Cross-Laminated Timber and Structural Resilience

A Major Qualifying Project

Submitted on:

March 4th, 2022

Submitted to:

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Abstract

The goal of this project was to design a Class A office building using mass timber, present the client with a fire analysis, design an alternative building for advanced structural resilience, and include a repair scope with cost estimate evaluation for each option.

Three options for design were analyzed. The first option was rated Type IV-A, but would require extensive structural repair after a time-equivalent fire. The second option was rated at Type IV-A and had the ability to host Class B office space after a time-equivalent fire with only non-structural repair. The third option was rated at Type IV-A and had the ability to host a Class A office space after a time-equivalent fire with only non-structural repair.

Acknowledgements

The team would like to acknowledge and thank Professor Leonard Albano for his continued guidance and support of this project and the team members. His expertise of wood design, structural systems, the construction industry, and numerous resources provided immense support to this project.

The team would also like to thank Michael Richard of Simpson Gumpertz & Heger for sponsoring this project and his support throughout this process. He provided the building plans and shared his expertise to the team regarding mass timber, CLT, and the building layout.

Both Professor Albano and Michael Richard made themselves easily available for any questions that arose and provided guidance that empowered the team toward project completion.

Authorship

This project is the first submittal of an ongoing Major Qualifying Project (MQP). This submittal was submitted by Peyton Graham, with collaboration from Stephanie Bishop and Isabelle Mellor. This project was a collaborative team effort, with each team member contributing equally to the project.

Below details areas of the report each member took leadership of:

Stephanie Bishop: Introduction, Background, Methodology, Material Inventory, Design Process, Post Fire Structural Damage, Repair Methods, Cost Comparison and Constructability
Peyton Graham: Introduction, Background, Methodology, Design Process, Post Fire Structural Damage, Repair Methods, Appendices
Isabelle Mellor: Introduction, Background, Methodology, Option 2 Design, Post Fire Structural Damage, Graphics

Capstone Design Statement

Worcester Polytechnic Institute requires all capstone design projects to meet ABET (Accreditation Board for Engineering and Technology) standards. At WPI, the Major Qualifying Project (MQP) is a high-level research project that addresses a problem found in a student's professional discipline. This MQP designed a four-story office building constructed of Cross-Laminated Timber (CLT) and glue-laminated timber (Glulam). This design addressed a fire analysis of CLT and a more structural resilient design of the building will be completed. A cost-benefits analysis was provided for the two designs. The following constraints were identified based on the following categories: Economic, Social, Political, Health & Safety, Manufacturability, Sustainability, and Ethics.

Economic

To address the economic constraint of our capstone design the team compared the cost of our building designed to the current code standard, the cost of our fire repairs, and the cost of the structural resilient building design. We looked at the cost of the materials, manufacturing, transportation, labor, and construction time. In addition, we considered the market flux of CLT.

Social

To address the social constraints of our capstone design we demystified the public stigma that wood and timber materials are less fire resistant than other common construction materials.

Health & Safety

To address the health and safety constraints of our capstone design, we utilized current building codes and requirements during our design. We ensured that fire protection materials and the building height and area are sufficient for a Type IV-A office building.

Manufacturability

To address manufacturability constraints of our capstone design, we considered the location and accessibility of CLT manufacturers in North America, including analyzing which regions have better access to CLT than others with the few current manufacturer locations. We used standard sections of CLT with section cutouts that are easily prefabricated with CNC machines. We also took into account availability of wood in the current climate, as the COVID-19 pandemic has created various material shortages.

Sustainability

To address the sustainability constraints of our capstone design, we used CLT as our main design material. CLT produces less greenhouse gasses, less waste, significantly lighter when compared to concrete, and has faster construction times than both concrete and steel.

Ethics

To maintain an ethical approach, we conducted ourselves with integrity and professionalism and use our project to advance the health, safety, and welfare of the public. We considered both the socioeconomic and health impacts of the growth of CLT on society. We also utilized the principles of sustainable development in our designs, act professionally to clients, communicate potential issues, and adequately credit the previous extensive research on CLT.

Professional Licensure Statement

The National Council of Examiners for Engineering and Surveying (NCEES) is an organization that provides professional licensure for engineers and surveyors. Only a certified Professional Engineer (PE) can approve and sign off on final engineering plans for a project, ensuring it meets the required safety standards.

To become a licensed Professional Engineer the following requirements must be meet:

1. Earn a four-year degree from an ABET accredited university
2. Pass the Fundamentals of Engineering (FE) exam to become an Engineer in Training (EIT)
3. Work under another PE for a minimum of four years
4. Pass the Principles and Practice of Engineering (PE) exam

In this project, a Professional Engineer would work with a team to design, plan, and stamp plans. The professional engineer can size members, run the fire analysis, do lateral design, and work with other parties to make sure the design satisfies all needs.

Table of Contents

Chapter 1: Introduction

Cross-Laminated Timber (CLT) is a type of prefabricated solid wood panel that consists of crosswise layers of kiln-dried lumber board. The engineered wood product was first developed in Germany and Austria during the early 1990s. Gerhard Schickhofer, an Austria-born researcher, completed his PhD thesis on CLT in 1994. After refining press technology between 1995 and 1996, the first multi-story building was constructed in Austria by 1998. The combined growth in CLT structures throughout Europe and research from Schickhofer sparked the first national CLT design guideline for Austria in 2002. By 2013, CLT started to make an appearance within North America and was soon featured in the National Design Specification (NDS) for wood construction by 2015 (American Wood Council, 2017). Since then, CLT has grown rapidly throughout the United States. However, there is still hesitation to construct multi-story buildings with CLT due to the flammability of wood structures that resulted in catastrophic fire damage.

The goal of this project was to design a Class A office building using mass timber, present the client with a fire analysis, design alternative designs for advanced structural resilience, and include a repair scope with cost estimate evaluation for each option.
The project was defined into four objectives:

Objective 1: *Design a Type IV-A Class A CLT Office Building*
Objective 2: *Evaluate Fire Resilience and Repair Options of Building*
Objective 3: *Design a CLT Office Building for Advanced Structural Resilience*
Objective 4: *Cost Analysis of Building Options*

The first phase of the project was the design of a Type IV-A Class A CLT office building. The fire analysis of the original design considered fire exposure and damage, charring, repairs, and post-fire capacity. The second post-fire design was calculated to support a Type IV-A Class B CLT office building. The last building option was to carry a Class A occupancy load post-fire. To conclude, a cost estimate including repairs was presented as financial comparison between the alternative structural designs.

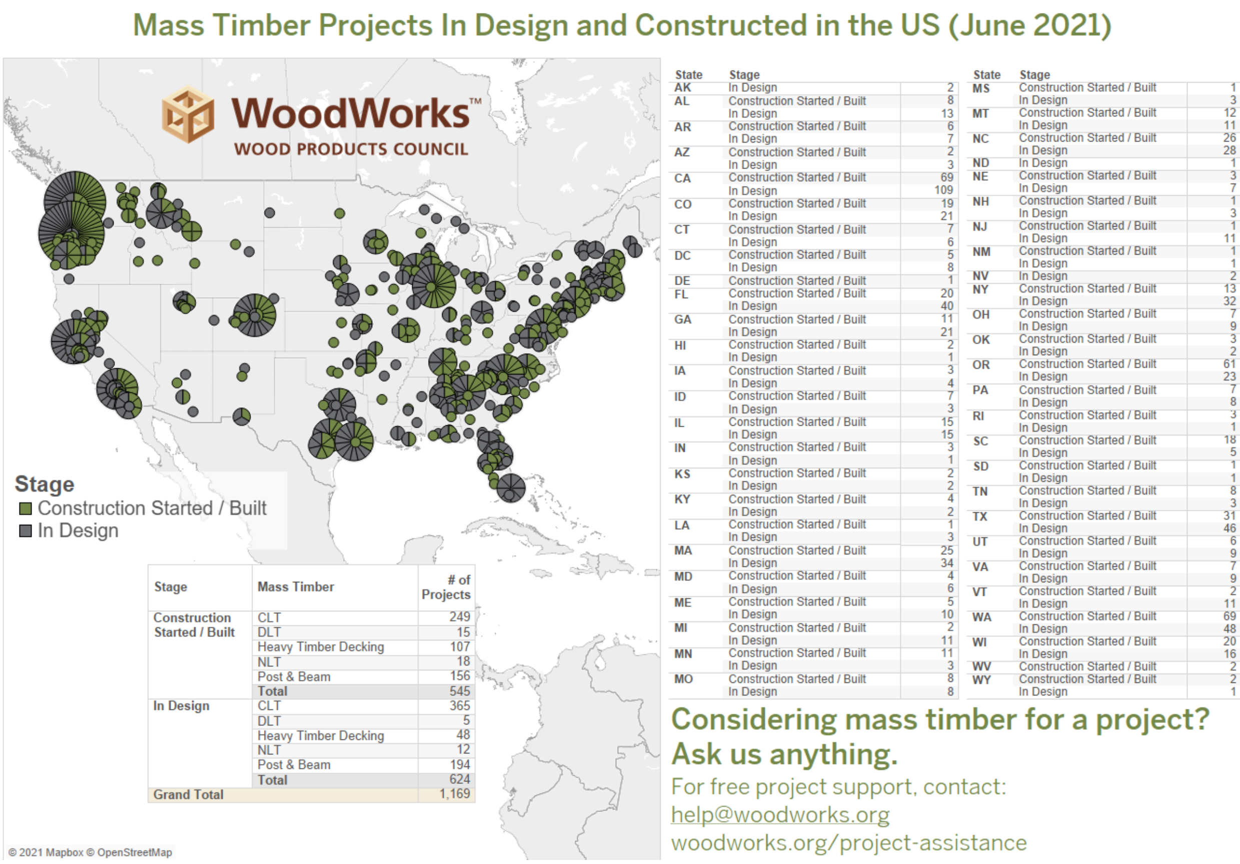
Chapter 2: Background

2.1: Mass Timber

Mass timber is a category of wood product used for columns, beams, flooring, walls, and roofing. Mass timber has a high strength rating due to compressed layers, panelized or single components, and adhesives. In addition to its strength rating, mass timber is significantly lighter than concrete and steel, and less carbon intensive. Products of mass timber include cross-laminated timber (CLT), glue-laminated timber (Glulam), dowel-laminated timber (DLT), nail-laminated timber (NLT), laminated strand lumber (LSL), laminated veneer lumber (LVL), and parallel strand lumber (PSL) (Mass Timber -Think Wood, 2022**).** Each product varies depending on number of panels, orientation, and how they are held together. For example, DLT uses wood dowels to join laminations together, while glulam components are positioned according to their stress-rated performance and bonded with a durable, moisture-resistant adhesive (Mass Timber – Naturally: Wood, 2022)

2.2: The Growth of CLT

During the early 2000s, CLT production and usage increased significantly in Europe due to its energy efficiency as a part of the Green Movement. This led to the construction of over 500 CLT buildings within England alone. One notable project was the first “timber tower”, Murray Grove, which was constructed in Hackney, London in 2009. This nine-story residential building was completely constructed with mass timber and featured a tight honeycomb design using CLT structural panels. This building paved the way for the potential of CLT as an environmentally sustainable and financially viable solution within construction, especially in urban areas. The use of CLT for Murray Grove allowed a faster project schedule by 30% (total of 49 weeks), saved 300 metric tons of CO2, and provided 29 fully insulated and soundproof apartment units simply by avoiding the use of precast concrete and other standard construction materials (Waughthistleton.com, 2021; American Wood Council, 2017). As of June 2021, there have been 1,169 mass timber projects in the United States, 249 of which are in construction or built and 365 in design (see Figure 1) (WoodWorks - Wood Products Council, 2021).



Stage	Mass Timber	# of Projects
Construction Started / Built	CLT	249
	DLT	15
	Heavy Timber Decking	107
	NLT	18
	Post & Beam	156
	Total	545
In Design	CLT	365
	DLT	5
	Heavy Timber Decking	48
	NLT	12
	Post & Beam	194
	Total	624
Grand Total		1,169

State	Stage	
AK	In Design	2
AL	Construction Started / Built	8
	In Design	13
AR	Construction Started / Built	6
	In Design	7
AZ	Construction Started / Built	2
	In Design	3
CA	Construction Started / Built	69
	In Design	109
CO	Construction Started / Built	19
	In Design	21
CT	Construction Started / Built	7
	In Design	6
DC	Construction Started / Built	5
	In Design	8
DE	Construction Started / Built	1
FL	Construction Started / Built	20
	In Design	40
GA	Construction Started / Built	11
	In Design	21
HI	Construction Started / Built	2
	In Design	1
IA	Construction Started / Built	3
	In Design	4
ID	Construction Started / Built	7
	In Design	3
IL	Construction Started / Built	15
	In Design	15
IN	Construction Started / Built	3
	In Design	1
KS	Construction Started / Built	2
	In Design	2
KY	Construction Started / Built	4
	In Design	2
LA	Construction Started / Built	1
	In Design	3
MA	Construction Started / Built	25
	In Design	34
MD	Construction Started / Built	4
	In Design	6
ME	Construction Started / Built	5
	In Design	10
MI	Construction Started / Built	2
	In Design	11
MN	Construction Started / Built	11
	In Design	3
MO	Construction Started / Built	8
	In Design	8

State	Stage	
MS	Construction Started / Built	1
	In Design	3
MT	Construction Started / Built	12
	In Design	11
NC	Construction Started / Built	26
	In Design	28
ND	In Design	1
NE	Construction Started / Built	3
	In Design	7
NH	Construction Started / Built	1
	In Design	3
NJ	Construction Started / Built	1
	In Design	11
NM	Construction Started / Built	1
	In Design	1
NV	In Design	2
NY	Construction Started / Built	13
	In Design	32
OH	Construction Started / Built	7
	In Design	9
OK	Construction Started / Built	3
	In Design	2
OR	Construction Started / Built	61
	In Design	23
PA	Construction Started / Built	7
	In Design	8
RI	Construction Started / Built	3
	In Design	1
SC	Construction Started / Built	18
	In Design	5
SD	Construction Started / Built	1
	In Design	1
TN	Construction Started / Built	8
	In Design	3
TX	Construction Started / Built	31
	In Design	46
UT	Construction Started / Built	6
	In Design	9
VA	Construction Started / Built	7
	In Design	9
VT	Construction Started / Built	2
	In Design	11
WA	Construction Started / Built	69
	In Design	48
WI	Construction Started / Built	20
	In Design	16
WV	Construction Started / Built	2
WY	Construction Started / Built	2
	In Design	1

Figure 1: Mass Timber Projects in Design and Constructed in the US (June 2021)

CLT has many benefits compared to standard construction materials such as steel, concrete, and masonry. The carbon emissions from the production of CLT is 50% of what is required for concrete and a shocking 1% of what is required for steel production. Since CLT does not have an abundance of production facilities in the United States, the carbon emissions for travel are far more. However, they still do not reach the emission level of concrete or steel (The B1M, 2017). Another advantage of CLT is the minimal waste during production, due to the ability to reuse sawdust, timber cutouts, and other byproducts. CLT is very energy efficient in performance, with an R-value of 1.25 per inch of thickness. For seismic performance, it is more forgiving due to its ability to flex without losing structural stability. It also provides high performing acoustics, especially with an added acoustic mat layer, which is beneficial for urban construction. Besides the performance and environmental benefits, CLT is 75% lighter than concrete which can reduce groundwork costs for buildings. It also has a significantly lower construction time because panels are prefabricated, so they can be installed immediately on site.

This is especially beneficial for urban areas with minimal on-site storage of materials, because the panels can be produced and transported the day they are needed (Landreman, Archie, and WoodWorks - Wood Products Council, 2017). CLT has grown significantly and has many benefits, but the common misconception of all wood as unsafe for fire conditions causes hesitation.

2.3: Design of Cross-Laminated Timber

Cross-Laminated Timber, or “CLT’ is made up of layers, or laminations, that are generally stacked crosswise with the direction of fiber 90 degrees to the previous. An illustration of a sample CLT panel is shown at right in Figure 2. Pairs of parallel layers can be included at the core or the outer layer for special applications. Layers are glued with structural adhesive. To create CLT panels, individual boards are finger jointed and glued. Odd numbers of layers are used so that both outer layers of wall panels can be oriented parallel to the vertical load path axis to maximize vertical load capacity in wall panels. For floor and roof panel systems, outer layers are oriented parallel to the span axis. Most commonly, CLT panels are composed of three, five, and seven layers (FPInnovations, 2013). Three and five layer panels are the most accessible to produce and are the most readily available from manufacturers.

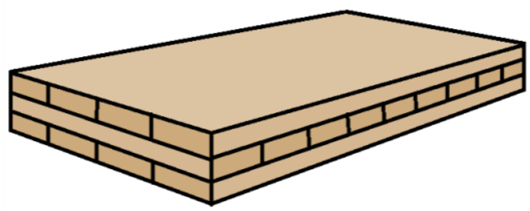


Figure 2: Sample CLT Panel Illustration

When designing CLT structures, one important factor is the material constraint. For Nordic X-Lam Cross-Laminated Timber, the maximum dimensions of panels are 106.25”(8.854’) x 64’ (Nordic Structures, 2020). Standard layup combinations for Nordic X-Lam are listed in Table 1 seen below.

Nordic X-Lam Panel	Longitudinal Layer Thickness	Transverse Layer Thickness	Layup Combination	Total Thickness
89-3s	35 mm = 1-⅜ in	19 mm = ¾ in	L-T-L	89 mm = 3 ½ in
105-3s	35 mm = 1-⅜ in	35 mm = 1-⅜ in	L-T-L	105 mm = 4 ⅛ in
143-5s	35 mm = 1-⅜ in	19 mm = ¾ in	L-T-L-T-L	143 mm = 5 ⅝ in
175-5s	35 mm = 1-⅜ in	35 mm = 1-⅜ in	L-T-L-T-L	175 mm = 6 ⅞ in

197-7s	35 mm = 1-⅜ in	19 mm = ¾ in	L-T-L-T-L-T-L	197 mm = 7 ¾ in
213-7l	35 mm = 1-⅜ in	19 mm = ¾ in	L-L-T-L-T-L-L	213 mm = 8 ⅜ in
244-7s	35 mm = 1-⅜ in	35 mm = 1-⅜ in	L-T-L-T-L-T-L	244 mm = 9 ⅝ in
244-7l	35 mm = 1-⅜ in	35 mm = 1-⅜ in	L-L-T-L-T-L-L	244 mm = 9 ⅝ in
267-9l	35 mm = 1-⅜ in	19 mm = ¾ in	L-L-T-L-T-L-T-L-L	267 mm = 10 ½ in

Table 1: Nordic X-Lam Standard Panel Layup Combinations (Nordic Structures, 2020)

CLT has a light unit-weight, so vibration and deflection often determine allowable spans, rather than bending or shear. Much of CLT design includes balancing panel capacity with desired interior clear height, as a larger required number of laminations lowers clear height (McLain, Ricky, and Greg Kingsley, 2020).

Another important factor in CLT design is grid efficiency. The most efficient grid designs of CLT often differ from that of steel or concrete. On average, CLT square floor grids are sized between 20’ x 20’ and 30’x 30’, and rectangular grids are sized between 10’x 20’ and 20’x 32’. Grids are generally made with glulam girders supporting CLT panels. When designing a larger square grid, intermediate glulam purlins can be utilized, but these usually are not needed in rectangular grids. There are also alternative grid solutions that account for challenges such as MEP placement and unusual required spans. One alternative that has been previously utilized included 2 layers of CLT panels running perpendicular to each other, providing room for MEP structures and negating the need for glulam girders. For larger spans, a composite system of mass timber with a concrete topping or a combination system of CLT floor panels and parallel glulam beams could be utilized (McLain, Ricky, and Greg Kingsley, 2020).

The final important factor for CLT building design is the type of member connections. There are many types of CLT connections, and different options may offer different advantages. Factors to consider in CLT connection designs are load transfer, cost-effectiveness, aesthetic impact, height impact, and crushing or shrinkage leading to differential material movement. Additionally, the connection must have the same fire resistance as the members (McLain, Ricky, and Greg Kingsley, 2020).

2.4: Building Codes

According to the 2021 IBC, there are five construction types. The construction types include I, II, III, IV, and V. Of these, there are further specification categories (see Figure 3 below - eg: A, B, C, HT). The purpose of these classification types is to evaluate and define the severity of building material combustibility and the fire resistance rating (FRR) of its building elements. Each construction type has a different FRR requirement per structural element. Different elements such as bearing walls and floors are not required to have equivalent FRRs (Codes.iccsafe.org, Oct. 2020).

TABLE 601 FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	$3^{a,b}$	$2^{a,b,c}$	$1^{b,c}$	0^{c}	$1^{b,c}$	0	3^{a}	2^{a}	2^{a}	HT	$1^{b,c}$	0
Bearing walls												
Exterior[e, f]	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3^{a}	2^{a}	1	0	1	0	3	2	2	$1/HT^{g}$	1	0
Nonbearing walls and partitions Exterior	See Table 705.5											
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary structural members (see Section 202)	$1^{1}/_{2}{}^{b}$	$1^{b,c}$	$1^{b,c}$	0^{c}	$1^{b,c}$	0	$1^{1}/_{2}$	1	1	HT	$1^{b,c}$	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.
b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members in roof construction shall not be required, including protection of primary structural frame members, roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.
c. In all occupancies, heavy timber complying with Section 2304.11 shall be allowed for roof construction, including primary structural frame members, where a 1-hour or less *fire-resistance rating is required.*
d. Not less than the fire-resistance rating required by other sections of this code.
e. Not less than the fire-resistance rating based on fire separation distance (see Table 705.5).
f. Not less than the fire-resistance rating as referenced in Section 704.10.
g. Heavy timber bearing walls supporting more than two floors or more than a floor and a roof shall have a *fire resistance* rating of not less than 1 hour.

Figure 3: Fire-Resistance Rating Requirements for Building Elements (Table 601 IBC, 2021)

The initial building was designed for a Class A occupancy load of 100 psf and a Type IV-A Classification. A Type IV-A building is considered more appealing for an advertised Class A building due to the higher FRR standard. However, this type does not allow exposed mass timber elements, which can be considered architecturally appealing. The height and square footage for the four-story building is 64 feet high and is just under 83,160 total square feet. The building features an atrium from the first floor to the second floor and a rooftop penthouse with stair and elevator access. The rooftop penthouse is 6,790 square feet with a height of 19 feet. According to the 2021 IBC, rooftop penthouses cannot exceed a third of the square area of the supporting roof deck and cannot exceed a height of 18 feet. However, there is an exception for penthouses that include an elevator to have a maximum height of 28 feet, hence the building is code compliant. The building is also within the 2021 IBC limit for Type IV-A buildings by a significant margin because it includes an automatic sprinkler system. By including an automatic sprinkler system, the building is limited to 18 stories with a total height of 270 feet and a 324,000 total square footage (WoodWorks - Wood Products Council, et al., 2019).

2.5: CLT and Fire

For this case study, we analyzed a fire that occurs in a 4-story office building. The number one cause of office fires is cooking equipment, which accounts for 29% of all office fires. Other causes of office fires include electrical distribution and lighting equipment, heating equipment, intentional, smoking materials, exposure, and electronic or entertainment equipment. The peak times of days for office fires were between noon and 2:00 PM. This is the time of day where the greatest number of people are in the office. However, fires that occur between 7:00 PM and 7:00 AM cause the greatest amount of property damage. Improving automatic detection systems, extinguishing equipment, and the fire resistance rating prevent further damage to be caused to the building ("NFPA Report").

Fire resistance rating (FRR) is the ability of a material to confine fire, continue to provide a structural function during fire, or both (International Code Council, 2021). The FRR is measured from the start of the fire until the material fails to function. Fire resistance of CLT depends upon the number of layers, thickness, adhesive, and panel assembly. Often, noncombustible materials are applied to mass timber to increase the FRR. Wall and floor assemblies that are made of CLT and exposed and covered with non-combustible material can provide up to a 3 hour FRR (Pogue, 2021). CLT's fire resistance is provided through charring. The charring of CLT is different from other timber panels due to the number of layers, glue composition, and joints. Charring is when a timber panel is exposed to a fire greater than 400 degrees C and causes the timber to ignite and burn at a steady rate. As the timber continues to burn, the char becomes an insulating layer. This layer protects the unburnt core of the panel and prevents an excess rise in temperature ("GreenSpec: Cross-Laminated").

Fire Dynamics Simulator (FDS) and Consolidated Model of Fire and Smoke Transport (CFAST) are the two main fire simulation software in use today. FDS is a Computational Fluid Dynamics (CFD) model of fire-driven fluid flows. It is most appropriate for simulations of low-speed, thermally-driven flow, with an emphasis on smoke and heat transfer from fires. CFAST is a two-zone fire model. It is best used to calculate the evolving distribution of smoke, fire gases and temperature throughout compartments of a building during a fire. From both softwares, a heat transfer model can be developed. This can be used to determine thermal gradients of the wood elements, and the impacts on the structural capacity. For the sake of our project, we will not be using fire simulation software. Instead we will borrow parametric models and equations from literature, such as Figure 4, 5, and 6 shown below, to analyze various fire scenarios. This alternative is best suited for our short time frame to complete this project (NIST, 2011).

Table 16.2.1B Effective Char Depths (for CLT with β_n = 1.5in./hr.)

Required Fire Resistance (hr.)	Effective Char Depths, a_{eff} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

Figure 4: Effective Char Depths for CLT

Step	Floor Design
Lamination fall-off time	$t_{fo} = \left(\frac{h_{lam}}{\beta_n}\right)^{1.23}$
Calculation of the effective char depth	$a_{char} = 1.2\left[n_{lam} \cdot h_{lam} + \beta_n(t - (n_{lam} \cdot t_{fo}))^{0.813}\right]$
Determination of effective residual cross-section	$h_{fire} = h - a_{char}$
Determination of location of neutral axis and section properties of the effective residual cross-section	$\underline{y} = \frac{\Sigma y_i h_i}{\Sigma h_i}$ $I_{eff} = \Sigma\frac{b_i h_i^3}{12} + \Sigma b_i h_i d_i^2$
Calculation of design resisting moment	$S_{eff} = \frac{I_{eff}}{h_{fire} - \underline{y}}$ $M' = KF_b S_{eff}$

Figure 5: Char Equations for Floor Design

Step	Wall Design
Lamination fall-off time	$t_{fo} = \left(\frac{h_{lam}}{\beta_n}\right)^{1.23}$
Calculation of the effective char depth	$a_{char} = 1.2\beta_n t^{0.813}$
Determination of effective residual cross-section	$h_{fire} = h - a_{char}$
Determination of location of neutral axis and section properties of the effective residual cross-section	$\underline{y} = \frac{\Sigma y_i h_i}{\Sigma h_i}$ $I_{eff} = \Sigma\frac{b_i h_i^3}{12} + \Sigma b_i h_i d_i^2$ $A_{eff} = \Sigma b_i h_i$
Calculation of resisting axial compression capacity	$S_{eff} = \frac{I_{eff}}{h_{fire} - \underline{y}}$ $M' = KF_b S_{eff}$

Figure 5: Char Equations for Wall Design

When CLT is damaged in a fire, there are multiple ways of fixing or replacing it. When charring is localized it can be removed with sanding, scraping, or abrasive blasting. This is done for minor fire damage and if the structural integrity can remain intact. If small areas are damaged, they can be repaired with equivalent wood sections, such as sections around doors or windows (Ranger, Lindsay, et al, 2019). If the char or fire damage impacts multiple layers of the CLT it is best to replace all layers affected. One solution is to remove and clean the damaged portions and replace it with new laminations attached with adhesive. This solution does not restore full structural capacity of the CLT panel, but it does restore the FRR. Another option is to remove the damaged portions and replace them with new laminations attached with adhered and screwed scarf joints or adhered only. This option reestablishes pre-fire structural capacity, maintains exposed CLT, and restores FRR ("*Post-Fire Restoration,*" 2018).

Our case study building will have some form of automatic sprinklers. Sprinklers are used as a means of active fire suppression but can be a balance between fire damage and damage from excess water discharge. Accidental or excess water discharge from sprinklers can result in frozen pipes, mechanical damage, installation defects, or corrosion of sprinkler elements. This water can adversely affect the wood structure and cause moisture damage. A high moisture content can affect the strength and stiffness, and lead to decay or mold. CLT does not absorb water very quickly and would only be an issue for prolonged water exposure. This exposure can be limited by concrete toppings which protect the wood from direct water contact (Ranger, Lindsay, et al, 2019).

Chapter 3: Methodology

Goal: Design a CLT office building, present the client with a fire resistance evaluation, design an option for advanced structural resilience, and provide a repair scope and cost-benefit analysis for each option.

3.1 Objective 1: Design a Type IV-A Class A CLT Office Building

The goal of this objective was to determine the mass timber members and CLT elements for our four-story office building. Each level of the floor plan was separated to determine the calculations and design of each component. The fourth-floor ceiling and atrium was often analyzed separately due to the weight of the penthouse above, and the exposure to the second floor. Within each level, members were separated into flooring, shear walls, joist, girders, and columns. CLT was used for the flooring and shear walls, while glulam and gypsum were used for the joist, girders, and columns. Spreadsheets were utilized to combine calculations of gravitational loads, lateral loads, fire adjustment factors, and design and allowable moment for every member.

References including the *IBC 2021*, *CLT Handbook*, *Nordic Technical Guides*, *AWC NDS 2018*, and *ASCE 7-10* were used during the design and calculation process. Spreadsheets for each member were created to assist with repetitive design calculations.

3.2 Objective 2: Evaluate Fire Resilience and Repair Options of Building

After the completion of the design of a Class A office building, the fire assessment was completed. Each member of the Option 1 building was designed according to the FRR or induced moment post fire. Similar to objective one, each level was separated to asset with identification and calculations. The char depth of the CLT and glulam members were determined by using the char rating and exposure time that corresponds to a Type IV-A building. Spreadsheets were created to assess the post fire members moment compared to the ultimate moment. Based off these calculations and char depth, it was determined if the member needed to be replaced or repaired.

References including the *IBC 2021, CLT Handbook, Nordic Technical Guides, AWC NDS 2018*, and *FDS 2021* were used during the design and calculation process. Spreadsheets for each member were created to assist with repetitive design calculations.

3.3 Objective 3: Design a CLT Office Building for Advanced Structural Resilience

Objective 3 was the completion of our redesign from a Class A building to a Class B building post fire. After the fire analysis was completed, every member was evaluated to support a reduction of the live load from 100 psf to 50 psf post fire. If the members could not support the reduction, they were resized. A new fire analysis was completed for the new resized members to determine if they could support the reduced live load post fire.

References including the *IBC 2021*, *CLT Handbook*, *Nordic Technical Guides*, *AWC NDS 2018*, and *FDS 2021* were used during the design and calculation process. Spreadsheets for each member were created to assist with repetitive design calculations.

3.4 Objective 4: Cost Analysis of Building Options

Once the fire analyses were completed, an inventory of alternative building elements designs were calculated. This inventory was directly transferred into a cost estimate for the alternative designs as a numerical comparison between structural decisions. This estimate also included the estimated cost of repairs for each design.

References including the *2022 National Construction Estimator* and *Building Construction Costs with RSMeans Data 2021* were used during the estimation process. A spreadsheet was created to assist with repetitive calculations.

Chapter 4: Design for a Type IV-A Office Building

4.1: Floor Layouts

At the beginning of the design process, the functionality of the office building was determined for later analysis. Each story was distinguished by its purpose. The first floor main entrance has an atrium which is welcoming and open. The entrance could be used as an open cafe/dining space for employees to visit on lunch breaks or host clients to a meal. On the back side of the building core, there is open space with the possibility for use as a mixed lounge and private conference rooms to host clients. On the second floor there is room for a potential conference room overlooking the atrium. The rest of the floor can be used as open workspace to encourage collaborative work. The second floor could promote teamwork and group work with large tables and moving white boards. On the third and fourth floors, areas can be designated to be quieter with private offices and cubicles. There are two kitchenettes, one on each side of the central core, for the ease of breaks and water or coffee refills.

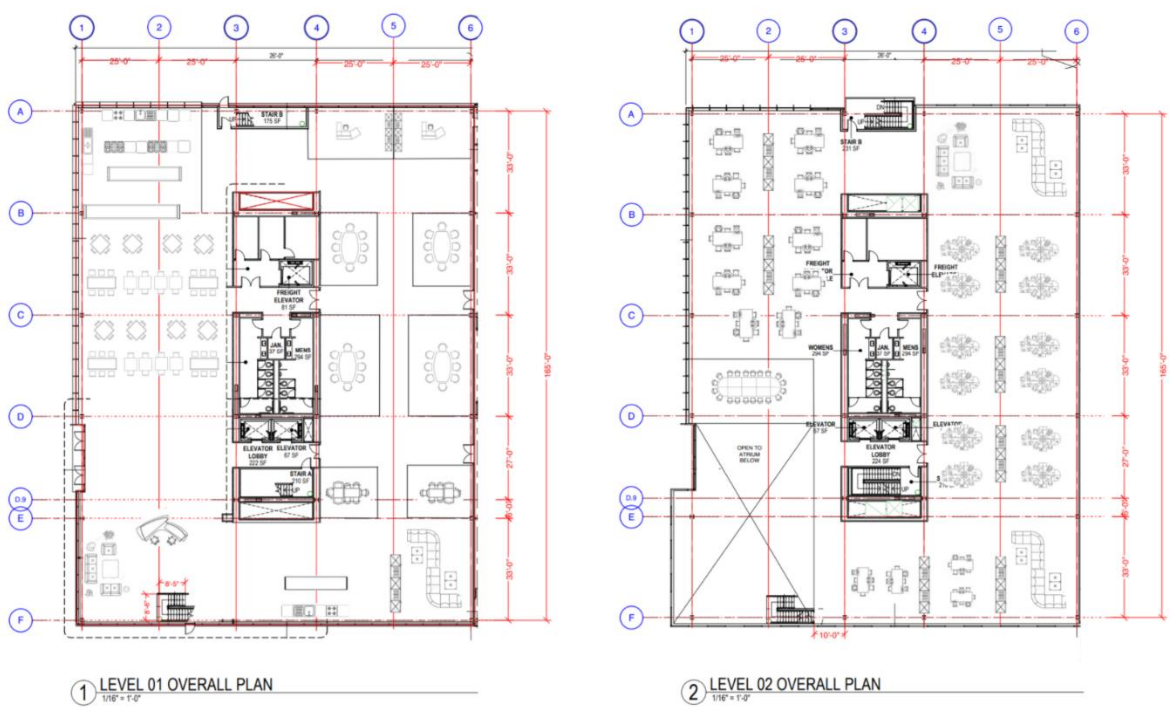


Figure 7: Potential Layout of Floor One and Two

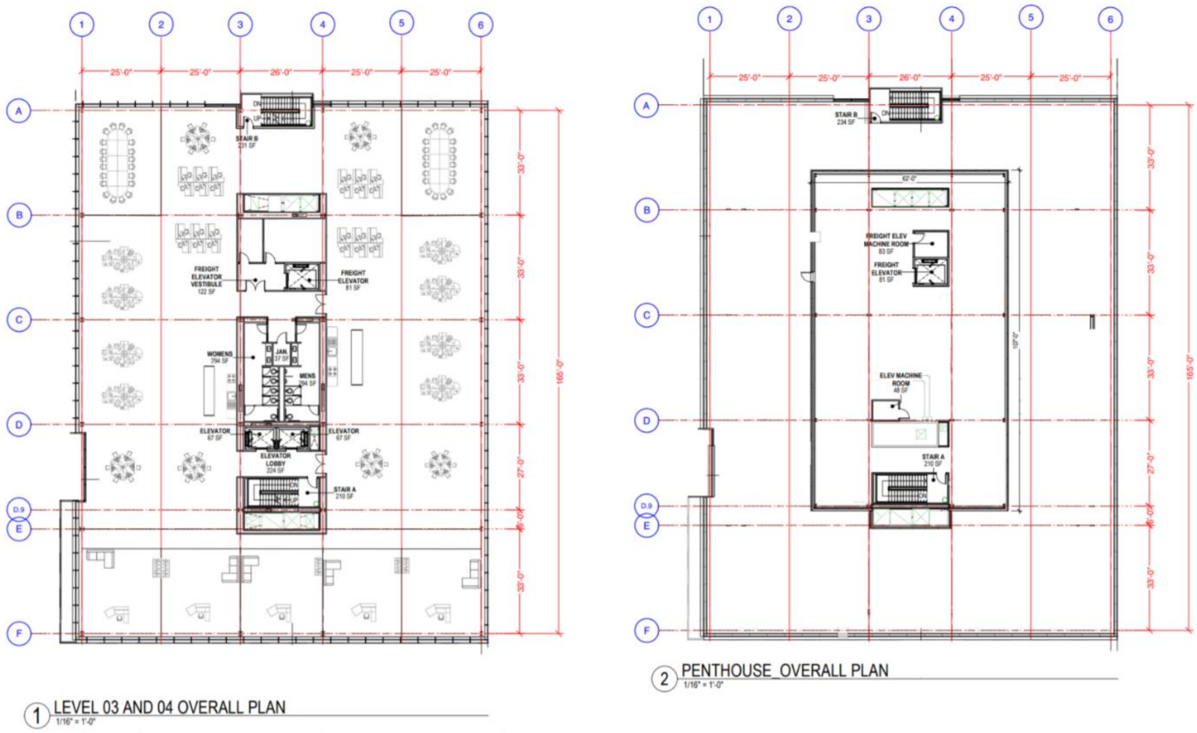


Figure 8: Potential Layout of Floor Three and Four

4.2: Gravitational Loads

The building site was assumed to be located in Worcester, MA. After the functionality of each story was determined, the gravitational loading design began. Starting on the roof, it was assumed there was proper drainage for the ponding effects of rain. This provided a governing load of snow instead of rain. ASCE 7-10 was utilized for all local information regarding live roof loading effects. Stacked framing was assumed for the design to promote room for mechanical, electrical, plumbing, and fire protection equipment throughout the building. This also allowed the design to be slightly more conservative than flushed framing. The official load path was as follows: roof into joists, joists into girders, girders into columns, and columns into foundation.

