Dormitory

Northeast USA

Technical Report 2

Rendering Courtesy of WTW Architects

Cadell G. Calkins

Structural Option

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Executive Summary

The following technical report evaluates the floor systems of Dormitory Building A located in Northeast USA. The plans were provided through the owner and WTW Architects. The report details the comparison of a hollow core concrete precast plank floor system, laminated veneer lumber floor system, open web wood floor truss system, and a dimensional lumber floor system.

The hollow core concrete precast plank floor system was designed using load charts from Pittsburgh Flexicore and AISC 14th Edition for the beams supporting the planks. This system was found to be the most inherent fire resistant at 2 hours but because of its weight at 85 psf, it was deemed too heavy for the soil conditions

Laminated veneer lumber was design according to the load tables for 1.9E Microllam by iLevel and a spacing of 16 in on center was utilized throughout. With the ability to add more layers of gypsum wall board to gain a 2 hour fire rating, this system proved to be a possibility due to its lighter weight at approximately 28.5 psf.

Wood floor trusses were designed according to the MiTek charts for L/360 deflection. However, for comparison of the original design, the charts did not work because they stated that 26 feet was too long for an 18 inch deep truss, as well as the table did not state what to do for a deflection limit of L/480. This system is a structural possibility at a weight of 21.7 psf, but not an architectural possibility due to the large increase in the thickness of the first floor.

Lastly, dimensional lumber was looked at according to the NDS-05 and this was found to weigh in at 20.9 psf. Because of the light weight, and no noticeable increase in floor thickness, this system is also a possibility.

In the end, laminated veneer lumber floor system and dimensional lumber floor systems can be looked at for additional consideration.

Building Introduction

Located in a rural Northeast United States university campus, Dormitory consists of two buildings, Building A and Building B, to be built simultaneously. These new buildings, to be built where tennis courts and a parking lot once sat, will house suite style dorm rooms in each wing with a study lounge and gathering space in the central glass core. The two buildings are nearly identical except mirrored about a North-South axis. For design analysis, only Building A will be considered. However, both buildings will be considered for sitework and cost.

Building A is a 4 story building primarily consisting of a wood frame structure sitting atop a concrete masonry foundation. For lateral load analysis, the building is considered to be a 5 story building due to the walkout basement / ground floor.

To adhere to the architecture of the surrounding university, the majority of the façade of Building A consists of face brick with a base of ground face concrete masonry units. To complement the brick and masonry units, precast window heads and sills can be seen at each suite window and maroon and gray metal panels can be seen throughout the building as well. In the central core, glass storefront walls can be seen complementing the façade of the brick wings. Traditional to the brick wings, a hip roof with asphalt shingles was used and sticking with the modern feel of the glass storefront walls, a flat roof was utilized over the central core.

Figure 1: Rendering Courtesy of WTW Architects

Structural Overview

Dormitory Building A rests on rammed aggregate piers at a depth of about 30 feet. Above this, the basement rests on spread footings and a slab on grade. The primary structural system for the gravity loads in the ground floor consists of concrete masonry units and from the first floor and above, the structural system for gravity loads is wood columns and walls. For lateral loads, oriented strand board and gypsum wall board provide the support needed for the wings, while concrete masonry units provide the support for the central core.

An Occupancy Class of II was used for all Importance Factors per IBC 2009. Occupancy Class II was used because the occupancy load of the building is under 5000 and it does not fall into the other categories.

Foundation

Empire Geo-Services, Inc. performed the subsurface exploration of the site. This included 8 test borings for Building A completed by SJB Services, Inc. (affiliated drilling company of Empire). The findings concluded that the first 0.5 feet below the surface was either asphalt or topsoil. Below this, fill soils were found to a depth of 2 feet in some bores and at least 22 feet in others. By use of a Standard Penetration Test, it was found that the fill soils were probably installed in an uncontrolled manner. At depths between 8.4 feet and 61.5 feet, the top of bedrock is believed to exist. Per Empire's findings and recommendations, with the given fill conditions, a slab on grade and spread foundations were not a viable option and they suggested using micro-piles or drilled piers. In addition, Empire also found that groundwater conditions do not appear to be within 15 feet of the surface.

To counter the poor soil fill conditions, rammed aggregate piers, as designed by Geopier, were installed by GeoConstructors. The piers utilized a 2 foot diameter drilled hole and the hole was compacted using 2 foot lifts. Placed on a semi-regular grid of 10 feet, the piers were drilled between 8 feet and 50 feet deep depending on bedrock and soil conditions and most were around 30 feet deep. This type of pier also compacted the surrounding soil resulting in a better structure for a slab on grade.

Below the surface, 12 inch reinforced concrete masonry units were utilized on spread footings with 8 inch concrete masonry units above the surface up to beneath the Second Floor. On the sides where soil was to be held back, 12 inch Ivany blocks grout solid on spread footings were utilized below the surface and 8 inch Ivany blocks grout solid were used above the Ground Floor up to the First Floor with 8 inch concrete masonry units to continue up to the Second Floor. A detail of the Ivany block wall can be seen in Figure 2 below. The floor of the Ground Floor was a 4 inch concrete slab over drainage course. The floor of the First Floor consisted of a 2 inch concrete cover over 8 inch hollow core precast concrete planks. This floor was utilized to provide a 2 hour fire rating between the Ground Floor and the First Floor.

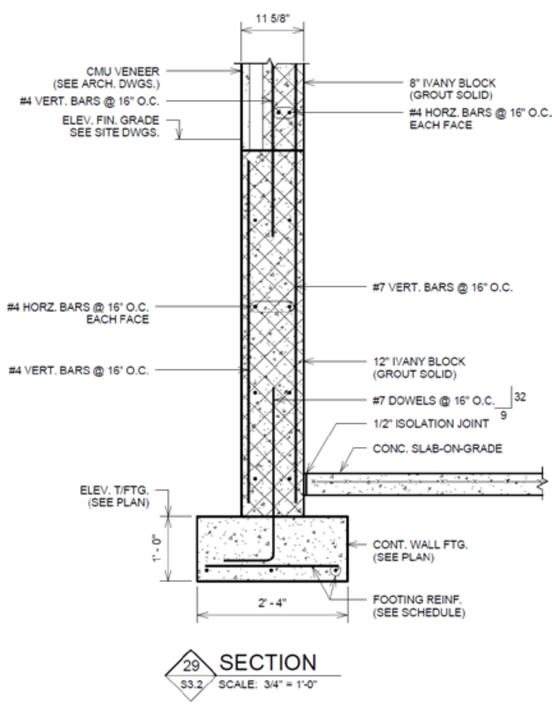

Figure 2: Typical Ivany Block Wall

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Floor Construction

Considering the First Floor as part of the foundation, the Second through Fourth Floors are nearly identical. Each suite rests on 18 inch deep wood floor trusses spaced at 19.2 inches on center. On top of the trusses consists of ¾ in. of Gypcrete on top of ¼ in. sound mat all resting on ¾ in. plywood sheathing. The corridors follow a similar structure, except that instead of trusses, the sheathing is supported by 2x10 Spruce-Pine-Fir or Douglas Fir wood joists at 16 inches on center resting on the corridor walls.

Within the central core, the floor structure consists of 1.75"x9.25" laminated veneer lumber wood joists at 16 in. on center topped with ¾ in. Gypcrete on top of ¾ in. plywood. For sound, 3.5 in. batt insulation is placed between the joists and the joists rest on W10x22 beams which in turn rest on W10x45 girders.

A typical partial floor plan can be seen below in Figure 3 with the central core outlined with a dash line.

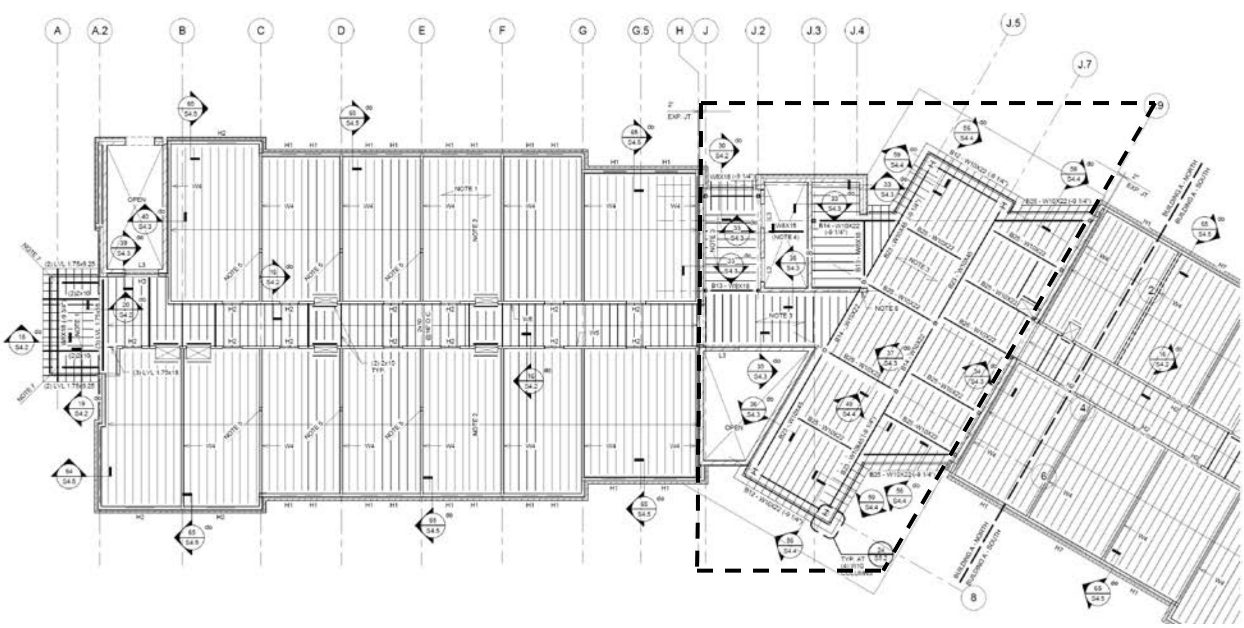

Figure 3: Typical South Wing Floor Plan

Lateral Systems

In regard to handling lateral forces, Building A is basically three separate buildings; South Wing, Central Core, North Wing.

In the North-South direction, the wings use shear walls that go from the first floor up to the roof. These shear walls consist of the exterior walls and the corridor walls. The exterior walls use ½ in. oriented strand board and 5/8 in. gypsum wall board per wall to resist the lateral forces, while the corridor walls use ¾ in. oriented strand board and two layers of 5/8 in. gypsum wall board per wall. In comparison, the corridor walls take more direct shear while the exterior walls help with torsional shear.

In the East-West direction, the wings use similar shear walls as the North-South direction for the exterior walls. For the interior walls, the walls that separate the suites, the lateral forces are taken up by utilizing three layers of 5/8 in. gypsum wall board per wall. This creates a fairly even distribution of lateral forces throughout the building.

For the Central Core, the lateral forces in each direction are taken by concrete masonry unit walls that surround the stairs and elevators and that line the walls where the core connects to the wings.

Materials Used

Materials listed in the tables below come from page S2.1, General Notes and Typical Details, of the structural drawings.

