8 Hz. Because of the exclusion of Gyp-crete and plywood, the resulting frequency is judged to be adequate. Using the same calculation, the fundamental frequency for the 5 1/4" x 18" PSL was determined to be 14.5 Hz.

This brief analysis shows that the redesigned structure meets the requirements for vibration control. In addition, the Alpine truss website assures that, based on research performed at Virginia Tech, restricting live load deflection to L/480 "provides a high degree of resistance to floor vibration." Because the maximum span length is more than one foot longer than the actual span, and because the table live and total loads are higher, the proposed system is acceptable.

A check of the existing structure was also performed to ensure that the original floor was adequately designed to resist floor vibrations. Because the framing consisted of steel and concrete, the analysis was done in accordance with Design Guide #11, and the floor design was found to be sufficient. Calculations for both analyses can be found in the Appendix.

Foundation Effects

The switch to a wood structural system significantly decreases the dead load of the building. The overall weight of the building was decreased from approximately 6000 kips to 2500 kips. As was the case with the existing structure, all the building loads are carried down and supported by the first floor. This was the reason why the first floor of the existing structure was so massive. The change in load allowed for a much lighter first floor consisting of steel beams and girders and a metal deck and concrete slab.

The first floor is supported by eight relatively evenly spaced concrete columns and the foundation wall is a 12" thick reinforced concrete wall supported by 12" deep concrete spread footings. There is a 5" slab on grade for the parking garage as well.

Due to time constraints, the foundation was not analyzed or redesigned. It could be expected that decreases in wall and column thicknesses and/ or concrete reinforcement could be made because of the decrease in building weight. Also, the parking layout could have been analyzed and the column grid could have been altered to shorten the span of some girders and beams.

Breadth Study: Construction Management

Introduction

In addition to the proposed structural revisions, two other breadth topics will be investigated the first of which is Construction Management. Switching from steel to a wood structural system will cause a significant difference from a construction standpoint in terms of cost and scheduling. A major goal of this investigation was to save both time and money by replacing the steel and concrete system with wood. Therefore, a detailed structural takeoff using the 2008 Edition of RS Means Facilities Construction Cost Data and a construction schedule using MS Project were completed for each structure.

Cost Analysis

In general, wood is a less expensive construction material than steel. However, wood cannot span as far as steel and is, therefore, not commonly used in commercial construction. Because Point Pleasant Apartments has fairly short spans, wood was thought to be a viable alternative means of construction.

A detailed structural takeoff was performed to compare the costs of each structural system. This takeoff was broken into two categories. The first comparison was for the first floor of each system. The original design was a 12" thick two-way concrete slab with 8, 11'x11'x8" deep drop panels. There was also a cost added in for finishing the concrete. The components of this system were entered into a spreadsheet to calculate the total cost including material, labor, and equipment. Steel reinforcing bars were counted and their linear footage summed to find the total weight and then cost. Because this method of construction was used for only one floor, 1-use formwork was priced. The same process was then done for the proposed structure of composite steel beams with Vulcraft1.5VLR20 metal deck with a 4.5" total depth concrete slab. The charts below show the breakdown of cost for each system.

Existing First Floor							
Material	Unit	Material	Labor	Equip.	Total	City Adj. Factor	Adj. Total
12" Conc. Slab	C.Y.	$ 100.00	$ 11.55	$ 4.32	$ 115.87	117.20%	$ 64,379.09
Rebar	Ton	$ 870.00	$ 600.00		$ 1,470.00	94.30%	$ 34,655.25
Formwork	S.F.	$ 4.79	$ 3.69		$ 8.48	113.10%	$ 122,763.26
Monolithic Screen	S.F.		$ 0.37		$ 0.37	121.80%	$ 7,025.97
						TOTAL	**$ 228,823.57**
Proposed First Floor							
Material	Unit	Material	Labor	Equip.	Total	City Adj. Factor	Adj. Total
W12x19	L.F.	$ 21.73	$ 2.66	$ 1.78	$ 26.17	94.30%	$ 19,024.26
W18x40	L.F.	$ 48.50	$ 3.53	$ 1.77	$ 53.80	94.30%	$ 15,085.58
W24x68	L.F.	$ 82.50	$ 3.06	$ 1.53	$ 87.09	94.30%	$ 38,626.26
W30x90	L.F.	$ 120.00	$ 2.83	$ 1.42	$ 124.25	94.30%	$ 25,307.06
4.5" Concrete Slab	C.Y.	$ 100.00	$ 14.90	$ 5.55	$ 120.45	117.20%	$ 20,913.69
Vulcraft 1.5VLR20	S.F.	$ 1.60	$ 0.38	$ 0.04	$ 2.02	94.30%	$ 24,382.21
Shear Studs	Ea.	$ 0.54	$ 0.75	$ 0.38	$ 1.67	94.30%	$ 2,124.42
						TOTAL	**$ 145,463.48**

The second comparison of cost included the framing for floors 2-4 and the interior and exterior walls of the building. As previously mentioned in the Depth Analysis, the framing for floors 2-4 consisted of 16" open web steel joists with a 1 5/16" 22 GA. metal form deck and 3.5" total depth concrete slab. The walls of the existing structure were 2x4 and 2x6 light gage metal studs. The straps used for lateral resistance were also included in the cost analysis. The proposed structure consisted of 18" wood floor trusses, 3/4" plywood subfloor, and 3/4" lightweight gypsum topping. The metal stud walls were replaced with 2x4 and 2x6 Spruce-Pine-Fir, Stud Grade members. There was no additional cost taken into consideration for the proposed shear walls because the walls were sheathed in both systems. The spreadsheet illustrating the breakdown of costs is shown below.