4.2.1: CLT Paneling for the Roof and Floor Systems

For the ease of constructability, the CLT panels were designed consistently with minor variations between purposes. In the case of the CLT roof, 3-ply panels were able to withhold the roof dead and live loads while the 5-ply panels had to be used throughout the rest of the building floor systems to hold the 100 psf occupancy live load. These panels alternated between five and six foot widths throughout each level to remain in transportation limit for semi-truck beds.

The process of determining a CLT panel size began with selecting a panel from Nordic Technical Guide for X-Lam. This guide provided panel sizing based on length, loading, and FRR. According to the IBC 2021, a Type IV-A building requires a 2 hour FRR for all flooring members and an 1 ½ hour FRR for roof members. Nordic provides CLT panels that support up to a 2 hour FRR. Due to loads of the penthouse and members in the core, panels of gypsum board were added to the CLT, providing additional time for the FRR. Gypsum was also added to prevent multiple laminations falling off due to charring.

After a panel was selected, spreadsheets were created to simplify the process of calculating the allowable moment, shear, and deflection. The gravitational loads on the corresponding floor were run through the eight ASD load combination equations, and the combination that provided the largest load governed. The actual moment, shear, and deflection were calculated. If any of these calculations were larger than the allowable values, a new panel size was selected. This process was repeated for all CLT panels. All members had acceptable shear, moment, and deflection values.

As shown in the figures below, the highlighted areas include the sections of paneling. An inventory of CLT and spreadsheets can be found in Appendix E and Appendix B

4.2.2: GLT Joists

Glue-Laminated Timber joists were stacked on top of the girders and utilized to support the CLT floors or roof. The determination of a joist member began with gravitational loads on the corresponding floor. The gravitational loads were inputted into the eight load combinations, and what combination provided the largest load governed. A joist was selected from Nordic Technical Guide Lam+. According to the IBC 2021 a Type IV-A building requires a 3 hour FRR for all structural members, except members only supporting the roof, which only require a 2 hour rating. Nordic provides glulam members that support up to a 2 hour FRR. As a result of this, the members were designed to withhold a 2-hour FRR on three sides of the beam where it would be exposed to fire, and 2 additional panels of gypsum board were added. The two panels of gypsum provide an additional hour FRR, bringing the glulam joist up to the require 3 hour FRR.

Spreadsheets were created to simplify the process of calculating the allowable moment and shear. A fire resistance adjustment factor, provided by Nordic, was applied to the adjusted bending moment. If the moment of the member was greater than the allowable moment, a new size and fire resistance adjustment factor was selected. This process was repeated for all glulam joists. All members had acceptable shear, moment, and deflection values.

As shown in the figures below, the highlighted vertical members include the typical and specially designed joists. An inventory of glulam members and spreadsheets for typical and special case joist can be found in Appendix E and Appendix B.

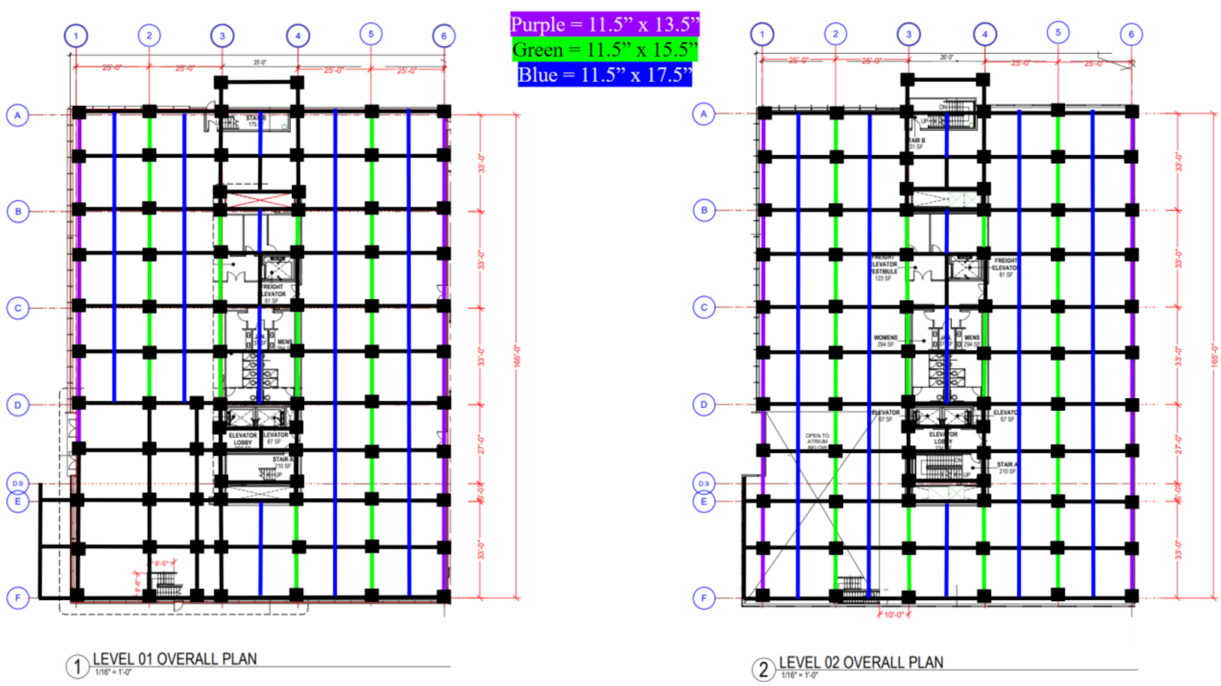


Figure 9: Typical Joist First and Second Floor Ceiling

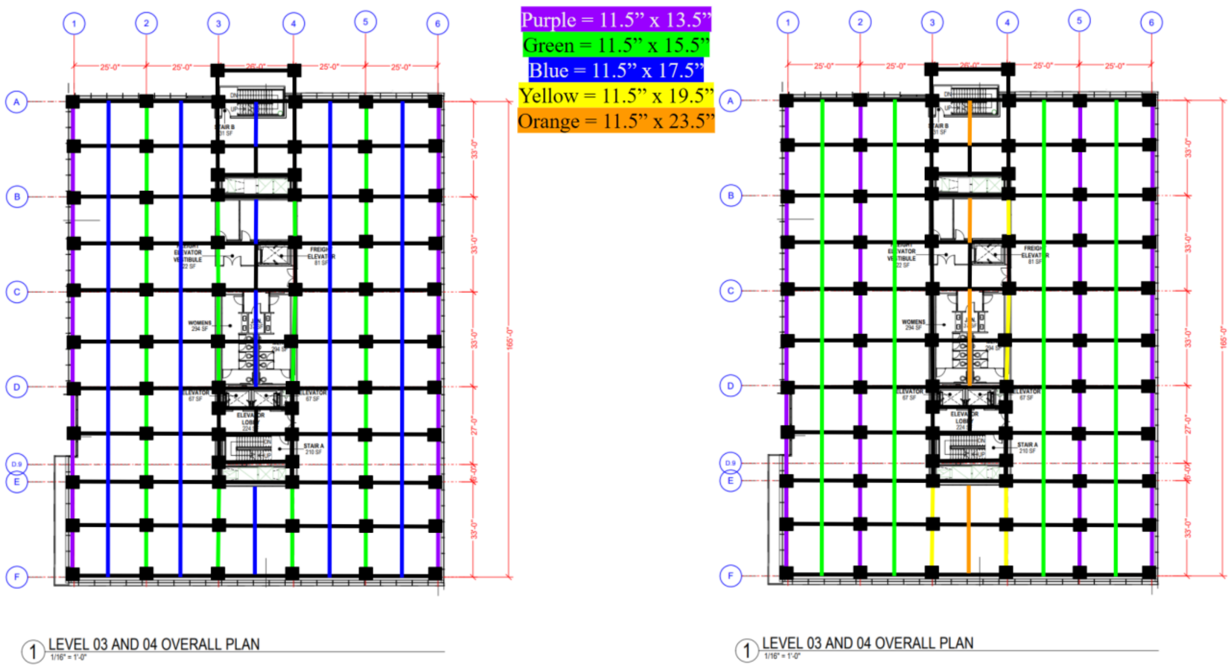


Figure 10: Typical Joist Floor Third and Fourth Floor Ceiling

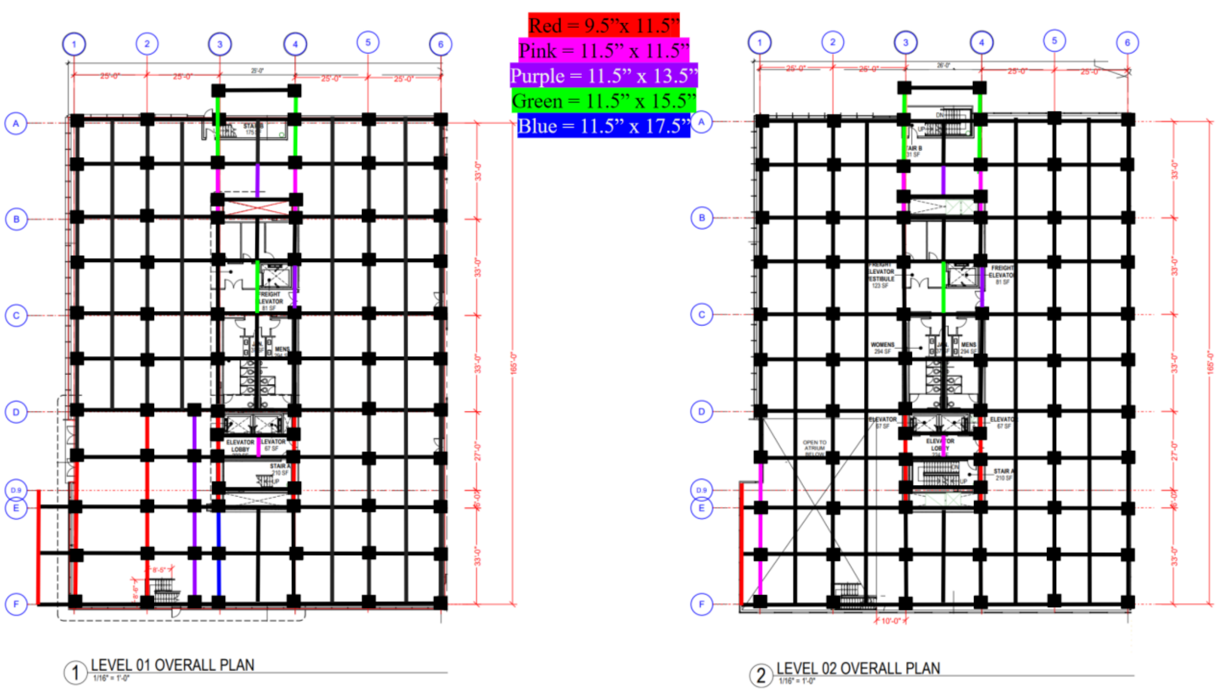


Figure 11: Special Case Joist First and Second Floor Ceiling

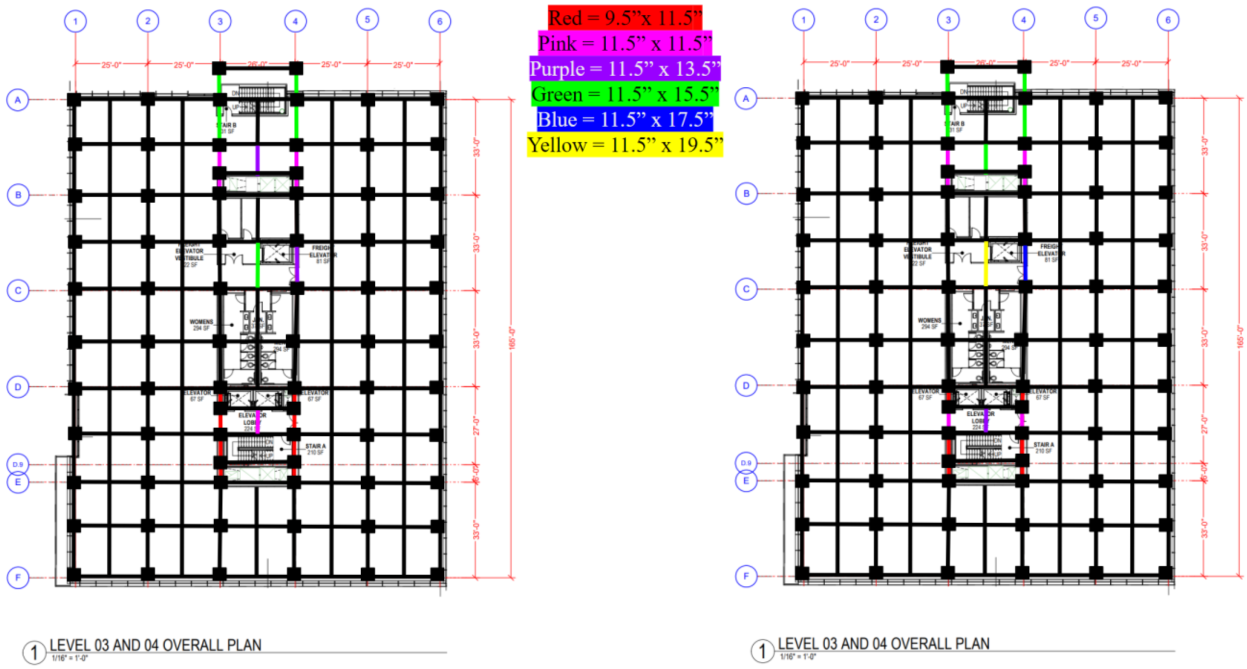


Figure 12: Special Case Joist Floor Third and Fourth Floor Ceiling

4.2.3: GLT Girders

The determination of a glulam girder member began with gravitational loads on the corresponding floor and joist. The gravitational loads were broken down into three-point loads from the joist stacked on the girders. The loads from each individual joist were inputted into the eight load combinations equations, and whatever combination provided the largest load governed. The self-weight of the glulam girder was also considered. A girder was selected from Nordic Technical Guide Lam+. According to the IBC 2021, for a Type IV-A building, it requires a 3-hour FRR for all structural members. Nordic provides glulam members that support up to a 2-hour FRR. As a result of this, the members were designed to withhold a 2-hour FRR on four sides of the beam where it would be exposed to fire, and 2 additional panels of gypsum board were added. The two panels of gypsum provide an additional hour FRR, bringing the glulam girder up to the require 3-hour FRR.

Spreadsheets were created to simplify the process of calculating the allowable moment and shear. A fire resistance adjustment factor, provided by Nordic, was applied to the adjusted bending moment. If the moment of the member was greater than the allowable moment, a new size and fire resistance adjustment factor was selected. This process was repeated for all glulam girders. All members had acceptable shear, moment, and deflection values.

The girders can be seen as the horizontal beams within the plan views shown below. An inventory of glulam members and spreadsheets for typical and special case girders can be found in Appendix E and Appendix B.

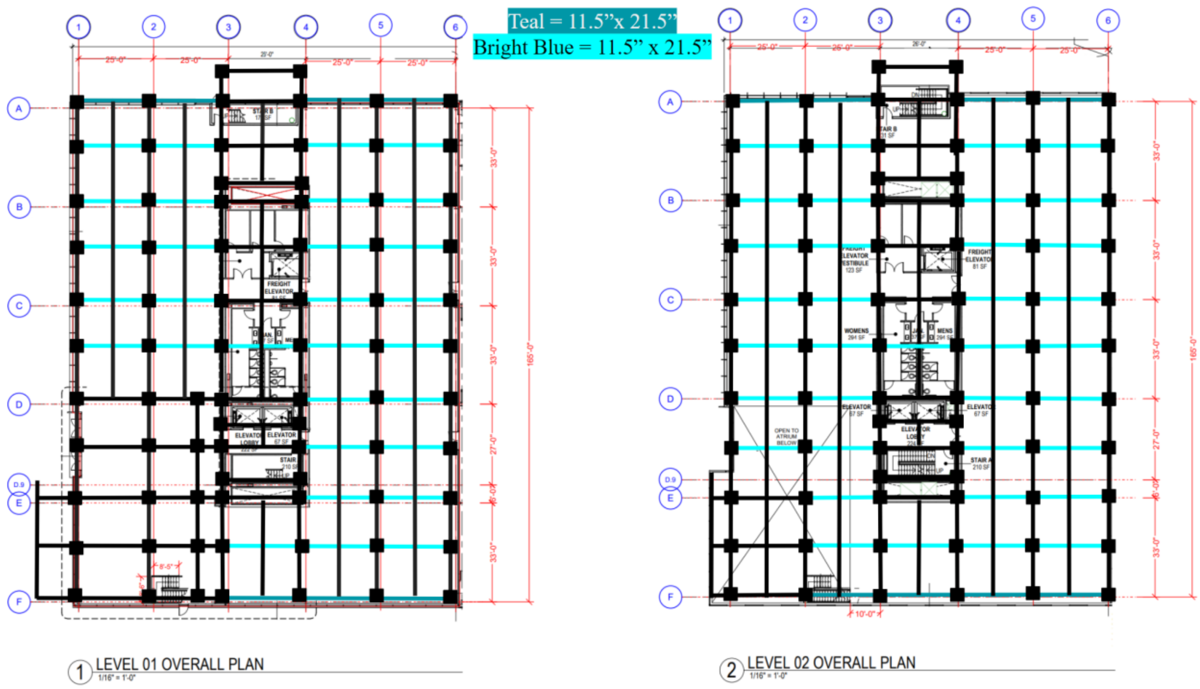


Figure 13: Typical Girders First and Second Floor Ceiling

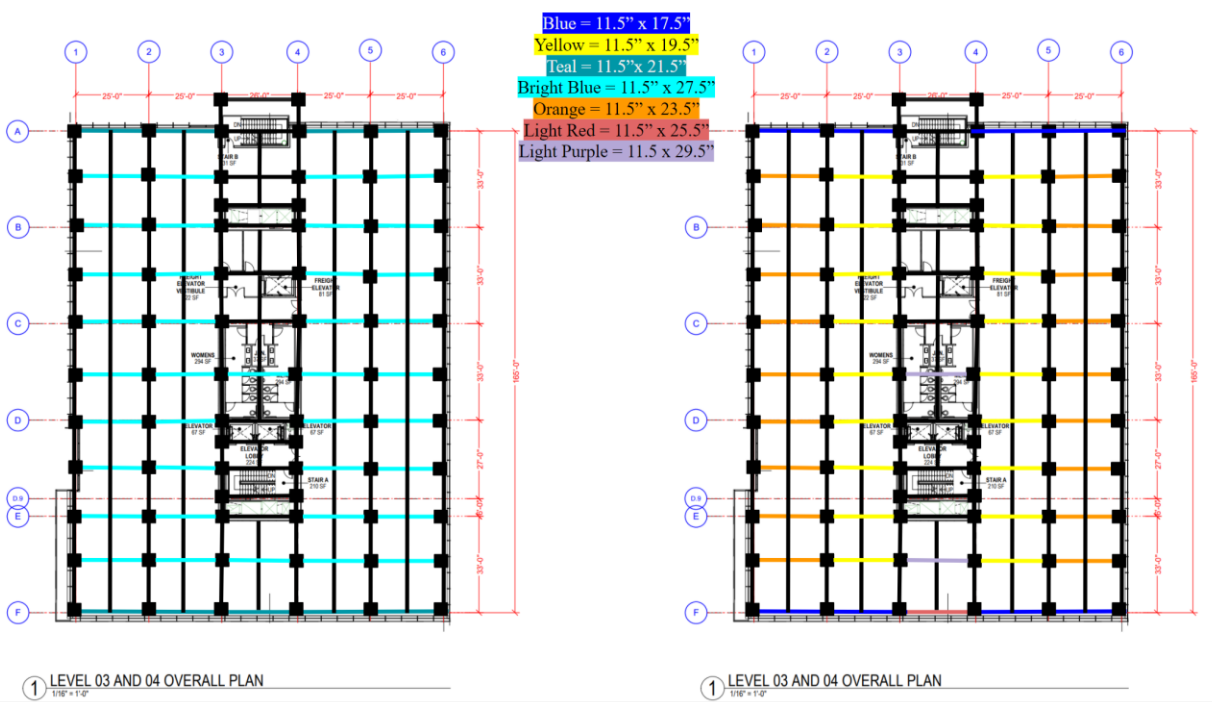


Figure 14: Typical Girders Third and Fourth Floor Ceiling

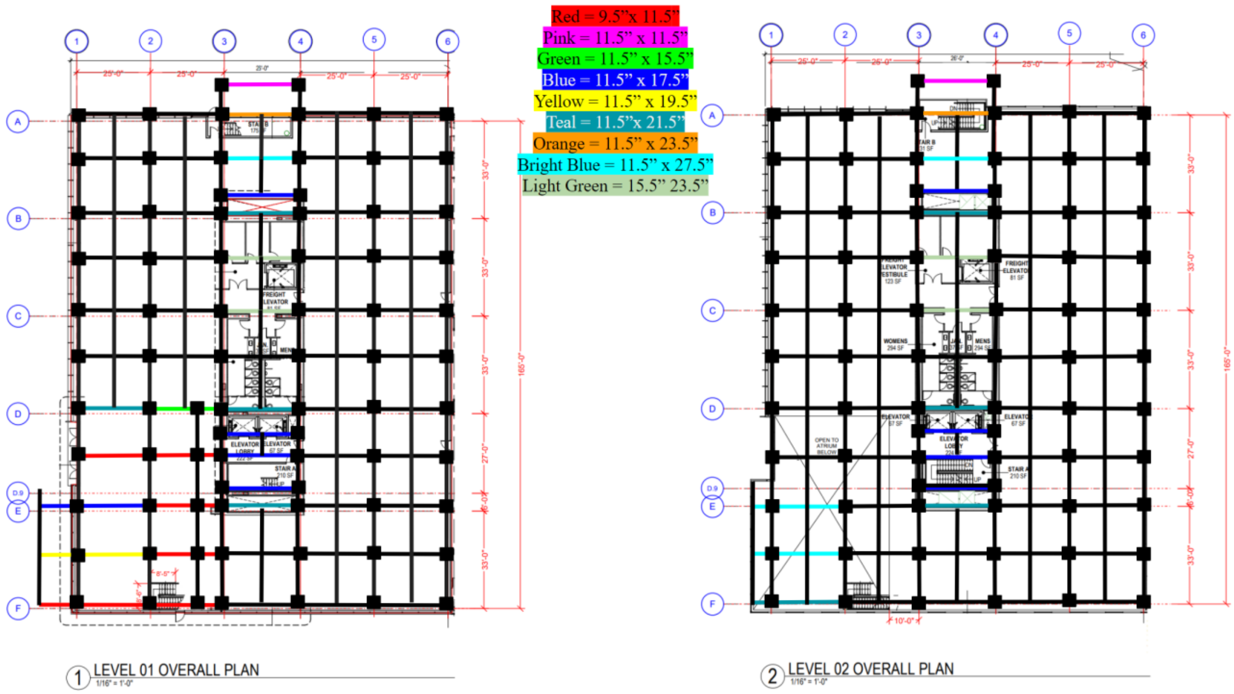


Figure 15: Special Case Girders Floor First and Second Floor Ceiling

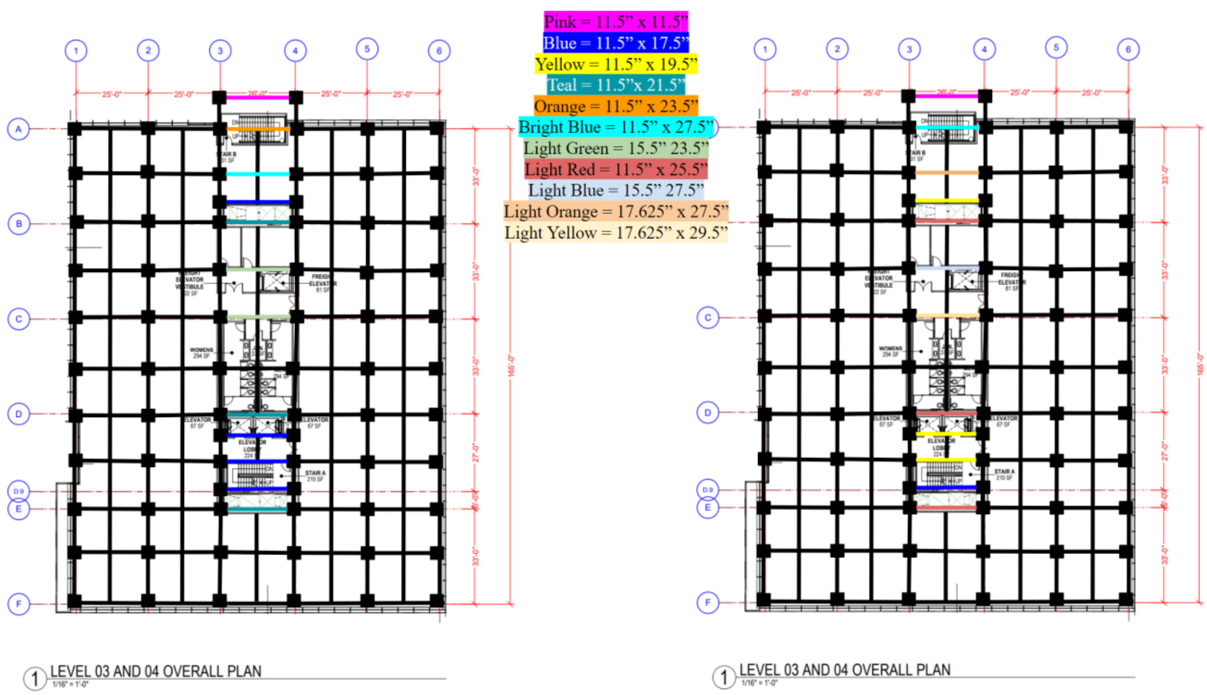


Figure 16: Special Case Girders Third and Fourth Floor Ceiling

4.2.4: GLT Columns

The last calculation for the gravity loads were within the columns. Columns were selected from Nordic’s Technical Guide Lam+. Due to a Type IV-A building having a required 3-hour FRR, all columns were initially selected based on their allowable concentric end load and corresponding FRR. The largest FRR Nordic provides is for 2 hours. As a result of this, the columns were covered with two gypsum wall boards, allowing for an additional 1-hour FRR. In addition, the columns were kept square to assist with the fire analysis and evenly char on all four sides.

Once this criterion was met, calculations were completed to ensure the column could support the axial loading. The first step was to determine the loading from the girders on either side of the column and the self-weight of the column. The adjusted compression parallel to the grain and the minimum modulus of elasticity were calculated. The ratio of effective length to depth was checked to be less than 50. If it was less than 50, the critical buckling design value and column stability factor could be computed. The axial buckling capacity was used to determine the allowable load and compared to the Nordic allowable concentric end load for a 3-hour FRR. Spreadsheets were created to repeat this process for the corresponding columns on floors 1-3.

The figures below show the typical and special case column sizes per floor. The column sizes increased with each floor from top to bottom, due to the additional weight from the floor above. The columns around the core are the largest because the need to withhold the weight of the penthouse. An inventory of glulam members and spreadsheets for typical and special case joist can be found in Appendix E and Appendix B.

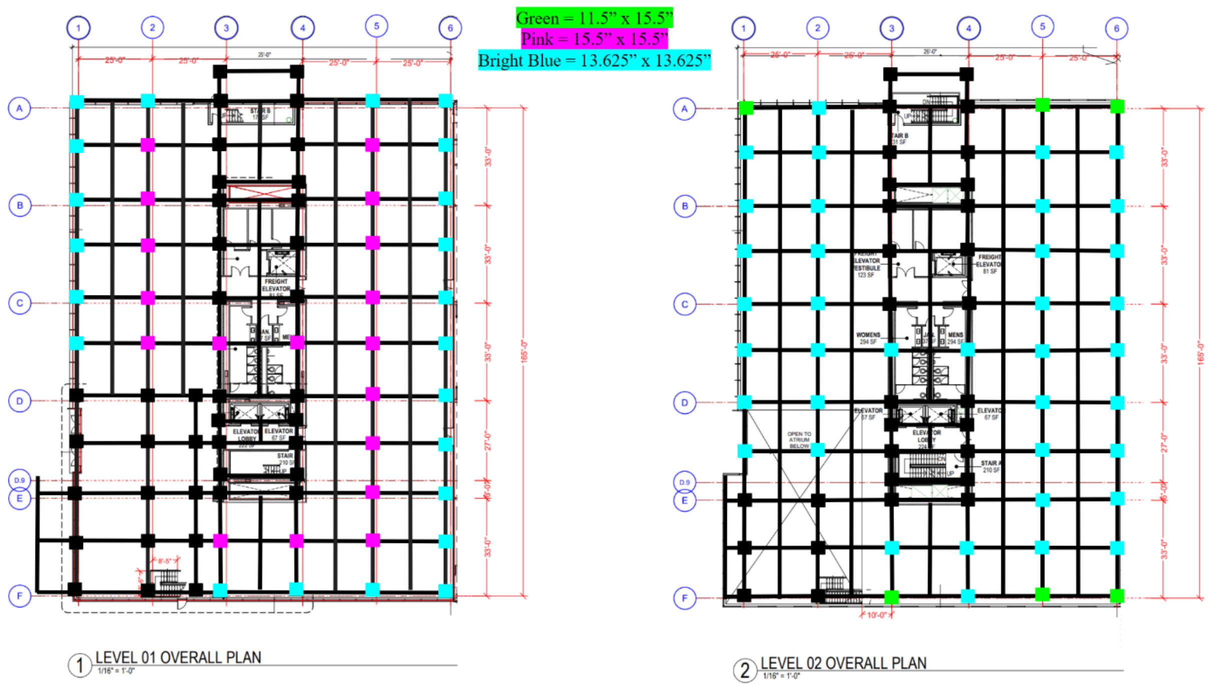


Figure 17: Typical Columns Floor One and Two

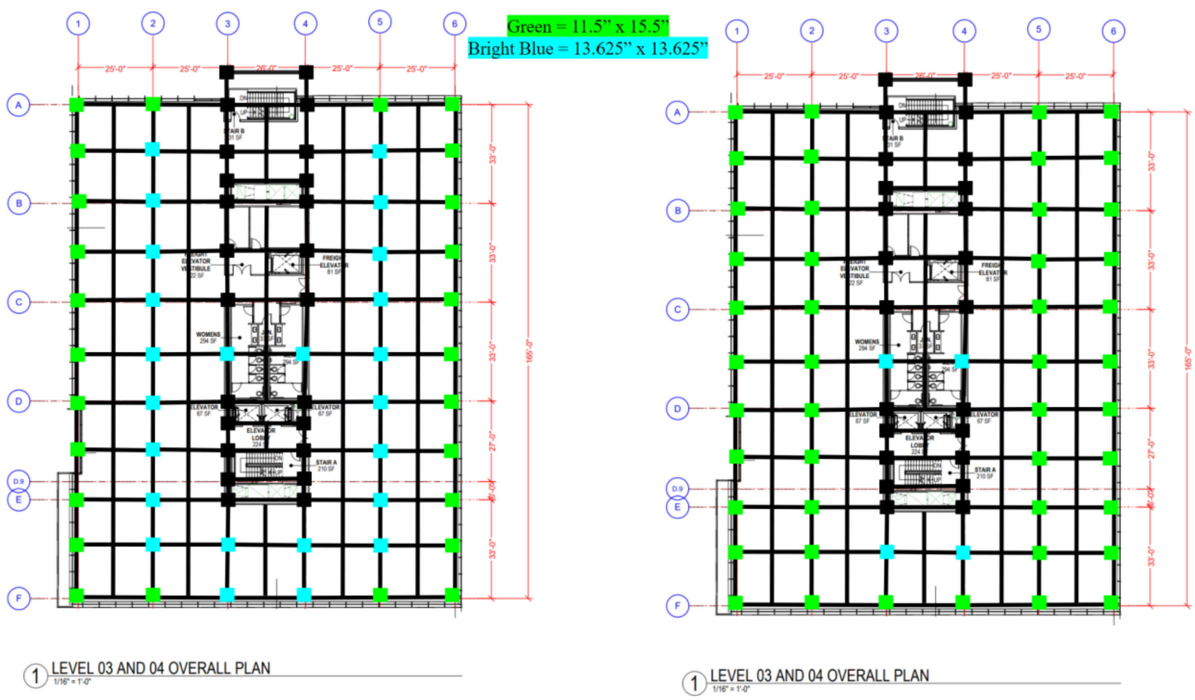


Figure 18: Typical Columns Floor Three and Four

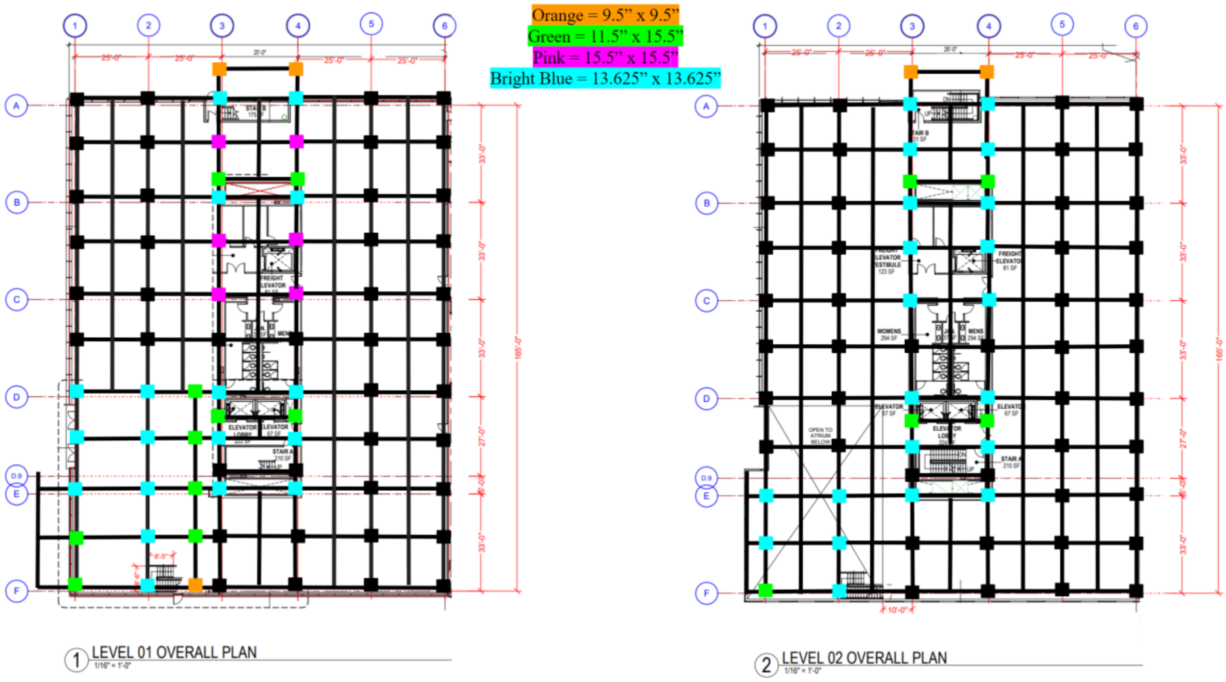


Figure 19: Special Case Columns Floor One and Two

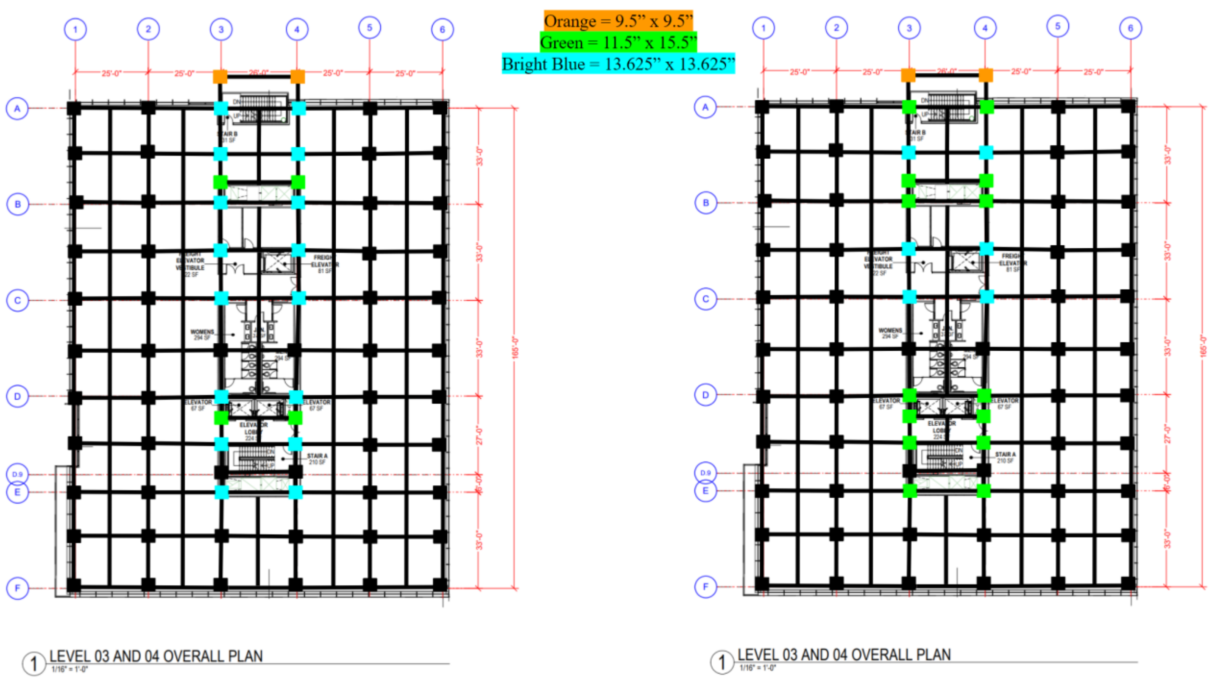


Figure 20: Special Case Columns Floor Three and Four

4.3: Lateral Loading

4.3.1: Seismic Loading

Seismic loading was determined with the use of *ASCE 7-10* Seismic Analysis Program. This program provided a spreadsheet that combined geographic location, soil classification, risk category, and weight of the building per floor to determine seismic loading. It was assumed the building was located in Worcester, Massachusetts, but a specific site was not selected. Based off this assumption, the unknown soil was classified as Site Class D. The building was determined to be in risk category II, as this category is assigned to most structures. The weight of the structural members and height per floor were inputted into the spreadsheets. The inventory of all the members was used to calculate the average weight per floor and converted into kips. Initially, it was thought wind loads were significantly greater. However, due to the weight of the penthouse and mechanical systems, seismic loading was quite similar to wind loading. The Seismic Analysis Program spreadsheet can be found in Figures 21 and 22.