Table 1 – Concrete Specifications

Concrete	f'_c (psi)	Max Water Cement Ratio	Weight	Max Aggregate Size
Foundations	3000	0.50	Normal	1 ½"
Interior Slabs	4000	0.45	Normal	¾"
Exterior Slabs	4000	0.40	Normal	¾"

Table 2 – Mortar and Grout Specifications

Mortar and Grout	Use	f'_c (psi)	Standard
Mortar	Above Grade	2100	ASTM C270, Type S
Mortar	Below Grade	2900	ASTM C270, Type M
Mortar	Ivany Block	2900	ASTM C270, Type M
Grout	All Masonry	3000	ASTM C476
Leveling Grout	Concrete	5000	CE-CRD-C621

Table 3 – Masonry Specifications

Masonry	f'_m (psi)	Standard
Hollow Units	1500	ASTM C90, Type N-1
Solid Units	1500	ASTM C145, Type N-1
Ivany Block	3000	ASTM C270, Type M

Table 4 – Steel Specifications

Steel	Standard	Grade
Wide Flange Shapes	ASTM A992	50
Other shapes, plates, bars	ASTM A36	Typical
Steel HSS Shapes	ASTM A500	B
Steel Pipes	ASTM A53, Type E	B
Bolts	ASTM A325, Type N, ¾" dia.	N/A
Anchor Rods	ASTM F1554, ¾" dia.	36
Deformed Reinforcing Bars	ASTM A615	60
Welded Wire Fabric	ASTM A185	N/A
E70 Welding Electrode	AWS D1.1	N/A

Table 5 – Wood Minimum Specifications

Wood Minimums	Grade	Fb (psi)	Fv (psi)	Fc (psi)	Ft (psi)	E (psi)
Spruce-Pine-Fir	#2	875	135	1150	450	1,400,000
Douglas Fir	#2	875	135	1150	450	1,400,000

Table 6 – Wood Sheathing Specifications

Wood Sheathing	APA Rated	Span Rating	Exposure
Floor	Yes	40/20	1
Roof	Yes	32/16	1
Wall	Yes	N/A	1

Design Codes and Standards

According to Sheets S2.1 and LS0-1, the Dormitory was designed according to:

- Pennsylvania Uniform Construction Code
  - (2009 International Building Code and other adopted ICC codes)
  - (American Society of Civil Engineers, ASCE 7-05)
- Building Code Requirements for Reinforced Concrete (ACI 318-08)
- Building Code Requirements for Masonry Structures (ACI 530-08)
- National Design Specification for Wood Construction 2005 (NDS-05)
- American Institute of Steel Construction (13^{th} Edition – 2005)
- Design Specifications for Metal Plate Connected Wood Trusses (TPI-85)

The same codes will be used for thesis with the following changes:

- ASCE 7-10 will be used in lieu of ASCE 7-05
- AISC 14^{th} Edition will be used in lieu of AISC 13^{th} Edition

These changes in code were made because these are the newest editions of the codes.

Gravity Loads

Per the requirements of this report, gravity loads, including dead, live and snow loads, were assessed and checked against the loads listed on page S2.1 of the structural drawings. These loads had to be looked up, calculated, or assumed. After determining the loads, spot checks of certain members were done and those checks can be seen in Appendix A.

Dead Loads

A summary of the dead loads for Building A can be seen in Table 7 and a more extensive list can be found in Appendix C, as part of the determination of building weight.

Table 7 – Material Weights

Material	Weight
Typical Brick Exterior Wall @ 10' tall	281 lb per linear foot of wall
Typical CMU Exterior Wall @ 10' tall	630 lb per linear foot of wall
Interior N-S Shear Wall @ 8.5' tall	84.75 lb per linear foot of wall
Interior E-W 2x6 Shear Wall @ 8.5' tall	79.05 lb per linear foot of wall
Interior E-W 2x4 Shear Wall @ 8.5' tall	84.49 lb per linear foot of wall
Precast Concrete Plank Floor	81 lb per square foot
Typical Sheathing on Wood Truss Floor	25.7 lb per square foot
Assumed Weight of Trussed Roof	16.4 lb per square foot of floor

Live Loads

Table 8 details what the structural drawings state as a design live load (page S2.1) and what is called for per ASCE 7-10. For equal comparison, the design load will be used for thesis computations.

Table 8 – Live Loads by Area

Area	Design Load	ASCE 7-10 Load
Private Rooms and Corridors Serving Them	40 PSF	40 PSF
Public Rooms and Corridors Serving Them	100 PSF	100 PSF
Lobbies and Gathering Areas	100 PSF	100 PSF
Attic Mechanical Rooms	60 PSF	40 PSF*
Attic Catwalks and Access ways	60 PSF	40 PSF
Stairs and Landings	100 PSF	100 PSF

* Assumed 40 psf because the corridors (catwalks) serving these areas is 40 psf.

Snow Loads

According to page S2.1 of the structural drawings, the design snow load for Building A is 30 psf, the same as the ground snow load. According to calculations performed using ASCE 7-10, the design roof snow load is actually permitted to be 18.9 psf. With this snow load, the roof live load per ASCE 7-10, 20 psf, would control the design. For design considerations, 30 psf will be used because that is what is used in the original design.

For snow drift calculations, only one area needed to be considered, the raised center section of the central glass core. Per the calculations, as can be seen in Appendix A, snow drift will only extend back 8 feet from the face of the glass and up 2 feet. This means that snow drift will only occur on the lower roofs of the central core. The hip roof did not need to be considered because the pitch of the snow drift (3:12) is less than the pitch of the roof (6:12), thus the snow drift doesn't need to be considered in the design for the hip roof.

Floor Systems

Throughout the building, four different floor systems can be found. The flooring system on the first floor consists of hollow core precast planks spanning between masonry walls and steel beams. For the second through fourth floors, the central core consists of laminated veneer lumber (LVL) on steel beams, girders, and columns. On the wings, the suite room floors are open web wood floor trusses while the corridor is typical dimension lumber. Both systems are supported by 2x4 wood stud walls.

For this report, the objective is to determine the applicability of three new floor systems alongside the original system. Because the Dormitory already uses four floor systems, each area (first floor, central core, suite floors, and wing corridors) will be examined for the original system used in that area as well as the applicability of the other systems to be used in that area. This section breaks down each floor system, while the next section breaks down the applicability of each system to each area.

For the specific design of each floor system, please see:

- Appendix A for the precast hollow core concrete plank design
- Appendix B for the laminated veneer lumber design
- Appendix C for the open web wood floor truss design
- Appendix D for the dimensional lumber design

In addition, for all applicable Layouts, please see Appendix F.

For any design tables used, please see Appendix G.

Hollow Core Concrete Planks

Hollow core concrete planks, supplied by Pittsburgh Flexicore, were used in the original design for the first floor system. These consisted of planks 48 inches wide, 8 inches deep and 2 inches of concrete topping with varying lengths. For reinforcing, ½ inch diameter prestressed strands were used and depending on the length and loads, between four and five of these strands were utilized.

Hollow core planks consist of 2 inches of topping on an 8 inch plank with acoustical ceiling beneath. Please see figure 4 for an example of the plank. The planks span between steel beams.

<u>General</u>
Throughout the large expanses the concrete planks would cover, most of the structural thickness will be 10 inches except where the planks will be supported by beams or walls. Most of the beams fall in walls, so the added depth of 10.1 inches for a W10x45 would be unnoticeable except for a small soffit to hide the width of the beam flange that hangs over the wall.

<u>Architectural</u>
The small soffits that the beam flange creates could add to the architectural features of the interior walls. As for fire protection, a precast plank would increase the fire protection to two hours, a one hour increase over the original design above the first floor.

<u>Structural</u>
Because of the light weight of the original wood structure, better foundations and lateral systems would need to be designed for the large increase in weight of the structure. In addition, new columns would need to be implemented to carry the loads that the stud walls can no longer carry.

<u>Constructability</u>

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Concrete planks will require a crane for placing and because of the rural nature of the project; local contractors will tend to stay away from large amounts of crane work, thus increasing construction cost for a contractor to come in from a distance away. In addition, with the extra support that the planks need, construction time can increase due to the needed supports

Pros and Cons

Pros	**Cons**
• Increased fire protection	• Heaviest alternative
• Low cost	• Larger foundations
	• Larger seismic loads
	• Increased construction time
	• Drilling through plank is difficult
	• Mechanical ductwork routing problems

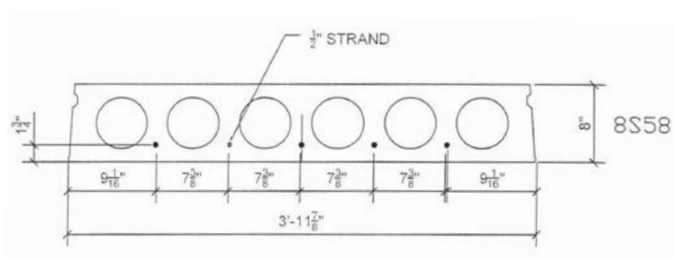

Figure 4. Typical precast hollow core concrete plank (Pittsburgh Flexicore)

Laminated Veneer Lumber on Steel Beams

Used in the central core on the second, third, and fourth floors, LVL on steel beams were used to carry the large loads of the assembly space. For design considerations, 1.9E Microllam by iLevel will be used at a spacing of 16 inches on center.

Laminated veneer lumber consists of a ¾ inch gypcrete topping on ¾ inch APA plywood on the LVL member with 1 to 3 layers of gypsum wall board beneath depending on the fire rating or 1 to 2 hours, respectively. Please see figure 5 for a sample section. The LVL joists span between steel beams.

<u>General</u>

Because LVL can rest in joist hangers on beams, the floor thickness with LVL can be kept thin compared with other systems. For instance, in the corridor, LVL is the thinnest alternative at just 9 inches. However, where the LVL has to span 26 feet, it has to be doubled up because LVL does not come in depths deeper than 11-7/8", creating a floor thickness of 15 inches.

<u>Architectural</u>

For the mechanical duct chases that would run through the halls, the LVL system provides the most room. By doubling up the LVL, the thickness of the entire floor system on the 2nd through 4th floors can decrease by 6 inches. For fire protection, LVL will provide a one hour fire rating for the upper floors and with additional gypsum wall board, it will also provide the 2 hour rating for the first floor.

<u>Structural</u>

Because the members in the dormitories will need to be doubled up, the weight of entire structure can increase, but the reduced weight of the first floor could result in a wash in regards to gravity loads, but would move the weight up the building and require more seismic resistance.

Constructability

LVL can be installed just like regular dimensional lumber, so contractors will have relatively no problems installing it. However, unlike regular lumber, LVL can span much longer distances and involve heavier self-weight per beam. This could slow some carpenters down, but the impact would be minimal.

Pros and Cons

Pros	Cons
• Ease of construction	• Weight distribution
• Increased fire protection	• Cost
• Shallow floors	• Mechanical ductwork routing problems

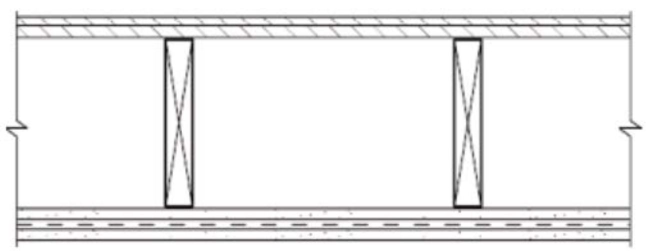

Figure 5. 2 hour fire rating using gypsum wall board and resilient channels. (Fire Resistance Design Manual)

Open Web Wood Floor Trusses

In the original design, open web wood floor trusses were used to span the suites in each wing above the first floor. For design considerations, MiTek trusses, the original truss designer, will be utilized with 4x2 cord member and spaced at 19.2 inches on center.

Wood floor trusses consists of a ¾ inch gypcrete topping on ¾ inch APA plywood on the floor truss with 1 to 3 layers of gypsum wall board beneath depending on the fire rating or 1 to 2 hours, respectively. Please see figure 6 for a sample section. The floor trusses span between bearing walls within the wings and first floor.

<u>General</u>

As a structural engineering student, it is evident that open web wood floor trusses are more difficult to design with. Unlike steel trusses, very few tables exist for wood floor trusses and thus a few assumptions had to be made. First, since the tables did not give a weight, it was assumed that since the weight of an 18 inch deep truss was known, that the other depths were linearly related. Also, it is evident that wood floor trusses are rarely used in high load conditions because the tables did not include live loads above 55 psf and this led to manipulation to determine the adequacy of a truss to carry a 100 psf live load.

The truss system determined to have a typical floor thickness of 15 inches for public areas and a thickness of 20 inches for the dormitory areas with the first floor being 22 inches thick.

<u>Architectural</u>

Assuming that the trusses will be hung off of steel hangers, the trusses don't create a major difference within the public spaces as they utilize drop ceilings, but the first floor increases significantly in floor thickness. For fire proofing, the wood truss systems achieve a 1 hour fire rating by use of gypsum wallboard. On the first floor, the increased depth comes from the increased load of having extra gypsum wallboard to achieve a 2 hour rating.

Structural

Wood floor trusses end up being very light compared to the concrete planks and not too much of a difference with the existing system for the public areas. If an increased floor thickness can be tolerated in the first floor, the building weight and seismic forces can be reduced.

Constructability

For construction, wood trusses might decrease the construction time for long spans, but could increase it for short spans. Most contractors are used to working with wood and trusses, so this method is pretty common with them. The short spans get cumbersome because of the narrow spaces in between (12 inches on center) and because a small 12 feet long truss can be too bulky to easily handle by hand and too light to warrant using a crane.