Existing Floor (2-4)							
Material	Unit	Material	Labor	Equip.	Total	City Adj. Factor	Adj. Total
16" Joists	L.F.	$ 4.76	$ 1.88	$ 1.02	$ 7.66	94.30%	$ 72,963.36
3.5" Conc.	C.Y.	$ 100.00	$ 14.90	$ 5.55	$ 120.45	117.20%	$ 58,558.33
1 5/16" 22 GA. Form Deck	S.F.	$ 1.60	$ 0.38	$ 0.04	$ 2.02	94.30%	$ 73,146.62
6x6, W4.0x4.0 WWW	C.S.F.	$ 29.00	$ 25.50	$ -	$ 54.50	94.30%	$ 19,735.10
Monolithic Screen	S.F.		$ 0.37		$ 0.37	121.80%	$ 17,305.34
W-Shape Support	L.F.	$ 31.50	$ 2.66		$ 34.16	94.30%	$ 27,058.82
						TOTAL	**$ 268,767.58**
Metal Stud Walls							
Material	Unit	Material	Labor	Equip.	Total	City Adj. Factor	Adj. Total
2x6	L.F.	$ 11.90	$ 8.35		$ 20.25	94.30%	$ 72,563.85
2x4	L.F.	$ 9.35	$ 8.25		$ 17.60	94.30%	$ 66,387.20
Bracing	Ea.	$ 22.50	$ 34.00		$ 56.50	94.30%	$ 5,114.83
						TOTAL	**$ 144,065.88**
Proposed Floor (2-4)							
Material	Unit	Material	Labor	Equip.	Total	City Adj. Factor	Adj. Total
18" Floor Trusses	M.L.F.	$ 1,950.00	$ 645.00		$ 2,595.00	113.10%	$ 78,833.25
3/4" Plywood	S.F.	$ 0.87	$ 0.39		$ 1.26	113.10%	$ 48,384.00
3/4" Gyp-crete	C.F.	$ 8.15	$ 0.55	$ 0.20	$ 8.90	117.20%	$ 21,360.00
PSL Beams	L.F.	$ 18.05	$ 1.26		$ 19.31	113.10%	$ 20,966.03
						TOTAL	**$ 169,543.27**
Wood Stud Walls							
Material	Unit	Material	Labor	Equip.	Total	City Adj. Factor	Adj. Total
2x6	L.F.	$ 5.45	$ 5.65		$ 11.10	113.10%	$ 50,216.40
2x4	L.F.	$ 3.48	$ 5.10		$ 9.58	113.10%	$ 43,339.92
						TOTAL	**$ 93,556.32**

The totals of these two systems were then compared to one another. The proposed structure resulted in a 36% reduction of cost in both the first floor construction and the construction of floors 2-4. The overall savings for the building structure was more than $230,000.

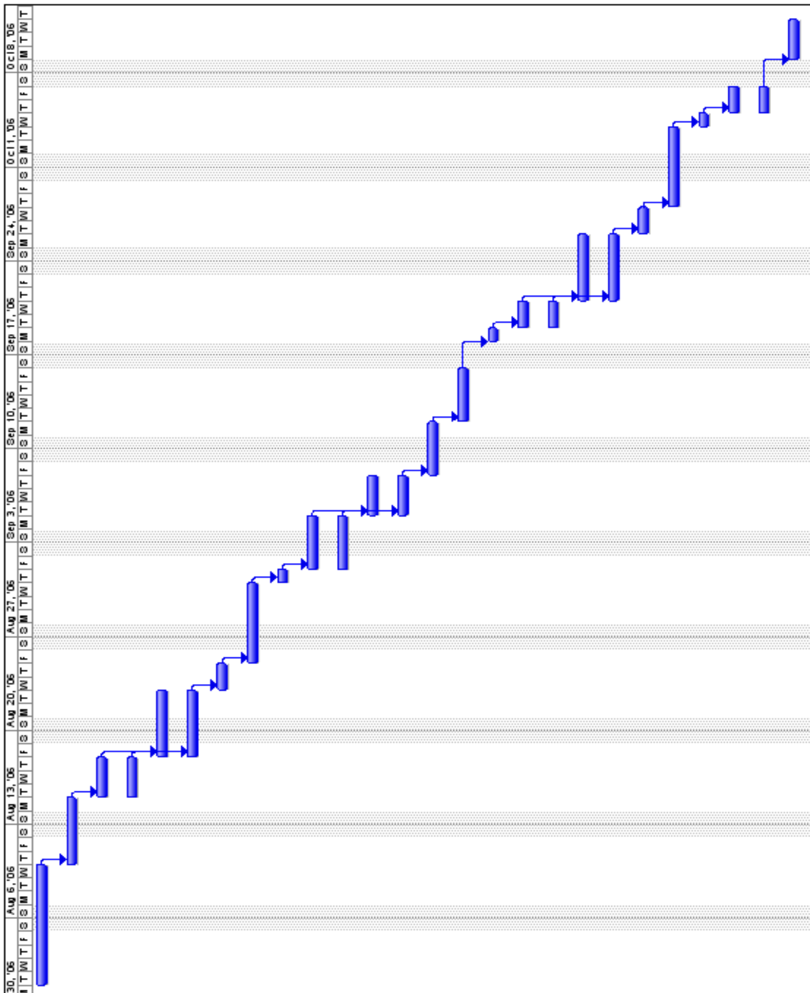
Final Cost Comparison	
First Floor	
Existing Structure	**Proposed Structure**
$ 228,823.57	$ 145,463.48
TOTAL SAVINGS	**$ 83,360.10**
PERCENT SAVED	**36%**
Floors 2-4 and Walls	
Existing Structure	**Proposed Structure**
$ 412,833.46	$ 263,099.59
TOTAL SAVINGS	**$ 149,733.87**
PERCENT SAVED	**36%**