Figure 21: Seismic Analysis Program Spreadsheet

SEISMIC BASE SHEAR AND VERTICAL SHEAR DISTRIBUTION

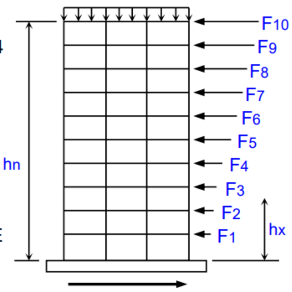
Per IBC 2012 and ASCE 7-10 Specifications

Using Equivalent Lateral Force Procedure for Regular Multi-Level Building/Structural Systems

Job Name:		Subject:			
Job Number:		Originator:		Checker:	

Input Data:

Risk Category =	II	IBC 2012, Table 1604.5, page 336
Importance Factor, I =	1.00	ASCE 7-10 Table 1.5-2, page 5
Soil Site Class =	D	ASCE 7-10 Table 20.3-1, page 204
Location Zip Code =	01609	
Spectral Accel., S_S =	0.180	ASCE 7-10 Figures 22-1 to 22-11
Spectral Accel., S_1 =	0.066	ASCE 7-10 Figures 22-1 to 22-11
Long. Trans. Period, T_L =	6.000	sec. ASCE 7 Fig's. 22-12 to 22-18
Structure Height, h_n =	83.000	ft.
Actual Calc. Period, T_c =	0.000	sec. from independent analysis
Seismic Resist. System =	B24	Light-framed walls with shear panels of all other materials (ASCE 7-10 Table 12.2-1)



$V = C_s*W = \Sigma(F_i) = 427.74$ kips

Seismic Base Shear

(Regular Bldg. Configurations Only)

Structure Weight Distribution:

No. of Seismic Levels = 5

Seismic Level x	Height, hx (ft.)	Weight, Wx (kips)
5	83.000	262.30
4	64.000	2657.98
3	48.000	883.82
2	32.000	898.80
1	16.000	866.59

Total Weight, $W = \Sigma W_x$ = 5569.49 kips (ASCE 7-10 Section 12.7.2)

Results:

Site Coefficients:

F_a =	1.600	ASCE 7-10 Table 11.4-1, page 66
F_v =	2.400	ASCE Table 11.4-2, page 66

Maximum Spectral Response Accelerations for Short and 1-Second Periods:

S_{MS} =	0.288	$S_{MS} = F_a*S_S$, ASCE Eqn. 11.4-1, page 65
S_{M1} =	0.158	$S_{M1} = F_v*S_1$, ASCE Eqn. 11.4-2, page 65

Design Spectral Response Accelerations for Short and 1-Second Periods :

S_{DS} =	0.192	$S_{DS} = 2*S_{MS}/3$, ASCE 7-10 Eqn. 11.4-3, page 65
S_{D1} =	0.106	$S_{D1} = 2*S_{M1}/3$, ASCE Eqn. 11.4-4, page 65

(continued:)

Figure 22: Seismic Analysis Program Spreadsheet

Seismic Design Category:

Category(for S_{DS}) =	B	ASCE 7-10 Table 11.6-1, page 67
Category(for S_{D1}) =	B	ASCE 7-10 Table 11.6-2, page 67
Use Category =	B	Most critical of either category case above controls

Fundamental Period:

Period Coefficient, C_T =	0.020	ASCE 7-10 Table 12.8-2, page 90
Period Exponent, x =	0.75	ASCE 7-10 Table 12.8-2, page 90
Approx. Period, T_a =	0.550	sec., $T_a = C_T*h_n$^(x), ASCE 7-10 Section 12.8.2.1, Eqn. 12.8-7
Upper Limit Coef., C_u =	1.689	ASCE 7-10 Table 12.8-1, page 90
Period max., $T_{(max)}$ =	0.929	sec., $T_{(max)} = C_u*T_a$, ASCE 7-10 Section 12.8.2, page 90
Fundamental Period, T =	0.550	sec., T = Ta <= Cu*Ta, ASCE 7-10 Section 12.8.2, page 90

Seismic Design Coefficients and Factors:

Response Mod. Coef., R =	2.5	ASCE 7-10 Table 12.2-1, pages 73-75
Overstrength Factor, Ω_o =	2.5	ASCE 7-10 Table 12.2-1, pages 73-75
Defl. Amplif. Factor, C_d =	2.5	ASCE 7-10 Table 12.2-1, pages 73-75
C_S =	0.077	$C_S = S_{DS}/(R/I)$, ASCE 7-10 Section 12.8.1.1, Eqn. 12.8-2
$C_{S(max)}$ =	0.077	For T<=TL, CS(max) = SD1/(T*(R/I)), ASCE 7-10 Eqn. 12.8-3
$C_{S(min)}$ =	0.010	CS(min) = 0.044*SDS*I >= 0.01, ASCE 7-10 Eqn. 12.8-5
Use: C_S =	0.077	$C_{S(min)} <= C_S <= C_{S(max)}$

Seismic Base Shear:

V = 427.74 kips, V = Cs*W, ASCE 7-10 Section 12.8.1, Eqn. 12.8-1

Seismic Shear Vertical Distribution:

Distribution Exponent, k = 1.02 k = 1 for T<=0.5 sec., k = 2 for T>=2.5 sec.

k = (2-1)*(T-0.5)/(2.5-0.5)+1, for 0.5 sec. < T < 2.5 sec.

Lateral Force at Any Level: $F_x = C_{vx}*V$, ASCE 7-10 Section 12.8.3, Eqn. 12.8-11, page 91

Vertical Distribution Factor: $C_{vx} = W_x*h_x$^k/(ΣW_i*h_i^k), ASCE 7-10 Eqn. 12.8-12, page 91

Seismic Level x	Weight, Wx (kips)	hx^k (ft.)	Wx*h^k (ft-kips)	Cvx (%)	Shear, Fx (kips)	Σ Story Shears
5	262.30	92.688	24312.2	0.079	33.98	33.98
4	2657.98	71.008	188737.7	0.617	263.82	297.80
3	883.82	52.875	46731.6	0.153	65.32	363.13
2	898.80	34.894	31363.1	0.102	43.84	406.97
1	866.59	17.148	14860.0	0.049	20.77	427.74
Σ =	5569.49		306004.5	1.000	427.74	

Comments:

4.3.1 Wind Loading

Wind Loading was determined with the use of *ASCE 7-10* and a wind loads spreadsheet, created by FLSmidth. This spreadsheet combined risk category, regional wind speed, exposure category, and enclosure classification to calculate the wind loads on the building. The building was classified as a risk category II and basic wind speed of 124 mph, per *ASCE 7-10 Table 1.5-1* and *Figure 26.5-1A*. Since there is no physical site for the building, it was classified as an exposure category C. The building was determined to be an enclosed structure, due to lack of openings or partially enclosed areas. The shorter side of the building was selected as the windward wall, while the longer side was the leeward wall. Similar to seismic loading, the wind loads varied per floor due to the differing height. In the end, wind load was determined to be the governing lateral load. The FLSmidth wind loads spreadsheet can be found below in Figure 23.

Figure 23: FLSmidth Wind Loads Spreadsheet

FLSMIDTH	MWFRS Wind Loads *ASCE 7-10* *Enclosed & Partially Enclosed Buildings of All Heights*	Job No: 11054 Designer: DCB Checker:
	Notes: Grinding Building (+/- Z Direction)	Date: 3/1/2022

Basic Parameters

Risk Category	II	Table 1.5-1
Basic Wind Speed, V	124 mph	Figure 26.5-1A
Wind Directionality Factor, K_d	0.85	Table 26.6-1
Exposure Category	C	Section 26.7
Topographic Factor, K_{zt}	1.00	Section 26.8
Gust Effect Factor, G or G_f	0.850	Section 26.9
Enclosure Classification	Enclosed	Section 26.10
Internal Pressure Coefficient, GC_{pi}	+/- 0.18	Table 26.11-1
Terrain Exposure Constant, α	9.5	Table 26.9-1
Terrain Exposure Constant, z_g	900 ft	Table 26.9-1

Wall Pressure Coefficients

Windward Wall Width, B	126 ft	
Side Wall Width, L	165 ft	
L/B Ratio	1.31	
Windward Wall Coefficient, C_p	0.80	Figure 27.4-1
Leeward Wall Coefficient, C_p	-0.44	Figure 27.4-1
Side Wall Coefficient, C_p	-0.70	Figure 27.4-1

Roof Pressure Coefficients

Roof Slope, θ	9.5°	
Median Roof Height, h	83 ft	
Velocity Pressure Exposure Coef., K_h	1.22	Table 27.3-1
Velocity Pressure, q_h	40.7 psf	Equation 27.3-1
h/L Ratio	0.50	
Windward Roof Area	0 ft²	
Roof Area Within 42 ft of WW Edge	0 ft²	

Location	*Min/Max*	*Horiz Distance From Windward Edge*			
		0 ft	*42 ft*	*83 ft*	*166 ft*
Windward Roof Coefficient Normal to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18
Leeward Roof Coefficient Normal to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18
Roof Coefficient Parallel to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18

Figure 27.4-1

Structure Pressure Summary (Add Internal Pressure q_zGC_{pi} or q_hGC_{pi} as Necessary)

Height, z	K_z	q_z	*Walls*				*Roof*			Internal	
							Normal to Ridge		*Parallel*		
			WW	*LW*	*WW + LW*	*Side*	*WW*	*LW*	*to Ridge*	Positive	Negative
0 ft	0.85	28.4 psf	19.3 psf		34.5 psf					7.3 psf	
8 ft	0.85	28.4 psf	19.3 psf		34.5 psf		Min:	Min:	Min:	7.3 psf	
16 ft	0.86	28.8 psf	19.6 psf		34.7 psf		-31.2 psf	-31.2 psf	-31.2 psf	7.3 psf	
24 ft	0.94	31.4 psf	21.3 psf		36.5 psf					7.3 psf	
32 ft	1.00	33.3 psf	22.7 psf		37.8 psf					7.3 psf	
40 ft	1.04	34.9 psf	23.7 psf	-15.2 psf	38.9 psf	-24.2 psf				7.3 psf	-7.3 psf
48 ft	1.08	36.3 psf	24.7 psf		39.8 psf					7.3 psf	
56 ft	1.12	37.5 psf	25.5 psf		40.6 psf		Max:	Max:	Max:	7.3 psf	
64 ft	1.15	38.5 psf	26.2 psf		41.4 psf		-6.2 psf	-6.2 psf	-6.2 psf	7.3 psf	
73 ft	1.18	39.6 psf	26.9 psf		42.1 psf					7.3 psf	
83 ft	1.22	40.7 psf	27.7 psf		42.8 psf					7.3 psf	

4.3.3: Shear Walls

To withstand the lateral loads, CLT shear walls were designed within the core of the building. The lateral load path started at the edges of the CLT flooring from the exterior of the building to the interior of the building and into the shear walls. From this, the required shear wall lengths in both East-West and North-South directions were finalized. The overturning effects were resisted through the dead loads accumulated throughout the building.

Chapter 5: Fire Analysis

5.1: Post-Fire Structural Damage

For the initial building design, members were sized to support gravitational and lateral loads before and during a time-equivalent fire event for a Type IV-A building. In the initial design of CLT members, the initial member sizes were influenced by allowable stress design and by manufacturer-provided fire ratings for various CLT sizes.

For each member, the initial design was confirmed by examining specific char rates and calculating the strength of the remaining cross-section. For fire design, ultimate strength of the member was used, rather than allowable strength for regular occupancy in accordance with the 2021 Fire Design Specification for Wood Construction (*2021 fire design specification for wood construction*). To design to fire rating, the ultimate strength of the beam is assessed, rather than the allowable load for regular occupancy, because confirmation is needed that emergency personnel have adequate time to evacuate occupants without structural failure. The typical FDS procedure does not design for occupancy after a fire event, and repairs may be needed with this method. A table below shows some design values for a typical member.

Figure 24:

Member	Total Req. Fire Rating (hr)	Member Req. Fire Rating (hr)	GYP fire protection (hr)	Member Remaining Cross Section	Allowable Moment (ft-lbs)	Ultimate Moment (x2.85) (ft-lbs)	Design Moment (ft-lbs)
11.5” x 15.5”	3	2	1	5.18” x 12.34”	19,167	54,627	43,062

Figure 25: Illustration of building Cross-Section with Charred Girder

For each member of the initial design, it was also noted whether that member would be able to support an allowable occupancy load after the fire event. It was found that most members were not able to support such a load, and for a time-equivalent fire, extensive repairs were needed.

5.2: Repair Methods

Several repair methods for damaged structural elements such as: CLT floors, GLT beams, GLT columns, and CLT shear walls were researched. For mass timber and CLT is the charring if localized, it can be removed with sanding, scraping, or abrasive blasting. This is done for minor fire damage and if the structural integrity can remain intact. If small areas are damaged, they can be repaired with equivalent wood sections, such as sections around doors or windows (Ranger, Lindsay, et al, 2019).

If the char or fire damage impacts multiple layers of the CLT it is best to replace all layers affected. One solution is to remove and clean the damaged portions and replace them with new laminations attached with adhesive. This solution does not restore full structural capacity of the CLT panel, but it does restore the FRR. Another option is to remove the damaged portions and replace them with new laminations attached with adhered and screwed scarf joints or adhered only. This option reestablishes pre-fire structural capacity, maintains exposed CLT, and restores FRR (“*Post-Fire Restoration*,” 2018). Chapter 6: Post Fire Class A to a Class B Office Building

6.1: Structural Design Change Overview

Three building options were examined for various levels of post-fire resiliency. These options are presented in the list and table below:

Option 1: Designed for Class A

Option 2: Designed for Class A, with ability to become Class B after a fire event

Option 3: Designed for Class A, with ability to remain Class A after a fire event

Table 6.1.1: Building Options

Option	**Building Class Before Fire Event 1***	**Building Type Before Fire Event 1**	**Building Class after Fire Event 1***	**Building Type After Fire Event 1***
Option 1	**Class A** *100 psf Occupancy Rating*	**Rated as a Type IV-A building** *3-hour rating for structural frame, except 2 hours at floor and roof frame*	**N/A** *members may not be fit for continued occupancy, may require extensive structural repair*	**N/A** *Members may no longer meet required fire rating, may require extensive structural repair*
Option 2	**Class A** *100 psf Occupancy Rating*	**Rated as a Type IV-A building** *3-hour rating for structural frame, except 2 hours at floor and roof frame*	**Class B** *50 psf Occupancy Rating*	**Rated as a Type IV-A building** *3-hour rating for structural frame, except 2 hours at floor and roof frame*
Option 3	**Class A** *100 psf Occupancy Rating*	**Rated as a Type IV-A building** *3-hour rating for structural frame, except 2 hours at floor and roof frame*	**Class A** *100 psf Occupancy Rating*	**Rated as a Type IV-A building** *3-hour rating for structural frame, except 2 hours at floor and roof frame*

*Fire Event 1 is defined using time equivalence

6.2: Option 1: Designed for Class A

The first option was designed to support gravitational and lateral loads before and during a time-equivalent fire event for a Type IV-A building. Chapter 4 details the design of this option, and Chapter 5 details the fire analysis.

6.3: Option 2: Designed for Class B post fire

From the fire analysis of option 1, strategies to improve the resilience of the building design were formed. Multiple strategies were used in the Option 2 design. First, members had to be resized to be large enough to sustain a Class B occupancy with minimal structural repairs post-fire. This specifically meant that member widths had to increase. Second, more layers of gypsum were added onto particularly vulnerable structural elements, such as CLT, Girders, and Columns, to minimize the member exposure time and char depth. Finally, certain joists were added below the penthouse to further distribute the equipment load and reduce member size. After a time-equivalent fire event, in this option damaged gypsum board would still have to be replaced, but there would still be sufficient member cross sections to maintain a Type IV-A fire rating and serve a Class B occupancy with minimal structural repairs. Below are various box-and-whisker plots which display the average increase in percent perimeter and area for members to be sufficient from Option 1 to Option 2. Percent increase in perimeter suggests the increase in Gypsum fireproofing needed.