Pros and Cons

Pros	Cons
• Fast construction with long spans	• Most susceptible to fire
• Most susceptible to fire	• Longer construction with short span
• Very lightweight	• Depth is highest
• Running utilities very easy	

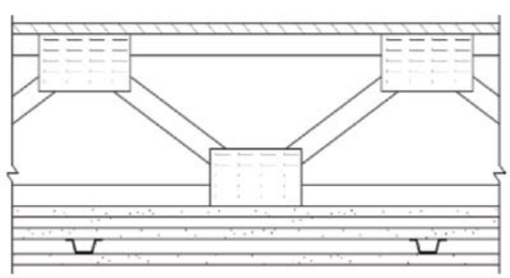

Figure 6. 2 hour fire rating using gypsum wall board and resilient channels.
(Fire Resistance Design Manual)

Dimensional Lumber

Used for the corridor floors in the original design, dimensional lumber will be looked at according to the NDS at a spacing of 16 inches on center. This system will be designed based on #2 Douglas Fir (North) as this is the weakest wood called for in the specification.

Dimensional lumber consists of a ¾ inch gypcrete topping on ¾ inch APA plywood on the dimensional lumber member with 1 to 3 layers of gypsum wall board beneath depending on the fire rating or 1 to 2 hours, respectively. Please see figure 7 for a sample layout. The joists span between steel beams.

General

By going with dimensional lumber, the depth in the central core (LVL) was obviously increased and the depth over the dormitories was decreased from the floor trusses. However, the depth on the first floor was increased by about an inch.

Architectural

The small changes in depth don't change things too much, especially because the central core utilizes a drop ceiling. For fire protection, dimensional lumber is able to provide a one hour fire rating in the upper floors and a two hour rating at the first floor.

Structural

Similar to the LVL system, a dimensional lumber system weighs less than the concrete plank, but more than the floor trusses and more than the LVL. This ends up to a near wash with the weight of the building distributed a little more on the top. This could increase seismic loads.

Constructability

All local contractors are used to working with dimensional lumber so there efficiency and time of construction is only dependent on the number of laborers.

Pros and Cons

Pros	Cons
• Fast construction time	• Weight distribution
• Shallow floors	• Mechanical ductwork routing

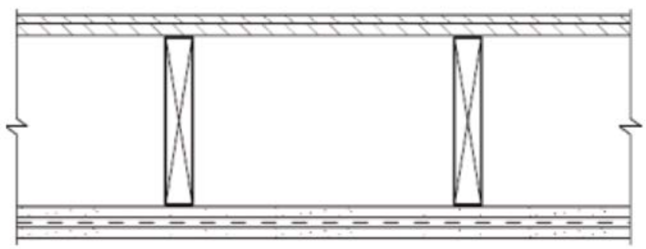

Figure 7. 2 hour fire rating using gypsum wall board and resilient channels. (Fire Resistance Design Manual)

Comparison

Table 9 – Comparison between Floor Systems

Consideration	System			
	Hollow Core Precast Plank	Laminated Veneer Lumber	Wood Floor Trusses	Dimensional Lumber
Cost* (per square foot)	$13.57	$14.02	N/A	$15.86
Fire Rating	2 hours	1 or 2 hours	1 or 2 hours	1 or 2 hours
Average Weight (psf)	85	28.5	21.7	20.9
Lateral Impact	Yes	Yes	No	Yes
Constructability	Low	Medium	Medium	Easy
Viable Option (1st Floor)	Yes	Yes	No	Yes
Viable Option (Corridor)	No	Yes	No	Yes
Viable Option (Core)	No	Yes	Yes	Yes
Viable Option (Suites)	No	Yes	Yes	Yes

*Approximate cost according to RS Means Assemblies Cost Data 2012

Foundations

Because the building already sits on a poor soil, the foundations are pretty much maxed out with the load they can carry. This means that for the entire building to utilize precast planks, the foundations would sink into the soil, not to mention the increase in overturning due to seismic forces. For the other systems, the foundations should be able to carry the load, as the additional weight they add is cancelled out by removing the precast planks on the first floor.

Summaries

First Floor

Originally, the first floor consisted of hollow core concrete planks. These were able to do an adequate job of carrying the dormitory suite loads while spanning 26 feet. More so, the concrete planks also provided a 2 hour fire rating while remaining structurally thin at 10 inches deep. However, the planks added weight to the structure at 85 psf.

For a possible redesign, laminated veneer lumber was examined. This was able to achieve the design loads and while keeping a low floor depth. At 37 psf, LVL was able to provide a 2 hour fire rating with additional gypsum wall board layers and come in at a depth of 15 inches. This shallow depth was due to the use 3.5 x 11.875 (2 ply) LVL at 16 inches on center.

Open web wood floor trusses were also examined for applicability and came in at the light weight of 26.4 psf. Being the lightest of the options, wood floor trusses could easily span the distance, but because of their size, they increased the floor depth to 25 inches. For a redesign, this could cause an architectural problem and perhaps a problem with getting the first floor to meet up at grade.

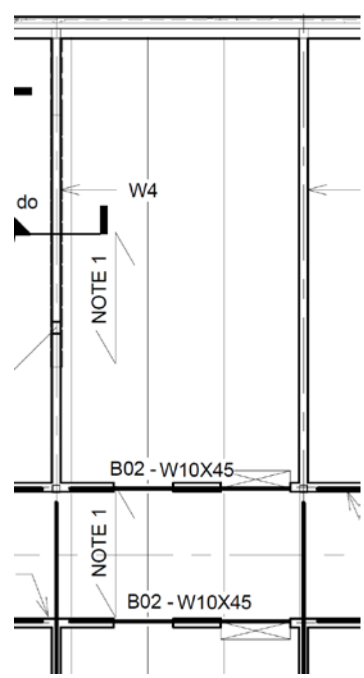

Figure 8. Typical first floor bay and corridor of 26 feet deep and 14 feet wide. (Plans S1.1A)

Lastly, dimensional lumber was looked at and the most efficient ended up being 2x10's at 16 inches on center which produced a weight of 23.4 psf. This would produce a need for a beam at the middle of the 26 feet span which could also be made using built up 2x10's. At 13 inches, dimensional lumber is the thinnest redesign, but the additional beam could lead to problems of designing columns to hide within the walls between adjacent suite rooms.

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Central Core

The central core was originally built utilizing laminated veneer lumber on steel beams. This proved to be adequate by yielding a floor depth of 11 inches at 24.7 psf. A fire rating of one hour was achieved by using one layer of gypsum wallboard. Special design considerations needed to be made due to the assembly space this floor is supporting, thus a 100 psf live load.

For a redesign, hollow core concrete planks were examined and it was determined that 8 inch deep planks with three ½ inch diameter strands could be used at 85 psf. This created a floor depth of 11 inches, but with an additional two hour fire rating. These planks would span between W10x45's anchored to the columns.

In addition, open web wood floor trusses were examined. Because of the limitations of the table, a 12 inch deep truss spaced at 12 inches on center was determined to be the most efficient. This created a floor depth of 14 inches with a weight of 20.8 psf. A one hour fire rating was achieved with one layer of gypsum wallboard.

Lastly, dimensional lumber was examined for its applicability and this yielded a weight of 18.4 psf. A one hour fire rating was achieved using one layer of gypsum wall board and this system yielded a floor depth of 13 inches. However, where all the other uses of dimensional lumber used #2 grade Douglas Fir, the live load in the core yielded a higher grade be used. For the core, a redesign determined that 2x12's of #1 or better grade Douglas Fir at 16 inches on center would need to be utilized.

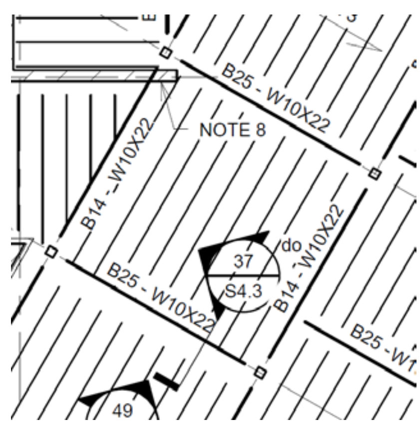

Figure 9. Typical central core bay of 12' 8" x 13' 4" (Plans S1.3A)

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Suite Floors

Originally designed using open web wood floor trusses, the suite floors had a depth of 20 inches and a weight of 20.8 psf. A one hour fire rating was achieved using one layer of gypsum wall board on the bottom chord. Because the table utilized did not match up with the original design, it was assumed for this truss that by the use of better materials, an 18 inch deep truss could span 26 feet and abide by the L/480 deflection limit.

For the first redesign, hollow core concrete planks were examined and it was determined that 8 inch deep planks with five ½ inch diameter strands could be used at 85 psf. This created a floor depth of 11 inches, but with an additional two hour fire rating. These planks would span between W10x45's anchored to new columns located at the corners of each suite room.

For the second redesign, laminated veneer lumber was examined. LVL was able to span the 26 feet by using 3.5 x 11.875 (2 ply) LVL at 16 inches on center. Increased load was considered to achieve a deflection limit of L/480, which resulted in a floor depth of 14 inches. This created a weight of 32.3 psf for the floor system.

Lastly, dimensional lumber was looked at and the most efficient ended up being 2x10's at 16 inches on center which produced a weight of 23.4 psf. This would produce a need for a beam at the middle of the 26 feet span which could also be made using built up 2x10's. At 13 inches, dimensional lumber is the thinnest redesign behind hollow core, but the additional beam could lead to problems of designing columns to hide within the walls between adjacent suite rooms.

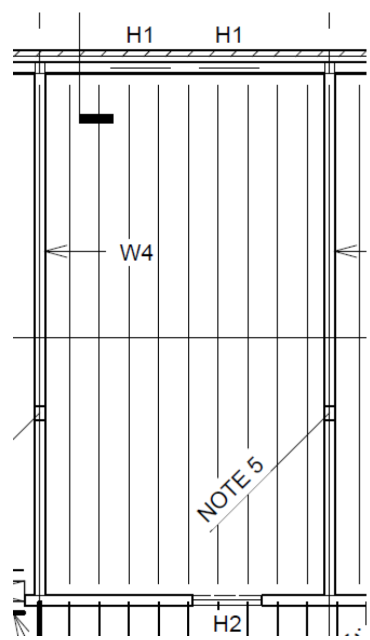

Figure 10. Typical wing bay of 26 feet deep by 14 feet wide (Plans S1.3A)

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Wing Corridors

For the original design, dimensional lumber was designed for a 100 psf live load within the corridor. This load produced the most efficient member of 2x10's at 16 inches on center which produced a weight of 18.4 psf at 13 inches deep. A fire rating of one hour was achieved using one layer of gypsum wall board on the underside of the system.

For the first redesign, hollow core concrete planks were examined and it was determined that 8 inch deep planks with three ½ inch diameter strands could be used at 85 psf. This created a floor depth of 11 inches, but with an additional two hour fire rating. These planks would span between W10x45's anchored to new columns located at the corners of each suite room.

For the second redesign, laminated veneer lumber was examined. LVL was able to span the 7 feet wide corridor by using 1.75 x 5.5 LVL at 16 inches on center. This created a weight of 19.9 psf with a thickness of 8 inches for the floor system. A one hour fire rating was achieved using one layer of gypsum wallboard on the underside of the system.

In addition, open web wood floor trusses were examined. Because of the limitations of the table, if a 12 inch deep truss spaced at 12 inches on center works for a span of almost 13 feet, then it is assumed that at about half the span, trusses spaced at 19.2 inches on center will suffice. This created a floor depth of 14 inches with a weight of 19 psf. A one hour fire rating was achieved with one layer of gypsum wallboard on the bottom chord.

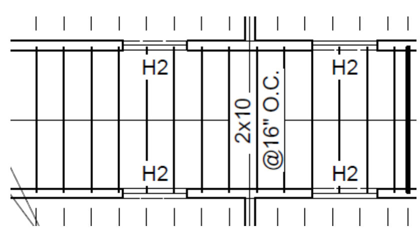

Figure 11. Typical corridor at 7' 2" wide
(Plans S1.3A)

Conclusion

Per the requirements of this assignment, four separate floor systems were examined for their applicability, one of them being the original system. Because the building started out with four systems, these systems were also chosen as the redesigned floor systems.

The hollow core concrete precast plank floor system was properly designed for the loads in its original place on the first floor. For the spaces above the first floor, the concrete planks could carry the required loads, but in some cases, they doubled the dead load. This would also create additional lateral forces that would need to be considered. Architecturally, this system would be a great benefit with thin floor depths and a high fire rating of two hours. Structurally, the foundation would likely not be able to support the increased weight, thus this option is not viable.