Structural Construction Schedule

The proposed structure clearly saves a significant amount of construction cost, but if there is an increase in construction time, these savings could be negated. For this reason, a construction schedule for each structural system was created using the MS Project scheduling software. All tasks for each system were entered into the program to determine the total time required to construct the structure. These schedules were developed only for the parts of the building studied in this report. Excavation, foundations, enclosures, finishes, etc. were not factored in to the construction time. Both schedules were constructed on a floor by floor basis. The schedules shown below each began on August 1, 2006, the approximate start date of the existing building. After compiling both schedules, it was determined that the proposed structure would also save construction time. The construction for the existing structure was slightly more than three months, while the proposed solution schedule was a little less than two months.

Existing Construction Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
1	Formwork Installation	7 days	Tue 8/1/06	Wed 8/9/06	
2	Rebar Installation	3 days	Thu 8/10/06	Mon 8/14/06	1
3	12" Concrete Slab	3 days	Tue 8/15/06	Thu 8/17/06	2
4	Monolithic Screen	3 days	Tue 8/15/06	Thu 8/17/06	
5	Metal Stud Walls (on 1st flr.)	3 days	Fri 8/18/06	Tue 8/22/06	4
6	W-Shapes (for 2nd flr.)	3 days	Fri 8/18/06	Tue 8/22/06	3
7	Steel Joists (for 2nd flr.)	2 days	Wed 8/23/06	Thu 8/24/06	6
8	Deck Installation (for 2nd flr.)	4 days	Fri 8/25/06	Wed 8/30/06	7
9	WWF (for 2nd flr.)	1 day	Thu 8/31/06	Thu 8/31/06	8
10	3.5" Conc. Slab (for 2nd flr.)	2 days	Fri 9/1/06	Mon 9/4/06	9
11	Monolithic Screen	2 days	Fri 9/1/06	Mon 9/4/06	
12	Metal Stud Walls (on 2nd flr.)	3 days	Tue 9/5/06	Thu 9/7/06	11
13	W-Shapes (for 3rd flr.)	3 days	Tue 9/5/06	Thu 9/7/06	10
14	Steel Joists (for 3rd flr.)	2 days	Fri 9/8/06	Mon 9/11/06	13
15	Deck Installation (for 3rd flr.)	4 days	Tue 9/12/06	Fri 9/15/06	14
16	WWF (for 3rd flr.)	1 day	Mon 9/18/06	Mon 9/18/06	15
17	3.5" Conc. Slab (for 3rd flr.)	2 days	Tue 9/19/06	Wed 9/20/06	16
18	Monolithic Screen	2 days	Tue 9/19/06	Wed 9/20/06	
19	Metal Stud Walls (on 3rd flr.)	3 days	Thu 9/21/06	Mon 9/25/06	18
20	W-Shapes (for 3rd flr.)	3 days	Thu 9/21/06	Mon 9/25/06	17
21	Steel Joists (for 3rd flr.)	2 days	Tue 9/26/06	Wed 9/27/06	20
22	Deck Installation (for 3rd flr.)	4 days	Thu 9/28/06	Tue 10/3/06	21
23	WWF (for 3rd flr.)	1 day	Wed 10/4/06	Wed 10/4/06	22
24	3.5" Conc. Slab (for 3rd flr.)	2 days	Thu 10/5/06	Fri 10/6/06	23
25	Monolithic Screen	2 days	Thu 10/5/06	Fri 10/6/06	
26	Metal Stud Walls (on 4th flr.)	3 days	Mon 10/9/06	Wed 10/11/06	25