Figure 26

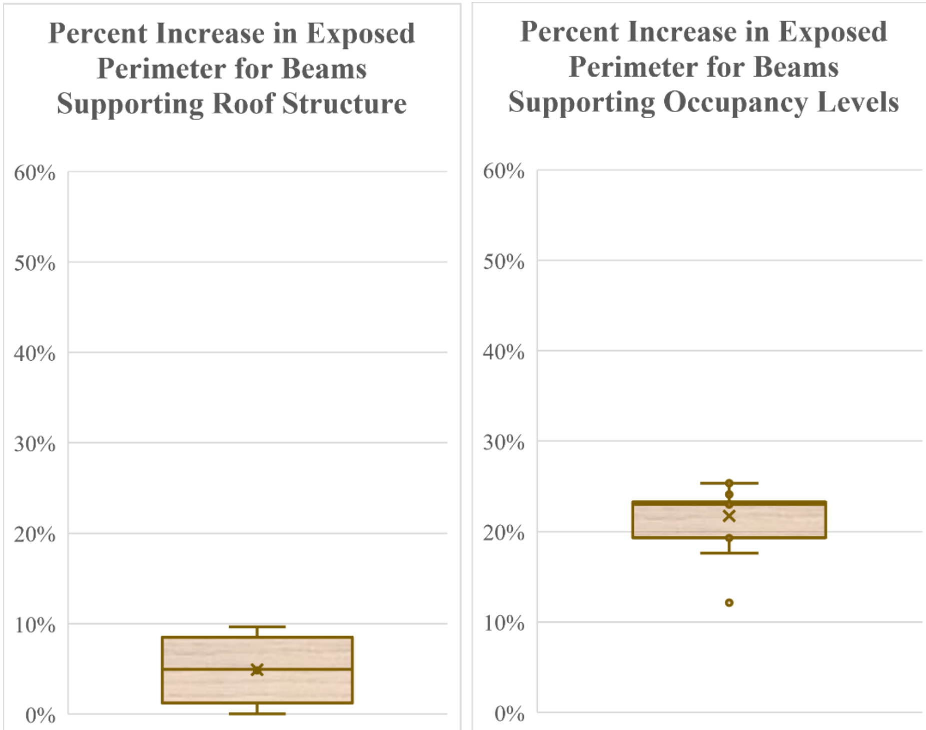


Figure 27

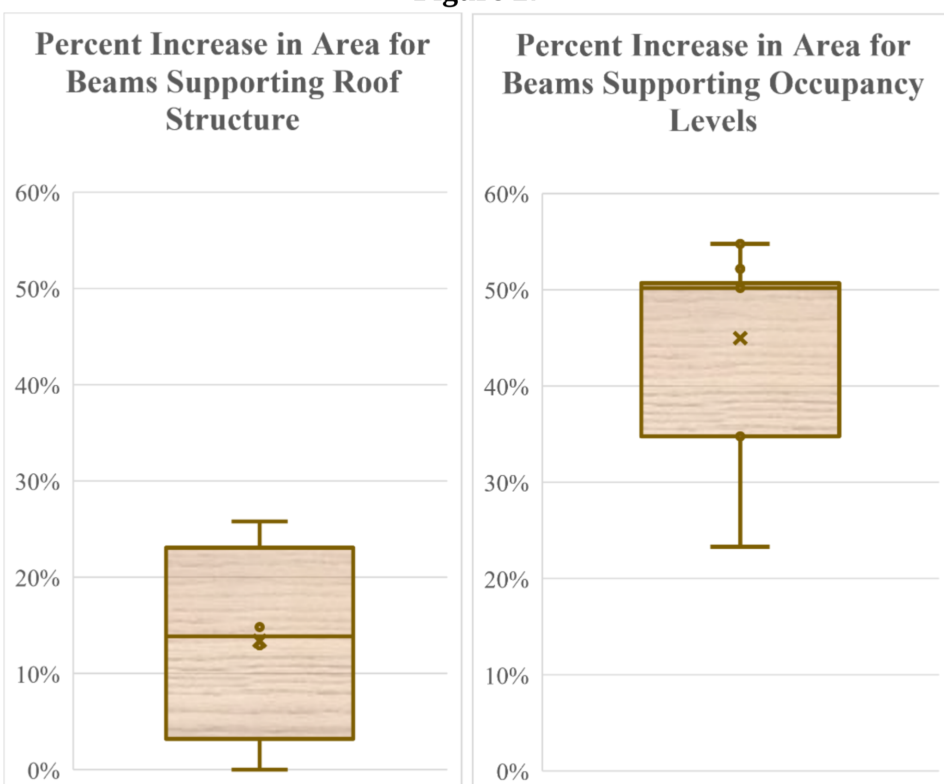


Figure 28

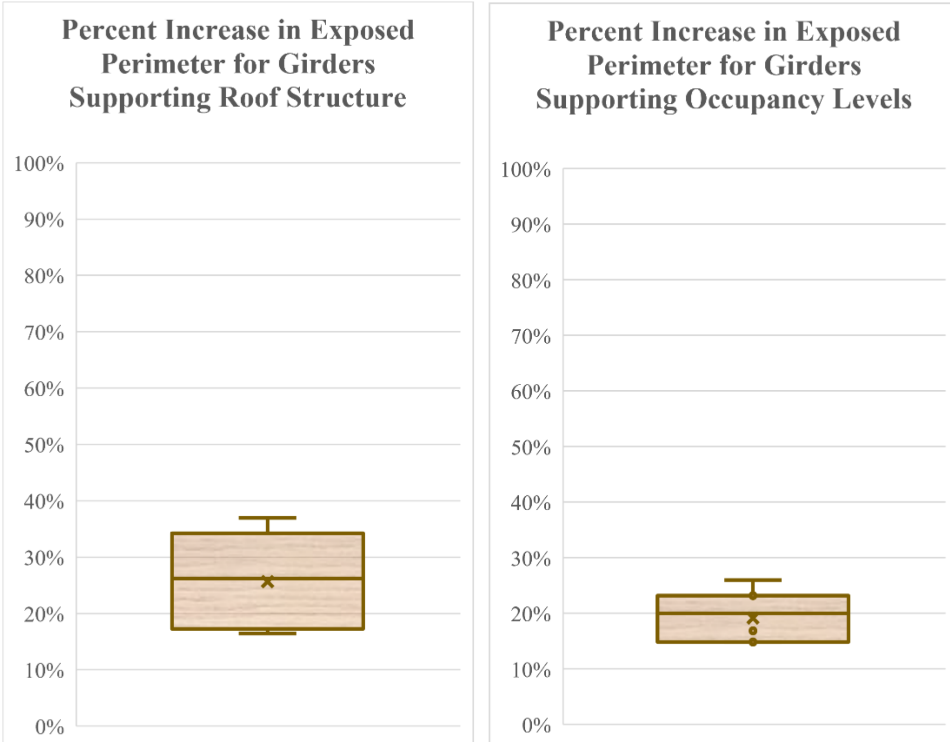


Figure 29

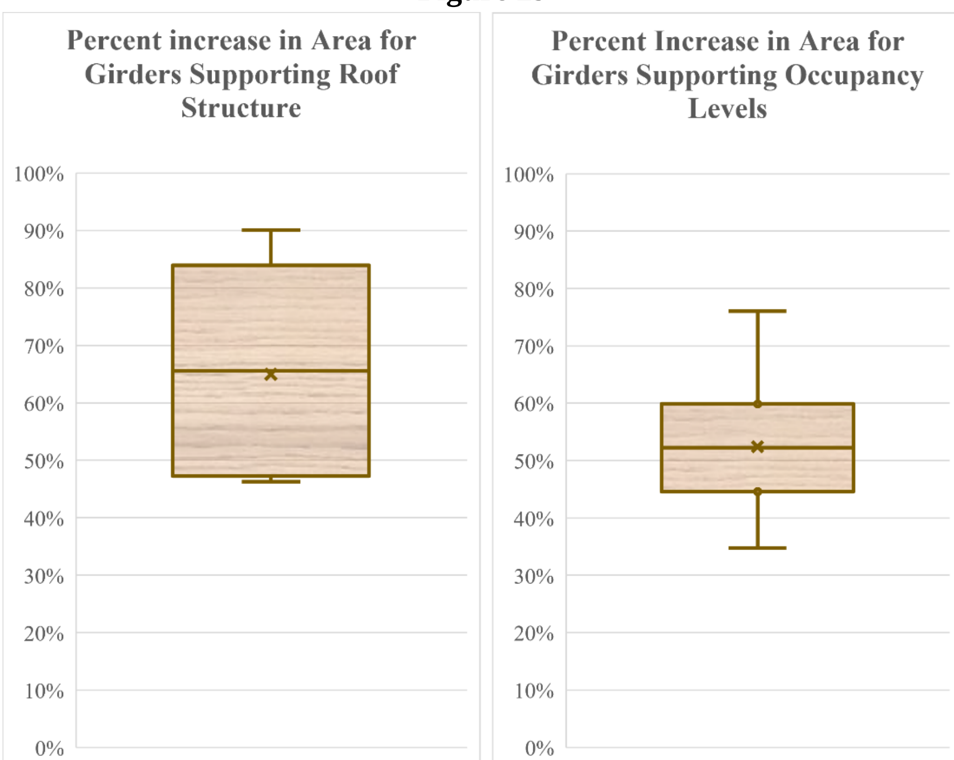


Figure 30

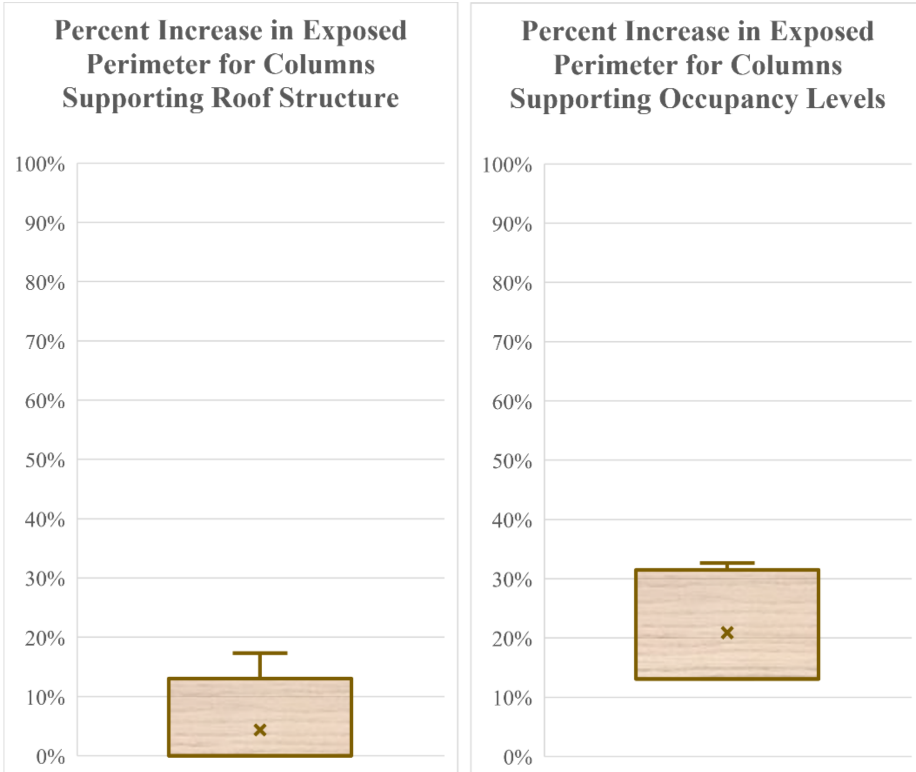


Figure 31

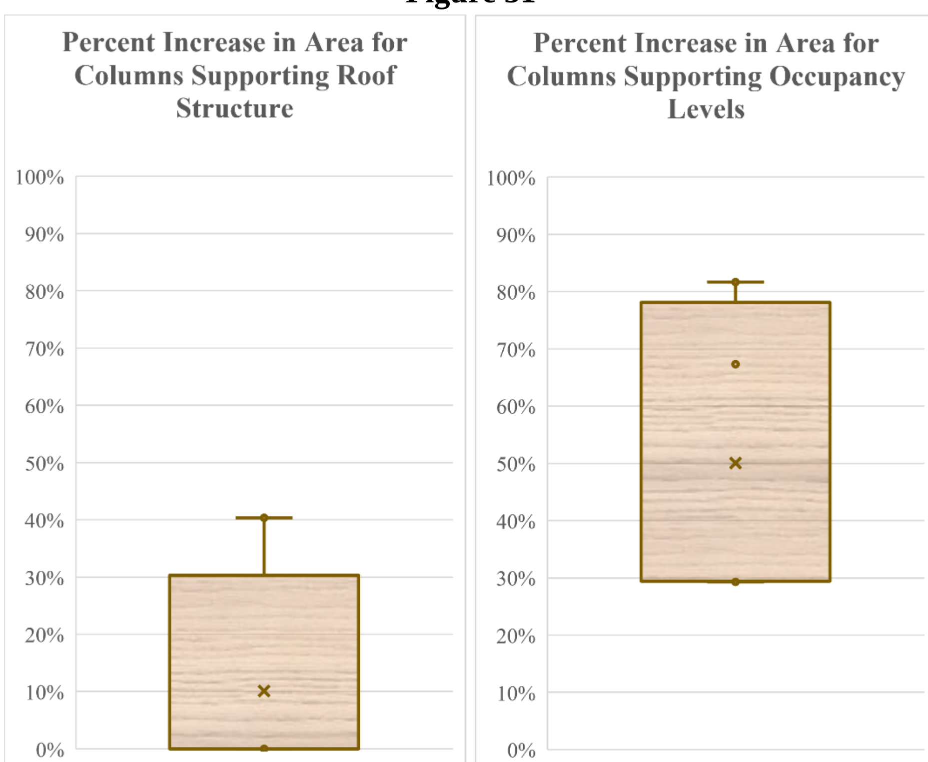


Figure 32: Option 2 Joist Sizing, level 3 and 4

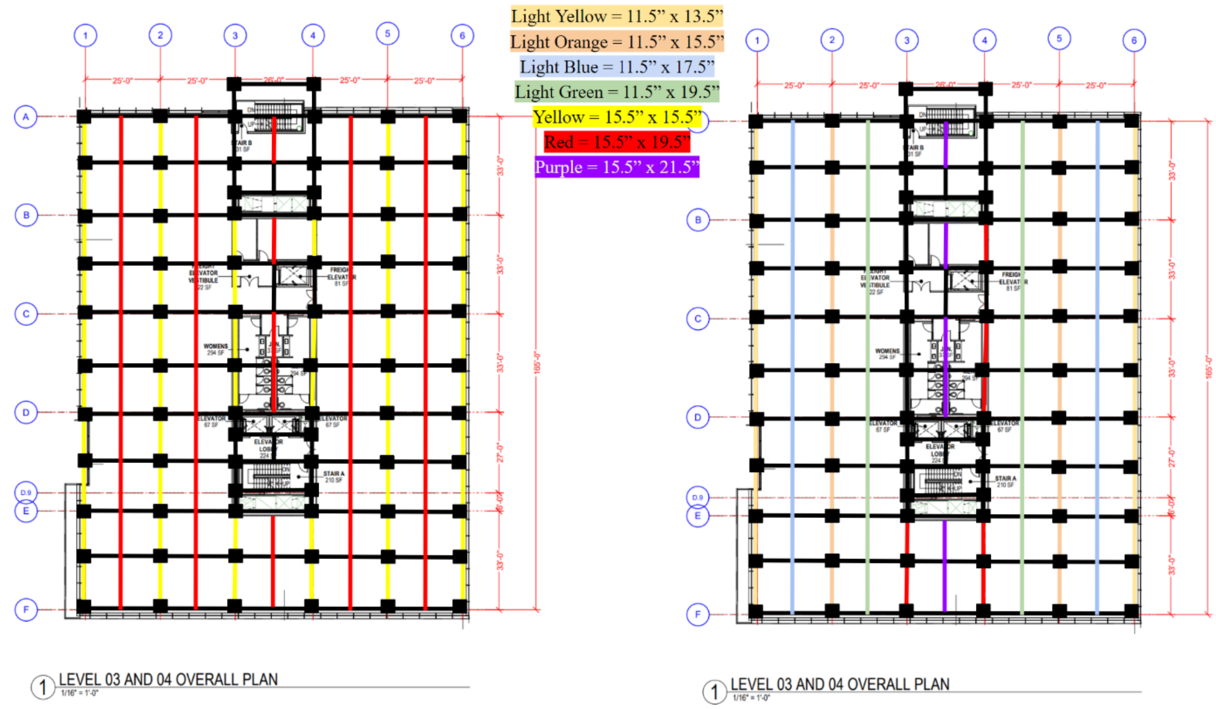


Figure 33: Option 2, level 1 and 2

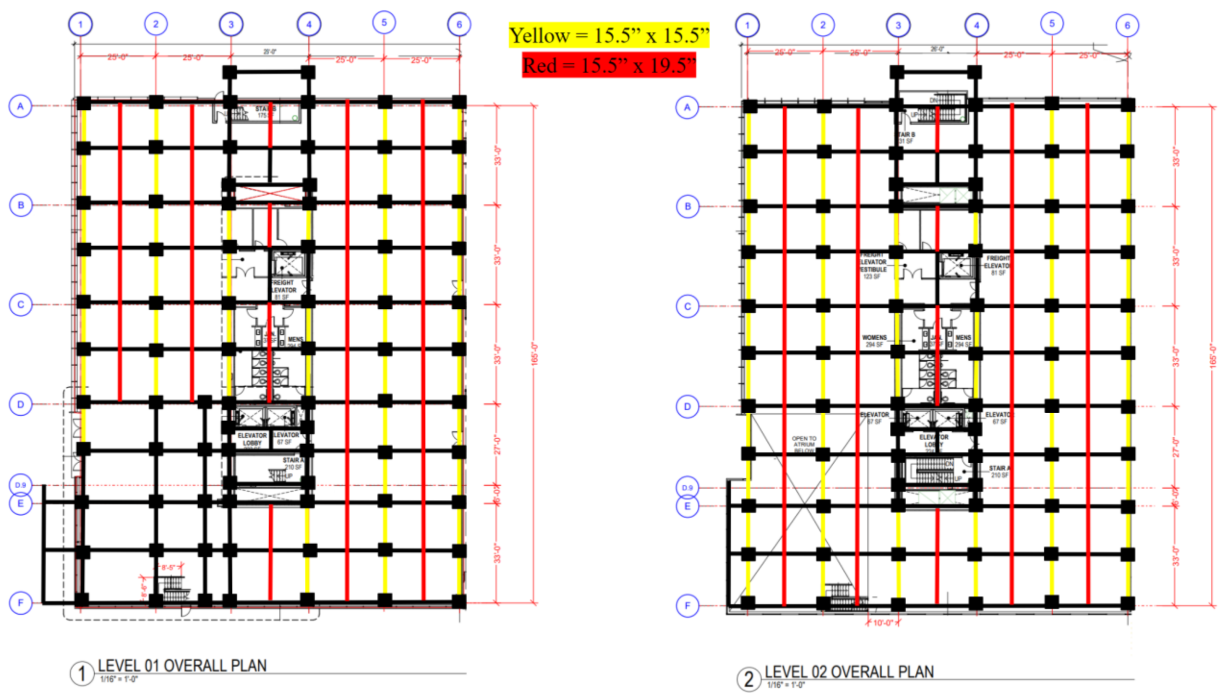


Figure 34: Special Case Joists, level 1 and 2

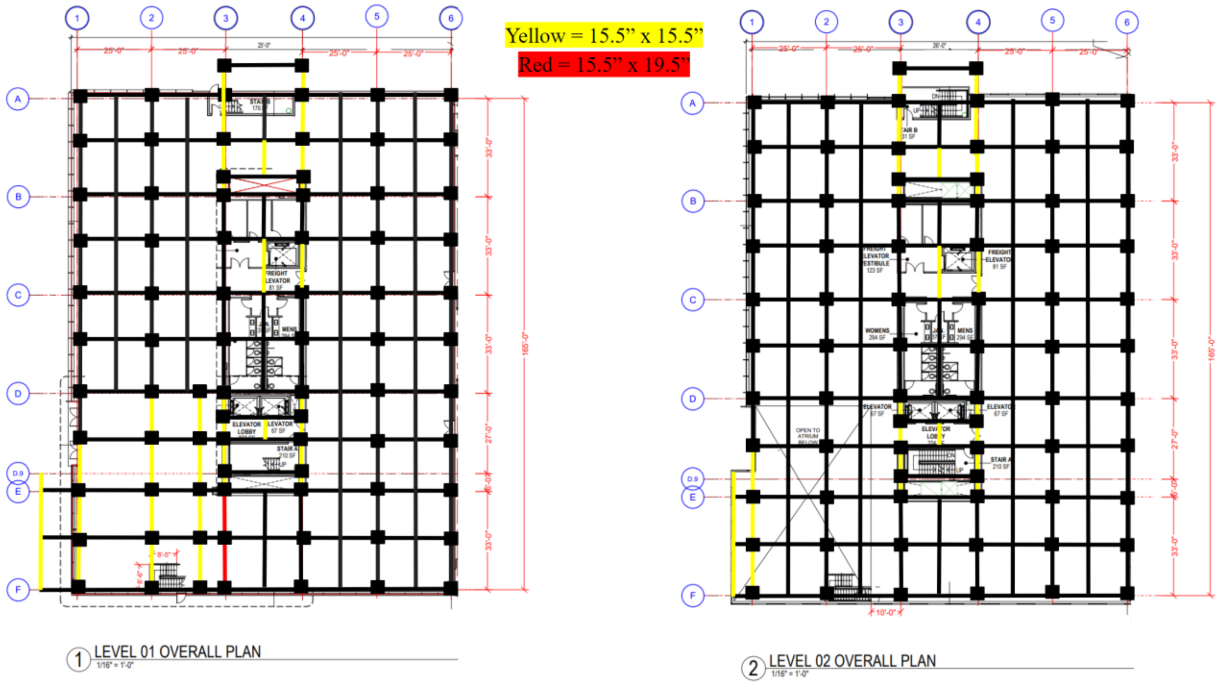


Figure 35: Special Case Joists, level 3 and 4

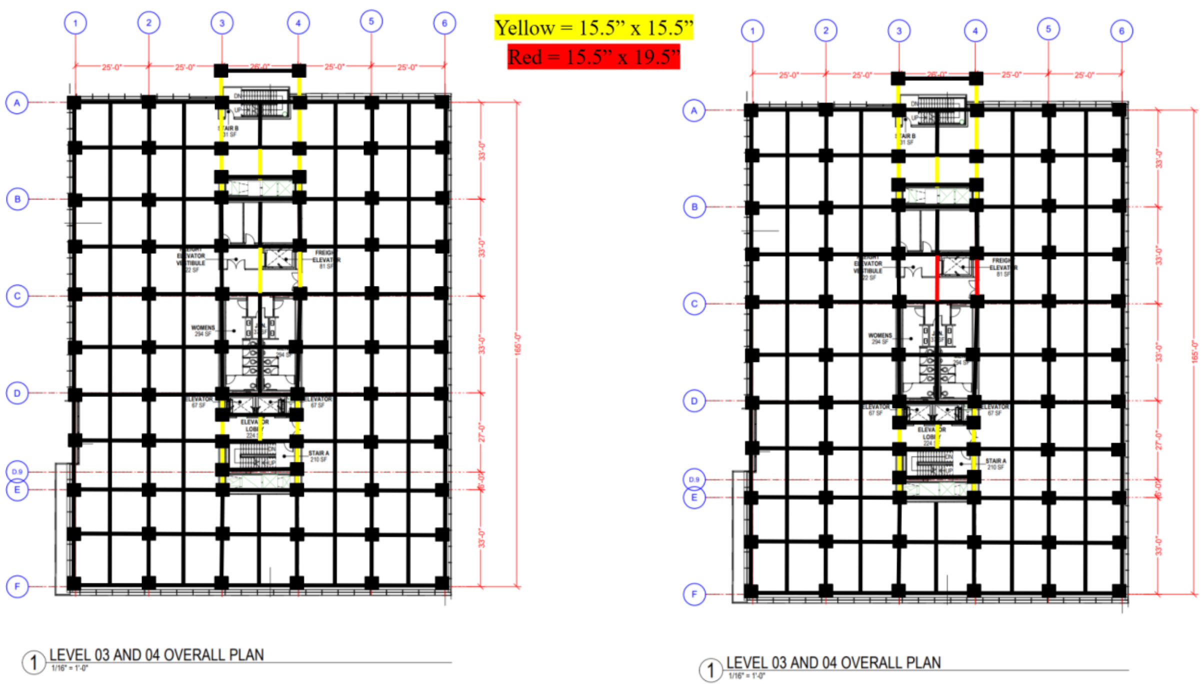


Figure 36 : Option 2 Girders, level 1 and 2

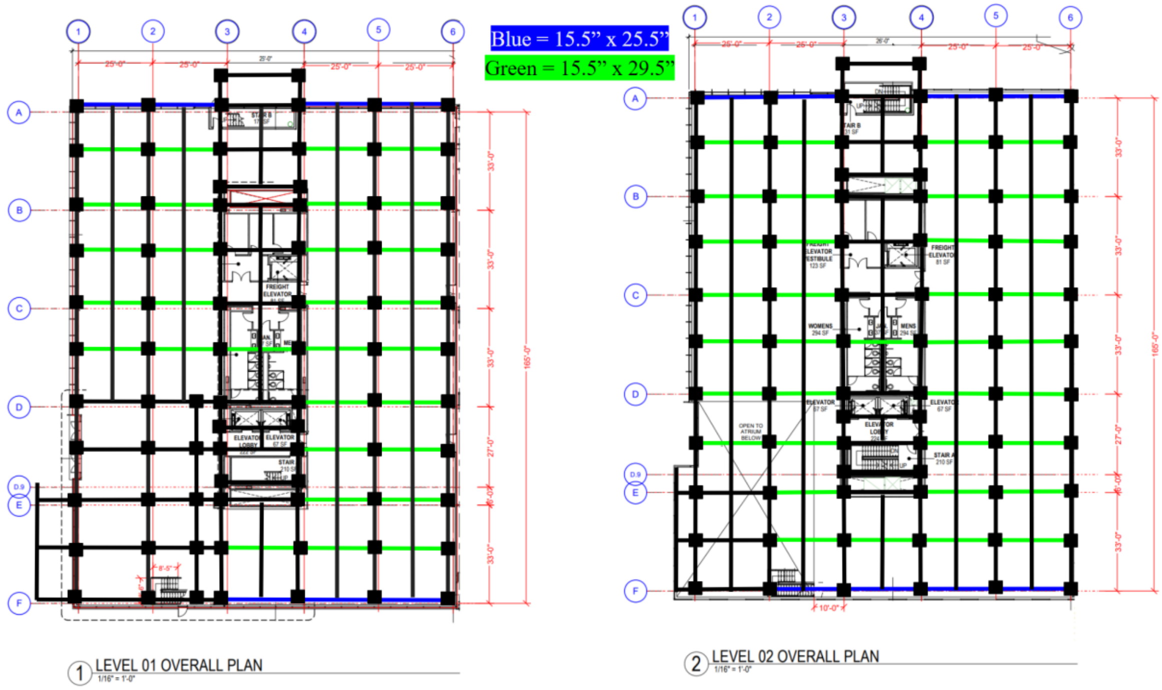


Figure 37 : Option 2 Girders, level 3 and 4

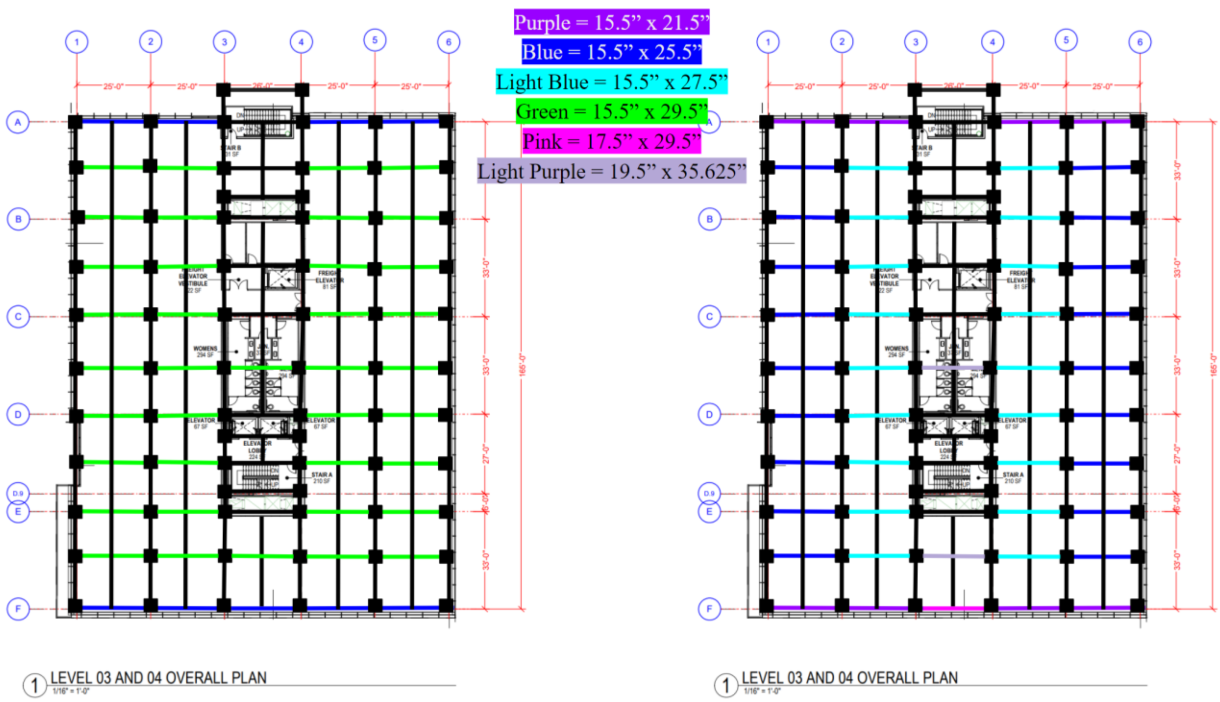


Figure 38 : Special Case Girders, Level 1 and 2

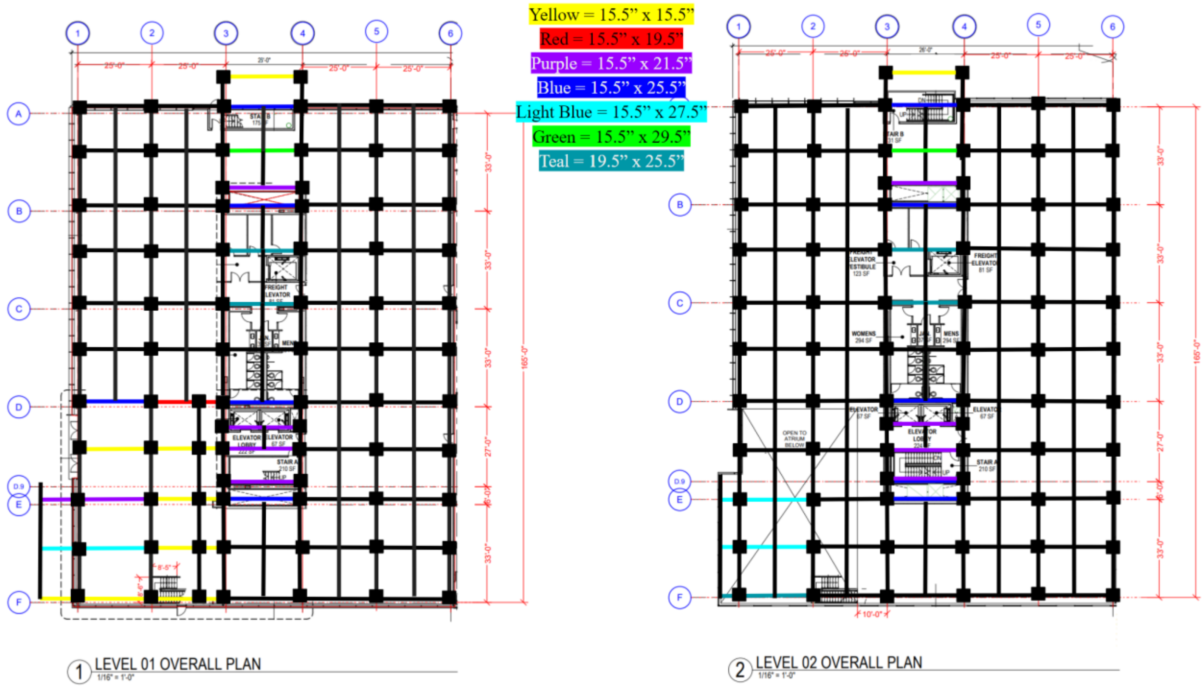


Figure 39 : Special Case Girders, Level 3 and 4

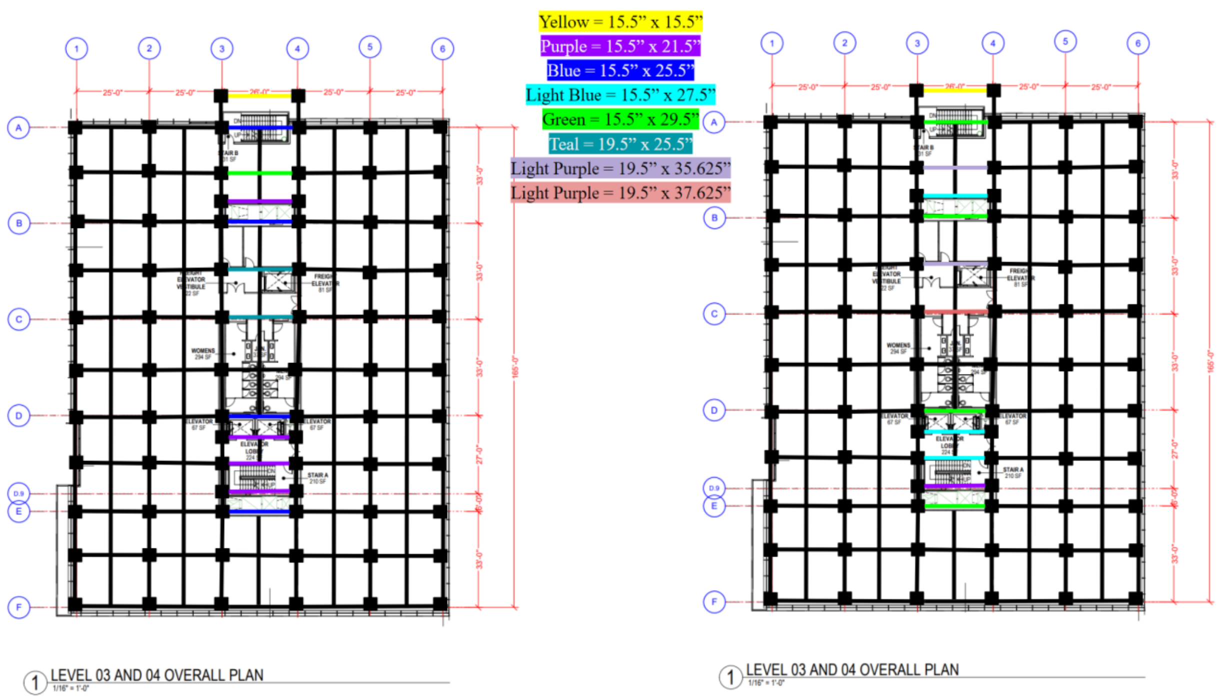


Figure 40: Option 2 Columns, level 1 and 2

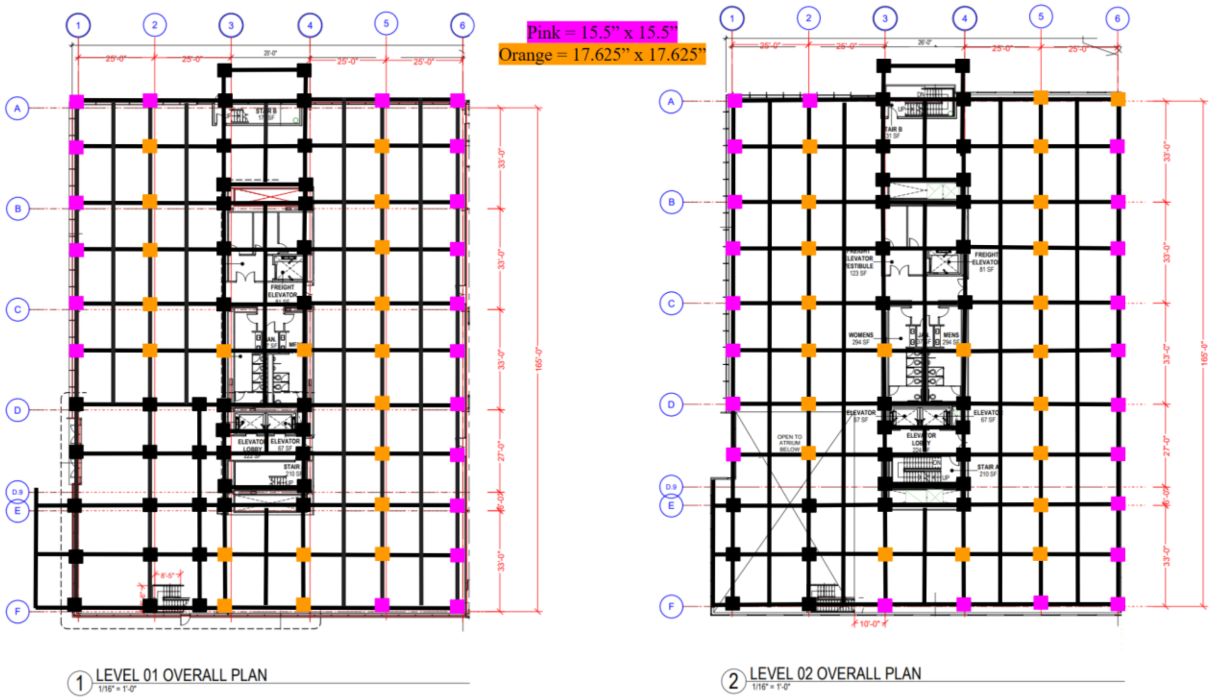


Figure 41: Option 2 Columns, level 3 and 4

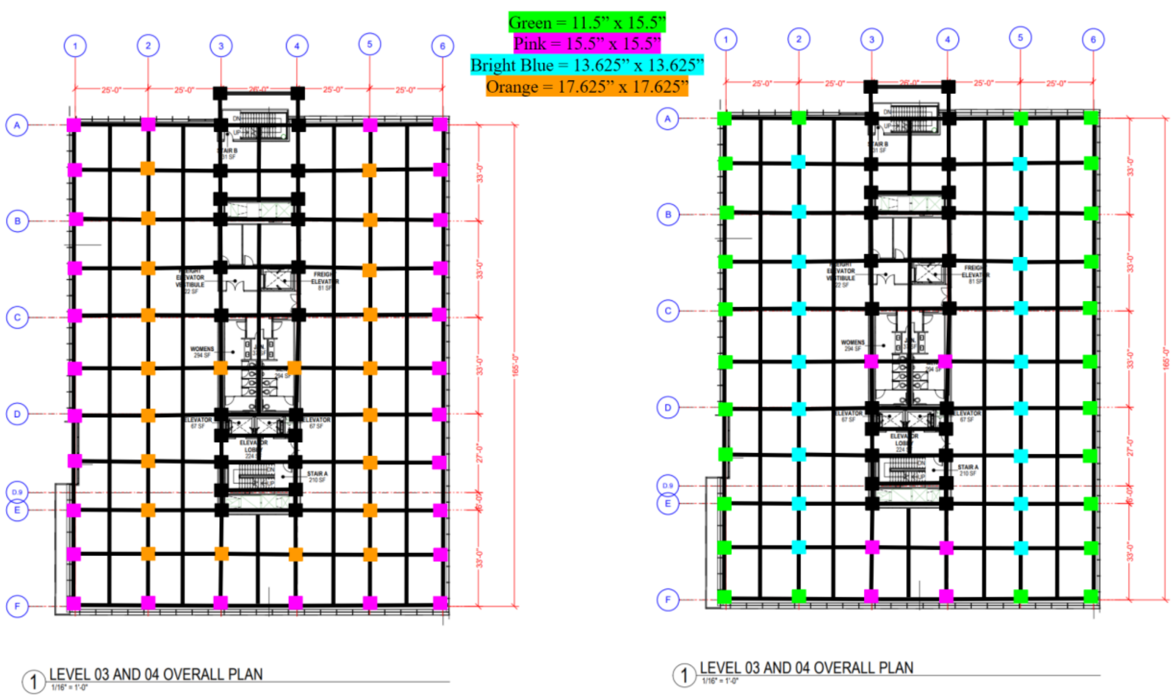


Figure 42: Special Case Columns, levels 1 and 2

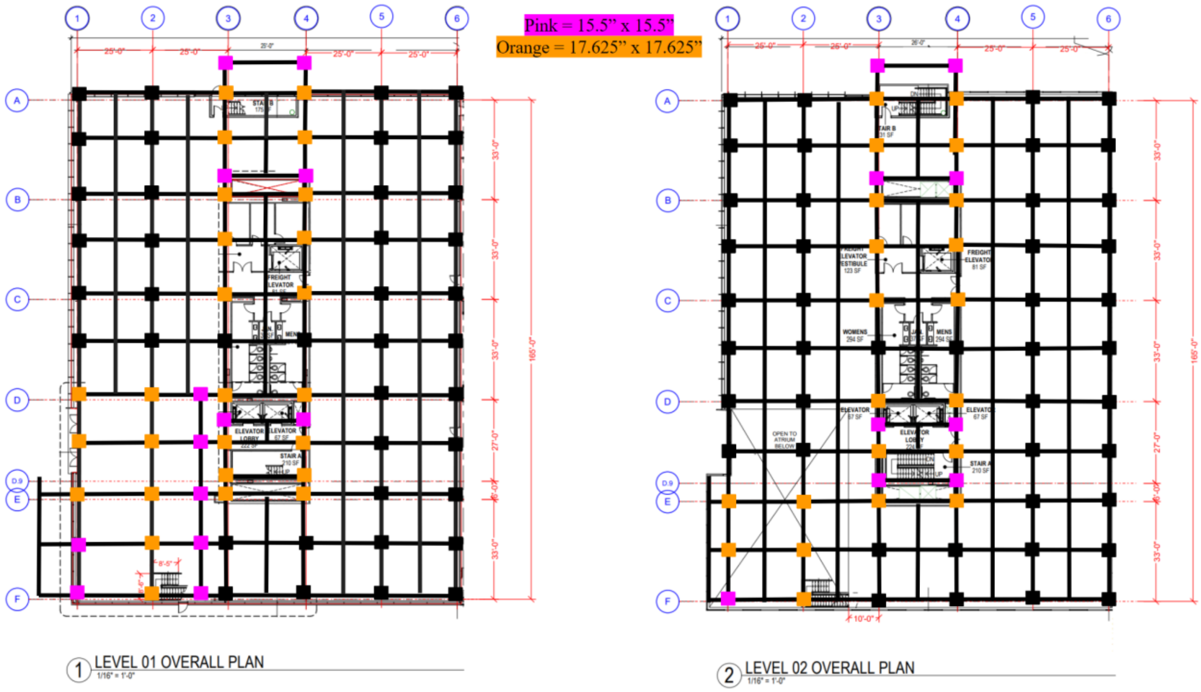
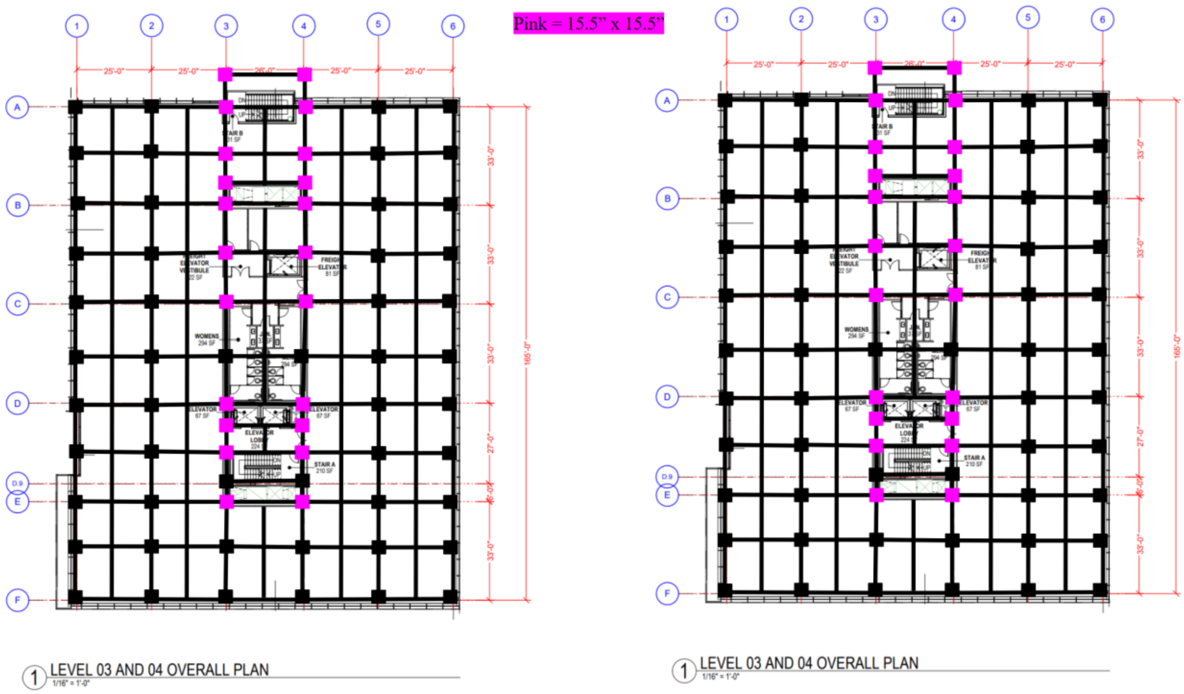


Figure 43: Special Case Columns, level 3 and 4



From the design of Option 2, it was discovered that there would be significantly more material needed to design a building that did not need major structural repairs after a time-equivalent fire. At the point with the most load under the equipment penthouse, the structure took up over 5 feet of ceiling height. Especially on the first floor and under the equipment penthouse, member sizes started to increase past the point of some standard fabrication.

6.4: Option 3: Designed for Class A, with ability to remain Class A after a fire event

Based on the design of option 2 and comparison with option 1, it can be concluded that in order to remain Class A after a time-equivalent fire, member sizes would increase significantly. Following percentages found in the option 2 design, the point that took up over 5 feet of ceiling height would now take up over 6.5 feet of ceiling height, leaving only a 9.5’ clearance. This option would also be more expensive than option 1 or 2.

Chapter 7: Evaluation

A final evaluation of our building and its alternative designs are significant in understanding the impacts of structural engineering decisions. Although, as a client or general contractor, it is important to evaluate the differences in design and how it may impact construction costs and duration. It must also be noted the constructability of a design directly effects the duration of a project. Labor and equipment were not directly included in the evaluation but as the construction project duration increases these factors would increase as well.

7.1: Cost Considerations in Design and Construction

The final cost estimates are shown in Table 7.1.1 and Table 7.1.2. The average market price of CLT was assumed as $21 per cubic foot which considered for the roof, floors, and shear walls in our structural system *CAWBIOM* (2015). The cost of GLT members averaged $0.03 per cubic inch according to *Building Construction Costs with RSMeans Data 2021*.

Table 7.1.1: Summarized Cost Estimate for Building Option 1

Structural Element	**Quantity (total area)**	**Unit Cost**	**Total Cost**
CLT Panels	50,156 ft^3	$21/ft^3	$1,053,266.16
GLT Beams	23,452,673 in^3	$0.03/in^3	$703,580.18
GLT Columns	7,044,257 in^3	$0.03/in^3	$211,327.72
		TOTAL	**$1,968,174.05** **$23.67 per sqft**

When determining the post-fire cost of repairs for building option 1, each mass timber element had major structural damage. For the CLT floors, roof, and walls it was safe to assume one lamination had been charred off and stripped equaling a total of 2.75 inches removed. To replace these laminations after a fire event costs upwards of $370,221. For the glue laminated beams and columns, there was significant damage where nearly every member would need to be replaced post-fire to withstand any occupancy load. In the case of repairing the building back to its initial Class A requirements, the GLT replacement would cost nearly the same as the original of $914,908. In addition to these structural components, the original FRR would require full replacement of all gypsum wall board.

Table 7.1.2: Summarized Cost Estimate for Building Option 2			
Structural Element	**Quantity (total area)**	**Unit Cost**	**Total Cost**
CLT Panels	56,340 ft^3	$21/ft^3	$1,183,140.66
GLT Beams	53,199,840 in^3	$0.03/in^3	$1,593,595.19
GLT Columns	10,789,895 in^3	$0.03/in^3	$323,696.86
		TOTAL	**$3,100,432.71** **$32.28 per sqft**

For the third building option, the structural elements and respective costs were statistically analyzed through a box-and-whisker chart to determine the scale up values.

7.2: Constructability of a Mass Timber Building

In comparison to standard construction materials such as concrete and steel, mass timber has a wide range of capabilities. The fabrication process for CLT ensures precision through Computer Numerical Controlled (CNC) machines which contributes to quicker completion for delivery on-site. Additionally, with the precut panels, safety increases and less demand for skilled laborers can be factored in labor costs. Stacked framing was utilized in the structural design phase which assisted in the freedom of mechanical, electrical, plumbing, and fire protection equipment to move throughout the building. The last constructability consideration was with the transportation of materials from the NORDIC mill in the region of Quebec, Canada to the on-site delivery of materials in Worcester, MA. Both CLT and glulam elements were sized appropriately to fit standard transportation vehicles under 53 feet in length and 8.5 foot width. The weight limit of a 5-axle semi-trailer is just over 25 tons in the United States which limits the number of materials delivered on-site at a time. Additionally, the route of delivery must be considered to accommodate local highway and motor carrier regulations. On-site considerations include wrapping all six sides of the mass timber and place on skids to account for thermal and moisture protection *FPInnovations* (2019).

Chapter 8: Conclusion

The four original objectives were completed for this project. The first objective was completed through the challenging building layout with the atrium and significant weight of the rooftop penthouse alongside all gravitational and lateral loading effects. The second objective was completed through fire analysis and evaluation of damage. The third objective was completed through the redesign of not only one but two alternative buildings considering different occupancy cases. The fourth and final objective was completed with a final cost estimate of the alternative structural designs and post-fire respective repair costs. In conclusion, building option two was the most cost effective for repairs and preventative measures.

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Appendix A: Project Proposal

Cross-Laminated Timber and Structural Resilience

A Major Qualifying Project

Submitted on:

March 4th, 2022

Submitted to:

Project Advisor: Professor Leonard D. Albano, Civil and Environmental Engineering, WPI

Submitted by: Stephanie A. Bishop, Civil Engineering

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Table of Contents

Capstone Design Statement

Worcester Polytechnic Institute requires all capstone design projects to meet ABET (Accreditation Board for Engineering and Technology) standards. At WPI, the Major Qualifying Project (MQP) is a high level research project that addresses a problem found in a student's professional discipline. This MQP will design a four-story office building constructed of Cross-Laminated Timber (CLT) and glue-laminated timber (Glulam). This design will address a fire analysis of CLT and a more structural resilient design of the building will be completed. A cost-benefits analysis will be provided for the two designs. The following constraints were identified based on the following categories: Economic, Social, Political, Health & Safety, Manufacturability, Sustainability, and Ethics.

Economic

To address the economic constraint of our capstone design we will compare the cost of our building designed to the current code standard, the cost of our fire repairs, and the cost of the structural resilient building design. We will look at the cost of the materials, manufacturing, transportation, labor, and construction time. In addition, we will consider the market flux of CLT.

Social

To address the social constraints of our capstone design we will be demystifying the public stigma that wood and timber materials are less fire resistant than other common construction materials.

Health & Safety

To address the health and safety constraints of our capstone design, we will utilize current building codes and requirements during our design. We ensure that fire protection materials and the building height and area are sufficient for a Type IV-B office building.

Manufacturability

To address manufacturability constraints of our capstone design, we will consider the location and accessibility of CLT manufacturers in North America, including analyzing which regions have better access to CLT than others with the few current manufacturer locations. We will use standard sections of CLT with section cutouts that are easily prefabricated with CNC machines. We will also take into account availability of wood in the current climate, as the COVID-19 pandemic has created various material shortages.

Sustainability

To address the sustainability constraints of our capstone design, we will be using CLT as our main design material. CLT produces less greenhouse gasses, less waste, significantly lighter when compared to concrete, and has faster construction times than both concrete and steel.

Ethics

To maintain an ethical approach, we will conduct ourselves with integrity and professionalism and use our project to advance the health, safety, and welfare of the public. We will consider both the socioeconomic and health impacts of the growth of CLT on society. We will also utilize the principles of sustainable development in our designs, act professionally to clients, communicate potential issues, and adequately credit the previous extensive research on CLT.

Chapter 1: Introduction

Cross-Laminated Timber (CLT) is a type of prefabricated solid wood panel that consists of crosswise layers of kiln-dried lumber board. After CLT was first patented in 1985 in France, the concept spread across Europe. After refining press technology between 1995-1996, the first multi-story building was constructed in Austria by 1998. CLT started to make an appearance within the United States in 2013 (American Wood Council, 2017). Since then, CLT has grown rapidly throughout the United States. However, there is hesitation to construct multi-story buildings out of wood because of historical events that resulted in mass fire damage to wood structures.

The goal of this project is to design a CLT office building, present the client with a fire resistance evaluation, design an option for advanced structural resilience, and provide a repair scope and cost-benefit analysis for each option. We will be designing a four story Type IV-B office building in Massachusetts based on a case study provided to us from the project sponsor.

To help us achieve our goal, we have identified 4 objectives:

Objective 1: *Design a Type IV-B CLT Office Building*

Objective 2: *Evaluate Fire Resilience and Repair Options of Building*

Objective 3: *Design a CLT Office Building for Advanced Structural Resilience*

Objective 4: *Cost Analysis of Building Options*

The first phase of this project is the design of a Type IV-B CLT office building. This will be our base design used to evaluate the fire resilience of the office building. The fire resilience evaluation will consider fire exposure and damage, charring, repairs, and post-fire capacity. Our second design will also be a Type IV-B CLT office building, but will be designed for advanced structural resilience. Finally, we will present two CLT office designs and the cost of multiple fire repair options.

Chapter 2: Background

2.1: The Growth of CLT

During the early 2000s, CLT production and usage increased significantly in Europe due to its energy efficiency. This led to the construction of over 500 CLT buildings within England alone. One notable project was the first “timber tower”, Murray Grove, which was constructed in Hackney, London in 2009. This nine story residential building was completely constructed with mass timber and featured a tight honeycomb design using CLT structural panels. This building paved the way for the potential of CLT as an environmentally sustainable and financially viable solution within construction, especially in urban areas. The use of CLT for Murray Grove allowed a faster project schedule by 30% (total of 49 weeks), saved 300 metric tons of CO2, and provided 29 fully insulated and soundproof apartment units simply by avoiding the use of precast concrete and other standard construction materials (Waughthistleton.com, 2021; American Wood Council, 2017). As of June 2021, there have been 1,169 mass timber projects in the United States, 249 of which are in construction or built and 365 in design (see Figure 1) (WoodWorks - Wood Products Council, 2021).

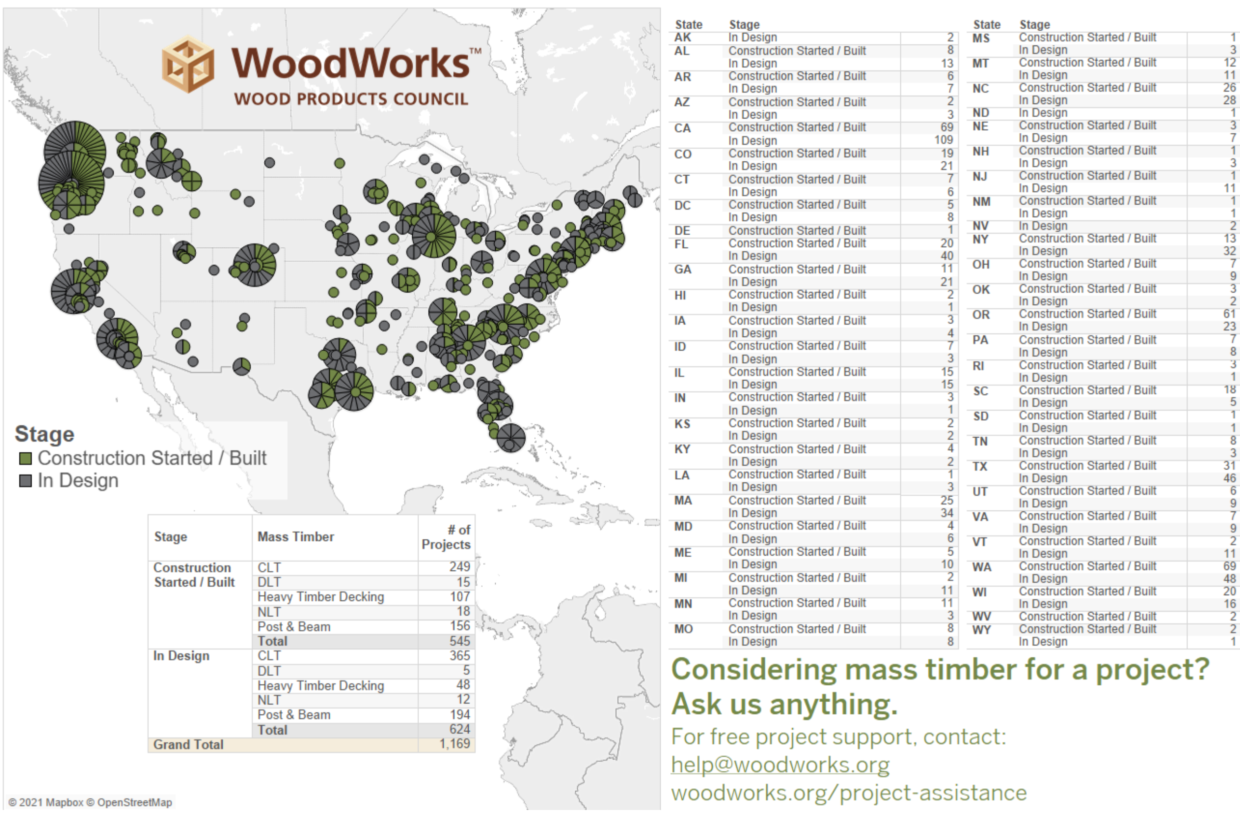

Figure 1: Mass Timber Projects in Design and Constructed in the US (June 2021)

CLT has many benefits compared to standard construction materials such as steel, concrete, and masonry. The carbon emissions from the production of CLT is 50% of what is required for concrete and a shocking 1% of what is required for steel production. Since CLT does not have an abundance of production facilities in the United States, the carbon emissions for travel are far more. However, they still do not reach the emission level of concrete or steel (The B1M, 2017). Another advantage of CLT is the minimal waste during production, due to the ability to reuse sawdust, timber cutouts, and other byproducts. CLT is very energy efficient in performance, with an R-value of 1.25 per inch of thickness. For seismic performance, it is more forgiving due to its ability to flex without losing structural stability. It also provides high performing acoustics, especially with an added acoustic mat layer, which is beneficial for urban construction. Besides the performance and environmental benefits, CLT is 75% lighter than concrete which can reduce groundwork costs for buildings. It also has a significantly lower construction time because panels are prefabricated, so they can be installed immediately on site. This is especially beneficial for urban areas with minimal on-site storage of materials, because the panels can be produced and transported the day they are needed (Landreman, Archie, and WoodWorks - Wood Products Council, 2017). CLT has grown significantly and has many benefits, but the common misconception of all wood as unsafe for fire conditions causes hesitation.