The laminated veneer lumber floor system proved be adequately designed for the central core, and could easily be designed for the rest of the structure. This system proved be architecturally viable because in some cases, it reduced the floor thickness and a two hour fire rating was achievable through additional gypsum wallboard. Structurally, this system is viable because it removes the weight of the concrete planks and redistributes it throughout the building. This will create a greater seismic load, but not a significant increase that the soil can't support.

Wood floor trusses were designed according to the MiTek charts for L/360 deflection. However the original design did not work because the charts stated that 26 feet was too long for an 18 inch deep truss, as well as the table did not state what to do for a deflection limit of L/480. At its light weight and ease of a two hour fire rating, this system is a structural possibility, but not an architectural possibility due to the large increase in the thickness of the first floor.

Lastly, dimensional lumber was looked at and the corridor design that uses it currently works well. Throughout the rest of the building, this system would work well, but some additional beams and columns would be needed to span the 26 feet spans of the suites. More so, this system could face construction issues as the central core would call for #1 grade lumber or better. Overall, this system would be viable in both respects because it is a light weight and it doesn't increase the floor thickness.

In the end, both laminated veneer lumber and dimensional lumber should be looked at for design considerations.

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Appendix A – Precast Hollow Core Concrete

Hollow Core Design | Tech 2 | Page 1

Original (First Floor)

Span = 26' Maximum

Live Load = 40 psf
Dead = 7 psf + 300 in · 1ft/4 · ft²/144 · 150 = ~~370 psf~~ $\boxed{85\ psf}$

Design using Pittsburgh Flexicore:

assume SI dead is added to live load: 47 psf

Yields: 8" x 48" Hollow core using (5) ½"ϕ strands (continuous design)

Wings Over Dormitories

Same Span & loads as above : $\boxed{\text{Weight} = 85\text{psf}}$

Yields: 8" x 48" Hollowcore using (5) ½" ϕ strands

Central Core

Span = 12'8" Maximum (use 14')

$\boxed{\text{Weight} = 85\ \text{psf}}$

Live Load = 100 psf = 107
Dead = 85 psf

Yields: 8" x 48" Hollowcore using (3) ½" ϕ strands

Corridors

Same assumed span & loads as above $\boxed{\text{Weight} = 85\text{psf}}$

Yields: 8" x 48" Hollowcore using (3) ½" ϕ strands

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Hollow Core Design | Tech 2 | Page 2

Beam Design / Support Design

Original

Span = 14'

Load = 1.2(85) + 1.6(40) = 166 psf

Trib width = $\frac{26'}{2} + \frac{7'2''}{2}$ = 16' 7" = 16.58'

Load = 166 · 16.58 = 2752 lb/ft = 2.75 k/ft

$M = \frac{wL^2}{8} = \frac{2.75 \cdot 14^2}{8} = 67.4$ k-ft   * Can't assumed braced laterally

$\Delta_L = \frac{5wL^4}{384EI} = \frac{5 \cdot \cancel{2.75}\ 40/1000 \cdot 16.58 \cdot 14^4 \cdot 1728\ \cancel{\cdot 1000}}{384 \cdot 29000 \cdot I} = \frac{L}{360} = \frac{14 \cdot 12}{360}$

~~I = 175.6 in⁴~~   I = 42.36

$\Delta_{TL} = \frac{5 \cdot 125/1000 \cdot 16.58 \cdot 14^4 \cdot 1728}{384 \cdot 29000 \cdot I} = \frac{L}{240}$ I = 88.25 ← controls

~~By Unbraced length: w10×26 works~~

Load calc is wrong.

13 · 166 = 2158

1.2(85) + 1.6(100) = 262   = 3096 = 3.1 k

3.58 · 262 = 937.96

$V = 3.1 \cdot \frac{14}{2} = 21.7$k

$M = \frac{3.1 \cdot 14^2}{8} = 76$ k-ft   ⇒ w10×30

	M	V	I	Flange width
w10×30	137 ok	94.5 ok	170 ok	5.81 NO 6" minimum

$\boxed{\text{Use w10×45}}$ Flange width = 8"

Hollow Core | Tech 2 | Page 3

Support Design

Wings over Dormitories & Corridors

Use Stud wall at 16" OC

Load = 3.1 k/ft @16" OC = 4.13 k per stud at 4th floor
12 k per stud at 1st floor
impractical

Go with steel beam: Same loads & span as previous.

$\boxed{\text{Use W10x45}}$

Central Core

~~Span~~ = ~~13'4"~~ 12'8" = Tributary Width

$1.2(85) + 1.6(100) = 262 \cdot \cancel{13.33}\ 12.66 = \cancel{3.5\ k/ft}\ 3.3\ k/ft$

Span = 13'4" = 13.33'

Try W10x45 for consistency

M	V
206	106
ok	ok

I ok by inspection
Wp ok

$M = \frac{13.33^2 \cdot 3.3}{8} = 73.3$

$\frac{3.3 \cdot 13.33}{2} = 22$

$\boxed{\text{Use W10x45}}$

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Appendix B – Laminated Veneer Lumber

LVL Design | Tech 2 | Page 1

Original = 1.75 x 9.25 LVL in core

$\boxed{\text{Weight} = 24.7\text{ psf}}$

Span = 12' 8" Maximum = 12.66'

Live Load = 100 psf
Dead Load = ~~20~~ 16.5 psf (from Tech 1 Gravity Check B25)

Design using i-level and 1.9E Microllam

$L_L = 100$ psf $T_L = \cancel{120}$ 116.5 psf (neglecting beam weight)

@ 16" OC

$L_L = 133$ plf $T_L = 155$ plf (neglecting beam weight)

Deflection = L/360

Yields: 1 3/4" x 9.25" $T_L = 228.3$ plf ∴ Good
$L_L = 155.21$ plf ∴ Good

Wings Over Dormitories - No Live Load Reduction

Span = 26' maximum

Live Load = 40 psf
Dead Load = 16.2 psf (from tech 1 Gravity Check Corridor 2x10, same floor components as dorm rooms w/o the trusses)

Design using i-level and 1.9E Microllam

$L_L = 40$ psf $T_L = 56.2$ psf

@ 16" OC

$L_L = 53.33$ plf $T_L = 75$ plf

Deflection = L/480 (Same as for Trusses) (LL/.75) adjustment

Adjusted = $L_L = 71.1$ plf $T_L = 75$ plf

Yields: 3 1/2" x 11 7/8" (2-ply) $T_L = 102$ plf ∴ Good
$L_L = 76$ plf ∴ Good

Weight = 16.2 + 12.1 · 16/12 = $\boxed{32.33\text{ psf}}$

LVL Design | Tech 2 | Page 2

First Floor – No live load reduction

Span = 26' Maximum

Live Load = 40 psf ← GWB needed in addition for 2 hour fire rating
Dead Load = 16.2 + 2.4(2) = 21 psf

L_L = 40 psf T_L = 61 psf

@ 16" oc

L_L = 53.3 plf T_L = 81.3 plf

Deflection = L/480 (assumed because floor is used for similar function as previous)

Adjusted =

L_L = 71.1 plf T_L = 81.3 plf

Yields: 3½" × 11⅞ (2 ply) T_L = 102 ∴ Good
L_L = 76 ∴ Good

Weight = 21 + 12.1/12 · 16 = $\boxed{37.13 \text{ psf}}$

Corridors

Span = 7'2"

Live = 100 psf
Dead = 16.2 psf
total = 116.2 psf

@ 16" oc

L_L = 133.3 plf T_L = 154.9 plf

Deflection: L/360 (No vibration control)

Yields: ~~1¾ × 7¼ (1 ply) T_L = L_L =~~

Interpolate: 14"

	T_L	L_L
0"(6') =	432	290
24"(8') =	146	126
14"(7'2") =	265	194
	ok	ok

Use: 1¾ × 5½ weight = 16.2 + 2.8 · 16/12 = $\boxed{19.9 \text{ psf}}$

Gravity Check B25	Tech 1	Page 1 of 1

Typical Beam
W10x22

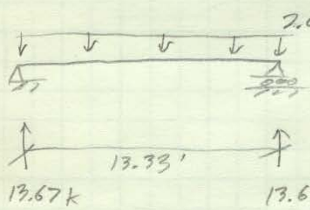
Length = 13'4" = 13.33'

Sheathing = 2.2 psf
Gypcrete (3/4) = 7.2 psf
Carpet = 2 psf
MEP = 4 psf
Ceiling = 1 psf
16.4 psf
+ 3.525
19.9 psf ⇒ 20 psf

LVL 1.75x9.25 @ 16" OC = 4.7 · 12/16 =
= 3.525

Tributary Area = 11' wide

20 · 11 = 220 plf + 22 = 242 plf D



Live = 100 psf · 11' = 1100 plf

$1.2D + 1.6L = 1.2(242) + 1.6(1100)$
$= 2050$

$L_b = 2'0"$ per Section 37 / 34.3

$M = \frac{wl^2}{8} = 45.55$ k-ft

Assume Laterally Braced

$\Delta_L = \frac{5wL^4}{384EI} = \frac{5 \cdot 1100 \cdot 13.33^4 \cdot 1728}{384 \cdot 29E6 \cdot I} = \frac{l}{360} = \frac{13.33 \cdot 12}{360}$

$I = 60.64 \text{ in}^4$ ⟸ Controls

$\Delta_{L+D} = \frac{5wL^4}{384EI} = \frac{5 \cdot 1342 \cdot 13.33^4}{384 \cdot 29E6 \cdot I} = \frac{l}{240} = I = 49.32 \text{ in}^4$

⇒ W12x14 = 88.6 > 60.64 Good, does not meet max uniform load tables

$\phi M_n = \phi F_y Z_x = 45.55 = .9 \cdot 50 \cdot Z_x$ $Z_x = 1.012$

Max Uniform Load: 2.05 k/ft

Using Table 3-10: $M = 45.55$, $L_b = 2'$ ⇒ W10x12

If the unbraced length is 13'4", then either:

	M	V	I
W8x21	51 k-ft	62.1 k	75.3
or			
W10x22	62 k-ft	73.4 k	118
	Good	Good	Good
Need	45.55	13.67	60.64

Both beams work, but if sticking with W10 shapes then W10x22 as per the design.

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Appendix C – Open Web Wood Floor Truss

Wood Truss | Tech 2 | Page 1

Original – Wings over Dormitories
~~Also First Floor~~

Span = 26' @ 19.2" oc

Top Chord Live = 40
Dead = ≈11.5
Bottom Chord Live = 0
Dead = ≈5

Assume 40/10/0/5

$\text{weight} = \left(16.5 + \frac{164}{24}\right)\frac{19.2}{12}$ ~~$= 37.33$ lb/ft²~~ $\boxed{= 22.4 \text{ lb/ft}^2}$ $\boxed{= 20.77 \text{ lb/ft}^3}$

Depth = 20 inches at a minimum live load deflection of L/360

* Problem: specs call for L/480 and 18" truss.

Assumption: The manufacturer was able to make an L/480 18" truss for the 26' span using higher grade materials.