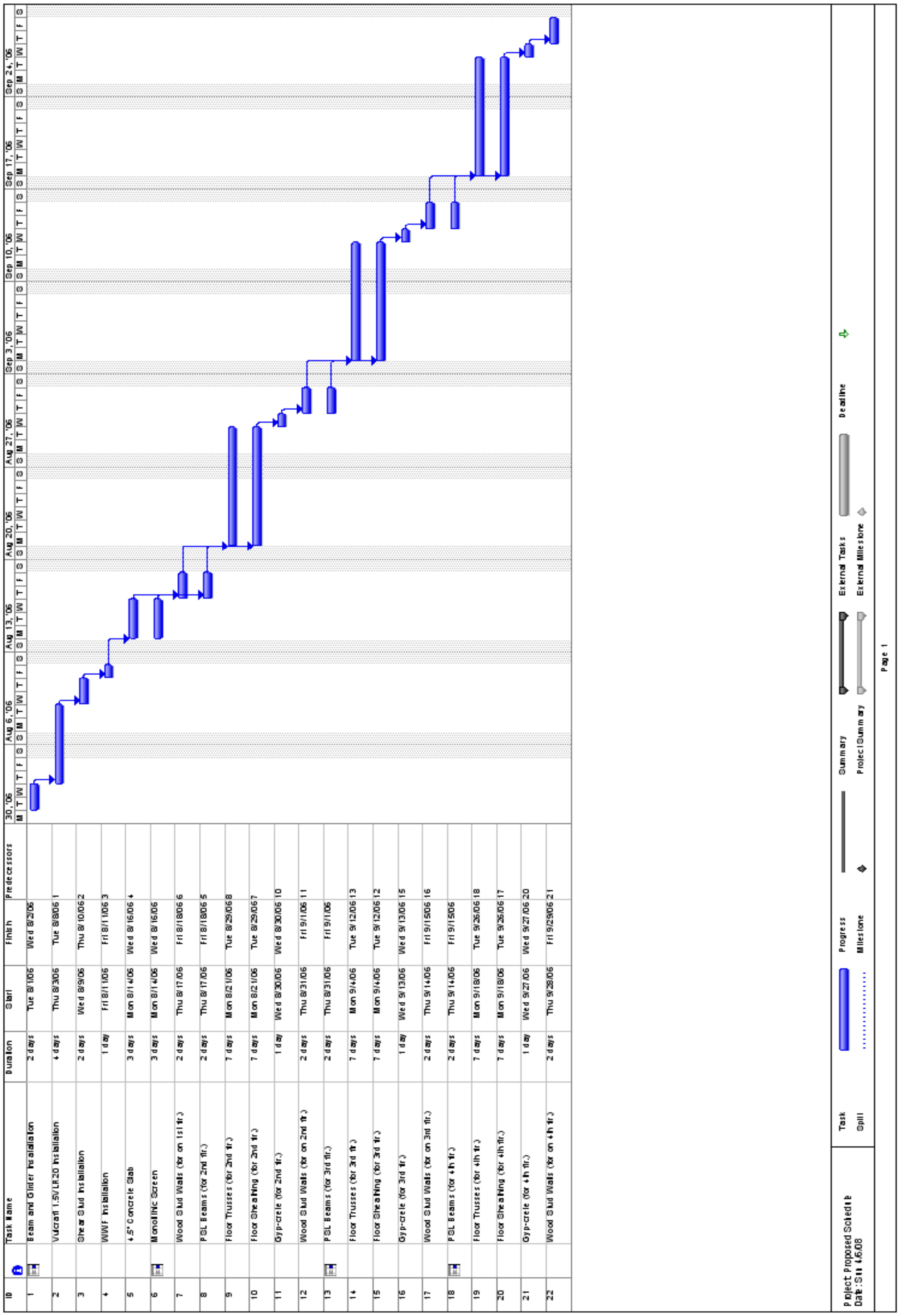


Project: Existing Schedule
Date: Sun 4/6/08

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Page 1

Proposed Construction Schedule



ID	Task Name	Duration	Start	Finish	Predecessors
1	Beam and Girder Installation	2 days	Tue 8/1/06	Wed 8/2/06	
2	Vulcraft 1.5VLR20 Installation	4 days	Thu 8/3/06	Tue 8/8/06	1
3	Shear Stud Installation	2 days	Wed 8/9/06	Thu 8/10/06	2
4	WWF Installation	1 day	Fri 8/11/06	Fri 8/11/06	3
5	4.5" Concrete Slab	3 days	Mon 8/14/06	Wed 8/16/06	4
6	Monolithic Screen	3 days	Mon 8/14/06	Wed 8/16/06	
7	Wood Stud Walls (for on 1st flr.)	2 days	Thu 8/17/06	Fri 8/18/06	6
8	PSL Beams (for 2nd flr.)	2 days	Thu 8/17/06	Fri 8/18/06	5
9	Floor Trusses (for 2nd flr.)	7 days	Mon 8/21/06	Tue 8/29/06	8
10	Floor Sheathing (for 2nd flr.)	7 days	Mon 8/21/06	Tue 8/29/06	7
11	Gyp-crete (for 2nd flr.)	1 day	Wed 8/30/06	Wed 8/30/06	10
12	Wood Stud Walls (for on 2nd flr.)	2 days	Thu 8/31/06	Fri 9/1/06	11
13	PSL Beams (for 3rd flr.)	2 days	Thu 8/31/06	Fri 9/1/06	
14	Floor Trusses (for 3rd flr.)	7 days	Mon 9/4/06	Tue 9/12/06	13
15	Floor Sheathing (for 3rd flr.)	7 days	Mon 9/4/06	Tue 9/12/06	12
16	Gyp-crete (for 3rd flr.)	1 day	Wed 9/13/06	Wed 9/13/06	15
17	Wood Stud Walls (for on 3rd flr.)	2 days	Thu 9/14/06	Fri 9/15/06	16
18	PSL Beams (for 4th flr.)	2 days	Thu 9/14/06	Fri 9/15/06	
19	Floor Trusses (for 4th flr.)	7 days	Mon 9/18/06	Tue 9/26/06	18
20	Floor Sheathing (for 4th flr.)	7 days	Mon 9/18/06	Tue 9/26/06	17
21	Gyp-crete (for 4th flr.)	1 day	Wed 9/27/06	Wed 9/27/06	20
22	Wood Stud Walls (for on 4th flr.)	2 days	Thu 9/28/06	Fri 9/29/06	21

Breadth Study: Acoustics

Introduction

One major concern when using wood construction, particularly in a multi-family facility consisting of luxury apartments, is acoustical performance. In this acoustics study, multiple alternatives were researched for both the common wall assembly and the floor assembly. The standard for Sound Transmission Class (STC) is a rating of 50. However, because Point Pleasant Apartments is designed as a luxury apartment complex and will be priced as such, tenants will be expecting higher performance. Therefore, the minimum STC rating for the new design will be 55, per U.S. Department of Housing and Urban Development recommendation.