2.2: Design of Cross-Laminated Timber

Cross-Laminated Timber, or "CLT' is made up of layers, or laminations, that are generally stacked crosswise with the direction of fiber 90 degrees to the previous. An illustration of a sample CLT panel is shown at right in Figure 2. Pairs of parallel layers can be included at the core or the outer layer for special applications. Layers are glued with structural adhesive. To create CLT panels, individual boards are finger jointed and glued. Odd numbers of layers are used so that both outer layers of wall panels can be oriented parallel to the vertical load path axis to maximize vertical load capacity in wall panels. For floor and roof panel systems, outer layers are oriented parallel to the span axis. Most commonly, CLT panels are composed of three, five, and seven layers (FPInnovations, 2013). Three and five layer panels are the most accessible to produce and are the most readily available from manufacturers.

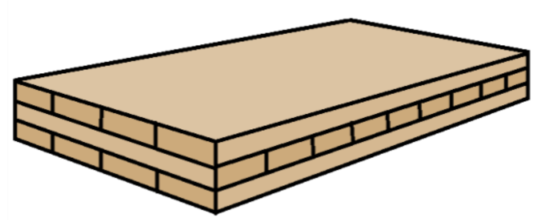

Figure 2: Sample CLT Panel Illustration

When designing CLT structures, one important factor is the material constraint. For Nordic X-Lam Cross-Laminated Timber, the maximum dimensions of panels are

106.25"(8.854') x 64' (Nordic Structures, 2020). Standard layup combinations for Nordic X-Lam are listed in Table 1 seen below.

Nordic X-Lam Panel	Longitudinal Layer Thickness	Transverse Layer Thickness	Layup Combination	Total Thickness
89-3s	35 mm = 1-⅜ in	19 mm = ¾ in	L-T-L	89 mm = 3 ½ in
105-3s	35 mm = 1-⅜ in	35 mm = 1-⅜ in	L-T-L	105 mm = 4 ⅛ in
143-5s	35 mm = 1-⅜ in	19 mm = ¾ in	L-T-L-T-L	143 mm = 5 ⅝ in
175-5s	35 mm = 1-⅜ in	35 mm = 1-⅜ in	L-T-L-T-L	175 mm = 6 ⅞ in
197-7s	35 mm = 1-⅜ in	19 mm = ¾ in	L-T-L-T-L-T-L	197 mm = 7 ¾ in
213-7l	35 mm = 1-⅜ in	19 mm = ¾ in	L-L-T-L-T-L-L	213 mm = 8 ⅜ in
244-7s	35 mm = 1-⅜ in	35 mm = 1-⅜ in	L-T-L-T-L-T-L	244 mm = 9 ⅝ in
244-7l	35 mm = 1-⅜ in	35 mm = 1-⅜ in	L-L-T-L-T-L-L	244 mm = 9 ⅝ in
267-9l	35 mm = 1-⅜ in	19 mm = ¾ in	L-L-T-L-T-L-T-L-L	267 mm = 10 ½ in

Table 1: Nordic X-Lam Standard Panel Layup Combinations (Nordic Structures, 2020)

CLT has a light unit-weight, so vibration and deflection often determine allowable spans, rather than bending or shear. Much of CLT design includes balancing panel capacity with desired interior clear height, as a larger required number of laminations lowers clear height (McLain, Ricky, and Greg Kingsley, 2020).

Another important factor in CLT design is grid efficiency. The most efficient grid designs of CLT often differ from that of steel or concrete. On average, CLT square floor grids are sized between 20' x 20' and 30'x 30', and rectangular grids are sized between 10'x 20' and 20'x 32'. Grids are generally made with glulam girders supporting CLT panels. When designing a larger square grid, intermediate glulam purlins can be utilized, but these usually are not needed in rectangular grids. There are also alternative grid solutions that account for challenges such as MEP placement and unusual required spans. One alternative that has been previously utilized included 2 layers of CLT panels running perpendicular to each other, providing room for MEP structures and negating the need for glulam girders. For larger spans, a composite system of mass timber with a concrete topping or a combination system of CLT floor panels and parallel glulam beams could be utilized (McLain, Ricky, and Greg Kingsley, 2020).

The final important factor for CLT building design is the type of member connections. There are many types of CLT connections, and different options may offer different advantages. Factors to consider in CLT connection designs are load transfer, cost-effectiveness, aesthetic impact, height impact, and crushing or shrinkage leading to differential material movement. Additionally, the connection must have the same fire resistance as the members (McLain, Ricky, and Greg Kingsley, 2020).

2.3: Building Codes

According to the 2021 IBC, there are five construction types. The construction types include I, II, III, IV, and V. Of these, there are further specification categories (see figure below - eg: A, B, C, HT). The purpose of these classification types is to evaluate and define the severity of building material combustibility and the fire resistance rating of its building elements. Each construction type has a different fire resistance rating (FRR) requirement per building element. Different elements such as bearing walls or floors receive higher or lower classifications (see Figure 3) (Codes.iccsafe.org, Oct. 2020).

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b, c]	1[b, c]	0[c]	1[b, c]	0	3[a]	2[a]	2[a]	HT	1[b, c]	0
Bearing walls												
Exterior[e, f]	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	3	2	2	1/HT[g]	1	0
Nonbearing walls and partitions Exterior	See Table 705.5											
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	HT	1	0
Roof construction and associated secondary structural members (see Section 202)	1 1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	1 1/2	1	1	HT	1[b,c]	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.
b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members in roof construction shall not be required, including protection of primary structural frame members, roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.
c. In all occupancies, heavy timber complying with Section 2304.11 shall be allowed for roof construction, including primary structural frame members, where a 1-hour or less *fire-resistance rating is required*.
d. Not less than the fire-resistance rating required by other sections of this code.
e. Not less than the fire-resistance rating based on fire separation distance (see Table 705.5).
f. Not less than the fire-resistance rating as referenced in Section 704.10.
g. Heavy timber bearing walls supporting more than two floors or more than a floor and a roof shall have a *fire resistance* rating of not less than 1 hour.

Figure 3: Fire-Resistance Rating Requirements for Building Elements (Table 601 IBC, 2021)

For our case study building, we will initially focus on a two-hour rating for a Type IV-B office building. Type IV-B was selected because it allows for a four story building, but doesn't require fire resistance ratings that are impractical for standard CLT construction. The height and square footage for our four story case-study building is 64 feet high and just under an 80,250 square foot area. Our building features an atrium to the second floor and a rooftop penthouse with stair and elevator access. The rooftop penthouse is 6,790 square feet with a height of 19 feet. According to the 2021 IBC, rooftop penthouses cannot exceed a third of the square area of the supporting roof deck and cannot exceed a height of 18 feet. However, there is an exception for penthouses that include an elevator to have a maximum height of 28 feet, hence our building is compliant. Our building is also within the 2021 IBC limit for Type IV-B buildings by a significant margin because we will include an automatic sprinkler system. By including an automatic sprinkler system, our building can be up to 12 stories with a total height of 180 ft and a 216,000 total square footage area (WoodWorks - Wood Products Council, et al., 2019).

2.4: CLT and Fire

For this case study, we will be analyzing a fire that occurs in a 4-story office building. The number one cause of office fires is cooking equipment, which accounts for 29% of all office fires. Other causes of office fires include electrical distribution and lighting equipment, heating equipment, intentional, smoking materials, exposure, and electronic or entertainment equipment. The peak times of days for office fires were between noon and 2:00 PM. This is the time of day where the greatest number of people are in the office. However, fires that occur between 7:00 PM and 7:00 AM cause the greatest amount of property damage. Improving automatic detection systems, extinguishing equipment, and the fire resistance rating prevent further damage to be caused to the building (“NFPA Report”).

Fire resistance rating (FRR) is the ability of a material to confine fire, continue to provide a structural function during fire, or both (International Code Council, 2021). The FRR is measured from the start of the fire until the material fails to function. Fire resistance of CLT depends upon the number of layers, thickness, adhesive, and panel assembly. Often, noncombustible materials are applied to mass timber to increase the FRR. Wall and floor assemblies that are made of CLT and exposed and covered with non-combustible material can provide up to a 3 hour FRR (Pogue, 2021). CLT’s fire resistance is provided through charring. The charring of CLT is different from other timber panels due to the number of layers, glue composition, and joints. Charring is when a timber panel is exposed to a fire greater than 400 degrees C and causes the timber to ignite and burn at a steady rate. As the timber continues to burn, the char becomes an insulating layer. This layer protects the unburnt core of the panel and prevents an excess rise in temperature (“GreenSpec: Cross-Laminated”).

Fire Dynamics Simulator (FDS) and Consolidated Model of Fire and Smoke Transport (CFAST) are the two main fire simulation software in use today. FDS is a Computational Fluid Dynamics (CFD) model of fire-driven fluid flows. It is most appropriate for simulations of low-speed, thermally-driven flow, with an emphasis on smoke and heat transfer from fires. CFAST is a two-zone fire model. It is best used to calculate the evolving distribution of smoke, fire gases and temperature throughout compartments of a building during a fire. From both softwares, a heat transfer model can be developed. This can be used to determine thermal gradients of the wood elements, and the impacts on the structural capacity. For the sake of our project, we will not be using fire simulation software. Instead we will borrow parametric models and equations from literature, such as Figure 4, 5, and 6 shown below, to analyze various fire scenarios. This alternative is best suited for our short time frame to complete this project (NIST, 2011).

Table 16.2.1B Effective Char Depths (for CLT with β_n = 1.5in./hr.)

Required Fire Resistance (hr.)	Effective Char Depths, a_{eff} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

Figure 4: Effective Char Depths for CLT

Step	Floor Design
Lamination fall-off time	$t_{fo} = \left(\frac{h_{lam}}{\beta_n}\right)^{1.23}$
Calculation of the effective char depth	$a_{char} = 1.2[n_{lam} \cdot h_{lam} + \beta_n(t - (n_{lam} \cdot t_{fo}))^{0.813}]$
Determination of effective residual cross-section	$h_{fire} = h - a_{char}$
Determination of location of neutral axis and section properties of the effective residual cross-section	$\underline{y} = \frac{\Sigma y_i h_i}{\Sigma h_i}$ $I_{eff} = \Sigma \frac{b_i {h_i}^3}{12} + \Sigma b_i h_i {d_i}^2$
Calculation of design resisting moment	$S_{eff} = \frac{I_{eff}}{h_{fire} - \underline{y}}$ $M' = K F_b S_{eff}$

Figure 5: Char Equations for Floor Design

Step	Wall Design
Lamination fall-off time	$t_{fo} = \left(\frac{h_{lam}}{\beta_n}\right)^{1.23}$
Calculation of the effective char depth	$a_{char} = 1.2\beta_n t^{0.813}$
Determination of effective residual cross-section	$h_{fire} = h - a_{char}$
Determination of location of neutral axis and section properties of the effective residual cross-section	$\underline{y} = \frac{\Sigma y_i h_i}{\Sigma h_i}$ $I_{eff} = \Sigma \frac{b_i {h_i}^3}{12} + \Sigma b_i h_i {d_i}^2$ $A_{eff} = \Sigma b_i h_i$
Calculation of resisting axial compression capacity	$S_{eff} = \frac{I_{eff}}{h_{fire} - \underline{y}}$ $M' = K F_b S_{eff}$

Figure 5: Char Equations for Wall Design

When CLT is damaged in a fire, there are multiple ways of fixing or replacing it. When charing is localized and can be removed with sanding, scraping, or abrasive blasting. This is done for minor fire damage and if the structural integrity can remain intact. If small areas are damaged they can be repaired with equivalent wood sections, such as sections around doors or windows (Ranger, Lindsay, et al, 2019). If the char or fire damage impacts multiple layers of the CLT it is best to replace all layers affected. One solution is to remove and clean the damaged portions and replace it with new laminations attached with adhesive. This solution does not restore full structural capacity of the CLT panel, but it does restore the FRR. Another option is to remove the damaged portions and replace them with new laminations attached with adhered and screwed scarf joints or adhered only. This option reestablishes pre-fire structural capacity, maintains exposed CLT, and restores FRR ("*Post-Fire Restoration,*" 2018).

Our case study building will have some form of automatic sprinklers. Sprinklers are used as a means of active fire suppression, but can be a balance between fire damage and damage from excess water discharge. Accidental or excess water discharge from sprinklers can result in frozen pipes, mechanical damage, installation defects, or corrosion of sprinkler elements. This water can adversely affect the wood structure and cause moisture damage. A high moisture content can affect the strength and stiffness, and lead to decay or mold. CLT does not absorb water very quickly and would only be an issue for prolonged water exposure. This exposure can be limited by concrete toppings which protect the wood from direct water contact (Ranger, Lindsay, et al, 2019).

Chapter 3: Methodology

Goal: Design a CLT office building, present the client with a fire resistance evaluation, design an option for advanced structural resilience, and provide a repair scope and cost-benefit analysis for each option.

Objective 1: Design a Type IV-B CLT Office Building

Steps	Scope	References
Option A: Office Building Design (Type IV-B)	● Design floors, walls, and ceilings with CLT based on floor plans provided by sponsor - For Class A office rating requirements ○ Design for gravitational and vertical loads ○ Design for lateral loads ○ Design Foundations ● Use glulam for beams and columns ● Complete design calculations ○ Check design calculations with Excel/Risa	● Sponsor provided building floor plans ● IBC 2021 ○ 2303.1.4 ○ 2304.11.3.1 ○ 2304.11.4.1 ○ 2305 ○ 2306 ○ 2307 ● CLT Handbook ○ Example problems ● ANSI/APA PRG 320 - manufacturing Standard for Performance Rated CLT ○ Nordic website ○ Adhesive types ○ Variable key ● AWC NDS Chapter 10, AWC Manual M10, SDPWS ○ Equations and tables for CLT ○ Wind - lateral forces ● ASCE 7-10 ○ Minimum design loads (ASD vs LRFD), factors
Office building economic cost	● Calculate total cost of construction and materials	● Nordic Material Costs / website ● Engineering News Record ○ Material and standard labor costs

Objective 2: Evaluate Fire Resilience and Repair Options of Building

Steps	Scope	References

Office Building fire damage evaluation	• Establish time equivalence for the fire exposure and location
	• Recalculate loading
	  ○ Excel and Graphs
		• AWC NDS Specification: Chapter 16
		  ○ Connections and design procedures for timber
		• CLT Design Manual
		  ○ Examples 4.1.8 and 4.1.9
		  ○ Flooring and wall assembly fire examples - post-fire loads

Discuss on post-fire options	• Assess fire damage and charring
	• Recalculate loading
	• Discuss repair options:
	  ○ Stripping the char
	  ○ Replacing layers with various methods
	  ○ Exposed CLT options for lower classification
	  ○ Connection options to assist in fire resilience and repairs
		• AWC Powerpoint
		• Sprinkler Damage

Objective 3: Design a CLT Office Building for Advanced Structural Resilience

Steps	Scope	References

Design for structural resilience	• Design floors, walls, and ceilings with CLT based on floor plans provided by sponsor - For above Class A office rating requirements
	  ○ Design for gravitational and
		• Sponsor provided building floor plans
		• IBC 2021
		  ○ Chapter 23
		• CLT Handbook
		  ○ Example problems
		• ANSI
		  ○ Nordic website

	vertical loads ○ Design for over Class A office so it will remain class A post-fire ● Use glulam for beams and columns ● Complete design calculations ○ Check design calculations with Excel/Risa	● AWC NDS ○ Equations for CLT ● ASCE 7-10 ○ Minimum design loads (ASD vs LRFD)

Objective 4: Cost Analysis of Building Options

Steps	Scope	References
To code cost of repair to desired building classification (Type IV-B repaired to Type IV-B)	● Determine repair options for scope of damage ● Determine cost of repairs	● Engineering News Record ● AWC Powerpoint
To code cost of repair to closest* building classification (Type IV-B cosmetic repair to lower building type)	● Assess the damage and cosmetic repairs ● Determine the new building classification	● Engineering News Record ● AWC Powerpoint
Structurally resilient design option economic cost (Type IV-A)	● Determine cost of preventative options to minimize damage	● CLT Handbook ● IBC 2021
Conclusion	● Economic summary and cost breakdown of each option	● CLT Handbook ● IBC 2021

*Closest building code relates to the amount of fire damage and the cost required for the building to be a lower code classification.

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Appendix B: Mass Timber Calculations

Calculation Results - Joist

Number (if special)	Floor	Section	Length 1	Length 2	Length 3	CLT Tributary Areas 1 (ft)	CLT Tributary Area 2 (ft)	CLT weight	b (in)	d (in)	Practical b (in)	Practical d (in)
4-1	4th floor ceiling	Edge	16.5			4.6875		11.1	9.5	13.5	11.5	13.5
4-2	4th floor ceiling	Middle	16.5			15.625		11.1	11.5	15.5	11.5	15.5
4-3	4th floor ceiling	larger clt outer edge	16.5			9.375		13.1 avg	11.5	13.5	11.5	13.5
4-4	4th floor ceiling	larger clt 12.5 middle	16.5			15.625		15.1	11.5	15.5	11.5	15.5
4-5	4th floor ceiling	Penthouse 13 edge	16.5			9.5625		15.1	11.5	19.5	11.5	19.5
4-6	4th floor ceiling	Penthouse 13 middle	16.5			16.25		15.1	11.5	23.5	11.5	23.5
4-2s	4th floor ceiling	special case A-B, 3-4 upper edges (2x)	16.5	8		9.5625	0	15.1	11.5	15.5	11.5	15.5
4-3s	4th floor ceiling	special case A-B, 3-4 lower edges (2x)	10.5	6		9.5625	4.6875	15.1	11.5	11.5	11.5	11.5
4-4s	4th floor ceiling	special case A-B, 3-4 short middle	10.5			16.25		15.1	11.5	15.5	11.5	15.5
4-6s	4th floor ceiling	special case B-C, 3-4 right edge	16.5			9.5625	4.6875	15.1	11.5	17.5	11.5	17.5
4-5s	4th floor ceiling	special case B-C, 3-4 middle	16.5			16.25	6.5	15.1	11.5	19.5	11.5	19.5
4-7s	4th floor ceiling	special case D, 3-4 elevator edges	8.25			4.6875		15.1	9.5	11.5	9.5	11.5
4-8s	4th floor ceiling	special case D, 3-4 lobby edges	8.25			9.5625		15.1	11.5	11.5	11.5	11.5
4-9s	4th floor ceiling	special case D, 3-4 stair edges	6	10.5		4.6875		15.1	9.5	11.5	9.5	11.5
4-10s	4th floor ceiling	special case D, 3-4 short middle	8.25			16.25		15.1	11.5	13.5	11.5	13.5
3-1	3rd floor ceiling	Outer Edge	16.5			4.6875		15.1	9.5	11.5	11.5	13.5
3-2	3rd floor ceiling	Middle	16.5			15.625		15.1	11.5	17.5	11.5	17.5
3-3	3rd floor ceiling	12.5 Inner Edges	16.5			9.375		15.1	11.5	15.5	11.5	15.5
3-4	3rd floor ceiling	12.5 Middle	16.5			15.625		15.1	11.5	17.5	11.5	17.5
3-5	3rd floor ceiling	13 Outer Edge	16.5			9.5625		15.1	9.5	15.5	11.5	15.5
3-6	3rd floor ceiling	13 Middle	16.5			16.25		15.1	11.5	17.5	11.5	17.5
3-2s	3rd floor ceiling	special case A-B, 3-4 upper edges (2x)	16.5	8		4.78125	0	15.1	11.5	15.5	11.5	15.5
3-3s	3rd floor ceiling	special case A-B, 3-4 lower edges (2x)	10.5	6		9.5625	4.6875	15.1	11.5	11.5	11.5	11.5
3-4s	3rd floor ceiling	special case A-B, 3-4 short middle	10.5			16.25		15.1	11.5	13.5	11.5	13.5
3-6s	3rd floor ceiling	special case B-C, 3-4 right edge	16.5			9.5625	4.6875	15.1	11.5	13.5	11.5	13.5
3-5s	3rd floor ceiling	special case B-C, 3-4 middle	16.5			16.25	6.5	15.1	11.5	15.5	11.5	15.5
3-7as	3rd floor ceiling	special case D, 3-4 elevator edges	8.25			4.6875		15.1	9.5	11.5	9.5	11.5
3-8s	3rd floor ceiling	special case D, 3-4 lobby edges	8.25			9.5625		15.1	9.5	11.5	9.5	11.5
3-9as	3rd floor ceiling	special case D, 3-4 stair edges	6	10.5		4.6875		15.1	9.5	11.5	9.5	11.5
3-10s	3rd floor ceiling	special case D, 3-4 short middle	8.25			16.25		15.1	11.5	11.5	11.5	11.5
2-1	2nd floor ceiling	Outer Edge	16.5			4.6875		15.1	9.5	11.5	11.5	13.5
2-2	2nd floor ceiling	Middle	16.5			15.625		15.1	11.5	17.5	11.5	17.5
2-3	2nd floor ceiling	12.5 Inner Edges	16.5			9.375		15.1	11.5	15.5	11.5	15.5
2-4	2nd floor ceiling	12.5 Middle	16.5			15.625		15.1	11.5	17.5	11.5	17.5
2-5	2nd floor ceiling	13 Outer Edge	16.5			9.5625		15.1	9.5	15.5	11.5	15.5
2-6	2nd floor ceiling	13 Middle	16.5			16.25		15.1	11.5	17.5	11.5	17.5
2-2s	2nd floor ceiling	special case A-B, 3-4 upper edges (2x)	16.5	8		4.78125	0	15.1	11.5	15.5	11.5	15.5
2-3s	2nd floor ceiling	special case A-B, 3-4 lower edges (2x)	10.5	6		9.5625	4.6875	15.1	11.5	11.5	11.5	11.5
2-4s	2nd floor ceiling	special case A-B, 3-4 short middle	10.5			16.25		15.1	11.5	13.5	11.5	13.5
2-6s	2nd floor ceiling	special case B-C, 3-4 right edge	16.5			9.5625	4.6875	15.1	11.5	13.5	11.5	13.5
2-5s	2nd floor ceiling	special case B-C, 3-4 middle	16.5			16.25	6.5	15.1	11.5	15.5	11.5	15.5
2-7as	2nd floor ceiling	special case D, 3-4 elevator edges	8.25			4.6875		15.1	9.5	11.5	9.5	11.5
2-8s	2nd floor ceiling	special case D, 3-4 lobby edges	8.25			9.5625		15.1	9.5	11.5	9.5	11.5
2-9as	2nd floor ceiling	special case D, 3-4 stair edges	6	10.5		4.6875		15.1	9.5	11.5	9.5	11.5
2-10s	2nd floor ceiling	special case D, 3-4 short middle	8.25			16.25		15.1	11.5	11.5	11.5	11.5
2-1s	2nd floor ceiling	special case D.9-F, Outside overhang	16.5	16.5	6	3.5		11.1	9.5	11.5	9.5	11.5
2-11s	2nd floor ceiling	special case D.9-F, Inside overhangs	16.5			3.5	4.6875	11.1/15.1	11.5	15.5	11.5	15.5
1-1	1st floor ceiling	Outer Edge	16.5			4.6875		15.1	9.5	11.5	11.5	13.5
1-7	1st floor ceiling	Column Line 3 D-F	16.5			9.875		15.1	11.5	15.5	11.5	15.5
1-8	1st floor ceiling	Edge of Walkway	16.5			5		15.1	9.5	11.5	11.5	13.5
1-2	1st floor ceiling	Middle	16.5			15.625		15.1	11.5	17.5	11.5	17.5
1-3	1st floor ceiling	12.5 Inner Edges	16.5			9.375		15.1	11.5	15.5	11.5	15.5
1-4	1st floor ceiling	12.5 Middle	16.5			15.625		15.1	11.5	17.5	11.5	17.5
1-5	1st floor ceiling	13 Outer Edge	16.5			9.5625		15.1	9.5	15.5	11.5	15.5
1-6	1st floor ceiling	13 Middle	16.5			16.25		15.1	11.5	17.5	11.5	17.5
1-2s	1st floor ceiling	special case A-B, 3-4 upper edges (2x)	16.5	8		4.78125	0	15.1	11.5	15.5	11.5	15.5
1-3s	1st floor ceiling	special case A-B, 3-4 lower edges (2x)	10.5	6		9.5625	4.6875	15.1	11.5	11.5	11.5	11.5
1-4s	1st floor ceiling	special case A-B, 3-4 short middle	10.5			16.25		15.1	11.5	13.5	11.5	13.5
1-6s	1st floor ceiling	special case B-C, 3-4 right edge	16.5			9.5625	4.6875	15.1	11.5	13.5	11.5	13.5
1-5s	1st floor ceiling	special case B-C, 3-4 middle	16.5			16.25	6.5	15.1	11.5	15.5	11.5	15.5
1-7as	1st floor ceiling	special case D, 3-4 elevator edges	8.25			4.6875		15.1	9.5	11.5	9.5	11.5
1-7bs	1st floor ceiling	special case D, 3-4 elevator edges	8.25			5		15.1	9.5	11.5	9.5	11.5
1-8as	1st floor ceiling	special case D, 3-4 lobby edges	8.25			9.5625		15.1	9.5	11.5	9.5	11.5
1-8bs	1st floor ceiling	special case D, 3-4 lobby edges	8.25			6.75		15.1	9.5	9.5	9.5	11.5
1-9as	1st floor ceiling	special case D, 3-4 stair edges	6	10.5		4.6875		15.1	9.5	11.5	9.5	11.5
1-9bs	1st floor ceiling	special case D, 3-4 stair edges	6	10.5				15.1	9.5	11.5	9.5	11.5
1-10s	1st floor ceiling	special case D, 3-4 short middle	8.25			16.25		15.1	11.5	11.5	11.5	11.5
1-1s	1st floor ceiling	special case D.9-F, outside overhang	16.5	16.5	6	3.5		11.1	9.5	11.5	9.5	11.5
1-11s	1st floor ceiling	special case E-F, 3	16.5			9.875		15.1	11.5	17.5	11.5	17.5
1-12s	1st floor ceiling	special case E-F, walkway	16.5			5		15.1	11.5	13.5	11.5	13.5
1-13s	1st floor ceiling	special case D.9-F, inside overhangs	16.5			3.5		11.1	9.5	11.5	9.5	11.5
1-14s	1st floor ceiling	Lobby middle joists	16.5			15.625		11.1	9.5	11.5	9.5	11.5

Calculation Results – Girders

Number	Floor	Section	Length 1	Length 2	Girder Tributary Width	Girder Tributary Width 2	b (in)	d (in)	Practical b (in)	Practical d (in)
4-1	**4th floor ceiling**	**1- Ext**	25		8.25		11.5	17.5	**11.5**	**17.5**
4-2	**4th floor ceiling**	**1- Int**	25		16.5		11.5	23.5	**11.5**	**23.5**
4-3	**4th floor ceiling**	**2- Ext**	25		8.25		11.5	17.5	**11.5**	**17.5**
4-4	**4th floor ceiling**	**2- Int**	25		16.5		11.5	23.5	**15.5**	**19.5**
4-5	**4th floor ceiling**	**3- Ext**	26		8.25		11.5	25.5	**11.5**	**25.5**
4-6	**4th floor ceiling**	**3- Int**	26		16.5		17.5	29.5	**17.5**	**29.5**
4-7	**4th floor ceiling**	**4- Ext**	25		8.25		11.5	17.5	**11.5**	**17.5**
4-8	**4th floor ceiling**	**4- Int**	25		16.5		11.5	23.5	**15.5**	**19.5**
4-9	**4th floor ceiling**	**5- Ext**	25		8.25		11.5	17.5	**11.5**	**17.5**
4-10	**4th floor ceiling**	**5- Int**	25		16.5		11.5	23.5	**11.5**	**23.5**
4-1s	**4th floor ceiling**		26		0		11.5	11.5	**11.5**	**11.5**
4-2s	**4th floor ceiling**		26		8.25		11.5	25.5	**11.5**	**27.5**
4-3s	**4th floor ceiling**		26		13.5		17.625	27.5	**17.625**	**27.5**
4-4s	**4th floor ceiling**		26		5.25		11.5	19.5	**11.5**	**19.5**
4-5s	**4th floor ceiling**	**Same as 4-5**	26		8.25		11.5	25.5	**11.5**	**25.5**
4-6s	**4th floor ceiling**		26		16.5	8.25	11.5	31.625	**15.5**	**27.5**
4-7s	**4th floor ceiling**		26		16.5		17.625	29.5	**17.625**	**29.5**
4-8s	**4th floor ceiling**	**Same as 4-5**	26		8.25		11.5	25.5	**11.5**	**25.5**
4-9s	**4th floor ceiling**		26		4.125		11.5	19.5	**11.5**	**19.5**
4-10s	**4th floor ceiling**		26		4.125+portion	4.125	11.5	19.5	**11.5**	**19.5**
4-11s	**4th floor ceiling**		26		0		any	any	**11.5**	**17.5**
4-12s	**4th floor ceiling**	**Same as 4-5**	26		8.25		11.5	25.5	**11.5**	**25.5**
3-1	**3rd floor ceiling**	**1- Ext**	25		8.25		11.5	21.5	**11.5**	**21.5**
3-2	**3rd floor ceiling**	**1- Int**	25		16.5		11.5	27.5	**11.5**	**27.5**
3-3	**3rd floor ceiling**	**2- Ext**	25		8.25		11.5	21.5	**11.5**	**21.5**
3-4	**3rd floor ceiling**	**2- Int**	25		16.5		11.5	27.5	**11.5**	**27.5**
3-5	**3rd floor ceiling**	**3- Ext**	26		8.25		11.5	21.5	**11.5**	**21.5**
3-6	**3rd floor ceiling**	**3- Int**	26		16.5		11.5	27.5	**11.5**	**27.5**
3-7	**3rd floor ceiling**	**4- Ext**	25		8.25		11.5	21.5	**11.5**	**21.5**
3-8	**3rd floor ceiling**	**4- Int**	25		16.5		11.5	27.5	**11.5**	**27.5**
3-9	**3rd floor ceiling**	**5- Ext**	25		8.25		11.5	21.5	**11.5**	**21.5**
3-10	**3rd floor ceiling**	**5- Int**	25		16.5		11.5	27.5	**11.5**	**27.5**
3-1s	**3rd floor ceiling**		26		0		11.5	11.5	**11.5**	**11.5**
3-2s	**3rd floor ceiling**		26		8.25		11.5	23.5	**11.5**	**23.5**
3-3s	**3rd floor ceiling**		26		13.5		11.5	17.5	**11.5**	**27.5**
3-4s	**3rd floor ceiling**		26		5.25		11.5	11.5	**11.5**	**17.5**
3-5s	**3rd floor ceiling**	**Same as 3-5**	26		8.25		11.5	21.5	**11.5**	**21.5**
3-6s	**3rd floor ceiling**		26		16.5	8.25	15.5	23.5	**15.5**	**23.5**
3-7s	**3rd floor ceiling**		26		16.5		15.5	23.5	**15.5**	**23.5**
3-8s	**3rd floor ceiling**	**Same as 3-5**	26		8.25		11.5	21.5	**11.5**	**21.5**
3-9s	**3rd floor ceiling**		26		4.125		11.5	17.5	**11.5**	**17.5**
3-10s	**3rd floor ceiling**		26		4.125+portion	4.125	11.5	17.5	**11.5**	**17.5**
3-11s	**3rd floor ceiling**		26		0		11.5	17.5	**11.5**	**17.5**
3-12s	**3rd floor ceiling**	**Same as 3-5**	26		8.25		11.5	21.5	**11.5**	**21.5**

2-1	2nd floor ceiling	1- A	25		8.25		11.5	21.5	11.5	21.5
2-2	2nd floor ceiling	1- B-E	25		16.5		11.5	27.5	11.5	27.5
2-3	2nd floor ceiling	2- A, F	25		8.25		11.5	21.5	11.5	21.5
2-4	2nd floor ceiling	2- B-E	25		16.5		11.5	27.5	11.5	27.5
2-5	2nd floor ceiling	3- A, F	26		8.25		11.5	21.5	11.5	21.5
2-6	2nd floor ceiling	3- B-E	26		16.5		11.5	27.5	11.5	27.5
2-7	2nd floor ceiling	4- A, F	25		8.25		11.5	21.5	11.5	21.5
2-8	2nd floor ceiling	4- B-E	25		16.5		11.5	27.5	11.5	27.5
2-9	2nd floor ceiling	5- A, F	25		8.25		11.5	21.5	11.5	21.5
2-10	2nd floor ceiling	5- B-E	25		16.5		11.5	27.5	11.5	27.5
2-1s	2nd floor ceiling				0		11.5	11.5	11.5	11.5
2-2s	2nd floor ceiling				8.25		11.5	23.5	11.5	23.5
2-3s	2nd floor ceiling				13.5		11.5	17.5	11.5	27.5
2-4s	2nd floor ceiling				5.25		11.5	11.5	11.5	17.5
2-5s	2nd floor ceiling	Same as 2-5	26		8.25		11.5	21.5	11.5	21.5
2-6s	2nd floor ceiling		26		16.5	8.25	15.5	23.5	15.5	23.5
2-7s	2nd floor ceiling		26		16.5		15.5	23.5	15.5	23.5
2-8s	2nd floor ceiling	Same as 2-5	26		8.25		11.5	21.5	11.5	21.5
2-9s	2nd floor ceiling		26				11.5	17.5	11.5	17.5
2-10s	2nd floor ceiling		26				11.5	17.5	11.5	17.5
2-11s	2nd floor ceiling		26		0		11.5	17.5	11.5	17.5
2-12s	2nd floor ceiling	Same as 2-5	26		8.25		11.5	21.5	11.5	21.5
2-13s	2nd floor ceiling		25	7	16.5	15.69(weigh	11.5	27.5	11.5	27.5
2-14s	2nd floor ceiling		25	7	16.5		11.5	27.5	11.5	27.5
2-15s	2nd floor ceiling		25	7	8.25		11.5	21.5	11.5	21.5
1-1	1st floor ceiling	1- A	25		8.25		11.5	21.5	11.5	21.5
1-2	1st floor ceiling	1- B-E	25		16.5		11.5	27.5	11.5	27.5
1-3	1st floor ceiling	2- A, F	25		8.25		11.5	21.5	11.5	21.5
1-4	1st floor ceiling	2- B-E	25		16.5		11.5	27.5	11.5	27.5
1-5	1st floor ceiling	3- A, F	26		8.25		11.5	21.5	11.5	21.5
1-6	1st floor ceiling	3- B-E	26		16.5		11.5	27.5	11.5	27.5
1-7	1st floor ceiling	4- A, F	25		8.25		11.5	21.5	11.5	21.5
1-8	1st floor ceiling	4- B-E	25		16.5		11.5	27.5	11.5	27.5
1-9	1st floor ceiling	5- A, F	25		8.25		11.5	21.5	11.5	21.5
1-10	1st floor ceiling	5- B-E	25		16.5		11.5	27.5	11.5	27.5
1-1s	1st floor ceiling				0		11.5	11.5	11.5	11.5
1-2s	1st floor ceiling				8.25		11.5	23.5	11.5	23.5
1-3s	1st floor ceiling				13.5		11.5	17.5	11.5	27.5
1-4s	1st floor ceiling				5.25		11.5	11.5	11.5	17.5
1-5s	1st floor ceiling	Same as 1-5	26		8.25		11.5	21.5	11.5	21.5
1-6s	1st floor ceiling		26		16.5	8.25	15.5	23.5	15.5	23.5
1-7s	1st floor ceiling		26		16.5		15.5	23.5	15.5	23.5
1-8s	1st floor ceiling	Same as 1-5	26		8.25		11.5	21.5	11.5	21.5
1-9s	1st floor ceiling		26		4.125		11.5	17.5	11.5	17.5
1-10s	1st floor ceiling		26		4.125+portion	4.125	11.5	17.5	11.5	17.5
1-11s	1st floor ceiling		26		0		11.5	17.5	11.5	17.5
1-12s	1st floor ceiling	Same as 1-5	26		8.25		11.5	21.5	11.5	21.5
1-13s	1st floor ceiling		10	15	8.25	16.5	11.5	15.5	11.5	15.5
1-14s	1st floor ceiling	Same as 1-1	25		8.25		11.5	21.5	11.5	21.5
1-15s	1st floor ceiling		10	15	16.5	0	9.5	11.5	9.5	11.5
1-16s	1st floor ceiling		25		0		9.5	11.5	9.5	11.5
1-17s	1st floor ceiling		10	15	16.5	0	9.5	11.5	9.5	11.5
1-18s	1st floor ceiling		25	7	8.25	6	11.5	17.5	11.5	17.5
1-19s	1st floor ceiling		10	15	16.5	0	9.5	11.5	9.5	11.5
1-20s	1st floor ceiling		25	7	0		11.5	19.5	11.5	19.5
1-21s	1st floor ceiling		10	15	8.25	0	9.5	11.5	9.5	11.5
1-22s	1st floor ceiling		25	7	8.25		9.5	11.5	9.5	11.5