Central Core

To eliminate existing beams, use span of 22'8"
Some beams will still be required, but not as many
– Won't work for required loading

Use 100/10/0/5 Span ~~22'8"~~ ⇒ 12'8"

Manipulate the table using 50/10/0/10 @ 24" oc
⇒ D = 12" works
or 100/10/0/5 ⇒ D = 12" works @ 12" oc

Assume: Weight is linearly dependent on depth

$\text{Weight} = 16.2 + \left(\frac{164}{24}\right)\left(\frac{12}{18}\right) = \boxed{20.76 \text{ psf}}$

Corridor:

If 12" @ 12" oc works at 12'8" span, then at about half the span 12" @ 19.2" will work

Use 12" @ 19.2" oc $\text{weight} = 16.2 + \left(\frac{164}{24}\right)\left(\frac{12}{18}\right)\left(\frac{12}{19.2}\right) = \boxed{19 \text{ psf}}$

First Floor

Use 40/10/0/10 for added fire protection needed

Depth of 22" @ 19.2 oc Required $\text{weight} = 21.2 + \left(\frac{164}{24}\right)\left(\frac{22}{18}\right)\left(\frac{12}{19.2}\right) = \boxed{26.42 \text{ psf}}$

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Appendix D – Dimensional Lumber Design

Dimension Lumber | Tech 2 | Page 1

Original - See gravity check for 2x10 corridor in Tech 1 $= \boxed{18.4\ psf}$

~~Assume~~

Weight $= 24.5 \cdot \frac{12}{16} = \boxed{18.4\ psf}$

Central Core

Use Dead $= 24.5\ psf = 24.5\ plf$
Live $= 100\ psf @ 16'' OC = 133.3\ plf$

ASD - 2x10"

$W = D + L = 133.3 + 24.5 = 157.8\ plf$

Span $= 12.66'$

Shear $= \frac{12.66 \cdot 157.8}{2} = 999 \approx 1000\ lb$

Moment $= \frac{12.66^2 \cdot 157.8}{8} = 3161\ ft\text{-}lb$

$f_b = \frac{6M}{bd^2} = \frac{6 \cdot 3161}{1.5 \times 9.25^2} \cdot \frac{1728}{144} = 1773\ psi$

$f_v = \frac{3V}{2db} = \frac{3 \cdot \cancel{999}\ 1000}{2 \cdot 1.5 \cdot 9.25} = 108.1\ psi$

$F_b' = 850 \cdot 1.0 \cdot 1.15 \cdot 1.1 \cdot 1.0 = 1075 < 1773$ No

Try 2"x12"

$f_b = \frac{6M}{bd^2} = 1773 \cdot \frac{9.25^2}{11.25^2} = 1199\ psi$

$f_v = 108.1 \cdot \frac{9.25}{11.25} = 88.9\ psi$

$F_b' = 850 \cdot 1.15 \cdot 1.0 \cdot 1.0 = 977.5 < 1199$ No

Use Grade #1 or better $= F_b' = 1150 \cdot 1.15 = 1322 > 1199$ Yes

$F_v' = 180 \cdot 1.0 = 180 > 88.9$ Yes

$\Delta_L = \frac{5 \cdot 133 \cdot 12.66^4 \cdot 1728}{384 \cdot 1.6E6 \cdot 178} = .2699\ in < \frac{L}{360} = \frac{12.66 \times 12}{360} = .422$ good

$\Delta_T = \frac{5 \cdot 158 \cdot 12.66^4 \cdot 1728}{384 \cdot 1.6E6 \cdot 178} = .321 \le \frac{L}{240}$ good by inspection

Use 2x12 @16" OC Number 1 or better

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Dimension Lumber | Tech 2 | Page 2

Dormitories & First Floor

Use an intermediate beam

$$\text{Dead} = 24.5\ \text{plf} + 5 \cdot \tfrac{16}{12} = 31.2$$
$$\text{Live} = 40\ \text{psf} \cdot 16/12 = 53.3$$

ASD – 2×10

$$w = D + L = 84.5$$

$$\text{Span} = 13'\ \text{Max} \quad (26'/2)$$
$$\text{Shear} = 13 \cdot 84.5/2 = 549$$
$$\text{Moment} = 13^2 \cdot 84.5/8 = 1785$$

$$f_b = \frac{6M}{bd^2} = \frac{6 \cdot 1785 \cdot 12}{1.5 \times 9.25^2} = 1001$$

$$f_v = \frac{3V}{2db} = \frac{3 \cdot 549}{2 \cdot 1.5 \cdot 9.25} = 59.4$$

$$F_b' = 850 \cdot 1.0 \cdot 1.15 \cdot 1.1 = 1075 > 1001 \quad \text{ok}$$

$$F_v' = 180 \cdot 1.0 = 180 > 59.4 \quad \text{ok}$$

$$\Delta_L = \frac{5 \cdot 53.3 \cdot 13^4 \cdot 1728}{384 \cdot 1.6E6 \cdot 99} = .216'' \underset{\text{Good}}{<} \frac{L}{360} = \frac{13 \cdot 12}{360} = .433$$

$$\Delta_T = \frac{5 \cdot 84.5 \cdot 13^4 \cdot 1728}{384 \cdot 1.6E6 \cdot 99} = .343 \quad \text{Good by inspection } \frac{L}{240}$$

$$\text{Weight} = 31.2 \cdot 12/16 = \boxed{23.4\ \text{psf}}$$

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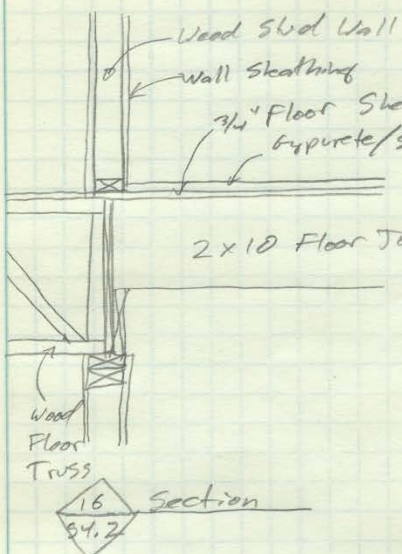
Gravity Check → | Tech 1 | Page 1 of 3

Corridor 2x10 Typical Floor



Assume
- Only loads on 2x10 are selfweight, 3/4" sheathing, sound mat assembly and live load.
- 16" spacing as is typical in wood construction.
- Pinned Connections
- #2 Douglas Fir (North)
- Too small Area for Load Reduction

Span = 7'2" = 7.1667'

Load from Materials Chart:

Sheathing = 2.2 psf
Gypcrete (3/4") = 7.2 psf
Carpet = 2 psf
MEP = 4 psf
Acoustic Ceiling = 1 psf
16.2 psf @ 16" oc = 16.2 · 16/12 = 21.6 lb/ft + SW

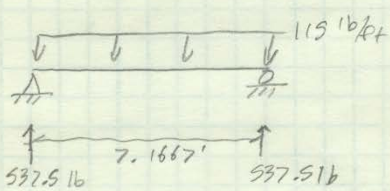
Selfweight (SW) Assumed as a 2x10 Douglas Fir @ 30 lb/ft³ = 2.9 lb/ft

Total Dead = 21.6 + 2.9 = 24.5 lb/ft
Live = 40 psf @ 16" oc = 53.33 lb/ft (private corridor)

LRFD

$W = 1.2D + 1.6L = 1.2(24.5) + 1.6(53.33) = 114.7 = 115 \text{ lb/ft}$

$24.5 + 53.33 = 78 \text{ lb/ft}$



Maximum Shear = 537.5 lb @ supports

Maximum Moment = 738.3 lb-ft @ center $\left(\frac{wL^2}{8}\right)$

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Gravity Check → | Tech 1 | Page 2 of 3

Corridor 2x10 Typical Floor

Bending

$f_b = \frac{6M}{bd^2} = \frac{6 \cdot 738.3}{1.5 \cdot 9.25^2} \cdot 1728 = 59642 \text{ lb/ft}^2 = 414.2 \text{ psi}$

$F_b' = F_b \cdot K_F \cdot \phi_b \cdot \lambda \cdot C_r \cdot C_F \cdot C_L$

$= 850 \text{ psi} \cdot (2.16/\phi_b)(\phi_b) \cdot (0.8) \cdot (1.15) \cdot (1.1) \cdot (1.0) = 1858 \text{ psi}$

$1858 > 414.2$ Good

Try a 2x8 assuming same dead load

$F_b' = 850 \cdot 2.16 \cdot .8 \cdot 1.15 \cdot 1.2 \cdot 1.0 = 2027 \text{ psi}$

$f_b = \frac{6 \cdot 738.3}{1.5 \cdot 7.25^2} \cdot \frac{1728}{144} = 674.2 \text{ psi}$

ok

Try a 2x6 assume same dead load

$F_b' = 850 \cdot 2.16 \cdot .8 \cdot 1.15 \cdot 1.3 \cdot 1.0 = 2196 \text{ psi}$

$f_b = \frac{6 \cdot 738.3}{1.5 \cdot 5.5^2} \cdot 12 = 1172$

Good

Shear 2x10

$f_v = \frac{3V}{2db} = \frac{3 \cdot 537.5}{2 \cdot 1.5 \cdot 9.25} = 58.1 \text{ lb/in}^2$

Good

$F_v = F_v' \cdot K_F \cdot \phi_v \cdot \lambda = 180 \cdot 2.16 \cdot .8 = 311 \text{ lb/in}^2$

Try a 2x6

$f_v = \frac{3 \cdot 537.5}{2 \cdot 1.5 \cdot 5.5} = 97.7 \text{ lb/in}^2$

Good

$F_v = 180 \cdot 2.16 \cdot .8 = 311 \text{ lb/in}^2$

Deflection

$2\text{x}10 \Rightarrow I = \frac{bd^3}{12} = \frac{1.5 \cdot 9.25^3}{12} = 99$

should be 53, but if it works now, 53 will work & it will also meet $\frac{\ell}{240}$ requirement

$\Delta = \frac{5wL^4}{384EI} = \frac{\ell}{360} = \frac{5 \cdot 78 \cdot 7.1667^4 \cdot 1728}{384 \cdot 1.656 \cdot 99} = .029 \text{ in}$

ok

$\frac{\ell}{360} = \frac{7.1667 \cdot 12}{360} = .239 \text{ in}$

Try 2x6 $I = \frac{1.5 \cdot 5.5^3}{12} = 20.8$

ok

$\Delta = \frac{5 \cdot 78 \cdot 7.1667^4 \cdot 1728}{384 \cdot 1.656 \cdot 20.8} = .139 \text{ in}$

$\boxed{2\text{x}6 \text{ works}}$

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Gravity Check → | Tech 1 | Page 3 of 3

Corridor 2x10

Assume Live Load = 100 psf = 133 plf

ASD

$W = D + L = 133 + 24.5 = 157.5 \Rightarrow 160$ plf

Max Shear = 573 k

Max Moment = 1027 k

$f_b = \frac{6M}{bd^2} = \frac{6 \cdot 1027}{1.5 \cdot 9.25^2} \cdot \frac{1728}{12 in^2} = 576$ psi

~~Per previous calculations, 1858 > 576 Good~~

$f_v = \frac{3V}{2db} = \frac{3 \cdot 573}{2 \cdot 1.5 \cdot 9.25} = 61.9$ psi

$F_b' = 850 \cdot 1.0 \cdot 1.15 \cdot 1.1 \cdot 1.0 = \boxed{1075 > 576 \text{ Good}}$

Try 2x6 $F_b' = 850 \cdot 1.0 \cdot 1.15 \cdot 1.3 = 1271$

$f_b = \frac{6 \cdot 1027 \cdot 12}{1.5 \cdot 5.5^2} = 1629 > 576$ No

$F_v' = 180 \cdot 1.0 = 180 > \boxed{61.9 \text{ Good}}$

Deflection

$\Delta_L = \frac{5 \cdot 133 \cdot 7.1667^4 \cdot 1728}{384 \cdot 1.6E6 \cdot 99} = .050$ in $\quad \frac{l}{360} = \frac{7.1667 \cdot 12}{360} = .239$ Good

$\Delta_T = \frac{5 \cdot 160 \cdot 7.1667^4 \cdot 1728}{384 \cdot 1.6E6 \cdot 99} = 0.060$ in $\quad \frac{l}{240} = \frac{7.1667 \cdot 12}{240} = .358$ Good