Table 8.3 Minimum STC for Party Walls and Floors Between Multifamily Residential Buildings

Barrier	HUD Recommendations [8.5]			Building code requirements
	Type of dwelling units			
	Grade I	Grade II	Grade III	
Partition wall	STC ≥ 55	STC ≥ 52	STC ≥ 48	STC ≥ 50
Floor ceiling assembly	STC ≥ 55 IIC ≥ 55	STC ≥ 52 IIC ≥ 52	STC ≥ 48 IIC ≥ 48	STC ≥ 50 IIC ≥ 50

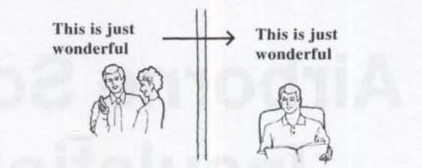
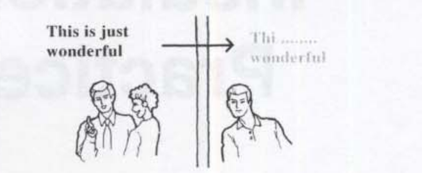
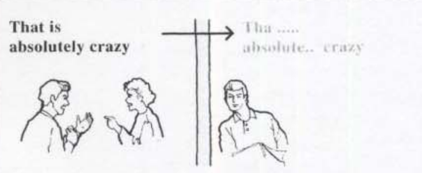
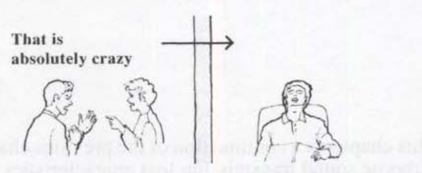
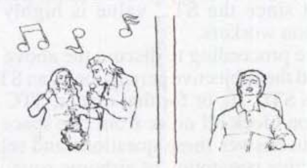
The U.S. Department of Housing and Urban Development (HUD) classifies multifamily dwellings into Grade I, II, and III. Grade I dwellings are those located in suburban or peripheral suburban areas, considered as "quiet" locations, with approximately 35-40 dBA, or lower, nighttime exterior noise levels.

Grade II dwellings are those located in urban and suburban areas considered to have "average" exterior noise environment, with nighttime exterior noise levels of about 40-45 dBA. Grade III dwellings are those located in noisy urban areas, with nighttime exterior noise levels of about 55 dBA or higher.

The building code requirements given in this table are from the Uniform Building Code, 1997. The same values appear in the draft document of the International Building Code, expected to replace all three U.S. model building codes in the year 2000.

The image on the following page shows what types of sounds can be heard through walls of varying STC ratings. In this study, efforts will be made to surpass the STC rating of 55 for common walls. The floor will also be designed to meet this goal by not only resisting airborne sound transmission, but also by resisting the affects of structural borne sounds that result from impact and vibration.

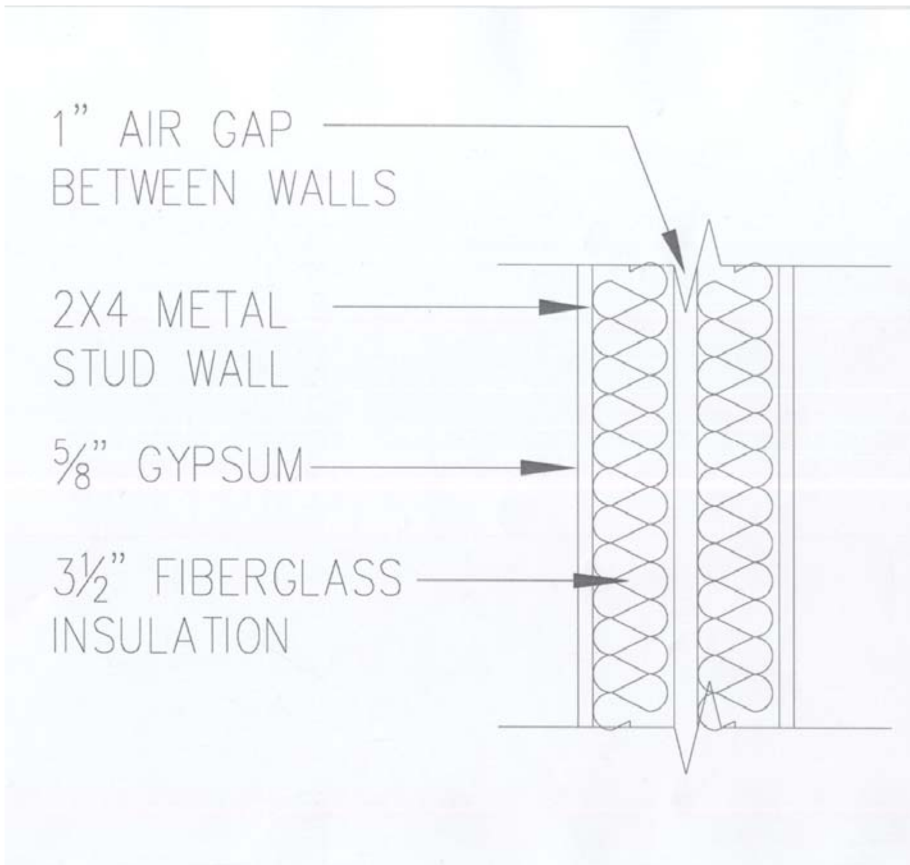
Table 6.1 Subjective Perception of STC Values*