Calculation Results – Columns

Number	Floor	Section	Height	Left Girder	Right Girder	b (in)	d (in)
4-1	4th floor ceiling	1- Ext	12	N/A	4-1	11.5	11.5
4-2	4th floor ceiling	1- Int	12	N/A	4-2	11.5	11.5
4-3	4th floor ceiling	2- Ext	12	4-1	4-3	11.5	11.5
4-4	4th floor ceiling	2- Int	12	4-2	4-4	11.5	11.5
4-5	4th floor ceiling	3- Ext	12	4-3	4-5	11.5	11.5
4-6	4th floor ceiling	3- Int	12	4-4	4-6	13.625	13.625
4-7	4th floor ceiling	4- Ext	12	4-5	4-7	11.5	11.5
4-8	4th floor ceiling	4- Int	12	4-6	4-8	13.625	13.625
4-9	4th floor ceiling	5- Ext	12	4-7	4-9	11.5	11.5
4-10	4th floor ceiling	5- Int	12	4-8	4-10	11.5	11.5
4-11	4th floor ceiling	6-Ext	12	4-9	N/A	11.5	11.5
4-12	4th floor ceiling	6-Int	12	4-10	N/A	11.5	11.5
4-1s	4th floor ceiling		12	N/A	4-1s	9.5	9.5
4-2s	4th floor ceiling		12	4-3	4-2s	11.5	11.5
4-3s	4th floor ceiling		12	4-4	4-3s	13.625	13.625
4-4s	4th floor ceiling		12	N/A	4-4s	11.5	11.5
4-5s	4th floor ceiling		12	4-4	4-5s	11.5	11.5
4-6s	4th floor ceiling		12	4-4	4-6s	13.625	13.625
4-7s	4th floor ceiling		12	4-4	4-7s	13.635	13.625
4-8s	4th floor ceiling		12	4-4	4-8s	11.5	11.5
4-9s	4th floor ceiling		12	N/A	4-9s	11.5	11.5
4-10s	4th floor ceiling		12	4-4	4-10s	11.5	11.5
4-11s	4th floor ceiling		12	N/A	4-11s	9.5	9.5
4-12s	4th floor ceiling		12	4-4	4-12s	11.5	11.5
4-13s	4th floor ceiling		12	4-6s	4-8	13.625	13.625
4-14s	4th floor ceiling		12	4-7s	4-8	13.625	13.625
3-1	3rd floor ceiling	1- Ext	12	N/A	3-1	11.5	11.5
3-2	3rd floor ceiling	1- Int	12	N/A	3-2	11.5	11.5
3-3	3rd floor ceiling	2- Ext	12	3-1	3-3	11.5	11.5
3-4	3rd floor ceiling	2- Int	12	3-2	3-4	13.625	13.615
3-5	3rd floor ceiling	3- Ext	12	3-3	3-5	13.625	13.615
3-6	3rd floor ceiling	3- Int	12	3-4	3-6	13.625	13.615
3-7	3rd floor ceiling	4- Ext	12	3-5	3-7	13.625	13.625
3-8	3rd floor ceiling	4- Int	12	3-6	3-8	13.625	13.625
3-9	3rd floor ceiling	5- Ext	12	3-7	3-9	11.5	11.5
3-10	3rd floor ceiling	5- Int	12	3-8	3-10	13.625	13.625
3-11	3rd floor ceiling	6-Ext	12	3-9	N/A	11.5	11.5
3-12	3rd floor ceiling	6-Int	12	3-10	N/A	11.5	11.5
3-1s	3rd floor ceiling		12	N/A	3-1s	9.5	9.5
3-2s	3rd floor ceiling		12	3-3	3-2s	13.625	13.625
3-3s	3rd floor ceiling		12	3-4	3-3s	13.625	13.625
3-4s	3rd floor ceiling		12	N/A	3-4s	11.5	11.5
3-5s	3rd floor ceiling		12	3-4	3-5s	13.625	13.625
3-6s	3rd floor ceiling		12	3-4	3-6s	13.625	13.625
3-7s	3rd floor ceiling		12	3-4	3-7s	13.625	13.625
3-8s	3rd floor ceiling		12	3-4	3-8s	13.625	13.625
3-9s	3rd floor ceiling		12	N/A	3-9s	11.5	11.5
3-10s	3rd floor ceiling		12	3-4	3-10s	13.625	13.625
3-11s	3rd floor ceiling		12	N/A	3-11s	9.5	9.5
3-12s	3rd floor ceiling		12	3-4	3-6s	13.625	13.625
3-13s	3rd floor ceiling		12	3-6s	3-8	13.625	13.625
3-14s	3rd floor ceiling		12	3-7s	3-8	13.625	13.625

2-1	**2nd floor ceiling**	**1- Ext**	12	N/A	2-1	**11.5**	**11.5**
2-2	**2nd floor ceiling**	**1- Int**	12	N/A	2-2	**13.625**	**13.625**
2-3	**2nd floor ceiling**	**2- Ext**	12	2-1	2-3	**13.625**	**13.625**
2-4	**2nd floor ceiling**	**2- Int**	12	2-2	2-4	**13.625**	**13.625**
2-5	**2nd floor ceiling**	**3- Ext**	12	2-3	2-5	**11.5**	**11.5**
2-6	**2nd floor ceiling**	**3- Int**	12	2-4	2-6	**13.625**	**13.625**
2-7	**2nd floor ceiling**	**4- Ext**	12	2-5	2-7	**13.625**	**13.625**
2-8	**2nd floor ceiling**	**4- Int**	12	2-6	2-8	**13.625**	**13.625**
2-9	**2nd floor ceiling**	**5- Ext**	12	2-7	2-9	**13.625**	**13.625**
2-10	**2nd floor ceiling**	**5- Int**	12	2-8	2-10	**13.625**	**13.625**
2-11	**2nd floor ceiling**	**6-Ext**	12	2-9	N/A	**11.5**	**11.5**
2-12	**2nd floor ceiling**	**6-Int**	12	2-10	N/A	**13.625**	**13.625**
2-1s	**2nd floor ceiling**		12	N/A	2-1s	**9.5**	**9.5**
2-2s	**2nd floor ceiling**		12	2-3	2-2s	**13.625**	**13.625**
2-3s	**2nd floor ceiling**		12	2-4	2-3s	**13.625**	**13.625**
2-4s	**2nd floor ceiling**		12	N/A	2-4s	**11.5**	**11.5**
2-5s	**2nd floor ceiling**		12	2-4	2-5s	**13.625**	**13.625**
2-6s	**2nd floor ceiling**		12	2-4	2-6s	**13.625**	**13.625**
2-7s	**2nd floor ceiling**		12	2-4	2-7s	**13.625**	**13.625**
2-8s	**2nd floor ceiling**		12	2-4	2-8s	**13.625**	**13.625**
2-9s	**2nd floor ceiling**		12	N/A	2-9s	**11.5**	**11.5**
2-10s	**2nd floor ceiling**		12	2-4	2-10s	**13.625**	**13.625**
2-11s	**2nd floor ceiling**		12	N/A	2-11s	**11.5**	**11.5**
2-12s	**2nd floor ceiling**		12	2-4	2-6s	**13.625**	**13.625**
2-13s	**2nd floor ceiling**		12	2-6s	2-8	**13.625**	**13.625**
2-14s	**2nd floor ceiling**		12	2-7s	2-8	**13.625**	**13.625**
2-15s	**2nd floor ceiling**		12	2-13s	2-4	**13.625**	**13.625**
2-16s	**2nd floor ceiling**		12	2-14s	2-4	**13.625**	**13.625**
2-17s	**2nd floor ceiling**		12	2-15s	2-3	**13.625**	**13.625**
2-18s	**2nd floor ceiling**		12	2-15s		**11.5**	**11.5**
2-19s	**2nd floor ceiling**		12	2-14s		**13.625**	**13.625**
2-20s	**2nd floor ceiling**		12	2-13s		**13.625**	**13.625**
1-1	**1st floor ceiling**	**1- Ext**	12	N/A	1-1	**13.625**	**13.625**
1-2	**1st floor ceiling**	**1- Int**	12	N/A	1-2	**13.625**	**13.625**
1-3	**1st floor ceiling**	**2- Ext**	12	1-1	1-3	**13.625**	**13.625**
1-4	**1st floor ceiling**	**2- Int**	12	1-2	1-4	**15.5**	**15.5**
1-5	**1st floor ceiling**	**3- Ext**	12	1-3	1-5	**13.625**	**13.625**
1-6	**1st floor ceiling**	**3- Int**	12	1-4	1-6	**15.5**	**15.5**
1-7	**1st floor ceiling**	**4- Ext**	12	1-5	1-7	**13.625**	**13.625**
1-8	**1st floor ceiling**	**4- Int**	12	1-6	1-8	**15.5**	**15.5**
1-9	**1st floor ceiling**	**5- Ext**	12	1-7	1-9	**13.625**	**13.625**
1-10	**1st floor ceiling**	**5- Int**	12	1-8	1-10	**15.5**	**15.5**
1-11	**1st floor ceiling**	**6-Ext**	12	1-9	N/A	**13.625**	**13.625**
1-12	**1st floor ceiling**	**6-Int**	12	1-10	N/A	**13.625**	**13.625**

1-1s	**1st floor ceiling**		12	N/A	1-1s	**9.5**	**9.5**
1-2s	**1st floor ceiling**		12	1-3	1-2s	**13.625**	**13.625**
1-3s	**1st floor ceiling**		12	1-4	1-3s	**15.5**	**15.5**
1-4s	**1st floor ceiling**		12	N/A	1-4s	**11.5**	**11.5**
1-5s	**1st floor ceiling**		12	1-4	1-5s	**13.625**	**13.625**
1-6s	**1st floor ceiling**		12	1-4	1-6s	**15.5**	**15.5**
1-7s	**1st floor ceiling**		12	1-4	1-7s	**15.5**	**15.5**
1-8s	**1st floor ceiling**		12	1-4	1-8s	**13.625**	**13.625**
1-9s	**1st floor ceiling**		12	N/A	1-9s	**11.5**	**11.5**
1-10s	**1st floor ceiling**		12	1-4	1-10s	**13.625**	**13.625**
1-11s	**1st floor ceiling**		12	N/A	1-11s	**11.5**	**11.5**
1-12s	**1st floor ceiling**		12	1-4	1-6s	**13.625**	**13.625**
1-13s	**1st floor ceiling**		12	1-6s	1-8	**15.5**	**15.5**
1-14s	**1st floor ceiling**		12	1-7s	1-8	**15.5**	**15.5**
1-15s	**1st floor ceiling**		12	1-13s		**11.5**	**11.5**
1-16s	**1st floor ceiling**		12	1-15s		**11.5**	**11.5**
1-17s	**1st floor ceiling**		12	1-17s		**11.5**	**11.5**
1-18s	**1st floor ceiling**		12	1-19s		**11.5**	**11.5**
1-19s	**1st floor ceiling**		12	1-21s		**9.5**	**9.5**
1-20s	**1st floor ceiling**		12	1-22s	1-21s	**13.625**	**13.625**
1-21s	**1st floor ceiling**		12	1-20s	1-19s	**13.625**	**13.625**
1-22s	**1st floor ceiling**		12	1-18s	1-17s	**13.625**	**13.625**
1-23s	**1st floor ceiling**		12	1-16s	1-15s	**13.625**	**13.625**
1-24s	**1st floor ceiling**		12	1-1	1-13s	**13.625**	**13.625**
1-25s	**1st floor ceiling**		12	1-14s		**13.625**	**13.625**
1-26s	**1st floor ceiling**		12	1-16s		**13.625**	**13.625**
1-27s	**1st floor ceiling**		12	1-18s		**13.625**	**13.625**
1-28s	**1st floor ceiling**		12	1-20s		**11.5**	**11.5**
1-29s	**1st floor ceiling**		12	1-22s		**11.5**	**11.5**

CLT Flooring

Roof Section 1

Location		Nordic Reference	CLT Type	
Roof		NS-DA2301	105-3s	

Nordic Reference Material				
For CLT Layup E1 (psi)				
Variable	Description	Major Strength Direction:	Minor Direction:	Units
Fb	Bending at Extreme Fiber	1,950	500	psi
E	Modulus of Elasticity	1700000	1200000	psi
Ft	Tension Parallel to Grain	1,375	250	psi
Fc	Compression Parellel to Grain	1,800	650	psi
Fv	Shear Parallel to Grain Strength	135	135	psi
Fs	Rolling Shear Strength	45	45	psi
Fcp	Compression Perpendicular to Grain	425	425	psi
G	Shear Modulus	106250	75000	psi
Gs	Rolling Shear Modulus	10625	7500	psi
For Roof CLT				
Variable	Description	Major Direction:	Minor Direction:	Units
FbS(eff)	Bending Moment Capacity	4525	160	lbf-ft/ft
V0	Shear Capacity	1490	495	lbf/ft
EI(eff,0)	Bending Stiffness	115000000	3100000	lbf-in.^2/ft
EI(eff,0)	Total Bending Stiffness of Section	690000000	18600000	lbf-in^2
GA(eff,0)	Shear Rigidity	460000	610000	lbf/ft
GA(eff,0)	Total Shear Rigidity	2760000	3660000	lbf

Section-Specific Loading and Dimensions			
Floor	4		
Section:	1A - 1		
Length	12.5		ft
Width	6		ft
Thickness	1.375	1.375	in
Ply	5		ply
Total Thickness (tv)	6.875		in
Roof Live Load (Lr)	20		psf
Ground snow load (S)	50		psf
Dead Loads - Total	14.1		psf
Insulation on CLT (D)	*3*		*psf*
Mechanical (D)	*0*		*psf*
CLT Self-Weight (D)	*11.1*		*psf*
Point Loads	*0*		*psf*
Wind (W)	0		mph
Earthquake (E)	0		psf
Live Load (L)	0		psf

Actual Loading			
Variable	Description	Calculation	Units
LC1	D	14.1	psf
LC2	D+L	14.1	psf
LC3	D+(Lr or S or R)	64.1	psf
LC4	D + 0.75L + 0.75(Lr or S or R)	51.6	psf
LC5	D + (0.6W or 0.7E)	14.1	psf
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)	51.6	psf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	51.6	psf
LC7	0.6D + 0.6W	8.46	psf
LC8	0.6D + 0.7E	8.46	psf

NDS Calculations			
Variable	Description	Calculation	Units
Cd		0.9	
Cm		1	
Ct		1	
Cl		1	

Allowable Values			
Variable	Description	Calculation	Units
Fb(Seff)'	Fb(Seff)(Cd)(Cm)(Ct)(Cl)	24435	lb-ft
Fs(Ib/Q)eff'	Fs(Ib/Q)eff(Cm)(Ct)	9548.337498	lb
(EI)app'	(EI)app(Cm)(Ct)	611822660.1	lb-ft2

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.03472222222	ft
Delta S	L/360	0.03472222222	ft
Delta D+L	L/240	0.05208333333	ft

(IB/Q)eff				
Layer	E	z (in)	Ehz	Units
1	1700000	1.375	3214062.5	
2	40000	0.6875	37812.5	
		Sum of EHZ	3251875	lb
		(Ib/Q)eff	212.1852777	in^2

EIapp			
Ks	constant for uniform with pinned	11.5	
EIapp	(EIeff)/(1+((Ks*EIeff)/(GAeff(L^2))))	611822660.1	lb-ft2

2 span

Actual Values			
Variable	Description	Calculation	Units
Mmax	(w*width*L^2)/8	7511.71875	lb-ft
Vmax	(5*w*width*L)/8	3004.6875	lb

2 span

Actual Deflection					
Variable	Description	Calculation	Units	Calc in inches	Demand/capacity
Delta L	(Lr*width(L^4))/(EIapp'*185)	0.0000258835601	ft	0.000310602722	0.0007454465335
Delta S	(S*width*L^4)/(EI(app)'*185)	0.0000647089004	ft	0.000776506805	0.001863616334
Delta D+L	((L+D)*width*L^4)/(EI(app)'*185	0.0000441314701	ft	0.000529577641	0.0008473242264

Penthouse Section 1

Location		Nordic Reference	CLT Type
Roof		NS-DA2301	175-5s

Nordic Reference Material				
For CLT Layup E1 (psi)				
Variable	Description	Major Strength Direction:	Minor Direction:	Units
Fb	Bending at Extreme Fiber	1,950	500	psi
E	Modulus of Elasticity	1700000	1200000	psi
Ft	Tension Parallel to Grain	1,375	250	psi
Fc	Compression Parellel to Grain	1,800	650	psi
Fv	Shear Parallel to Grain Strength	135	135	psi
Fs	Rolling Shear Strength	45	45	psi
Fcp	Compression Perpendicular to Grain	425	425	psi
G	Shear Modulus	106250	75000	psi
Gs	Rolling Shear Modulus	10625	7500	psi
For Roof CLT (175-5s)				
Variable	Description	Major Direction:	Minor Direction:	Units
FbS(eff)	Bending Moment Capacity	10400	1370	lbf-ft/ft
V0	Shear Capacity	2480	1490	lbf/ft
EI(eff,0)	Bending Stiffness	440000000	81000000	lbf-in.^2/ft
EI(eff,0)	Total Bending Stiffness of Section	2640000000	486000000	lbf-in^2
GA(eff,0)	Shear Rigidity	920000	1200000	lbf/ft
GA(eff,0)	Total Shear Rigidity	5520000	7200000	lbf

Section-Specific Loading and Dimensions				
Floor		4		
Section:		1A - 1		
Length		13		ft
Width		6		ft
Thickness		1.375	1.375	in
Ply		5		ply
Total Thickness (tv)		6.875		in
Roof Live Load (Lr)		0		psf
Ground snow load (S)		0		psf
Dead Loads - Total		168.1		psf
	Insulation on CLT (D)	*3*		*psf*
	Mechanical (D)	*150*		*psf*
	CLT Self-Weight (D)	*15.1*		*psf*
	Point Loads	*0*		*psf*
Wind (W)		0		mph
Earthquake (E)		0		psf
Live Load (L)		20		psf

Actual Loading			
Variable	Description	Calculation	Units
LC1	D	168.1	psf
LC2	D+L	188.1	psf
LC3	D+(Lr or S or R)	168.1	psf
LC4	D + 0.75L + 0.75(Lr or S or R)	183.1	psf
LC5	D + (0.6W or 0.7E)	168.1	psf
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)	183.1	psf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	183.1	psf
LC7	0.6D + 0.6W	100.86	psf
LC8	0.6D + 0.7E	100.86	psf

NDS Calculations			
Variable	Description	Calculation	Units
Cd		0.9	
Cm		1	
Ct		1	
Cl		1	

Allowable Values			
Variable	Description	Calculation	Units
Fb(Seff)'	Fb(Seff)(Cd)(Cm)(Ct)(Cl)	56160	lb-ft
Fs(Ib/Q)eff'	Fs(Ib/Q)eff(Cm)(Ct)	14647.17101	lb
(EI)app'	(EI)app(Cm)(Ct)	2153339590	lb-ft2

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.03611111111	ft
Delta S	L/360	0.03611111111	ft
Delta D+L	L/240	0.05416666667	ft

(IB/Q)eff				
Layer	E	z (in)	Ehz	Units
1	1700000	2.75	6428125	
2	40000	1.375	75625	
3	1700000	0.6875	1607031.25	
		Sum of EHZ	8110781.25	lb
		(Ib/Q)eff	325.4926891	in^2

EIapp			
Ks	constant for uniform with pinned	11.5	
EIapp	(EIeff)/(1+((Ks*EIeff)/(GAeff(L^2))))	2153339590	lb-ft2

Actual Values			
Variable	Description	Calculation	Units
Mmax	0.1*w*width*L^2	23841.675	lb-ft
Vmax	0.6*w*width*L	9169.875	lb

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(0.0069*Lr*width(L^4))/(EIapp')	0.0000086034	ft
Delta D+L	(0.0069*(L+D)*width*L^4)/(EI(ap	0.0000723116	ft

Normal Floors

Location		Nordic Reference	CLT Type	
Roof		NS-DA2301	175-5s	
Nordic Reference Material				
For CLT Layup E1 (psi)				
Variable	Description	Major Strength Direction:	Minor Direction:	Units
Fb	Bending at Extreme Fiber	1,950	500	psi
E	Modulus of Elasticity	1700000	1200000	psi
Ft	Tension Parallel to Grain	1,375	250	psi
Fc	Compression Parellel to Grain	1,800	650	psi
Fv	Shear Parallel to Grain Strength	135	135	psi
Fs	Rolling Shear Strength	45	45	psi
Fcp	Compression Perpendicular to Grain	425	425	psi
G	Shear Modulus	106250	75000	psi
Gs	Rolling Shear Modulus	10625	7500	psi
For CLT				
Variable	Description	Major Direction:	Minor Direction:	Units
FbS(eff)	Bending Moment Capacity	10400	1370	lbf-ft/ft
V0	Shear Capacity	2480	1490	lbf/ft
EI(eff,0)	Bending Stiffness	440000000	81000000	lbf-in.^2/ft
EI(eff,0)	Total Bending Stiffness of Section	2640000000	486000000	lbf-in^2
GA(eff,0)	Shear Rigidity	920000	1200000	lbf/ft
GA(eff,0)	Total Shear Rigidity	5520000	7200000	lbf
Section-Specific Loading and Dimensions				
Floor		All		
Section:		All except E1		
Length		13		ft
Width		6		ft
Thickness		1.375	1.375	in
Ply		5		ply
Total Thickness (tv)		6.875		in
Roof Live Load (Lr)		0		psf
Ground snow load (S)		50		psf
Dead Loads - Total		18.1		psf
	Insulation on CLT (D)	*3*		*psf*
	Mechanical (D)	*0*		*psf*
	CLT Self-Weight (D)	*15.1*		*psf*
	Point Loads	*0*		*psf*
Wind (W)		0		mph
Earthquake (E)		0		psf
Live Load (L)		100		psf

Actual Loading			
Variable	Description	Calculation	Units
LC1	D	18.1	psf
LC2	D+L	118.1	psf
LC3	D+(Lr or S or R)	68.1	psf
LC4	D + 0.75L + 0.75(Lr or S or R)	130.6	psf
LC5	D + (0.6W or 0.7E)	18.1	psf
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)	130.6	psf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	130.6	psf
LC7	0.6D + 0.6W	10.86	psf
LC8	0.6D + 0.7E	10.86	psf

NDS Calculations			
Variable	Description	Calculation	Units
Cd		0.9	
Cm		1	
Ct		1	
Cl		1	

Allowable Values			
Variable	Description	Calculation	Units
Fb(Seff)'	Fb(Seff)(Cd)(Cm)(Ct)(Cl)	56160	lb-ft
Fs(Ib/Q)eff'	Fs(Ib/Q)eff(Cm)(Ct)	14647.17101	lb
(EI)app'	(EI)app(Cm)(Ct)	2153339590	lb-ft2

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.03611111111	ft
Delta S	L/360	0.03611111111	ft
Delta D+L	L/240	0.05416666667	ft

Fire Rating Calcs (ignore for now)			
Variable	Description	Calculation	Units
Bt	1.5	0.1388888889	ft
a -char	Char Depth	0.1388888889	ft
Delta D+L	L/240	0.2083333333	ft

(IB/Q)eff				
Layer	E	z (in)	Ehz	Units
1	1700000	2.75	6428125	
2	40000	1.375	75625	
3	1700000	0.6875	1607031.25	
		Sum of EHZ	8110781.25	lb
		(Ib/Q)eff	325.4926891	in^2

EIapp			
Ks	constant for uniform with pinned	11.5	
EIapp	(EIeff)/(1+((Ks*EIeff)/(GAeff(L^2))))	2153339590	lb-ft2

Actual Values			
Variable	Description	Calculation	Units
Mmax	0.1*w*width*L^2	16553.55	lb-ft
Vmax	0.6*w*width*L	6366.75	lb

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(0.0069*Lr*width(L^4))/(EIapp')	0.0000430170	ft
Delta D+L	(0.0069*(L+D)*width*L^4)/(EI(ap	0.0000077860	ft

Atrium Ceiling

Location		Nordic Reference	CLT Type	
Roof		NS-DA2301	175-5s	

Nordic Reference Material				
For CLT Layup E1 (psi)				
Variable	Description	Major Strength Direction:	Minor Direction:	Units
Fb	Bending at Extreme Fiber	1,950	500	psi
E	Modulus of Elasticity	1700000	1200000	psi
Ft	Tension Parallel to Grain	1,375	250	psi
Fc	Compression Parellel to Grain	1,800	650	psi
Fv	Shear Parallel to Grain Strength	135	135	psi
Fs	Rolling Shear Strength	45	45	psi
Fcp	Compression Perpendicular to Grain	425	425	psi
G	Shear Modulus	106250	75000	psi
Gs	Rolling Shear Modulus	10625	7500	psi
For CLT				
Variable	Description	Major Direction:	Minor Direction:	Units
FbS(eff)	Bending Moment Capacity	10400	1370	lbf-ft/ft
V0	Shear Capacity	2480	1490	lbf/ft
EI(eff,0)	Bending Stiffness	440000000	81000000	lbf-in.^2/ft
EI(eff,0)	Total Bending Stiffness of Section	2640000000	486000000	lbf-in^2
GA(eff,0)	Shear Rigidity	920000	1200000	lbf/ft
GA(eff,0)	Total Shear Rigidity	5520000	7200000	lbf

Section-Specific Loading and Dimensions			
Floor	All		
Section:	2nd Floor Ceiling above atrium		
Length	16		ft
Width	6		ft
Thickness	1.375	1.375	in
Ply	5		ply
Total Thickness (tv)	6.875		in
Roof Live Load (Lr)	0		psf
Ground snow load (S)	50		psf
Dead Loads - Total	18.1		psf
Insulation on CLT (D)	*3*		*psf*
Mechanical (D)	*0*		*psf*
CLT Self-Weight (D)	*15.1*		*psf*
Point Loads	*0*		*psf*
Wind (W)	0		mph
Earthquake (E)	0		psf
Live Load (L)	100		psf

Actual Loading			
Variable	Description	Calculation	Units
LC1	D	18.1	psf
LC2	D+L	118.1	psf
LC3	D+(Lr or S or R)	68.1	psf
LC4	D + 0.75L + 0.75(Lr or S or R)	130.6	psf
LC5	D + (0.6W or 0.7E)	18.1	psf
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)	130.6	psf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	130.6	psf
LC7	0.6D + 0.6W	10.86	psf
LC8	0.6D + 0.7E	10.86	psf

NDS Calculations			
Variable	Description	Calculation	Units
Cd		0.9	
Cm		1	
Ct		1	
Cl		1	

Allowable Values			
Variable	Description	Calculation	Units
Fb(Seff)'	Fb(Seff)(Cd)(Cm)(Ct)(Cl)	56160	lb-ft
Fs(Ib/Q)eff'	Fs(Ib/Q)eff(Cm)(Ct)	14647.17101	lb
(EI)app'	(EI)app(Cm)(Ct)	2297256161	lb-ft2

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04444444444	ft
Delta S	L/360	0.04444444444	ft
Delta D+L	L/240	0.06666666667	ft

Fire Rating Calcs (ignore for now)			
Variable	Description	Calculation	Units
Bt	1.5	0.1388888889	ft
a -char	Char Depth	0.1388888889	ft
Delta D+L	L/240	0.2083333333	ft

(IB/Q)eff				
Layer	E	z (in)	Ehz	Units
1	1700000	2.75	6428125	
2	40000	1.375	75625	
3	1700000	0.6875	1607031.25	
		Sum of EHZ	8110781.25	lb
		(Ib/Q)eff	325.4926891	in^2

EIapp			
Ks	constant for uniform with pinned	11.5	
EIapp	(EIeff)/(1+((Ks*EIeff)/(GAeff(L^2))))	2297256161	lb-ft2

Actual Values			
Variable	Description	Calculation	Units
Mmax	(1/8)*w*width*L^2	25075.2	lb-ft
Vmax	(5/8)*w*width*L	7836	lb

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(0.0069*Lr*width(L^4))/(EIapp')	0.0000925230	ft
Delta D+L	(0.0069*(L+D)*width*L^4)/(EI(ap	0.0000167466	ft

Typical Glulam Joist

4th Floor Outer Edge

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1			
Tributary Width		4.6875	ft		
Roof Live Load (Lr)		20	psf		
Reduced Roof LL		20	psf	93.75	plf
Ground snow load (S)		50	psf	234.375	plf
Dead Loads - Total		27.7	psf	167.578125	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Glulam Self-weight	35	pcf	37.734375	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf	0	plf
Live Load (L)		0	psf	0	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	167.578125	plf
LC2	D+L	27.7	psf	167.578125	plf
LC3	D+(Lr or S or R)	77.7	psf	401.953125	plf
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	343.359375	plf
LC5	D + (0.6W or 0.7E)	27.7	psf	167.578125	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	343.359375	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.	65.2	psf	343.359375	plf
LC7	0.6D + 0.6W	16.62	psf	100.546875	plf
LC8	0.6D + 0.7E	16.62	psf	100.546875	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		11.5	in
d		13.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		155.25	in^2
Sxx		349.3	in^3
Ixx		2357.9	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		3.885	
FBe		115	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	363.24	
Rb	sqrt((le*d)/b^2)	6.08927906	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	30757.84605	
Cfu		1	
CL	look at nds	0.996252802	
CV	look at nds	0.7283493905	
Fire Resistance Adjustment Factor		0.75	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1179.926013	psi
Allowable Moment		34346.90877	ft-lb
Moment		13678.96729	ft-lb
Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	3316.113281	lb
Actual fv	3V/2bd	4613.722826	psf
Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	3316.113281	lb
Fc actual		48.05961277	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	
Manual pg 72			

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0.00767463852	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.01316200506	ft

4^{th} Floor Inner

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		15.625	ft		
Roof Live Load (Lr)		20	psf		
Reduced Roof LL (if allowed)		18.84375	psf	294.4335938	plf
Ground snow load (S)		50	psf	781.25	plf
Dead Loads - Total		29.7	psf	507.3871528	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*13.1*	*psf*		
	Glulam Self-weight	35	pcf	43.32465278	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		0	psf	0	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	29.7	psf	507.3871528	plf
LC2	D+L	29.7	psf	507.3871528	plf
LC3	D+(Lr or S or R)	79.7	psf	1288.637153	plf
LC4	D + 0.75L + 0.75(Lr or S or	67.2	psf	1093.324653	plf
LC5	D + (0.6W or 0.7E)	29.7	psf	507.3871528	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	67.2	psf	1093.324653	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.'	67.2	psf	1093.324653	plf
LC7	0.6D + 0.6W	17.82	psf	304.4322917	plf
LC8	0.6D + 0.7E	17.82	psf	304.4322917	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		11.5	in
d		15.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		178.25	in^2
Sxx		460.5	in^3
Ixx		3568.7	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.163	
FBe		100	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	369.24	
Rb	sqrt((le*d)/b^2)	6.578431849	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	26353.77987	
Cfu		1	
CL	look at nds	0.9955771883	
CV	look at nds	0.7183564047	
Fire Resistance Adjustment Factor		0.81	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1256.836366	psi
Allowable Moment		48228.91352	ft-lb
Moment		43853.93311	ft-lb
Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	10631.25651	lb
Actual fv	3V/2bd	12882.75684	psf
Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	10631.25651	lb
Fc actual		154.0761813	psi
Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	
Manual pg 72			

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0.01690218634	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.02787940516	ft

4^{th} Floor Middle

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		16.25	ft		
Roof Live Load (Lr)		0	psf	0	plf
Ground snow load (S)		0	psf	0	plf
Dead Loads - Total		176.7	psf	2937.060764	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*150*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Glulam Self-weight	35	pcf	65.68576389	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		20	psf	325	plf
Reduced Live Load - no because Kll*At <400 ft2		17.95500551	psf	291.7688396	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	176.7	psf	2937.060764	plf
LC2	D+L	196.7	psf	3228.829603	plf
LC3	D+(Lr or S or R)	176.7	psf	2937.060764	plf
LC4	D + 0.75L + 0.75(Lr or S or	191.7	psf	3155.887394	plf
LC5	D + (0.6W or 0.7E)	176.7	psf	2937.060764	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	191.7	psf	3155.887394	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.	191.7	psf	3155.887394	plf
LC7	0.6D + 0.6W	106.02	psf	1762.236458	plf
LC8	0.6D + 0.7E	106.02	psf	1762.236458	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		11.5	in
d		23.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		270.25	in^2
Sxx		1058.5	in^3
Ixx		12437.1	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		5.125	
FBe		66	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	393.24	
Rb	sqrt((le*d)/b^2)	8.359204202	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	16321.41489	
Cfu		1	
CL	look at nds	0.9924962547	
CV	look at nds	0.6890747747	
Fire Resistance Adjustment Factor		0.96	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1428.865453	psi
Allowable Moment		126035.3595	ft-lb
Moment		109881.1074	ft-lb
Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	26637.84423	lb
Actual fv	3V/2bd	21290.5619	psf
Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	26637.84423	lb
Fc actual		386.0557135	psi

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	26637.84423	lb
Fc actual		386.0557135	psi
Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	
Manual pg 72			

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.01823296483	ft

Typical Glulam Joist

3^{rd} – 1^{st} Floor Outer Edge

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		4.6875	ft		
Roof Live Load (Lr)		0	psf	0	plf
Ground snow load (S)		0	psf	0	plf
Dead Loads - Total		30.7	psf	181.640625	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Glulam Self-weight	35	pcf	37.734375	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		100	psf	468.75	plf
Reduced Live Load - edge beam- no bc KllAt<400 ft		100	psf	468.75	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	181.64	plf
LC2	D+L	130.7	psf	650.39	plf
LC3	D+(Lr or S or R)	30.7	psf	181.64	plf
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	533.20	plf
LC5	D + (0.6W or 0.7E)	30.7	psf	181.64	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	533.20	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.	105.7	psf	533.20	plf
LC7	0.6D + 0.6W	18.42	psf	108.98	plf
LC8	0.6D + 0.7E	18.42	psf	108.98	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		11.5	in
d		13.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		155.25	in^2
Sxx		349.3	in^3
Ixx		2357.9	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		3.885	
FBe		115	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	363.24	
Rb	sqrt((le*d)/b^2)	6.08927906	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	30757.84605	
Cfu		1	
CL	look at nds	0.996252802	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		0.75	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1312.2	psi
Allowable Moment		38197.32	ft-lb
Moment		22133.61	ft-lb
Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	5365.722656	lb
Actual fv	3V/2bd	7465.353261	psf
Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	5365.722656	lb
Fc actual		77.76409647	psi
Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	
Manual pg 72			

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.005947844853	ft

3rd – 1st Floor Inner

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		15.625	ft		
Roof Live Load (Lr)		0	psf	0	plf
Ground snow load (S)		0	psf	0	plf
Dead Loads - Total		30.7	psf	528.6024306	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Glulam Self-weight	35	pcf	48.91493056	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		100	psf	1562.5	plf
Reduced Live Load - edge beam- yes bc KllAt>400 ft		91.05782591	psf	1422.77853	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	528.60	plf
LC2	D+L	130.7	psf	1951.38	plf
LC3	D+(Lr or S or R)	30.7	psf	528.60	plf
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	1595.69	plf
LC5	D + (0.6W or 0.7E)	30.7	psf	528.60	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	1595.69	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.	105.7	psf	1595.69	plf
LC7	0.6D + 0.6W	18.42	psf	317.16	plf
LC8	0.6D + 0.7E	18.42	psf	317.16	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		11.5	in
d		17.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		201.25	in^2
Sxx		587.0	in^3
Ixx		5136.1	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.423	
FBe		89	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	375.24	
Rb	sqrt((le*d)/b^2)	7.046537178	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	22968.68747	
Cfu		1	
CL	look at nds	0.9948657544	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		0.86	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1504.656	psi
Allowable Moment		73600.14	ft-lb
Moment		66407.93	ft-lb
Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	16098.89292	lb
Actual fv	3V/2bd	17278.81178	psf
Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	16098.89292	lb
Fc actual		233.3172887	psi
Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	
Manual pg 72			

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.007946263443	ft

3rd – 1st Floor Core

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		16.25	ft		
Roof Live Load (Lr)		0	psf	0	plf
Ground snow load (S)		0	psf	0	plf
Dead Loads - Total		30.7	psf	547.7899306	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Glulam Self-weight	35	pcf	48.91493056	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		100	psf	1625	plf
Reduced Live Load - edge beam- yes bc KllAt>400 ft		89.77502756	psf	1458.844198	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	547.79	plf
LC2	D+L	130.7	psf	2006.63	plf
LC3	D+(Lr or S or R)	30.7	psf	547.79	plf
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	1766.54	plf
LC5	D + (0.6W or 0.7E)	30.7	psf	547.79	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	1641.92	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.7	105.7	psf	1641.92	plf
LC7	0.6D + 0.6W	18.42	psf	328.67	plf
LC8	0.6D + 0.7E	18.42	psf	328.67	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		11.5	in
d		17.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		201.25	in^2
Sxx		587.0	in^3
Ixx		5136.1	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.423	
FBe		89	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	375.24	
Rb	sqrt((le*d)/b^2)	7.046537178	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	22968.68747	
Cfu		1	
CL	look at nds	0.9948657544	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		0.86	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1504.656	psi
Allowable Moment		73600.14	ft-lb
Moment		68288.27	ft-lb
Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	16554.73156	lb
Actual fv	3V/2bd	17768.05971	psf
Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	16554.73156	lb
Fc actual		239.9236458	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	
Manual pg 72			

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.008234701258	ft

Special Glulam Joist

4th Floor Core

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Top Half - Single Span

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		4.6875	ft		
Roof Live Load (Lr)		20	psf	93.75	plf
Ground snow load (S)		50	psf	234.375	plf
Dead Loads - Total		31.7	psf	175.1475694	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Glulam Self-weight	35	pcf	26.55381944	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		0	psf	0	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	31.7	psf	175.1475694	plf
LC2	D+L	31.7	psf	175.1475694	plf
LC3	D+(Lr or S or R)	81.7	psf	409.5225694	plf
LC4	D + 0.75L + 0.75(Lr or S or R)	69.2	psf	350.9288194	plf
LC5	D + (0.6W or 0.7E)	31.7	psf	175.1475694	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)	69.2	psf	350.9288194	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	69.2	psf	350.9288194	plf
LC7	0.6D + 0.6W	19.02	psf	105.0885417	plf
LC8	0.6D + 0.7E	19.02	psf	105.0885417	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		9.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		109.25	in^2
Sxx		209.4	in^3
Ixx		1204.0	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.340	
FBe		92	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	357.24	
Rb	sqrt((le*d)/b^2)	6.746916809	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	25053.99366	
Cfu		1	
CL	look at nds	0.9953286347	
CV	look at nds	0.7543984327	
Fire Resistance Adjustment Factor		0.5	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	814.7503073	psi
Allowable Moment		14217.10996	ft-lb
Moment		4260	ft-lb

Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v	allowable	38880	psf
Actual V	wL/2	2560	lb
Actual fv	3V/2bd	5061	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	2560	lb
Fc actual		45	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L		0.006011736543	ft
Delta S		0.01502934136	ft
Delta D+L		0.002383333333	ft