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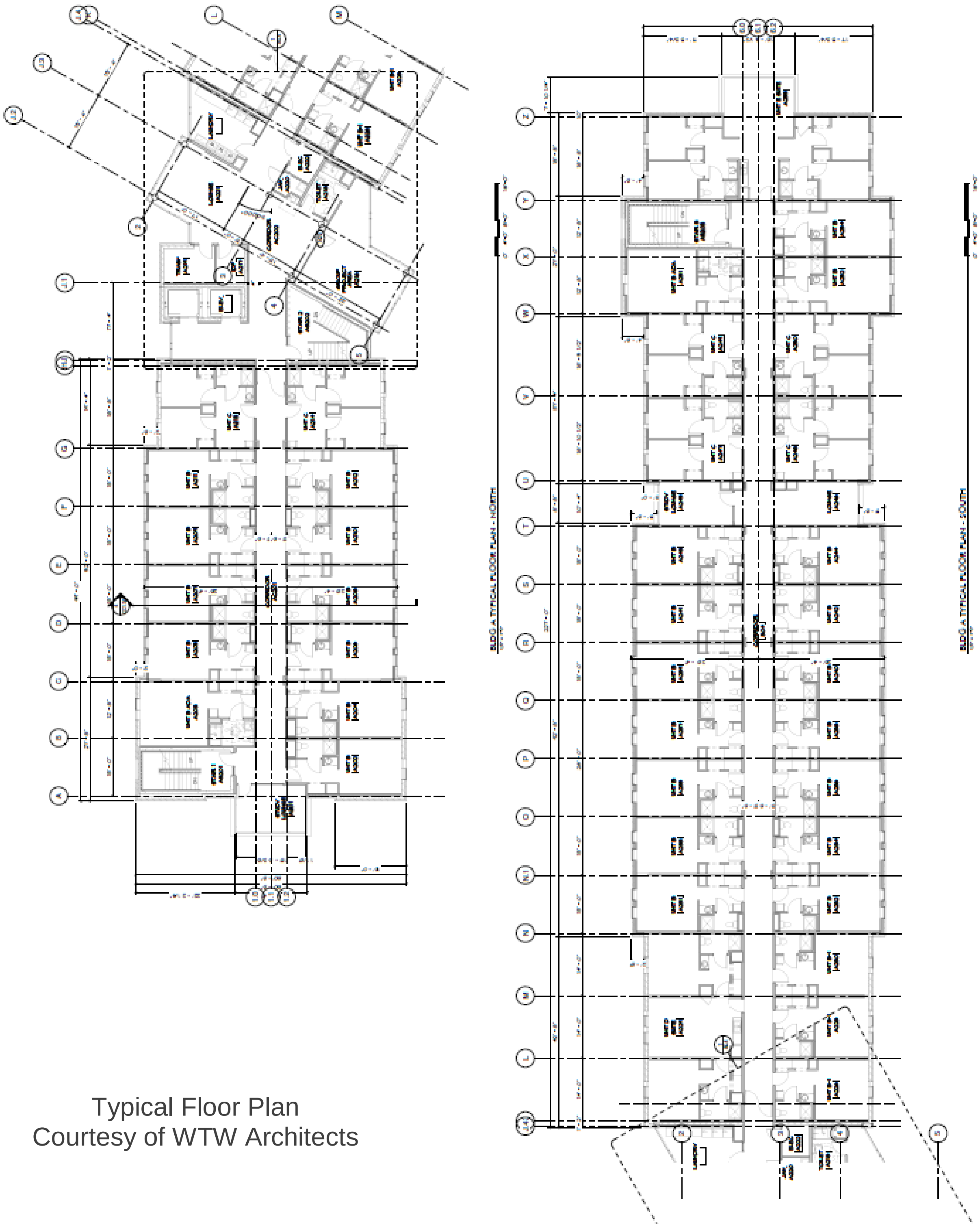
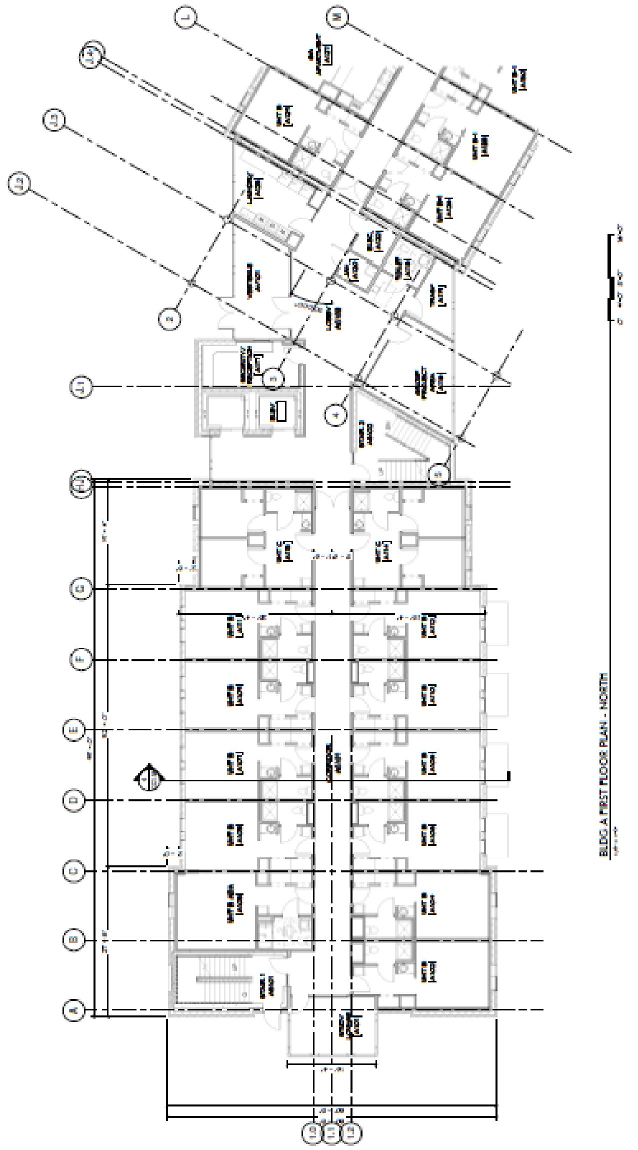
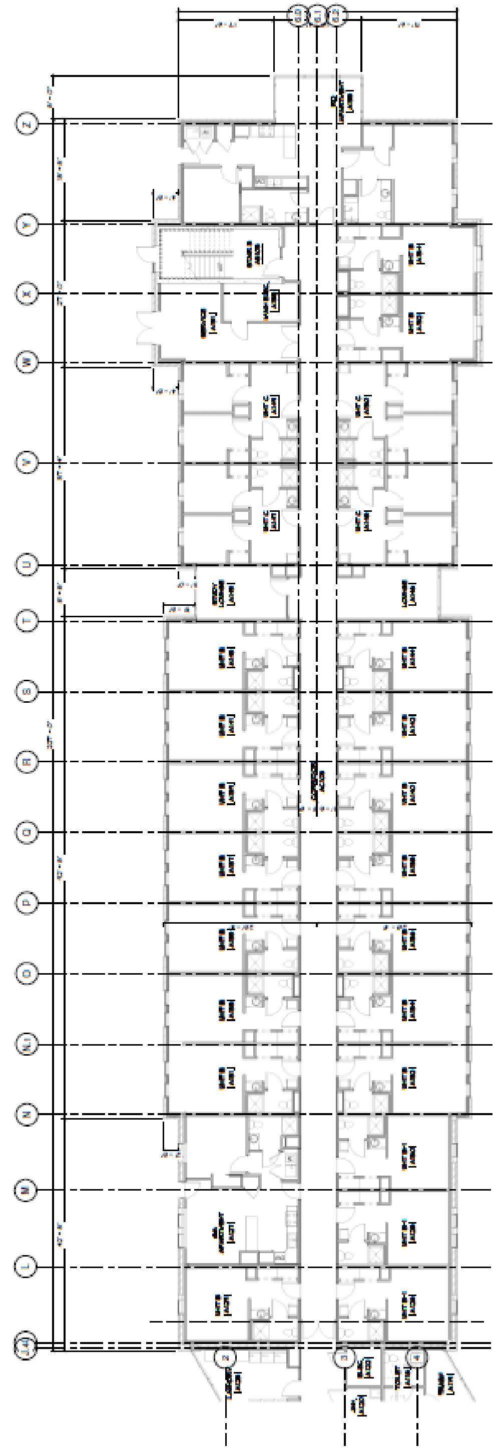
Appendix E – Typical Floor Plans



Typical Floor Plan
Courtesy of WTW Architects





First Floor Plan
Courtesy of WTW Architects

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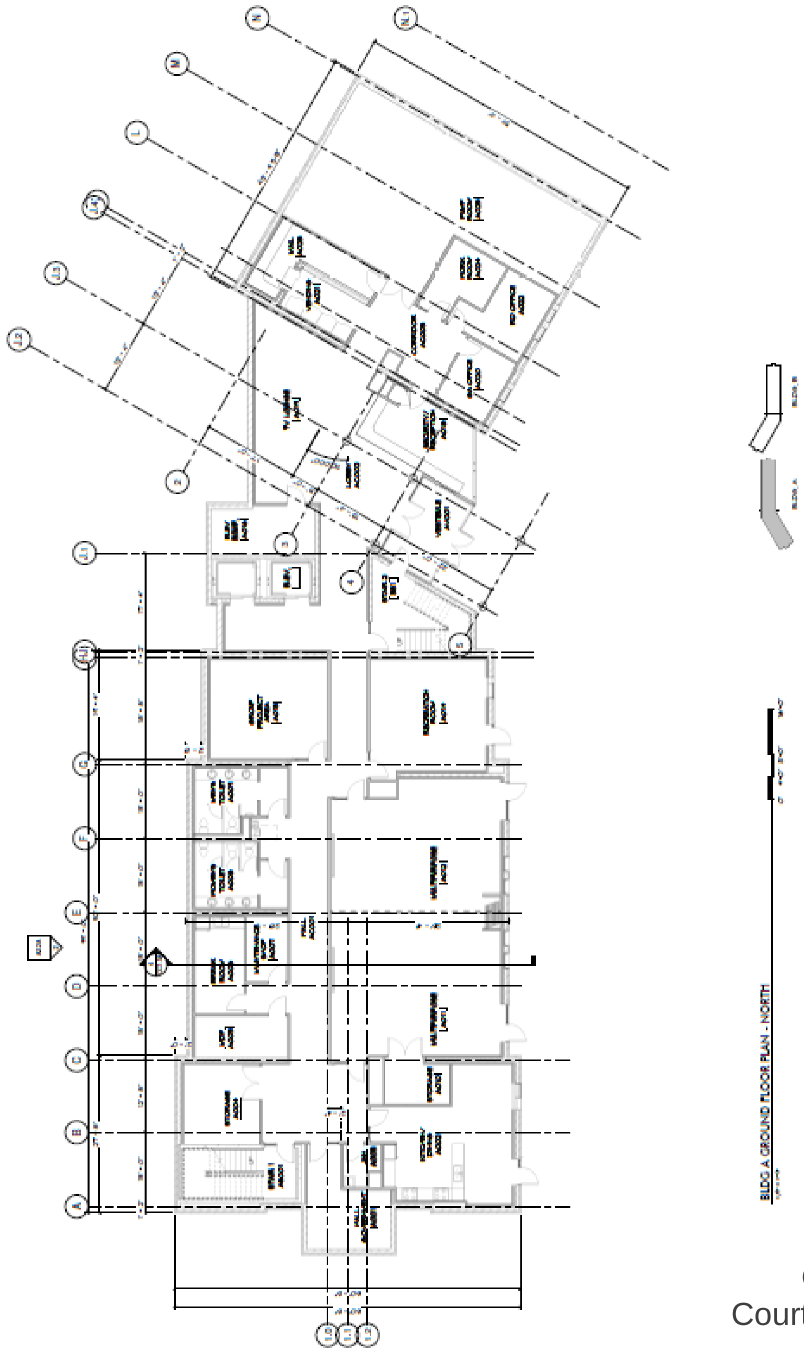

Ground Floor Plan
Courtesy of WTW Architects

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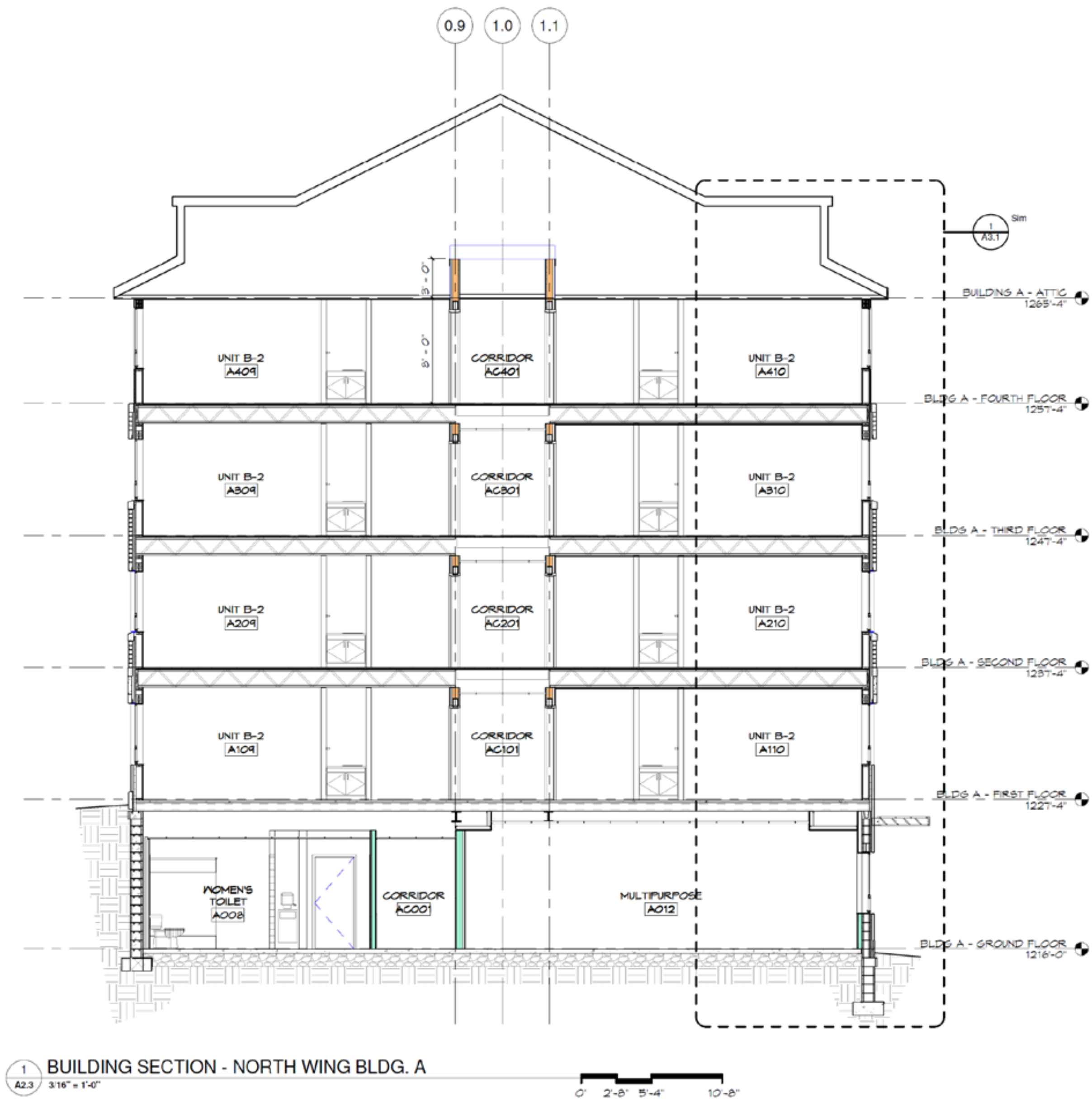