STC	FSTC	Subjective description	
30	22 - 25		Most sentences clearly understood.
40	32 - 35		Speech can be heard with some effort. Individual words and occasional phrases heard.
50	42 - 45		Loud speech can be heard with some effort. Music easily heard.
60	52 - 55		Loud speech essentially inaudible. Music heard faintly; bass note disturbing.
70	62 - 65		Loud music heard faintly, which could be a problem if the adjoining space is highly sensitive to sound intrusion, such as a recording studio, concert hall, etc.
75 and above			Most noises effectively blocked.

* This table assumes a reasonably quiet background noise level in the receiving room — NC 35 or less. See Chapter 8 for NC values.

Common Wall Analysis

The common wall assembly for the existing structure consists of double 3 5/8” thick metal studs with 5/8” gypsum wallboard on one side of each wall, a 1” air gap between the walls, and 3 1/2” fiberglass insulation between studs. The studs for this assembly are spaced at 16” o.c. This wall assembly provides an STC rating of approximately 56 and a detail of the wall is shown below.



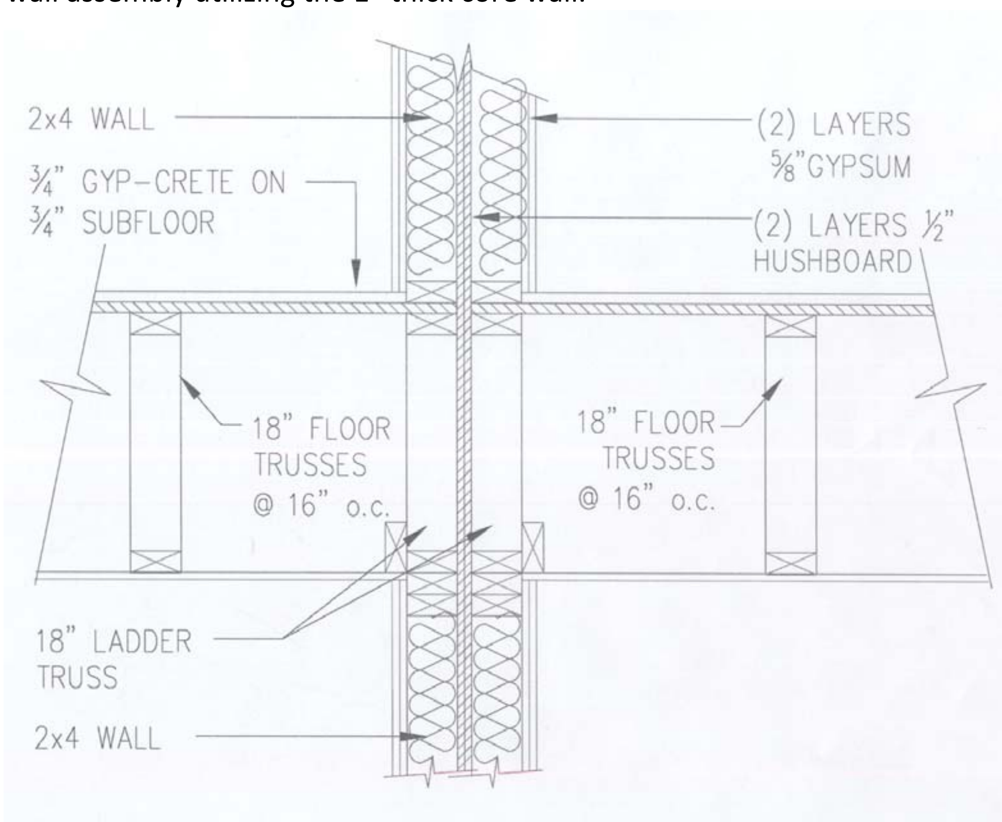
In switching from lightweight metal studs to wood studs, there is a decrease of approximately 5-6 STC points because of the flexibility of the metal stud flange which provides a more resilient connection. This is the first obstacle of switching from metal studs to wood studs. If the assembly were to be left as originally designed, the STC rating would drop from 56 to 50 or 51, which just barely meets the requirement.

One way to increase the STC rating of a wall assembly is to increase the spacing from 16” o.c. to 24” o.c. This method increases the rating by 2 for wood stud walls. Another possibility would be to attach resilient channels to the studs and then attach the gypsum. This negates the impact of switching to wood studs and actually provides a slight increase in STC rating over that produced by lightweight metal studs.

Utilizing both of the previously mentioned features in the new common wall design was originally thought to be a viable solution. However, both of the walls in the assembly were designed as shear walls with studs at 16” o.c. in the depth analysis. Adding resilient channels would eliminate the structural integrity of the common wall by decoupling the studs and the gypsum wallboard.

The next option explored was to use a double 2x4 wood stud wall assembly with a 1” air gap, fiberglass insulation between studs, and a double layer of 5/8” gypsum wallboard on the room side of each stud wall. This solution creates a potential increase over the existing condition, raising the STC rating to 56 or 57.

A possible improvement to this last system would be to add a “core wall” to the assembly. Instead of leaving a 1” air gap between the two sets of studs, a 1/2” inch thick sound deadening board would be attached to the bare side of each wall. One commonly used product for this application produced by Georgia-Pacific is called Hushboard. Hushboard is a non-structural fiberboard panel that can provide an additional 3 points to the systems STC rating. Applying Hushboard to each stud wall would raise the STC rating of the entire assembly over 60. This does, however, increase both construction time and building cost due to the difficulty of installation. Because the fiberboard is placed between the two walls, it would have to be attached before the walls are lifted into place. The detail below illustrates the proposed common wall assembly utilizing the 1” thick core wall.



Floor Framing Analysis

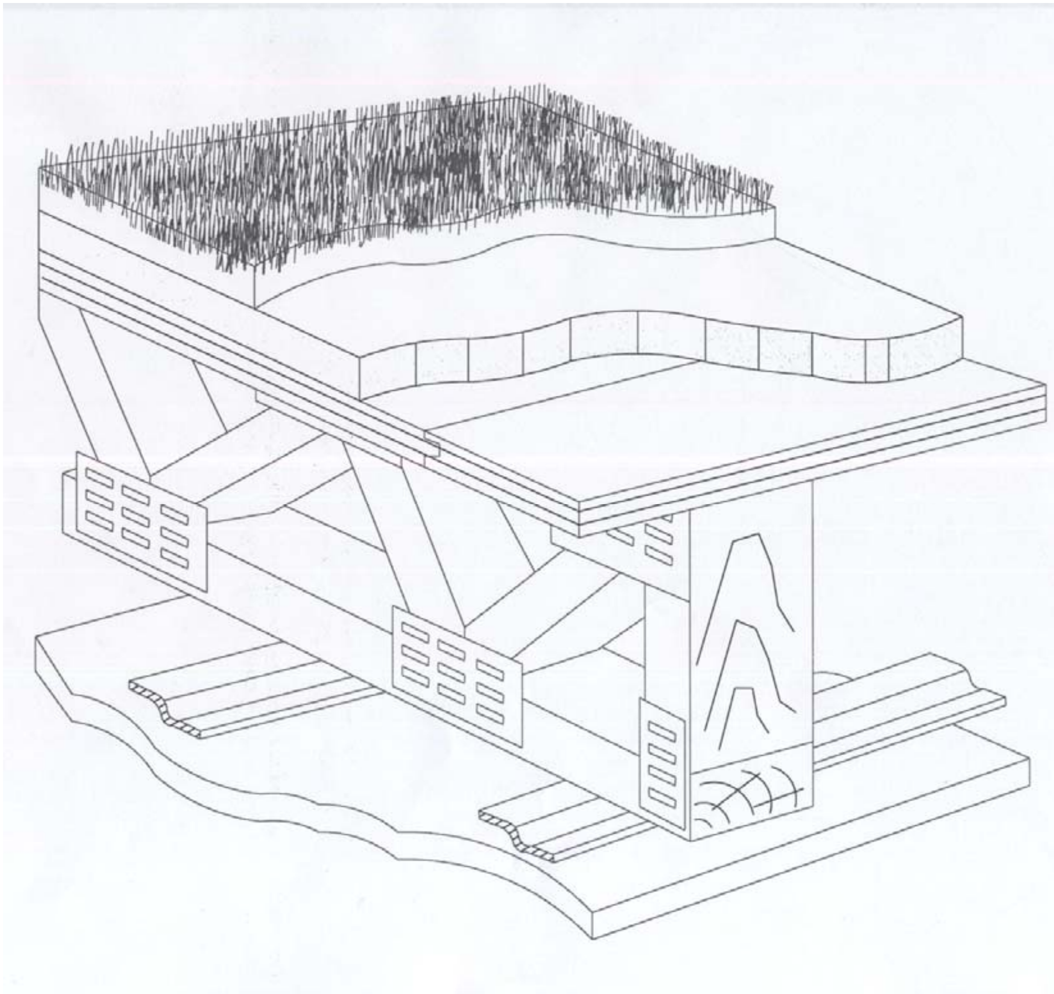
Sound transmission through a floor system in an apartment complex can be a major area of concern, particularly when the floor is composed of a wood structural system. Not only do tenants not want to hear their neighbors' conversations, music, televisions, etc., they do not want to hear footsteps or feel the ceiling above them vibrate. This type of sound transmission is referred to as structure-borne. Structure-borne sound transmission creates another criteria that must be met. In addition to the STC rating, an impact insulation class (IIC) rating of 55 must also be attained.

The existing floor system for floors 2-4 consists of a 3.5" total depth concrete slab on a 1 5/16" metal form deck, supported by 16" open web steel joists. There is batt insulation between the joists which are spaced at 48" o.c. and 5/8" gypsum is applied attached to the joists using resilient channels.

Throughout this study a number of different materials were researched in order to meet the recommended STC and IIC ratings for the new floor assembly. As previously mentioned, resilient channels can be attached to the studs, or in this case floor trusses, to decouple the structural member and the gypsum covering. Since the existing structure uses the channels and the gypsum on the ceiling does not serve any structural purpose, the first and most obvious strategy is to use resilient channels to attach the drywall to the trusses. As in the existing design, batt insulation will be placed between the trusses to help block sound transmission in the floor and ceiling assembly.