Building Section
Courtesy of WTW Architects

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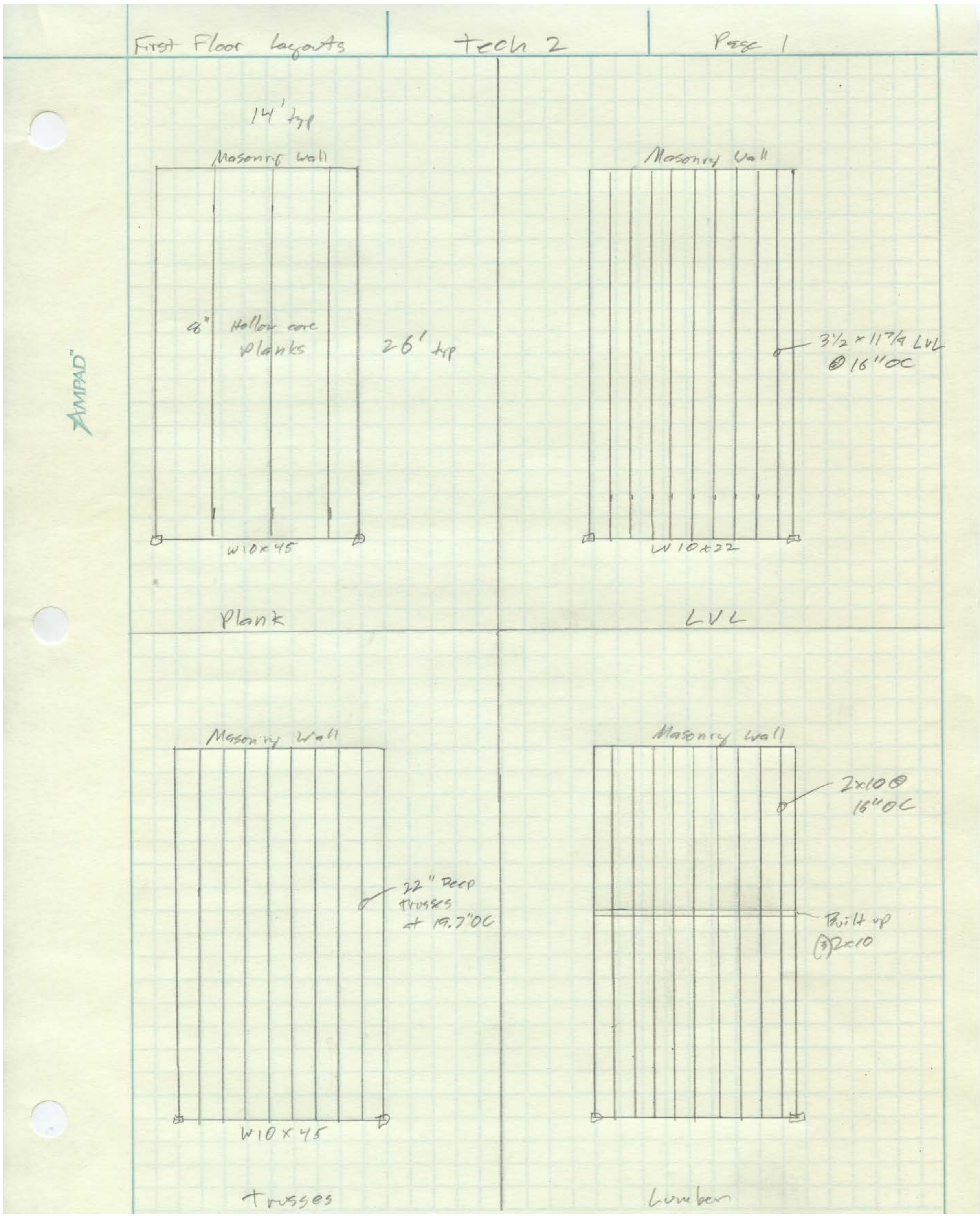
Appendix F – Building Section



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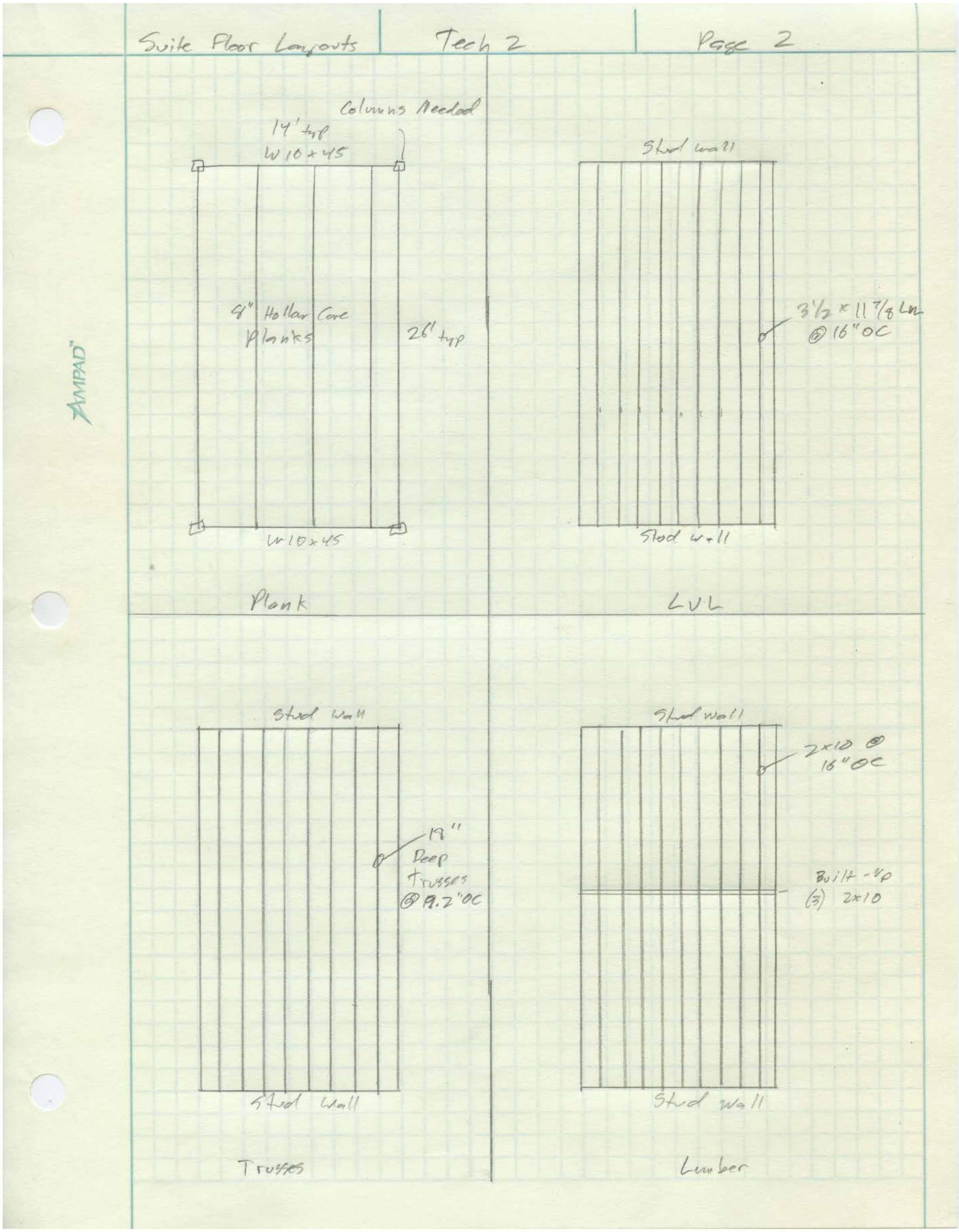

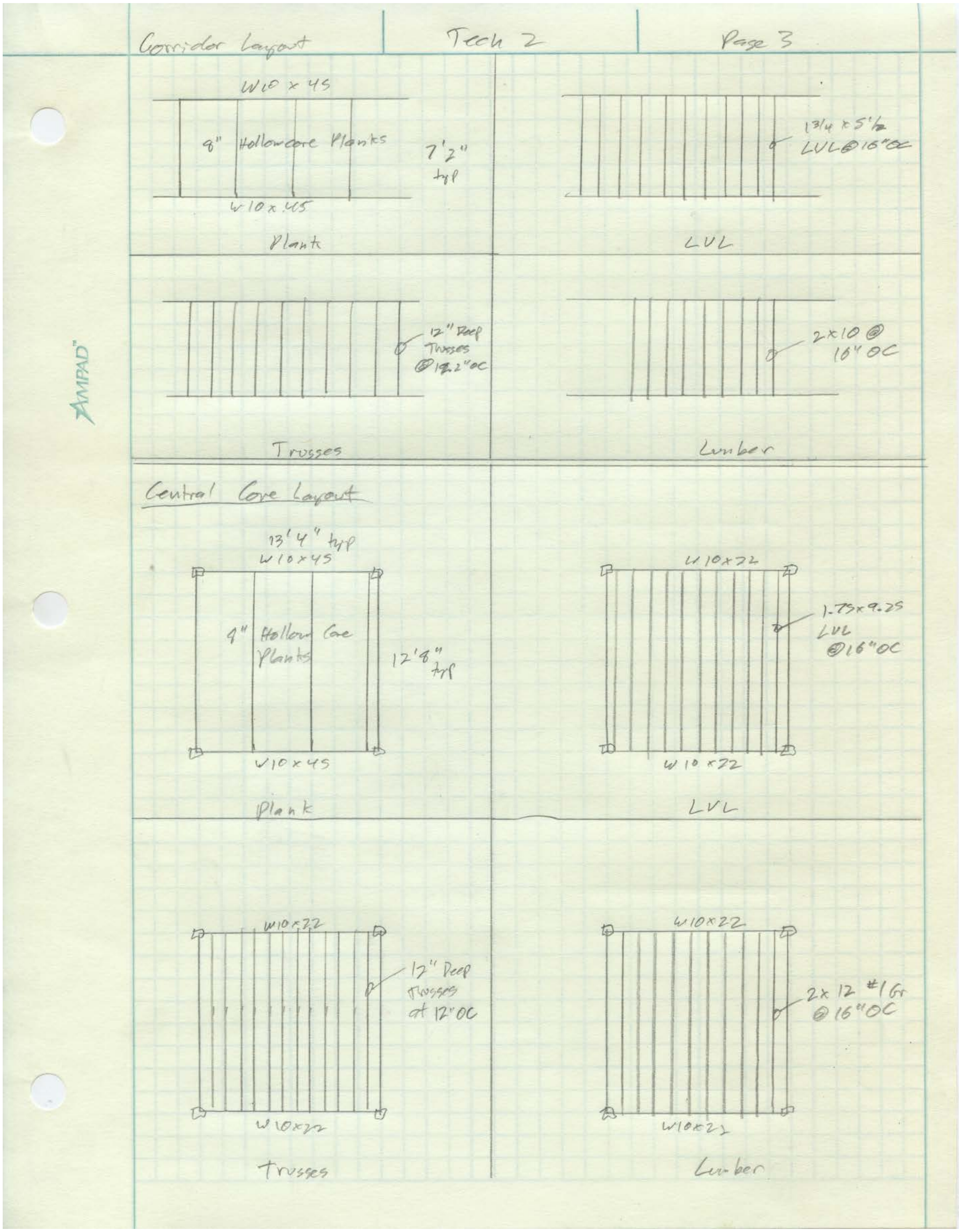
Corridor Layout
Tech 2
Page 3
W10 x 45
8" Hollowcore Planks
7'2" typ
W10 x 45
Plank
1 3/4 x 5 1/2 LVL @16"OC
LVL
12" Deep Trusses @19.2"OC
Trusses
2x10 @ 16" OC
Lumber
Central Core Layout
13'4" typ
W10x45
8" Hollow Core Planks
12'8" typ
W10x45
Plank
W10x22
1.75x9.25 LVL @16"OC
W10x22
LVL
W10x22
12" Deep Trusses at 12"OC
W10x22
Trusses
W10x22
2x12 #1 Gr @16"OC
W10x22
Lumber

Cadell Calkins
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Appendix G – Charts

MITEK® FLOOR TRUSS MAX-SPANS

Note: The following max-spans are valid for lumber design only. Plating or other considerations may further limit the truss design.