The use of a lightweight gypsum topping has become a popular design practice for multi-family facilities. One product in particular, produced by Maxxon, is call Gyp-Crete. First a moisture barrier must be laid on the plywood subfloor and then a 3/4" layer of the Gyp-Crete topping is poured. This practice significantly adds to the STC and IIC ratings of the assembly.

Maxxon also manufactures another product called Enkasonic Sound Control. This is a 0.4" thick pad that is rolled out and placed under the Gyp-Crete topping. Because a moisture barrier must placed below the Gyp-Crete, the use of this sound blanket is a practical solution to increasing the sound barrier between floors. This blanket will definitely add to the cost of the building, but since the savings are so high when switching to a wood system, the use of Enkasonic Sound Control is definitely worth the added expense. On the following page is a detail illustrating the basic floor assembly designed for Point Pleasant Apartments. The sound blanket is not shown in the detail, but as previously described, it would be placed between the Gyp-Crete and plywood subfloor. The calculated Field Sound Transmission Class (FSTC) which is typically several points below the STC rating is 59 for this assembly. This means the STC is well over 60.



Conclusions and Recommendations

Design Issues Not Addressed in This Report

As with any report of this nature, there are bound to be design issues that are neglected. There are a number of structural aspects not taken into account during the course of this study.

The first issue not addressed is the roof structure. The existing roof consists of pre-fabricated metal roof trusses spaced at 48" o.c. Because these trusses can be connected to wood studs as well, a wood truss roof was not explored. Along the same lines, the drag trusses that resist lateral load at the roof level were not changed.

The second design issue that could have been further explored is the balconies at the front and rear of each unit. The balconies use a shorter depth steel joist and concrete slab for structural support. The load from this system is supported by HSS columns that carry the load down to the foundation. This system would no longer be practical with the proposed solution. Possible alternatives could be pressure treated dimension lumber or flat slabs. A composite lumber such as Trex could possibly be used for the decking.

While effects of the proposed system on the foundation were noted in the Depth Analysis, a redesign was not explored. Because of the significant reduction in dead load throughout the building, footing sizes, foundation walls, and columns supporting the first floor could have potentially been reduced. The parking grid in the garage could have also been examined and possibly altered to allow for more columns, shortening the span of the beams in the first floor framing.

An architecture study would have possibly made the structure even more efficient. The layout of the apartments could have been slightly altered to allow for more bearing points. This could have in turn shortened some of the truss and beam spans and decreased the floor depth.

Another possible flooring solution could have been to use concrete for all the floors instead of just the first. This would produce similar construction for each floor. Fewer crews would have to be hired because the entire structure would be uniform. This could decrease the subcontractor fees and potentially reduce construction time. Concrete floors would also perform better acoustically.

In addition to the aforementioned design studies, there are probably still many others. These are just a few specific issues that, if time allowed, could have produced a more complete study of Point Pleasant Apartments.

Final Recommendation

The purpose of this report was to design a more efficient alternative to the existing structural system, which for floors 2-4 consisted of open web steel joists, concrete slab, and metal form deck. The relatively short spans and existing wall layout make a wood structural system a potential solution. In this report, wood floor trusses, PSL beams, and built up and PSL posts were designed in place of the composite system of the existing structure. To accommodate the shorter span capacity of wood trusses, several 2x4 partition walls were also converted to 2x6 bearing walls.

In addition to the redesign of floors 2-4, the existing 12" thick two-way concrete slab for the first floor was analyzed. With the significant reduction in dead load due to the implementation of a wood structural system, less support is needed at the first floor level. Therefore, a composite floor was designed using RAM Structural System. All loads were carried down from the roof to the first floor and their locations and magnitudes were entered into the RAM Model. Due to sporadic load location, the beams locations were entered such that a beam or girder fell under each post or bearing wall load from above.

The switch to a wood structural system made it logical to redesign the existing metal stud bearing walls and braced frames as wood studs with shear walls as the lateral resisting element. The braced frames of the existing structure consisted of 4" metal straps placed diagonally across a wall section with HSS shapes at each end. For the proposed system, interior shear walls were designed and sheathed with 5/8" gypsum to resist the load due to wind, which controlled the lateral design.

After the structural redesign was complete, a detailed structural takeoff was conducted to determine the economic feasibility of a wood structural system and of the first floor redesign. The results showed significant savings in construction and material costs. The analysis was broken into two sections: a comparison of the upper floors and wall construction and of the proposed and existing first floor. Results showed savings of 36% in both areas and a total savings of more $230,000. The design changes also resulted in a construction schedule reduction of more than one month.

Any time a wood structure is utilized in a multi-family facility, acoustical considerations must be taken into account. In this study, multiple common wall designs were explored to find the most effective in blocking sound transmission from one apartment to the next. The floor design was also impacted by sound transmission. To create an effective sound barrier from floor to floor, resilient channels, insulation, Gyp-crete, and a noise blanket underlayment were incorporated into the floor design.

After performing all of the previously mentioned analyses, the proposed changes to the structural system of Point Pleasant Apartments resulted in significant cost savings and a decrease in construction time. All systems designed are adequate to support the loads of the building and only very slight changes had to be made to the floor plan. An effective sound barrier for both the common walls and floor system was designed to negate the consequences of switching to a wood system. Therefore, it is the recommendation of this educational study that the changes proposed in this report be implemented in place of the existing structural conditions.