The chord max-spans shown below, presented for six representative floor loadings, are intended for use in bidding, estimating, and preliminary design applications. For proper interpretation of these max-spans, note:

- The max-spans are valid for the following (or better) lumber: No. 1 KD Southern Yellow Pine. Shorter spans will be achieved using lesser grade 4x2 lumber, while longer spans are generally possible with higher grade lumber.
- The max-spans represent truss overall lengths, assuming 3-1/2" bear ing at each end. The spans are equally valid for top chord-bearing and bottom chord bearing support conditions.
- The minimum truss span-to-live load deflection is 360 for floor application. For example, the maximum permissible live load deflection for a 20' span floor truss is (20 x 12)/360 = 0.67".
- In addition to the consideration of lumber strength and deflection limitations, the maximum truss span-to-depth ratio is limited to 20 for floor loadings.
  For example the maximum span of a floor application truss 15" deep is 15" x 20' = 300" span = 25' - 0" span.
- Floor loadings have included 1.00 Load Duration Increase and 1.15 Repetitive Stress Increase.

40/10/0/5 = 55 PSF @ 0%

Depth (inches)	24" o.c	19.2" o.c.	16" o.c.	12" o.c.
12	17-11	20-03	20-06	20-06
13	18-09	21-02	22-02	22-02
14	19-17	22-01	23-11	23-11
15	20-04	22-11	25-03	25-07
16	21-01	23-09	26-02	27-04
17	21-09	24-07	27-01	29-00
18	22-06	25-04	27-11	30-09
20	23-10	26-10	29-07	34-02
22	25-01	28-03	31-02	36-03
24	26-03	29-07	32-07	37-11

40/10/0/10 = 60 PSF @ 0%

Depth (inches)	24" o.c	19.2" o.c.	16" o.c.	12" o.c.
12	16-04	18-08	20-06	20-06
13	17-02	19-06	21-08	22-02
14	17-11	20-04	22-07	23-11
15	18-07	21-02	23-06	25-07
16	19-03	21-11	24-04	27-03
17	19-11	22-08	25-02	29-00
18	20-06	23-05	25-11	30-05
20	21-09	24-09	27-06	32-03
22	22-11	26-01	28-11	33-11
24	24-00	27-04	30-04	35-06

50/10/0/10 = 70 PSF @ 0%

Depth (inches)	24" o.c.	19.2" o.c.	16" o.c.	12" o.c.
12	15-02	17-03	19-02	20-06
13	15-10	18-01	20-00	22-02
14	16-06	18-10	20-11	23-11
15	17-02	19-07	21-09	25-06
16	17-10	20-04	22-06	26-05
17	18-05	21-00	23-03	27-04
18	19-00	21-08	24-00	28-02
20	20-02	22-11	25-05	29-10
22	21-02	24-02	26-09	31-05
24	22-02	25-04	28-01	32-11

40/25/0/10 = 75 PSF @ 0%

Depth (inches)	24" o.c.	19.2" o.c.	16" o.c.	12" o.c.
12	14-08	16-08	18-06	20-06
13	15-04	17-06	19-04	22-02
14	16-00	18-02	20-02	23-08
15	16-07	18-11	21-00	24-07
16	17-02	19-07	21-09	25-06
17	17-09	20-03	22-06	26-04
18	18-04	20-11	23-03	27-03
20	19-05	22-02	24-07	28-10
22	20-06	23-04	25-11	30-04
24	21-05	24-05	27-01	31-09

50/20/0/10 = 85 PSF 0%

Depth (inches)	24" o.c.	19.2" o.c.	16" o.c.	12" o.c.
12	13-09	15-08	17-05	20-05
13	14-05	16-05	18-02	21-04
14	15-00	17-01	19-00	22-03
15	15-07	17-09	19-09	23-02
16	16-02	18-05	20-05	23-11
17	16-08	19-00	21-02	24-09
18	17-03	19-08	21-10	25-07
20	18-03	20-10	23-01	27-01
22	19-03	21-11	24-04	28-06
24	20-02	22-11	25-06	29-10

50/35/0/10 = 95 @ 0%

Depth (inches)	24" o.c.	19.2" o.c.	16" o.c.	12" o.c.
12	13-00	14-10	16-05	19-03
13	13-07	15-06	17-02	20-02
14	14-02	16-02	17-11	21-00
15	14-09	16-10	18-08	21-11
16	15-03	17-05	19-04	22-08
17	15-10	18-00	20-00	23-05
18	16-04	18-07	20-07	24-02
20	17-03	19-08	21-10	25-07
22	18-02	20-09	23-00	26-11
24	19-00	21-09	24-01	28-03

WWW.MII.COM 19

FLOOR LOAD TABLES

How to Use This Table

1. Calculate total and live load (neglect beam weight) on the beam or header in pounds per linear foot (plf).
2. Select appropriate **Span** (center-to-center of bearing).
3. Scan horizontally to find the proper width, and a depth with a capacity that exceeds actual total and live loads.
4. Review bearing length requirements to ensure adequacy.

*Also see **General Notes** on page 19.*

1.9E Microllam® LVL: Floor—100% (PLF)

Span	Condition	1¾" Width							3½" Width (2-ply)					
		5½"	7¼"	9¼"	9½"	11¼"	11⅞"	14"	5½"	7¼"	9¼"	9½"	11¼"	11⅞"
6'	Total Load	432	762	1,027	1,062	1,324	1,424	1,794	864	1,525	2,055	2,125	2,648	2,848
	Live Load L/360	290	626	*	*	*	*	*	580	1,253	*	*	*	*
	Min. End/Int. Bearing (in.)	1.5/3.5	1.8/4.4	2.4/5.9	2.4/6.1	3.0/7.6	3.3/8.2	4.1/10.3	1.5/3.5	1.8/4.4	2.4/5.9	2.4/6.1	3.0/7.6	3.3/8.2
8'	Total Load	146	326	695	731	915	978	1,207	292	652	1,391	1,462	1,830	1,956
	Live Load L/360	126	280	555	597	*	*	*	253	561	1,110	1,195	*	*
	Min. End/Int. Bearing (in.)	1.5/3.5	1.5/3.5	2.1/5.3	2.2/5.6	2.8/7.0	3.0/7.5	3.7/9.3	1.5/3.5	1.5/3.5	2.1/5.3	2.2/5.6	2.8/7.0	3.0/7.5
9'-6"	Total Load	73	166	491	517	709	784	968	146	332	983	1,034	1,418	1,570
	Live Load L/360	*	*	344	370	592	687	*	*	*	688	741	1,185	1,374
	Min. End/Int. Bearing (in.)	1.5/3.5	1.5/3.5	1.8/4.5	1.9/4.7	2.6/6.5	2.9/7.2	3.5/8.8	1.5/3.5	1.5/3.5	1.8/4.5	1.9/4.7	2.6/6.5	2.9/7.2
10'	Total Load	59	135	441	466	639	707	908	118	270	883	932	1,279	1,415
	Live Load L/360	*	*	297	321	514	597	*	*	*	595	642	1,029	1,195
	Min. End/Int. Bearing (in.)	1.5/3.5	1.5/3.5	1.7/4.3	1.8/4.5	2.5/6.1	2.7/6.8	3.5/8.7	1.5/3.5	1.5/3.5	1.7/4.3	1.8/4.5	2.5/6.1	2.7/6.8
12'	Total Load		64	260	281	442	489	666	54	128	521	563	885	979
	Live Load L/360		*	176	190	309	360	569	*	*	353	381	618	720
	Min. End/Int. Bearing (in.)		1.5/3.5	1.5/3.5	1.5/3.5	2.0/5.1	2.3/5.7	3.1/7.7	1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5	2.0/5.1	2.3/5.7
14'	Total Load			164	178	293	342	487		66	329	357	586	685
	Live Load L/360			113	122	199	232	370		*	226	244	398	465
	Min. End/Int. Bearing (in.)			1.5/3.5	1.5/3.5	1.6/4.0	1.9/4.7	2.6/6.6		1.5/3.5	1.5/3.5	1.5/3.5	1.6/4.0	1.9/4.7
16'-6"	Total Load			100	108	180	211	342			200	217	360	422
	Live Load L/360			69	75	123	145	232			139	151	247	290
	Min. End/Int. Bearing (in.)			1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5	2.2/5.5			1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5
18'-6"	Total Load			70	76	127	149	244			140	152	254	299
	Live Load L/360			49	54	88	103	167			99	108	177	207
	Min. End/Int. Bearing (in.)			1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5	1.8/4.4			1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5
20'	Total Load			54	59	100	118	193			109	119	200	236
	Live Load L/360			39	42	70	82	133			79	85	141	165
	Min. End/Int. Bearing (in.)			1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.8			1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5
22'	Total Load					74	87	144			80	87	148	175
	Live Load L/360					53	62	101			59	64	106	125
	Min. End/Int. Bearing (in.)					1.5/3.5	1.5/3.5	1.5/3.5			1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5
24'	Total Load					56	66	110			60	65	112	133
	Live Load L/360					41	48	78			46	50	82	96
	Min. End/Int. Bearing (in.)					1.5/3.5	1.5/3.5	1.5/3.5			1.5/3.5	1.5/3.5	1.5/3.5	1.5/3.5
26'	Total Load						51	86					86	102
	Live Load L/360						38	62					65	76
	Min. End/Int. Bearing (in.)						1.5/3.5	1.5/3.5					1.5/3.5	1.5/3.5
28'	Total Load							67					67	80
	Live Load L/360							49					52	61
	Min. End/Int. Bearing (in.)							1.5/3.5					1.5/3.5	1.5/3.5
30'	Total Load							54					52	62
	Live Load L/360							40					42	50
	Min. End/Int. Bearing (in.)							1.5/3.5					1.5/3.5	1.5/3.5

* Indicates **Total Load** value controls.

Cadell Calkins
Faculty Advisor: Dr. Richard A. Behr

8" Hollowcore load tables

PITTSBURGH FLEXICORE CO., INC.

8" x 48" Spiroll Corefloor Load Table

8" x 48" Hollowcore (Untopped)
CLEAR SPAN IN FEET

Designation	14'	16'	18'	20'	22'	24'	26'	28'	30'	32'	34'	36'	38'
8S38-1.75	257	186	137	102	75	55	40	X	X	X	X	X	X
8S48-1.75	350	258	194	148	113	87	67	51	38	X	X	X	X
8S58-1.75	369	314	241	186	146	114	90	71	55	42	32	X	X
8S68-1.75	381	325	281	232	184	146	117	94	76	60	48	37	X
8S78-1.75	393	335	290	255	214	172	140	113	92	75	61	49	38

8" x 48" Hollowcore (2" Concrete Topping)
CLEAR SPAN IN FEET

Designation	14'	16'	18'	20'	22'	24'	26'	28'	30'	32'	34'	36'	38'
T8S38-1.75	343	248	182	134	99	72	51	31	X	X	X	X	X
T8S48-1.75	451	346	260	198	151	116	88	62	38	X	X	X	X
T8S58-1.75	465	395	335	259	202	159	125	91	65	43	X	X	X
T8S68-1.75	478	406	351	307	242	193	154	120	89	64	44	X	X
T8S78-1.75	491	417	361	316	279	238	187	146	113	85	62	42	X