3rd Floor Core

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		9.5625	ft		
Roof Live Load (Lr)		0	psf	0	plf
Ground snow load (S)		0	psf	0	plf
Dead Loads - Total		30.7	psf	320.1225694	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Glulam Self-weight	35	pcf	26.55381944	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		100	psf	956.25	plf
Reduced Live Load - no bc Kll*At<400		100	psf	956.25	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	320.12	plf
LC2	D+L	130.7	psf	1276.37	plf
LC3	D+(Lr or S or R)	30.7	psf	320.12	plf
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	1037.31	plf
LC5	D + (0.6W or 0.7E)	30.7	psf	320.12	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	1037.31	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.	105.7	psf	1037.31	plf
LC7	0.6D + 0.6W	18.42	psf	192.07	plf
LC8	0.6D + 0.7E	18.42	psf	192.07	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.02291666667	ft
Delta S	L/360	0.02291666667	ft
Delta D+L	L/240	0.034375	ft

Member Lengths and Properties

Variable		Value	Unit
l		8.25	ft
b		9.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		109.25	in^2
Sxx		209.4	in^3
Ixx		1204.0	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.340	
FBe		92	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	99	
Le	1.63Lu+3D	195.87	
Rb	sqrt((le*d)/b^2)	4.995848692	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	45695.04618	
Cfu		1	
CL	look at nds	0.9975317733	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		0.5	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	874.8	psi
Allowable Moment		15,264.96	ft-lb
Moment		10,859.14	ft-lb
Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	5265	lb
Actual fv	3V/2bd	10409.59231	psf
Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	5265.036849	lb
Fc actual		92.36906753	psi
Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	
Manual pg 72			

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.001282995033	ft

2^{nd} Floor Outside Overhang

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		3.5	ft		
Roof Live Load (Lr)		20	psf	70	plf
Ground snow load (S)		50	psf	175	plf
Dead Loads - Total		27.7	psf	123.5038194	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Glulam Self-weight	35	pcf	26.55381944	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		0	psf	0	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	123.5038194	plf
LC2	D+L	27.7	psf	123.5038194	plf
LC3	D+(Lr or S or R)	77.7	psf	298.5038194	plf
LC4	D + 0.75L + 0.75(Lr or S or R)	65.2	psf	254.7538194	plf
LC5	D + (0.6W or 0.7E)	48.7	psf	139.4361111	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)	80.95	psf	266.7030382	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	65.2	psf	254.7538194	plf
LC7	0.6D + 0.6W	37.62	psf	90.03458333	plf
LC8	0.6D + 0.7E	16.62	psf	74.10229167	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.1083333333	ft
Delta S	L/360	0.1083333333	ft
Delta D+L	L/240	0.1625	ft

Member Lengths and Properties

Variable		Value	Unit
l		39	ft
b		9.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		109.25	in^2
Sxx		209.4	in^3
Ixx		1204.0	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.340	
FBe		92	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	468	
Le	1.63Lu+3D	797.34	
Rb	sqrt((le*d)/b^2)	10.07968803	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	11225.18461	
Cfu		1	
CL	look at nds	0.9883933388	
CV	look at nds	0.6922177178	
Fire Resistance Adjustment Factor		0.5	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	747.5951352	psi
Allowable Moment		13045.27553	ft-lb
Moment		8820	ft-lb
Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	3000	lb
Actual fv	3V/2bd	5931.350114	psf
Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	5670	lb
Fc actual		99	psi
Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	
Manual pg 72			

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0.1401036194	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0.3502590484	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.00592	ft

1st Floor Atrium

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		5	ft		
Roof Live Load (Lr)		0	psf	0	plf
Ground snow load (S)		0	psf	0	plf
Dead Loads - Total		30.7	psf	191.234375	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Glulam Self-weight	35	pcf	37.734375	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		100	psf	500	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	191.234375	plf
LC2	D+L	130.7	psf	691.234375	plf
LC3	D+(Lr or S or R)	30.7	psf	191.234375	plf
LC4	D + 0.75L + 0.75(Lr or S or R)	105.7	psf	566.234375	plf
LC5	D + (0.6W or 0.7E)	51.7	psf	213.875	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(Lr or S or R)	121.45	psf	583.2148438	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	105.7	psf	566.234375	plf
LC7	0.6D + 0.6W	39.42	psf	137.38125	plf
LC8	0.6D + 0.7E	18.42	psf	114.740625	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		11.5	in
d		13.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		155.25	in^2
Sxx		349.3	in^3
Ixx		2357.9	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		3.885	
FBe		115	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	363.24	
Rb	sqrt((le*d)/b^2)	6.08927906	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	30757.84605	
Cfu		1	
CL	look at nds	0.996252802	
CV	look at nds	0.7283493905	
Fire Resistance Adjustment Factor		0.75	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1179.926013	psi
Allowable Moment		34346.90877	ft-lb
Moment		23523.56982	ft-lb

Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	5702.683594	lb
Actual fv	3V/2bd	7934.168478	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	5702.683594	lb
Fc actual		82.64758832	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.00626199339	ft

Typical Glulam Girder

4th Floor 4-2

Member Lengths and Properties			
Variable		**Value**	**Unit**
l		25	ft
b		11.5	in
d		23.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		270.25	in^2
Sxx		1058.5	in^3
Ixx		12437.1	in^4
Isupport		6	in

Beam Stability Factor			
Variable		**Value**	**Unit**
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		5.125	
FBe		66	psi
CL			

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions					
Joist Number		4-1			
Joist b		11.5	in		
joist d		13.5	in		
Girder Tributary Width		16.5	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		20	psf	1546.875	lbs
Ground snow load (S)		50	psf	3867.1875	lbs
Dead Loads - Total		27.7	psf	2765.039063	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Joist Weight	35	pcf	622.6171875	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	2765.04	lbs
LC2	D+L	27.7	psf	2765.04	lbs
LC3	D+(Lr or S or R)	77.7	psf	6632.23	lbs
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	5665.43	lbs
LC5	D + (0.6W or 0.7E)	27.7	psf	2765.04	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	5665.43	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.7	65.2	psf	5665.43	lbs
LC7	0.6D + 0.6W	16.62	psf	1659.02	lbs
LC8	0.6D + 0.7E	16.62	psf	1659.02	lbs

Point Load 2 - Middle

Section-Specific Loading and Dimensions					
Joist Number		4-2			
Joist b		11.5	in		
joist d		15.5	in		
Girder Tributary Width		16.5	ft		
CLT Tributary Area		15.625	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		18.84375	psf	4858.154297	lbs
Ground snow load (S)		50	psf	12890.625	lbs
Dead Loads - Total		27.7	psf	7856.263021	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Joist Weight	35	pcf	714.8567708	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	7856.26	lbs
LC2	D+L	27.7	psf	7856.26	lbs
LC3	D+(Lr or S or R)	77.7	psf	20746.89	lbs
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	17524.23	lbs
LC5	D + (0.6W or 0.7E)	27.7	psf	7856.26	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	17524.23	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	65.2	psf	17524.23	lbs
LC7	0.6D + 0.6W	16.62	psf	4713.76	lbs
LC8	0.6D + 0.7E	16.62	psf	4713.76	lbs

Point Load 3 - Right

Section-Specific Loading and Dimensions					
Joist Number		4-3			
Joist b		11.5	in		
joist d		13.5	in		
Girder Tributary Width		16.5	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		20	psf	1546.875	lbs
Ground snow load (S)		50	psf	3867.1875	lbs
Dead Loads - Total		29.7	psf	2919.726563	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*13.1*	*psf*		
	Joist Weight	35	pcf	622.6171875	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	29.7	psf	2919.73	lbs
LC2	D+L	29.7	psf	2919.73	lbs
LC3	D+(Lr or S or R)	79.7	psf	6786.91	lbs
LC4	D + 0.75L + 0.75(Lr or S or	67.2	psf	5820.12	lbs
LC5	D + (0.6W or 0.7E)	29.7	psf	2919.73	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	67.2	psf	5820.12	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	67.2	psf	5820.12	lbs
LC7	0.6D + 0.6W	17.82	psf	1751.84	lbs
LC8	0.6D + 0.7E	17.82	psf	1751.84	lbs

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	65.68576389	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Actual Loading						
Variable	Description	Calculation	Units	Total DL (lbs)	Total LI	Total Roof SL (lbs)
LC1	D	15183.17	lbs	0	0	0
LC2	D+L	15183.17	lbs	0	0	0
LC3	D+(Lr or S or R)	35808.17	lbs	15183.17274	0	7951.904
LC4	D + 0.75L + 0.75(Lr or S or	30651.92	lbs	0	0	0
LC5	D + (0.6W or 0.7E)	15183.17	lbs	0	0	0
LC6a	D + 0.75L + 0.75(0.6W) + 0.	30651.92	lbs	0	0	0
LC6b	D + 0.75L + 0.75(0.7E) + 0.	30651.92	lbs	0	0	0
LC7	0.6D + 0.6W	9109.90	lbs	0	0	0
LC8	0.6D + 0.7E	9109.90	lbs	0	0	0

Column reaction	Formula	Value	Unit
Total	112	35808.17	lb

Left Column	Formula	Value	Unit
Total	Pt load 1 + (12.5*self weig	17826.74	lb
Dead		7558.791525	lb
live		0	lb
Snow		3958.776458	lb

Right c	Formula	Value	Unit
Total	Pt load 3	17981.43	lb
Dead		7624.381218	lb
live		0	lb
Snow		3993.127839	lb

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	300	
Le	1.63Lu+3D	559.5	
Rb	sqrt((le*d)/b^2)	9.970940765	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	11471.373	
Cfu		1	
CL	look at nds	0.9886917832	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		0.96	0.96
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1679.616	psi
Allowable Moment		148,153.21	ft-lb
Moment		134,799.75	ft-lb

Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38,880.00	psf
Actual V	wL/2	11,194.52	lb
Actual fv	3V/2bd	8,947.33	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	11194.51606	lb
Fc actual		162.2393632	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column	0.0101723173	ft
Delta S	See next column	0.02699122336	ft
Delta D+L	See next column	0.01232134173	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.06944444444	ft
Delta S	L/360	0.06944444444	ft
Delta D+L	L/240	0.1041666667	ft

3rd – 1st Floor 2

Member Lengths and Properties			
Variable		**Value**	**Unit**
l		25	ft
b		11.5	in
d		27.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		316.25	in^2
Sxx		1449.5	in^3
Ixx		19930.3	in^4
Isupport		6	in

Beam Stability Factor			
Variable		**Value**	**Unit**
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		5.545	
FBe		57	psi
CL			

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions					
Joist Number		3-1			
Joist b		11.5	in		
joist d		15.5	in		
Girder Tributary Width		16.5	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	0	lbs
Dead Loads - Total		30.7	psf	3089.309896	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	714.8567708	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		100	psf	7734.375	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	3089.31	lbs
LC2	D+L	130.7	psf	10823.68	lbs
LC3	D+(Lr or S or R)	30.7	psf	3089.31	lbs
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	8890.09	lbs
LC5	D + (0.6W or 0.7E)	30.7	psf	3089.31	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	8890.09	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	105.7	psf	8890.09	lbs
LC7	0.6D + 0.6W	18.42	psf	1853.59	lbs
LC8	0.6D + 0.7E	18.42	psf	1853.59	lbs

Point Load 2 - Middle

Section-Specific Loading and Dimensions					
Joist Number		3-2			
Joist b		11.5	in		
joist d		17.5	in		
Girder Tributary Width		16.5	ft		
CLT Tributary Area		15.625	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	0	lbs
Dead Loads - Total		30.7	psf	8721.940104	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	807.0963542	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		91.0578	psf	23475.83906	lbs

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	8721.94	lbs
LC2	D+L	121.7578	psf	32197.78	lbs
LC3	D+(Lr or S or R)	30.7	psf	8721.94	lbs
LC4	D + 0.75L + 0.75(Lr or S or	98.99335	psf	26328.82	lbs
LC5	D + (0.6W or 0.7E)	30.7	psf	8721.94	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	98.99335	psf	26328.82	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.7	98.99335	psf	26328.82	lbs
LC7	0.6D + 0.6W	18.42	psf	5233.16	lbs
LC8	0.6D + 0.7E	18.42	psf	5233.16	lbs

Point Load 3 - Right

Section-Specific Loading and Dimensions					
Joist Number		3-3			
Joist b		11.5	in		
joist d		15.5	in		
Girder Tributary Width		16.5	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	0	lbs
Dead Loads - Total		30.7	psf	3089.309896	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	714.8567708	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		100	psf	7734.375	lbs

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	3089.31	lbs
LC2	D+L	130.7	psf	10823.68	lbs
LC3	D+(Lr or S or R)	30.7	psf	3089.31	lbs
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	8890.09	lbs
LC5	D + (0.6W or 0.7E)	30.7	psf	3089.31	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	8890.09	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	105.7	psf	8890.09	lbs
LC7	0.6D + 0.6W	18.42	psf	1853.59	lbs
LC8	0.6D + 0.7E	18.42	psf	1853.59	lbs

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	76.86631944	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	76.86631944	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Actual Loading						
Variable	Description	Calculation	Units	Total DL (lbs)	Total LL	Total Roof SL (lbs)
LC1	D	16822.22	lbs	0	0	0
LC2	D+L	55766.81	lbs	16822.21788	38944.5	0
LC3	D+(Lr or S or R)	16822.22	lbs	0	0	0
LC4	D + 0.75L + 0.75(Lr or S or	46030.66	lbs	0	0	0
LC5	D + (0.6W or 0.7E)	16822.22	lbs	0	0	0
LC6a	D + 0.75L + 0.75(0.6W) + 0.	46030.66	lbs	0	0	0
LC6b	D + 0.75L + 0.75(0.7E) + 0.	46030.66	lbs	0	0	0
LC7	0.6D + 0.6W	10093.33	lbs	0	0	0
LC8	0.6D + 0.7E	10093.33	lbs	0	0	0

Column reaction	Formula	Value	Unit
Total	112	55766.81	lb

Left Column	Formula	Value	Unit
Total	Pt load 1 + (12.5*self weig	27883.40	lb
Dead		8411.108941	lb
live		19472.29453	lb
Snow		0	lb

Right co	Formula	Value	Unit
Total	Pt load 3	27883.40	lb
Dead		8411.108941	lb
live		19472.29453	lb
Snow		0	lb

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	300	
Le	1.63Lu+3D	571.5	
Rb	sqrt((le*d)/b^2)	10.90125814	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	9596.976378	
Cfu		1	
CL	look at nds	0.9859408423	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		1	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1749.6	psi
Allowable Moment		211334.06	ft-lb
Moment		207241.30	ft-lb

Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	17059.71858	lb
Actual fv	3V/2bd	11651.85522	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	17059.71858	lb
Fc actual		247.2422982	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column	0.03067433974	ft
Delta S	See next column	0	ft
Delta D+L	See next column	0.03224366012	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.06944444444	ft
Delta S	L/360	0.06944444444	ft
Delta D+L	L/240	0.1041666667	ft

Special Glulam Girder

4th Floor Core Member

Member Lengths and Properties			
Variable		**Value**	**Unit**
l		26	ft
b		17.625	in
d		27.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		484.6875	in^2
Sxx		2221.5	in^3
Ixx		30545.4	in^4
Isupport		6	in

Beam Stability Factor			
Variable		**Value**	**Unit**
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		3.618	
FBe		133	psi
CL			

Loading					
Point Load 1 - left					
Section-Specific Loading and Dimensions					
Joist Number		4-3s			
Joist b		11.5	in		
joist d		11.5	in		
Girder Tributary Width		13.5	ft		
CLT Tributary Area		4.875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	433.9453125	
Dead Loads - Total		176.7	psf	12063.01406	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*150*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	433.9453125	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		20	psf	1316.25	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	176.7	psf	12063.01	lbs
LC2	D+L	196.7	psf	13379.26	lbs
LC3	D+(Lr or S or R)	176.7	psf	12496.96	lbs
LC4	D + 0.75L + 0.75(Lr or S or	191.7	psf	13375.66	lbs
LC5	D + (0.6W or 0.7E)	176.7	psf	12063.01	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	191.7	psf	13375.66	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	191.7	psf	13375.66	lbs
LC7	0.6D + 0.6W	106.02	psf	7237.81	lbs
LC8	0.6D + 0.7E	106.02	psf	7237.81	lbs

Point Load 2 - Middle

Section-Specific Loading and Dimensions					
Joist Number		4-4			
Joist b		11.5	in		
joist d		15.5	in		
Girder Tributary Width		13.5	ft		
CLT Tributary Area		16.25	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf		
Dead Loads - Total		176.7	psf	39348.44531	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*150*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	584.8828125	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		20	psf	4387.5	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	176.7	psf	39348.45	lbs
LC2	D+L	196.7	psf	43735.95	lbs
LC3	D+(Lr or S or R)	176.7	psf	39348.45	lbs
LC4	D + 0.75L + 0.75(Lr or S or	191.7	psf	42639.07	lbs
LC5	D + (0.6W or 0.7E)	176.7	psf	39348.45	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	191.7	psf	42639.07	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	191.7	psf	42639.07	lbs
LC7	0.6D + 0.6W	106.02	psf	23609.07	lbs
LC8	0.6D + 0.7E	106.02	psf	23609.07	lbs

Point Load 3 - Right

Section-Specific Loading and Dimensions					
Joist Number		4-3s			
Joist b		11.5	in		
joist d		11.5	in		
Girder Tributary Width		13.5	ft		
CLT Tributary Area		4.875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	433.9453125	
Dead Loads - Total		176.7	psf	12063.01406	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*150*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	433.9453125	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		20	psf	1316.25	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	176.7	psf	12063.01	lbs
LC2	D+L	196.7	psf	13379.26	lbs
LC3	D+(Lr or S or R)	176.7	psf	12496.96	lbs
LC4	D + 0.75L + 0.75(Lr or S or	191.7	psf	13375.66	lbs
LC5	D + (0.6W or 0.7E)	176.7	psf	12063.01	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	191.7	psf	13375.66	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	191.7	psf	13375.66	lbs
LC7	0.6D + 0.6W	106.02	psf	7237.81	lbs
LC8	0.6D + 0.7E	106.02	psf	7237.81	lbs

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	117.8059896	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	117.8059896	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Actual Loading						
Variable	Description	Calculation	Units	Total DL (lbs)	Total LL (lbs)	Total Roof SL (lbs)
LC1	D	66537.43	lbs	0	0	0
LC2	D+L	73557.43	lbs	66537.42917	7020	0
LC3	D+(Lr or S or R)	67405.32	lbs	0	0	0
LC4	D + 0.75L + 0.75(Lr or S or	72453.35	lbs	0	0	0
LC5	D + (0.6W or 0.7E)	66537.43	lbs	0	0	0
LC6a	D + 0.75L + 0.75(0.6W) + 0.	72453.35	lbs	0	0	0
LC6b	D + 0.75L + 0.75(0.7E) + 0.'	72453.35	lbs	0	0	0
LC7	0.6D + 0.6W	39922.46	lbs	0	0	0
LC8	0.6D + 0.7E	39922.46	lbs	0	0	0

Column reaction	Formula	Value	Unit
Total		73557.43	lb

Left Column	Formula	Value	Unit
Total	Pt load 1 + (12.5*self weig	36778.71	lb
Dead		33268.71458	lb
live		3510	lb
Snow		0	lb

Right column	Formula	Value	Unit
Total	Pt load 3 + (12.5*s	36778.71	lb
Dead		33268.71458	lb
live		3510	lb
Snow		0	lb

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	312	
Le	1.63Lu+3D	591.06	
Rb	sqrt((le*d)/b^2)	7.233575287	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	21796.24404	
Cfu		1	
CL	look at nds	0.9945628646	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		1	0.86
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*(	1749.6	psi
Allowable Moment		323892.42	ft-lb
Moment		294,238.25	ft-lb

Adjusted Shear Parallel to Grain Design Value (F			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	23399.45052	lb
Actual fv	3V/2bd	10427.9176	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	23399.45052	lb
Fc actual		221.2713997	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column	0.004207653436	ft
Delta S	See next column	0	ft
Delta D+L	See next column	0.006043545297	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.07222222222	ft
Delta S	L/360	0.07222222222	ft
Delta D+L	L/240	0.1083333333	ft

3rd Floor Core Member

Member Lengths and Properties			
Variable		**Value**	**Unit**
l		26	ft
b		11.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		132.25	in^2
Sxx		253.5	in^3
Ixx		1457.5	in^4
Isupport		6	in

Beam Stability Factor			
Variable		**Value**	**Unit**
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		3.585	
FBe		135	psi
CL			

Loading					
Point Load 1 - left					
Section-Specific Loading and Dimensions					
Joist Number		3-2s			
Joist b		11.5	in		
joist d		15.5	in		
Girder Tributary Width		0	ft		
Joist Tributary Area		4.875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	0	
Dead Loads - Total		21.7	psf	0	lbs
	Insulation on CLT (D)	*0*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	0	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		109	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	21.7	psf	0.00	lbs
LC2	D+L	130.7	psf	0.00	lbs
LC3	D+(Lr or S or R)	21.7	psf	0.00	lbs
LC4	D + 0.75L + 0.75(Lr or S or	103.45	psf	0.00	lbs
LC5	D + (0.6W or 0.7E)	21.7	psf	0.00	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	103.45	psf	0.00	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	103.45	psf	0.00	lbs
LC7	0.6D + 0.6W	13.02	psf	0.00	lbs
LC8	0.6D + 0.7E	13.02	psf	0.00	lbs

Point Load 2 - Middle					
Section-Specific Loading and Dimensions					
Joist Number					
Joist b		11.5	in		
joist d		23.5	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		16.25	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf		
Dead Loads - Total		0	psf	0	lbs
	Insulation on CLT (D)	*0*	*psf*		
	MEP Allowance (D)	*0*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*0*	*psf*		
	CLT Weight (D)	*0*	*psf*		
	Joist Weight	0	pcf	0	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	0	psf	0.00	lbs
LC2	D+L	0	psf	0.00	lbs
LC3	D+(Lr or S or R)	0	psf	0.00	lbs
LC4	D + 0.75L + 0.75(Lr or S or	0	psf	0.00	lbs
LC5	D + (0.6W or 0.7E)	0	psf	0.00	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	0	psf	0.00	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	0	psf	0.00	lbs
LC7	0.6D + 0.6W	0	psf	0.00	lbs
LC8	0.6D + 0.7E	0	psf	0.00	lbs

Point Load 3 - Right

Section-Specific Loading and Dimensions					
Joist Number		3-2s			
Joist b		11.5	in		
joist d		15.5	in		
Girder Tributary Width		0	ft		
CLT Tributary Area		4.875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	0	
Dead Loads - Total		21.7	psf	0	lbs
	Insulation on CLT (D)	*0*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	0	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		109	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	21.7	psf	0.00	lbs
LC2	D+L	130.7	psf	0.00	lbs
LC3	D+(Lr or S or R)	21.7	psf	0.00	lbs
LC4	D + 0.75L + 0.75(Lr or S or	103.45	psf	0.00	lbs
LC5	D + (0.6W or 0.7E)	21.7	psf	0.00	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	103.45	psf	0.00	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	103.45	psf	0.00	lbs
LC7	0.6D + 0.6W	13.02	psf	0.00	lbs
LC8	0.6D + 0.7E	13.02	psf	0.00	lbs

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	32.14409722	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	32.14409722	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Actual Loading						
Variable	Description	Calculation	Units	Total DL (lbs)	Total LL (lbs)	Total Roof SL (lbs)
LC1	D	835.75	lbs	835.7465278	0	0
LC2	D+L	835.75	lbs	835.7465278	0	0
LC3	D+(Lr or S or R)	835.75	lbs	835.7465278	0	0
LC4	D + 0.75L + 0.75(Lr or S or	835.75	lbs	835.7465278	0	0
LC5	D + (0.6W or 0.7E)	835.75	lbs	835.7465278	0	0
LC6a	D + 0.75L + 0.75(0.6W) + 0.	835.75	lbs	835.7465278	0	0
LC6b	D + 0.75L + 0.75(0.7E) + 0.	835.75	lbs	835.7465278	0	0
LC7	0.6D + 0.6W	501.45	lbs	0	0	0
LC8	0.6D + 0.7E	501.45	lbs	0	0	0

Column reaction	Formula	Value	Unit
Total		835.75	lb

Left Column	Formula	Value	Unit
Total	Pt load 1 + (12.5*self weig	417.87	lb
Dead		417.8732639	lb
live		0	lb
Snow		0	lb

Right column	Formula	Value	Unit
Total	Pt load 3 + (12.5*s	417.87	lb
Dead		417.8732639	lb
live		0	lb
Snow		0	lb

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	312	
Le	1.63Lu+3D	543.06	
Rb	sqrt((le*d)/b^2)	6.871870829	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	24151.14352	
Cfu		1	
CL	look at nds	0.9951388836	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		0.67	0.86
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*C	1172.232	psi
Allowable Moment		24,761.37	ft-lb
Moment		2,716.18	ft-lb

Adjusted Shear Parallel to Grain Design Value (F			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	417.8732639	lb
Actual fv	3V/2bd	682.5	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	417.8732639	lb
Fc actual		6.056134259	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column	0	ft
Delta S	See next column	0	ft
Delta D+L	See next column	0.01049816215	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.07222222222	ft
Delta S	L/360	0.07222222222	ft
Delta D+L	L/240	0.1083333333	ft

2rd Floor Atrium Member

Member Lengths and Properties

Variable		Value	Unit
l		26	ft
b		11.5	in
d		21.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		247.25	in^2
Sxx		886.0	in^3
Ixx		9524.3	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.902	
FBe		72	psi
CL			

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions					
Joist Number		2-1s			

Actual Loading					
Variable	Description	Calculation	Units		
LC3	D+(Lr or S or R)	31.7	psf	1930.00	lbs

Point Load 2 - Middle

Section-Specific Loading and Dimensions				
Joist Number	2-11s			
Joist b	11.5	in		
joist d	17.5	in		
Girder Tributary Width	8.25	ft		

Actual Loading					
Variable	Description	Calculation	Units		
LC3	D+(Lr or S or R)		psf	6140.48	lbs

Point Load 3 and 4 - Middle

Section-Specific Loading and Dimensions					
Joist Number		2-2			
Joist b		11.5	in		
joist d		17.5	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		15.625	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	403.5481771	
Dead Loads - Total		30.7	psf	4360.970052	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	403.5481771	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		100	psf	12890.625	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	4360.97	lbs
LC2	D+L	130.7	psf	17251.60	lbs
LC3	D+(Lr or S or R)	30.7	psf	4764.52	lbs
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	14331.60	lbs
LC5	D + (0.6W or 0.7E)	30.7	psf	4360.97	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	14331.60	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	105.7	psf	14331.60	lbs
LC7	0.6D + 0.6W	18.42	psf	2616.58	lbs
LC8	0.6D + 0.7E	18.42	psf	2616.58	lbs

Point Load 4 - end					
Section-Specific Loading and Dimensions					
Joist Number		2-3			
Joist b		11.5	in		
joist d		15.5	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		9.375	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	357.4283854	
Dead Loads - Total		30.7	psf	2731.88151	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Joist Weight	35	pcf	357.4283854	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		100	psf	7734.375	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	2731.88	lbs
LC2	D+L	130.7	psf	10466.26	lbs
LC3	D+(Lr or S or R)	30.7	psf	3089.31	lbs
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	8800.73	lbs
LC5	D + (0.6W or 0.7E)	30.7	psf	2731.88	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	8800.73	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	105.7	psf	8800.73	lbs
LC7	0.6D + 0.6W	18.42	psf	1639.13	lbs
LC8	0.6D + 0.7E	18.42	psf	1639.13	lbs
			1/2 weight	5233.128255	lbs

Uniform Load from Glulam Self weight				
Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	60.09548611	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Left Column	Formula	Value	Unit
Total	Manual enter	18800	lb

Right column	Formula	Value	Unit
Total	Manual Enter	14200	lb

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	312	
Le	1.63Lu+3D	573.06	
Rb	sqrt((le*d)/b^2)	9.652091657	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	12241.78644	
Cfu		1	
CL	look at nds	0.9895341357	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		0.93	0.86
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*C	1627.128	psi
Allowable Moment		120133.46	ft-lb
Moment		106,000.00	ft-lb
Adjusted Shear Parallel to Grain Design Value (F			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	10200	lb
Actual fv	3V/2bd	8910.819009	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	10200	lb
Fc actual		147.826087	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column		ft
Delta S	See next column		ft
Delta D+L	See next column	0.04541666667	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.07222222222	ft
Delta S	L/360	0.07222222222	ft
Delta D+L	L/240	0.1083333333	ft

1st Floor Atrium Walkway Member

Member Lengths and Properties

Variable		Value	Unit
l		32	ft
b		9.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		109.25	in^2
Sxx		209.4	in^3
Ixx		1204.0	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.340	
FBe		92	psi
CL			

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions					
Joist Number		1-1s			
Actual Loading					
Variable	Description	Calculation	Units		
LC3	D+(Lr or S or R)	31.7	psf	1230.00	lbs

Point Load 2 - Middle

Section-Specific Loading and Dimensions				
Joist Number	1-13s			
Joist b	9.5	in		
joist d	11.5	in		
Girder Tributary Width	8.25	ft		

Point Load 3 - end					
Section-Specific Loading and Dimensions					
Joist Number		1-14s			
Joist b		9.5	in		
joist d		11.5	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		0.7916666667	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		0	psf	0	lbs
Ground snow load (S)		0	psf	219.0690104	
Dead Loads - Total		6.6	psf	262.1752604	lbs
	Insulation on CLT (D)	*0*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*0*	*psf*		
	Joist Weight	35	pcf	219.0690104	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	6.6	psf	262.18	lbs
LC2	D+L	6.6	psf	262.18	lbs
LC3	D+(Lr or S or R)	6.6	psf	481.24	lbs
LC4	D + 0.75L + 0.75(Lr or S or	6.6	psf	426.48	lbs
LC5	D + (0.6W or 0.7E)	6.6	psf	262.18	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	6.6	psf	426.48	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	6.6	psf	426.48	lbs
LC7	0.6D + 0.6W	3.96	psf	157.31	lbs
LC8	0.6D + 0.7E	3.96	psf	157.31	lbs

Uniform Load from Glulam Self weight				
Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	26.55381944	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Left Column	Formula	Value	Unit
Total	Manual enter	4160	lb

Right column	Formula	Value	Unit
Total	Pt load 3 + (12.5*s	760	lb

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	384	
Le	1.63Lu+3D	660.42	
Rb	sqrt((le*d)/b^2)	9.173507562	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	13552.41921	
Cfu		1	
CL	look at nds	0.990711658	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		0.5	0.86
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*C	874.8	psi
Allowable Moment		15264.96	ft-lb
Moment		9,670.00	ft-lb
Adjusted Shear Parallel to Grain Design Value (F			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	1530	lb
Actual fv	3V/2bd	3024.988558	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	1530	lb
Fc actual		26.84210526	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column		ft
Delta S	See next column		ft
Delta D+L	See next column	0.002341666667	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.08888888889	ft
Delta S	L/360	0.08888888889	ft
Delta D+L	L/240	0.1333333333	ft

Typical Glulam Column

4th Floor

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**

Member Lengths and Properties

Variable		Value	Unit
l		12	ft
b		11.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		132.25	in^2
Sxx		253.5	in^3
Ixx		33522.6	in^4
Isupport		6	in

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions			
Load from girder to the left	0.00	lbs	
Load from girder to the right	17,826.74	lbs	LC 3 Governs
Self-weight of column	385.73	lbs	LC 3 Governs

Cp Calculations!

Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi

E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	

le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		12.52173913	in/in

FcE	critical buckling design value		
FcE	((0.822)*E'min)/((le/d)^2)	4996.35908	psi

Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		2.361228299	
Cp	$C_P := \frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}} - \sqrt{\left[\frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}}\right]^2 - \frac{\frac{F_{cE}}{F_{c*}}}{c_{sawn}}}$		0.9381529001	

F'c	Axial Buckling Capacity		
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp	1,985.13	psi
Overall Tributary Area		132.25	in2
Allowable Load		262,533.65	lbs
Allowable Load for 2h fire (90 min + gyp)		52,000.00	lbs
Total Actual Load		17,826.74	lbs
Total Actual Load including column		18,212.47	lbs

3rd Floor

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**

Member Lengths and Properties

Variable		Value	Unit
l		12	ft
b		11.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		132.25	in^2
Sxx		253.5	in^3
Ixx		33522.6	in^4
Isupport		6	in

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions			
Load from girder to the left	0	lbs	
Load from girder to the right	27,883.40	lbs	
Load from column above	18,212.47	lbs	
Self-weight of column	385.73	lbs	

Cp Calculations!

Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi

E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	

le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		12.52173913	in/in

FcE	critical buckling design value			
FcE	((0.822)*E'min)/((le/d)^2)		4996.35908	psi

Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		2.361228299	
Cp	$C_P := \frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}} - \sqrt{\left[\frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}}\right]^2 - \frac{\frac{F_{cE}}{F_{c*}}}{c_{sawn}}}$		0.9381529001	

F'c	Axial Buckling Capacity			
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp		1,985.13	psi
Overall Tributary Area			132.25	in2
Allowable Load			262,533.65	lbs
Allowable Load for 2h fire (90 min + gyp)			52,000.00	lbs
Total Actual Load			46,095.87	lbs
Total Actual Load including column			46,481.60	lbs

2nd Floor

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**

Member Lengths and Properties

Variable		Value	Unit
l		12	ft
b		13.625	in
d		13.625	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		185.640625	in^2
Sxx		421.6	in^3
Ixx		78258.5	in^4
Isupport		6	in

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions			
Load from girder to the left	0	lbs	
Load from girder to the right	27,883.40	lbs	
Load from column above	46,481.60	lbs	
Self-weight of column	541.45	lbs	

Cp Calculations!

Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi

E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	

le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		10.56880734	in/in

FcE	critical buckling design value		
FcE	((0.822)*E'min)/((le/d)^2)	7013.438354	psi

Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		3.314479373	
Cp	(see equation below)		0.9607808776	

$$C_p := \frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}} - \sqrt{\left[\frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}}\right]^2 - \frac{\frac{F_{cE}}{F_{c*}}}{c_{sawn}}}$$

F'c	Axial Buckling Capacity		
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp	2,033.01	psi
Overall Tributary Area		185.64	in2
Allowable Load		377,409.68	lbs
Allowable Load for 2h fire (90 min + gyp)		188,750.00	lbs
Total Actual Load		74,365.00	lbs
Total Actual Load		74,906.45	lbs

1st Floor

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**

Member Lengths and Properties

Variable		Value	Unit
l		12	ft
b		13.625	in
d		13.625	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		185.640625	in^2
Sxx		421.6	in^3
Ixx		78258.5	in^4
Isupport		6	in

Loading				
Point Load 1 - left				
Section-Specific Loading and Dimensions				
Load from girder to the left		0	lbs	
Load from girder to the right		27,883.40	lbs	
Load from column above		74,906.45	lbs	
Self-weight of column		541.45	lbs	
Cp Calculations!				
Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi
E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	
le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		10.56880734	in/in
FcE	critical buckling design value			
FcE	((0.822)*E'min)/((le/d)^2)		7013.438354	psi
Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		3.314479373	
Cp	$C_p := \frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}} - \sqrt{\left[\frac{\left(1+\frac{F_{cE}}{F_{c*}}\right)}{2c_{sawn}}\right]^2 - \frac{\left(\frac{F_{cE}}{F_{c*}}\right)}{c_{sawn}}}$		0.9607808776	
F'c	Axial Buckling Capacity			
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp		2,033.01	psi
Overall Tributary Area			185.64	in2
Allowable Load			377,409.68	lbs
Allowable Load for 2h fire (90 min + gyp)			188,750.00	lbs
Total Actual Load			102,789.85	lbs
Total Actual Load			103,331.30	lbs

Special Glulam Column

4th Floor Core

Variable	Name	Value	Unit
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**
	Member Lengths and Properties		
Variable		**Value**	**Unit**
l		12	ft
b		11.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		132.25	in^2
Sxx		253.5	in^3
Ixx		33522.6	in^4
Isupport		6	in

Loading				
Point Load 1 - left				
Section-Specific Loading and Dimensions				
Load from girder to the left		19025.68	lbs	4-4
Load from girder to the right		22,068.72	lbs	4-5s
Self-weight of column		385.73	lbs	
Cp Calculations!				
Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi
E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	
le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		12.52173913	in/in
FcE	critical buckling design value			
FcE	((0.822)*E'min)/((le/d)^2)		4996.35908	psi
Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		2.361228299	
Cp	$C_p := \dfrac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}} - \sqrt{\left[\dfrac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}}\right]^2 - \dfrac{\frac{F_{cE}}{F_{c*}}}{c_{sawn}}}$		0.9381529001	
F'c	Axial Buckling Capacity			
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp		1,985.13	psi
Overall Tributary Area			132.25	in2
Allowable Load			262,533.65	lbs
Allowable Load for 3h fire (2 hr + 2 gyp)			52,000.00	lbs
Total Actual Load on column			41,094.40	lbs
Total Actual Load including column			41,480.13	lbs

3rd Floor Core

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**

Member Lengths and Properties

Variable		Value	Unit
l		12	ft
b		13.625	in
d		13.625	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		185.640625	in^2
Sxx		421.6	in^3
Ixx		78258.5	in^4
Isupport		6	in

Loading				
Point Load 1 - left				
Section-Specific Loading and Dimensions				
Load from girder to the left		27883.4	lbs	3-4
Load from girder to the right		14,331.98	lbs	3-5s
Load from column above		41,480.13	lbs	
Self-weight of column		541.45	lbs	
Cp Calculations!				
Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi
E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	
le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		10.56880734	in/in
FcE	critical buckling design value			
FcE	((0.822)*E'min)/((le/d)^2)		7013.438354	psi
Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		3.314479373	
Cp	$C_P := \frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}} - \sqrt{\left[\frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}}\right]^2 - \frac{\frac{F_{cE}}{F_{c*}}}{c_{sawn}}}$		0.9607808776	
F'c	Axial Buckling Capacity			
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp		2,033.01	psi
Overall Tributary Area			185.64	in2
Allowable Load			377,409.68	lbs
Allowable Load for 3h fire (2 hr + 2 gyp)			188,750.00	lbs
Total Actual Load on column			83,695.51	lbs
Total Actual Load including column			84,236.96	lbs

2nd Floor Atrium

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**

Member Lengths and Properties

Variable		Value	Unit
l		12	ft
b		13.625	in
d		13.625	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		185.640625	in^2
Sxx		421.6	in^3
Ixx		78258.5	in^4
Isupport		6	in

Loading

Section-Specific Loading and Dimensions				
Load from girder to the left		14200	lbs	2-15s
Load from girder to the right		14,212.48	lbs	2-3
Load from column above		47,714.97	lbs	3-3
Self-weight of column		541.45	lbs	
Cp Calculations!				
Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi
E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	
le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		10.56880734	in/in
FcE	critical buckling design value			
FcE	((0.822)*E'min)/((le/d)^2)		7013.438354	psi
Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		3.314479373	
Cp	$C_p := \frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}} - \sqrt{\left[\frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}}\right]^2 - \frac{\frac{F_{cE}}{F_{c*}}}{c_{sawn}}}$		0.9607808776	
F'c	Axial Buckling Capacity			
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp		2,033.01	psi
Overall Tributary Area			185.64	in2
Allowable Load			377,409.68	lbs
Allowable Load for 3h fire (2 hr + 2 gyp)			188,750.00	lbs
Total Actual Load on column			76,127.45	lbs
Total Actual Load including column			76,668.90	lbs

1st Floor Atrium Walkway

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**

Member Lengths and Properties

Variable		Value	Unit
l		12	ft
b		11.5	in
d		11.5	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		132.25	in^2
Sxx		253.5	in^3
Ixx		33522.6	in^4
Isupport		6	in

Loading				
Section-Specific Loading and Dimensions				
Load from girder to the left		0	lbs	
Load from girder to the right		8,870.00	lbs	1-20s
Load from column above		85,100.55	lbs	2-19s
Self-weight of column		385.73	lbs	
Cp Calculations!				
Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi
E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	
le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		12.52173913	in/in
FcE	critical buckling design value			
FcE	((0.822)*E'min)/((le/d)^2)		4996.35908	psi
Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		2.361228299	
Cp	(formula below)		0.9381529001	
F'c	Axial Buckling Capacity			
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp		1,985.13	psi
Overall Tributary Area			132.25	in2
Allowable Load			262,533.65	lbs
Allowable Load for 3h fire (2 hr + 2 gyp)			123,650.00	lbs
Total Actual Load on column			93,970.55	lbs
Total Actual Load including column			94,356.28	lbs

$$C_p := \frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}} - \sqrt{\left[\frac{1+\frac{F_{cE}}{F_{c*}}}{2c_{sawn}}\right]^2 - \frac{\frac{F_{cE}}{F_{c*}}}{c_{sawn}}}$$

Shear Walls

Windward/Leeward side								
Floor	b (width, ft)	Wind load (psf)	Height of story (ft)	Wind wu (plf)	Vu=(wu*b)/2 (LBS)	Length of shear walls	Vt (distributed shear applied on top of wall) lb/ft	C=T=Vt*height of wall
4	126	41.4	8	331.2	20,865.60	115.5	180.6545455	2529.163636
3	126	39.8	16	636.8	40,118.40	115.5	528	7392
2	126	37.8	16	604.8	38,102.40	115.5	857.8909091	12010.47273
1	126	34.7	16	555.2	34,977.60	115.5	1160.727273	16250.18182
						134,064.00		

Capacity - loading perp to layers, ww/lw				
Floor DIAPHRAM	CLT	Rolling shear (ps	IB/Q	Allowable shear
4	105-3s	45	212.1852777	9548.337497
3	175-5s	45	325.49	14647.05
2	175-5s	45	325.49	14647.05
1	175-5s	45	325.49	14647.05

Capacity - loading parallel to layers, ww/lw					
Floor WALLS	CLT	edgewise shear design val Fv (psi) through the thickness	Width (in)	Allowable Ve (lbs/ft)	allowable C=T=Vt*height of wall
4	175-5s	215	6.875	1,478.13	20693.75
3	175-5s	215	6.875	1,478.13	20693.75
2	175-5s	215	6.875	1,478.13	20693.75
1	175-5s	215	6.875	1,478.13	20693.75

long side								
Floor	b (width, ft)	Wind load (psf)	Height of story (ft)	Wind wu (plf)	Vu=(wu*b)/2 (on shear wall)	Length of shear walls	Vt (distributed shear applied on top of wall) lb/ft	C=T=Vt*height of wall
4	165	24.4	8	195.2	16104	78	206.4615385	2477.538462
3	165	24.4	16	390.4	32208	78	619.3846154	7432.615385
2	165	24.4	16	390.4	32208	78	1032.307692	12387.69231
1	165	24.4	16	390.4	32208	78	1445.230769	17342.76923

Capacity - loading perp to layers, long side				
Floor DIAPHRAM	CLT	Rolling shear (psi)	IB/Q	Allowable shear
4	105-3s	45	212.1852777	9548.337497
3	175-5s	45	325.49	14647.05
2	175-5s	45	325.49	14647.05
1	175-5s	45	325.49	14647.05

Capacity - loading parallel to layers, Long side					
Floor WALLS	CLT	edgewise shear design val Fv (psi) through the thickness	Gross cross sectional area (in2)	Allowable Ve (lbs)	allowable C=T=Vt*height of wall
4	175-5s	215	6.875	1478.125	20693.75
3	175-5s	215	6.875	1478.125	20693.75
2	175-5s	215	6.875	1478.125	20693.75
1	175-5s	215	6.875	1478.125	20693.75

Appendix C: Fire Analysis – Option 1

Fire Analysis Results - CLT

Floor	CLT	Req total fire rating	req. Fire rating of member	Initial layers of Gyp	Char loss	Final Laminations	New resistance rating	Good for Ratio	Good at initial load	Good for ultimate load	Good for initial load after 100->50
4	105-3s	2	1	2	1.8	1		Yes	Yes	Yes	
3,2,1	175-5s	2	1	2	1.8	3		Yes	No	Yes	

Fire Analysis Results - Joist

	Width	Initial Depth	Req total fire rating	req. Fire rating of member	Initial layers of Gyp	Char loss	Final Width	Final Depth	Good for Ratio	Good at initial load	Good for ultimate load	Good for initial load after 100->50	Notes
4-1	11.5	13.5	2	1	2	1.8	7.9	11.7	Yes	Yes	Yes	[redacted]	
4-2	11.5	15.5	2	1	2	1.8	7.9	13.7	Yes	No	Yes	[redacted]	
4-3	11.5	13.5	2	1	2	1.8	7.9	11.7	Yes	No	Yes	[redacted]	
4-4	11.5	15.5	2	1	2	1.8	7.9	13.7	Yes	No	Yes	[redacted]	
4-5	11.5	19.5	3	2	2	3.16	5.18	16.34	Yes	No	Yes	[redacted]	
4-6	11.5	23.5	3	2	2	3.16	5.18	20.34	Yes	No	Yes	[redacted]	
3-1	11.5	13.5	3	2	2	3.16	5.18	10.34	Yes	No	Yes	No	
3-2	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	
3-3	11.5	15.5	3	2	2	3.16	5.18	12.34	Yes	No	Yes	No	
3-4	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	
3-5	11.5	15.5	3	2	2	3.16	5.18	12.34	Yes	No	Yes	No	
3-6	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	Resize Up
2-1	11.5	13.5	3	2	2	3.16	5.18	10.34	Yes	No	Yes	No	
2-2	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	
2-3	11.5	15.5	3	2	2	3.16	5.18	12.34	Yes	No	Yes	No	
2-4	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	
2-5	11.5	15.5	3	2	2	3.16	5.18	12.34	Yes	No	Yes	No	
2-6	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	Resize Up
1-1	11.5	13.5	3	2	2	3.16	5.18	10.34	Yes	No	Yes	No	
1-7	11.5	15.5	3	2	2	3.16	5.18	12.34	Yes	No	Yes	No	
1-8	11.5	13.5	3	2	2	3.16	5.18	10.34	Yes	No	Yes	No	
1-2	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	
1-3	11.5	15.5	3	2	2	3.16	5.18	12.34	Yes	No	Yes	No	
1-4	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	
1-5	11.5	15.5	3	2	2	3.16	5.18	12.34	Yes	No	Yes	No	
1-6	11.5	17.5	3	2	2	3.16	5.18	14.34	Yes	No	Yes	No	Resize Up

Fire Analysis Results – Girders

	Width	Initial Depth	Initial total hours fire	Initial member fire rating	Initial layers of Gyp	Char loss	Final Width	Final Depth	Good for Ratio	Good at initial load	Good for ultimate load	Good after initial load 100->50
4-1	11.5	17.5	2	1	2	1.8	7.9	13.9	Yes	No	Yes	
4-2	11.5	23.5	2	1	2	1.8	7.9	19.9	Yes	No	Yes	
4-3	11.5	17.5	2	1	2	1.8	7.9	13.9	Yes	No	Yes	
4-4	11.5	19.5	2	0.66666	2(5/8 in)	1.2	9.1	17.1	Yes	No	Yes	
4-5	11.5	25.5	3	1.5	3	2.5	6.5	20.5	Yes	No	Yes	
4-6	17.5	29.5	3	2	2	3.16	11.18	23.18	Yes	No	Yes	
4-7	11.5	17.5	2	1	2	1.8	7.9	13.9	Yes	No	Yes	
4-8	11.5	19.5	2	0.66666	2(5/8 in)	1.2	9.1	17.1	Yes	No	Yes	
4-9	11.5	17.5	2	1	2	1.8	7.9	13.9	Yes	No	Yes	
4-10	11.5	23.5	2	1	2	1.8	7.9	19.9	Yes	Yes	Yes	
3-1	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
3-2	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
3-3	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
3-4	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
3-5	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
3-6	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
3-7	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
3-8	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
3-9	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
3-10	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
2-1	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
2-2	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
2-3	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
2-4	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
2-5	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
2-6	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
2-7	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
2-8	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
2-9	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
2-10	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
1-1	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
1-2	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
1-3	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
1-4	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
1-5	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
1-6	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
1-7	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
1-8	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No
1-9	11.5	21.5	3	1.5	3	2.5	6.5	16.5	Yes	No	Yes	No
1-10	11.5	27.5	3	1.5	3	2.5	6.5	22.5	Yes	No	Yes	No

Fire Analysis Results – Columns

	Width	Initial Depth	Initial layers of Gyp	Initial hours fire rating	Char loss	Final Width	Final Depth	New resistance rating	Good at initial load	Good at ultimate Load	Good after 100->50
4-1	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	[redacted]
4-2	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	
4-3	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	
4-4	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	
4-5	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	
4-6	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	
4-7	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	
4-8	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	
4-9	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	
4-10	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	
4-11	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	
4-12	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	
3-1	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	No
3-2	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	No
3-3	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	No
3-4	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
3-5	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	No
3-6	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
3-7	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	No
3-8	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
3-9	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	No
3-10	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
3-11	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	No
3-12	11.5	11.5	2	3	3.16	5.18	5.18		Yes	Yes	No
2-1	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	No
2-2	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	No
2-3	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	No
2-4	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
2-5	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
2-6	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
2-7	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
2-8	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
2-9	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	No
2-10	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
2-11	11.5	11.5	2	3	3.16	5.18	5.18		No	Yes	No
2-12	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	No
1-1	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	No
1-2	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
1-3	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
1-4	15.5	15.5	2	3	3.16	9.18	9.18		No	Yes	No
1-5	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
1-6	15.5	15.5	2	3	3.16	9.18	9.18		No	Yes	No
1-7	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
1-8	15.5	15.5	2	3	3.16	9.18	9.18		No	Yes	No
1-9	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No
1-10	15.5	15.5	2	3	3.16	9.18	9.18		No	Yes	No
1-11	13.625	13.625	2	3	3.16	7.305	7.305		Yes	Yes	No
1-12	13.625	13.625	2	3	3.16	7.305	7.305		No	Yes	No

Fire Analysis Calculations – Option 1CLT

Lamination Fall-Off Time			
Variable	Description	Calculation	Units
h_lam	Lamella thickness	1.375	in
Bn	Char Rating	1.5	in/hr
t_fo	Time to reach glued interface	54	min
n_lam	Number of laminations that fall	1	laminations
t	Required FRR	60	min
Effective Char Depth			
Variable	Description	Calculation	Units
a_char	Effective Char Depth	1.93	in
Effective Residual Cross Section			
Variable	Description	Calculation	Units
h	Initial Cross-Section Depth	4.125	in
h_fire	Effective Cross-Section Depth	2.19	in
	Ply Effected - Manually Enter	2	ply

Section-Specific Loading and Dimensions				
Floor		4		
Section:		1A-1		
Length		13		ft
Width		6		ft
Roof Live Load (Lr)		20		psf
Ground snow load (S)		50		psf
Dead Loads - Total		14.10		psf
	Insulation on CLT (D)	*3*		*psf*
	Mechanical (D)	*0*		*psf*
	CLT Self-Weight (D)	*11.1*		*psf*
	Point Loads	*0*		*psf*
Wind (W)		0		mph
Earthquake (E)		0		psf
Live Load (L)				psf

Section-Specific Loading and Dimensions				
Floor		4		
Section:		1A-1		
Length		13		ft
Width		6		ft
Roof Live Load (Lr)		20		psf
Ground snow load (S)		50		psf
Dead Loads - Total		14.10		psf
	Insulation on CLT (D)	*3*		*psf*
	Mechanical (D)	*0*		*psf*
	CLT Self-Weight (D)	*11.1*		*psf*
	Point Loads	*0*		*psf*
Wind (W)		0		mph
Earthquake (E)		0		psf
Live Load (L)				psf

Actual Loading			
Variable	Description	Calculation	Units
LC1	D	14.10	psf
LC2	D+L	14.10	psf
LC3	D+(Lr or S or R)	64.10	psf
LC4	D + 0.75L + 0.75(Lr or S or R)	51.60	psf
LC5	D + (0.6W or 0.7E)	14.10	psf
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(Lr or S	51.60	psf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	51.60	psf
LC7	0.6D + 0.6W	8.46	psf
LC8	0.6D + 0.7E	8.46	psf

Important Values			
Variable	Description	Calculation	Units
M	Induced Bending Moment (Fire)	8124.68	lb-ft
V	Induced Shear (Fire)	3124.88	lb
n_lam	Number of laminations that fall	1	laminations

Fire Analysis Calculations – Option 1 Joist

Joists

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Loading

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Tributary Width		15.625	ft		
Roof Live Load (Lr)		0	psf	0	plf
Ground snow load (S)		0	psf	0	plf
Dead Loads - Total		30.7	psf	497.6160556	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*0*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*15.1*	*psf*		
	Glulam Self-weight	35	pcf	17.92855556	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L)		100	psf	1562.5	plf
Reduced Live Load - edge beam- yes bc KllAt>400 ft		91.05782591	psf	1422.77853	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	30.7	psf	497.62	plf
LC2	D+L	130.7	psf	1920.39	plf
LC3	D+(Lr or S or R)	30.7	psf	497.62	plf
LC4	D + 0.75L + 0.75(Lr or S or	105.7	psf	1564.70	plf
LC5	D + (0.6W or 0.7E)	30.7	psf	497.62	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	105.7	psf	1564.70	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.	105.7	psf	1564.70	plf
LC7	0.6D + 0.6W	18.42	psf	298.57	plf
LC8	0.6D + 0.7E	18.42	psf	298.57	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		5.18	in
d		14.24	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		73.7632	in^2
Sxx		175.1	in^3
Ixx		1246.5	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		8.858	
FBe		22	psi

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	198	
Le	1.63Lu+3D	365.46	
Rb	sqrt((le*d)/b^2)	13.92660186	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	5880.271168	
Cfu		1	
CL	look at nds	0.9729444626	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		1	
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*Cfu*Ci*Fire adjust	1749.6	psi
Ultimate Fire Fb	F'b*2.85	4986.36	psi
Allowable Moment		25524.43	ft-lb
Ultimate Allowable Moment		72744.62	ft-lb
Moment		65353.43	ft-lb

Adjusted Shear Parallel to Grain Design Value (F'v) using ASD			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	15843.25533	lb
Actual fv	3V/2bd	46393.63736	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	15843.25533	lb
Fc actual		509.75725	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	(5*Lr*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta S	(5*S*(L^4))/(E'app*Ixx*384)*144	0	ft
Delta D+L	(5*(L+D)*(L^4))/(E'app*Ixx*384)*144	0.03082339321	ft

Fire Analysis Calculations – Option 1 Girder

Member Lengths and Properties			
Variable		**Value**	**Unit**
l		25	ft
b		7.9	in
d		13.9	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		109.81	in^2
Sxx		254.4	in^3
Ixx		1768.0	in^4
Isupport		6	in

Beam Stability Factor			
Variable		**Value**	**Unit**
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		5.738	
FBe		53	psi
CL			

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions					
Joist Number		4-1			
Joist b		11.5	in		
joist d		13.5	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		20	psf	1933.59375	lbs
Ground snow load (S)		50	psf		
Dead Loads - Total		27.7	psf	1382.519531	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Joist Weight	35	pcf	311.3085938	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	1382.52	lbs
LC2	D+L	27.7	psf	1382.52	lbs
LC3	D+(Lr or S or R)	77.7	psf	3316.11	lbs
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	2832.71	lbs
LC5	D + (0.6W or 0.7E)	27.7	psf	1382.52	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	2832.71	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	65.2	psf	1382.52	lbs
LC7	0.6D + 0.6W	16.62	psf	829.51	lbs
LC8	0.6D + 0.7E	16.62	psf	829.51	lbs

Point Load 2 - Middle

Section-Specific Loading and Dimensions					
Joist Number		4-2			
Joist b		11.5	in		
joist d		15.5	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		15.625	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		18.84375	psf	6445.3125	lbs
Ground snow load (S)		50	psf		
Dead Loads - Total		27.7	psf	3928.13151	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Joist Weight	35	pcf	357.4283854	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	3928.13	lbs
LC2	D+L	27.7	psf	3928.13	lbs
LC3	D+(Lr or S or R)	77.7	psf	10373.44	lbs
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	8762.12	lbs
LC5	D + (0.6W or 0.7E)	27.7	psf	3928.13	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	8762.12	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	65.2	psf	3928.13	lbs
LC7	0.6D + 0.6W	16.62	psf	2356.88	lbs
LC8	0.6D + 0.7E	16.62	psf	2356.88	lbs

Point Load 3 - Right

Section-Specific Loading and Dimensions					
Joist Number		4-3			
Joist b		11.5	in		
joist d		13.5	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		20	psf	1933.59375	lbs
Ground snow load (S)		50	psf		
Dead Loads - Total		29.7	psf	1459.863281	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*13.1*	*psf*		
	Joist Weight	35	pcf	311.3085938	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	29.7	psf	1459.86	lbs
LC2	D+L	29.7	psf	1459.86	lbs
LC3	D+(Lr or S or R)	79.7	psf	3393.46	lbs
LC4	D + 0.75L + 0.75(Lr or S or	67.2	psf	2910.06	lbs
LC5	D + (0.6W or 0.7E)	29.7	psf	1459.86	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	67.2	psf	2910.06	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	67.2	psf	1459.86	lbs
LC7	0.6D + 0.6W	17.82	psf	875.92	lbs
LC8	0.6D + 0.7E	17.82	psf	875.92	lbs

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions				
Floor	4			
Section:	1A - 1			
Dead Load - from Glulam self weight	35	pcf	26.68993056	plf
Wind (W)	0	mph		
Earthquake (E)	0	psf		

Actual Loading						
Variable	Description	Calculation	Units	Total DL (lbs)	Total LL (lbs)	Total Roof SL (lbs)
LC1	D	7437.76	lbs	0	0	0
LC2	D+L	7437.76	lbs	0	0	0
LC3	D+(Lr or S or R)	17750.26	lbs	7437.762587	0	10312.5
LC4	D + 0.75L + 0.75(Lr or S or	15172.14	lbs	0	0	0
LC5	D + (0.6W or 0.7E)	7437.76	lbs	0	0	0
LC6a	D + 0.75L + 0.75(0.6W) + 0.	15172.14	lbs	0	0	0
LC6b	D + 0.75L + 0.75(0.7E) + 0.	7437.76	lbs	0	0	0
LC7	0.6D + 0.6W	4462.66	lbs	0	0	0
LC8	0.6D + 0.7E	4462.66	lbs	0	0	0

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	300	
Le	1.63Lu+3D	530.7	
Rb	sqrt((le*d)/b^2)	10.87188507	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	9648.90362	
Cfu		1	
CL	look at nds	0.9860348921	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		1	0.86
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*C	1749.6	psi
Ultimate F'b	x2.85	4986.36	psi
Allowable Moment		37090.52	ft-lb
Ultimate Allowable Moment		105707.99	ft-lb
Moment		66919.18	ft-lb

Adjusted Shear Parallel to Grain Design Value (F			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	5520.346137	lb
Actual fv	3V/2bd	10858.70837	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	5520.346137	lb
Fc actual		116.4629987	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column	0.09493415924	ft
Delta S	See next column	0	ft
Delta D+L	See next column	0.1010766968	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.06944444444	ft
Delta S	L/360	0.06944444444	ft
Delta D+L	L/240	0.1041666667	ft

Fire Analysis Calculations – Option 1 Column

Variable	Name	Value	Unit
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**
	Member Lengths and Properties		
Variable		**Value**	**Unit**
l		12	ft
b		5.18	in
d		5.18	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		26.8324	in^2
Sxx		23.2	in^3
Ixx		621.6	in^4
Isupport		6	in

Loading			
Point Load 1 - left			
Section-Specific Loading and Dimensions			
Load from girder to the left	0	lbs	
Load from girder to the right	9,114.27	lbs	LC 3 Governs
Self-weight of column	78.26	lbs	LC 3 Governs

Cp Calculations!				
Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi
E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	
le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		27.7992278	in/in
FcE	critical buckling design value			
FcE	((0.822)*E'min)/((le/d)^2)		1013.718755	psi
Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		0.4790731357	
Cp	$C_p := \frac{\left(1+\frac{F_{cE}}{F_{c*}}\right)}{2c_{sawn}} - \sqrt{\left[\frac{\left(1+\frac{F_{cE}}{F_{c*}}\right)}{2c_{sawn}}\right]^2 - \frac{\left(\frac{F_{cE}}{F_{c*}}\right)}{c_{sawn}}}$		0.4436869293	

F'c	Axial Buckling Capacity			
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp		938.84	psi
Ultimate F'c			2,422.21	psi
Overall Tributary Area			26.83	in2
Allowable Load			25,191.37	lbs
Ultimate Allowable Load			64,993.74	
Allowable Load for 3h fire (2 hr + 2 gyp)			52,000.00	lbs
Total Actual Load on column			9,114.27	lbs
Total Actual Load including column			9,192.53	lbs

Appendix D: Fire Analysis – Option 2

Fire Analysis Results – CLT

Floors	CLT	Req total fire rating	req. Fire rating of member	Initial layers of Gyp	Final Laminations	New resistance rating	Good for Ratio	Good at initial load	Good for ultimate load	Good for initial load after 100->50
4	105-3s	2	1	2	1.8	1	Yes	Yes	Yes	Yes
1,2,3	175-5s	2	1	2	3		Yes	Yes	Yes	Yes
penthouse	197-7s	2	1	2 (5/8 in)	5		Yes	Yes	Yes	Yes

Fire Analysis Results – Shear Walls

Floors	CLT	Req total fire rating	req. Fire rating of member	Initial layers of Gyp	Final Laminations	New resistance rating	Good for Ratio	Good at initial load	Good for ultimate load	Good for initial load after 100->50
4,3,2	175-5s	2	1	2	3		Yes	Yes	Yes	Yes
1	197-7s	2	1	2 (5/8 in)	5		Yes	Yes	Yes	Yes

Fire Analysis Results – Joist

	Width	Initial Depth	Req total fire rating	Fire rating of member	Initial layers of Gyp	Char loss	Final Width	Final Depth	Post fire-fire rating of member	Layers of gyp to add post fire	Post-fire Nordic fire estimate (check column E)	Good for Ratio	Good at initial load	Good for ultimate load	Good for initial load after 100->50
4-1	11.5	13.5	2	1	2	1.8	7.9	11.7	1	2	1	Yes	Yes	Yes	
4-2	11.5	17.5	2	1	2	1.8	7.9	15.7	1	2	1	Yes	Yes	Yes	
4-3	11.5	15.5	2	1	2	1.8	7.9	13.7	1	2	1	Yes	Yes	Yes	
4-4	11.5	19.5	2	1	2	1.8	7.9	17.7	1	2	1	Yes	Yes	Yes	
4-5	15.5	19.5	3	1.5	3	2.5	10.5	17	1.5	3	0.95	Yes	Yes	Yes	
4-6	15.5	21.5	3	1.5	3	2.5	10.5	19	1.5	3	1	Yes	Yes	Yes	
3-1	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	Yes	Yes	Yes
3-2	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes
3-3	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	No	Yes	Yes
3-4	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes
3-5	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	No	Yes	Yes
3-6	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes
2-1	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	Yes	Yes	Yes
2-2	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes
2-3	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	No	Yes	Yes
2-4	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes
2-5	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	No	Yes	Yes
2-6	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes
1-1	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	Yes	Yes	Yes
1-7	15.5	17.5	3	2	2	3.16	9.18	14.34	1.5	3	0.852	Yes	No	Yes	Yes
1-8	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	No	Yes	No
1-2	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes
1-3	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	No	Yes	Yes
1-4	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes
1-5	15.5	15.5	3	2	2	3.16	9.18	12.34	1.5	3	0.8294 (int)	Yes	No	Yes	Yes
1-6	15.5	19.5	3	2	2	3.16	9.18	16.34	1.5	3	0.8943	Yes	No	Yes	Yes

Fire Analysis Results – Girder

	Width	Initial Depth	Initial total hours fire rating	Initial member fire rating	Initial layers of Gyp	Char loss	Final width (1 fire exp)	Final depth (1 fire exp)	Post fire- fire rating of membe r	Layers of gyp to add post fire	Char rate 2nd fire	Final Width (2 fire exp)	Final Depth (2 fire exp)	Good for Ratio	Good at initial load before fire	Good at initial load after fire	Good after initial load 100->50	Good for Ultimate Loads for 2nd fire with 50 psf
4-1	15.5	19.5	2	1	2	1.8	11.9	15.9	1	2	1.8	8.3	12.3	Yes	Yes	Yes	[redacted]	Yes
4-2	15.5	25.5	2	1	2	1.8	11.9	21.9	1	2	1.8	8.3	18.3	Yes	Yes	Yes	[redacted]	Yes
4-3	15.5	21.5	2	1	2	1.8	11.9	17.9	1	2	1.8	8.3	14.3	Yes	Yes	Yes	[redacted]	Yes
4-4	15.5	27.5	2	1	2	1.8	11.9	23.9	1	2	1.8	8.3	20.3	Yes	Yes	Yes	[redacted]	Yes
4-5	17.5	29.5	3	1.5	3	2.5	12.5	24.5	1.5	3	2.5	7.5	19.5	Yes	Yes	Yes	[redacted]	Yes
4-6	19.5	35.675	3	1.5	3	2.5	14.5	30.675	1.5	3	2.5	9.5	25.675	Yes	Yes	Yes	[redacted]	Yes
4-7	15.5	21.5	2	1	2	1.8	11.9	17.9	1	2	1.8	8.3	14.3	Yes	Yes	Yes	[redacted]	Yes
4-8	15.5	27.5	2	1	2	1.8	11.9	23.9	1	2	1.8	8.3	20.3	Yes	Yes	Yes	[redacted]	Yes
4-9	15.5	21.5	2	1	2	1.8	11.9	17.9	1	2	1.8	8.3	14.3	Yes	Yes	Yes	[redacted]	Yes
4-10	15.5	25.5	2	1	2	1.8	11.9	21.9	1	2	1.8	8.3	18.3	Yes	Yes	Yes	[redacted]	Yes
3-1	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
3-2	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
3-3	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
3-4	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
3-5	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
3-6	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
3-7	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
3-8	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
3-9	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
3-10	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
2-1	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
2-2	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
2-3	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
2-4	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
2-5	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
2-6	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
2-7	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
2-8	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
2-9	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
2-10	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
1-1	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
1-2	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
1-3	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
1-4	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
1-5	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
1-6	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
1-7	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
1-8	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes
1-9	15.5	25.5	3	1.5	3	2.5	10.5	20.5	3	1.5	3	5.5	15.5	Yes	Yes	No	Yes	Yes
1-10	15.5	29.5	3	1.5	3	2.5	10.5	24.5	3	1.5	3	5.5	19.5	Yes	Yes	No	Yes	Yes

Fire Analysis Results – Columns

	Width	Initial Depth	Initial layers of Gyp (1/2 in unless noted)	Member fire rating	Initial hours fire rating	Char loss	Final Width	Final Depth	New resistance rating	Initial layers of Gyp (1/2 in unless noted)	Member fire rating	new char rate	Good at initial load	Good at ultimate Load	Good after 100->50
4-1	11.5	11.5	2	1	2	1.8	7.9	7.9		2	1		Yes	Yes	
4-2	11.5	11.5	2	1	2	1.8	7.9	7.9	Detail ana	2	1		Yes	Yes	
4-3	11.5	11.5	2	1	2	1.8	7.9	7.9	Detail ana	2	1		Yes	Yes	
4-4	13.625	13.625	2	1	2	1.8	10.025	10.025		2	1		Yes	Yes	
4-5	15.5	15.5	3	1.5	3	2.5	10.5	10.5	53375	3	1.5		Yes	Yes	
4-6	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail ana	3	1.5		Yes	Yes	
4-7	15.5	15.5	3	1.5	3	2.5	10.5	10.5	53375	3	1.5		Yes	Yes	
4-8	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail ana	3	1.5		Yes	Yes	
4-9	11.5	11.5	2	1	2	1.8	7.9	7.9	Detail ana	2	1		Yes	Yes	
4-10	13.625	13.625	2	1	2	1.8	10.025	10.025		2	1		Yes	Yes	
4-11	11.5	11.5	2	1	2	1.8	7.9	7.9	Detail An	2	1		Yes	Yes	
4-12	11.5	11.5	2	1	2	1.8	7.9	7.9	Detail An	2	1		Yes	Yes	
3-1	15.5	15.5	3	1.5	3	2.5	10.5	10.5		3	1.5		Yes	Yes	Yes
3-2	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3	1.5		Yes	Yes	Yes
3-3	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3	1.5		Yes	Yes	Yes
3-4	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3	1.5		Yes	Yes	Yes
3-5	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3 (5/8+1/2+1/2 = 100 minutes	1.33333	2.4	Yes	Yes	Yes
3-6	17.625	17.625	3	1.5	3	2.5	12.625	12.625	Detail An	3	1.5		Yes	Yes	Yes
3-7	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3	1.5		Yes	Yes	Yes
3-8	17.625	17.625	3	1.5	3	2.5	12.625	12.625	Detail An	3	1.5		Yes	Yes	Yes
3-9	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3	1.5		Yes	Yes	Yes
3-10	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3 (5/8+1/2+1/2 = 100 minutes	1.33333	2.4	Yes	Yes	Yes
3-11	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3	1.5		Yes	Yes	Yes
3-12	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3	1.5		Yes	Yes	Yes
2-1	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	2			Yes	Yes	Yes
2-2	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	2			Yes	Yes	Yes
2-3	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	2			Yes	Yes	Yes
2-4	17.625	17.625	3	1.5	3	2.5	12.625	12.625	Detail An	2			Yes	Yes	Yes
2-5	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3 (5/8+1/2+1/2 = 100 minutes	1.33333	2.4	Yes	Yes	Yes
2-6	17.625	17.625	3	1.5	3	2.5	12.625	12.625	Detail An	2			Yes	Yes	Yes
2-7	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	3 (5/8+1/2+1/2 = 100 minutes	1.33333	2.4	Yes	Yes	Yes
2-8	17.625	17.625	3	1.5	3	2.5	12.625	12.625	Detail An	2			Yes	Yes	Yes
2-9	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	2			Yes	Yes	Yes
2-10	17.625	17.625	3	1.5	3	2.5	12.625	12.625	Detail An	2			Yes	Yes	Yes
2-11	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	2			Yes	Yes	Yes
2-12	15.5	15.5	3	1.5	3	2.5	10.5	10.5	Detail An	2			Yes	Yes	Yes
1-1	15.5	15.5	3	1.5	3	2.5	10.5	10.5		2			Yes	Yes	Yes
1-2	15.5	15.5	3	1.5	3	2.5	10.5	10.5		3 (5/8+1/2+1/2 = 100 minutes	1.33333	2.4	Yes	Yes	Yes
1-3	15.5	15.5	3	1.5	3	2.5	10.5	10.5		3 (5/8+1/2+1/2 = 100 minutes	1.33333	2.4	Yes	Yes	Yes
1-4	17.625	17.625	3	1.5	3	2.5	12.625	12.625		2			Yes	Yes	Yes
1-5	17.625	17.625	3	1.5	3	2.5	12.625	12.625		2			Yes	Yes	Yes
1-6	17.625	17.625	3	1.5	3	2.5	12.625	12.625		2			Yes	Yes	Yes
1-7	17.625	17.625	3	1.5	3	2.5	12.625	12.625		2			Yes	Yes	Yes
1-8	17.625	17.625	3	1.5	3	2.5	12.625	12.625		2			Yes	Yes	Yes
1-9	15.5	15.5	3	1.5	3	2.5	10.5	10.5		3 (5/8+1/2+1/2 = 100 minutes	1.33333	2.4	Yes	Yes	Yes
1-10	17.625	17.625	3	1.5	3	2.5	12.625	12.625		2			Yes	Yes	Yes
1-11	15.5	15.5	3	1.5	3	2.5	10.5	10.5		2			Yes	Yes	Yes
1-12	15.5	15.5	3	1.5	3	2.5	10.5	10.5		3 (5/8+1/2+1/2 = 100 minutes	1.33333	2.4	Yes	Yes	Yes

Fire Analysis Calculations – Option 2 CLT

Lamination Fall-Off Time			
Variable	Description	Calculation	Units
h_lam	Lamella thickness	1.375	in
Bn	Char Rating	1.5	in/hr
t_fo	Time to reach glued interface	54	min
n_lam	Number of laminations that fal	1	laminations
t	Required FRR	60	min

Effective Char Depth			
Variable	Description	Calculation	Units
a_char	Effective Char Depth	1.93	in

Effective Residual Cross Section			
Variable	Description	Calculation	Units
h	Initial Cross-Section Depth	4.125	in
h_fire	Effective Cross-Section Depth	2.19	in
	Ply Effected - Manually Enter	2	ply

Section-Specific Loading and Dimensions				
Floor		4		
Section:		1A-1		
Length		13		ft
Width		6		ft
Roof Live Load (Lr)		20		psf
Ground snow load (S)		50		psf
Dead Loads - Total		14.10		psf
	Insulation on CLT (D)	*3*		*psf*
	Mechanical (D)	*0*		*psf*
	CLT Self-Weight (D)	*11.1*		*psf*
	Point Loads	*0*		*psf*
Wind (W)		0		mph
Earthquake (E)		0		psf
Live Load (L)				psf

Actual Loading			
Variable	Description	Calculation	Units
LC1	D	14.10	psf
LC2	D+L	14.10	psf
LC3	D+(Lr or S or R)	64.10	psf
LC4	D + 0.75L + 0.75(Lr or S or R)	51.60	psf
LC5	D + (0.6W or 0.7E)	14.10	psf
LC6a	D + 0.75L + 0.75(0.6W) + 0.7:	51.60	psf
LC6b	D + 0.75L + 0.75(0.7E) + 0.75	51.60	psf
LC7	0.6D + 0.6W	8.46	psf
LC8	0.6D + 0.7E	8.46	psf

Important Values			
Variable	Description	Calculation	Units
M	Induced Bending Moment (Fir	8124.68	lb-ft
V	Induced Shear (Fire)	3124.88	lb
n_lam	Number of laminations that fal	1	laminations

Fire Analysis Calculations – Option 2 Joist

Variable	Name	Value	Unit
X-X Bending			
Fbx+	Bottom of Beam in Tension	2400	psi
Fbx-	Top of Beam in Tension	1450	psi
Fcx	Compression Perpendicular to grain	600	psi
Fvx	Shear parallel to grain	300	psi
Ex	Modulus of elasticity	1900000	psi
Ex app	Modulus of elasticity (applied)	1800000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	950400	**psi**
Y-Y Bending			
Fby+	Bottom of Beam in Tension	2400	psi
Fby-	Top of Beam in Tension	1450	psi
Fcy	Compression Perpendicular to grain	600	psi
Fvy	Shear parallel to grain	300	psi
Ey	Modulus of elasticity	1900000	psi
Ey app	Modulus of elasticity (applied)	1800000	psi
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
CD		1.15	-
CM		1	-
Ct		1	-
Cfu		1	-
Cc		1	-
Cb		1	-
CI		1	-
Cvr		1	-
E'x		1800000	psi
E'xmin		1450	psi

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1			
Tributary Width		4.6875	ft		
Roof Live Load (Lr)		20	psf		
Reduced Roof LL		20	psf	93.75	plf
Ground snow load (S)		50	psf	234.375	plf
Dead Loads - Total		27.7	psf	163.409375	plf
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Glulam Self-weight	35	pcf	22.465625	plf
	Gyp weight	4	psf	11.1	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf	0	plf
Live Load (L)		0	psf	0	plf

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	163.409375	plf
LC2	D+L	27.7	psf	163.409375	plf
LC3	D+(Lr or S or R)	77.7	psf	397.784375	plf
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	339.190625	plf
LC5	D + (0.6W or 0.7E)	27.7	psf	163.409375	plf
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	339.190625	plf
LC6b	D + 0.75L + 0.75(0.7E) + 0.	65.2	psf	339.190625	plf
LC7	0.6D + 0.6W	16.62	psf	98.045625	plf
LC8	0.6D + 0.7E	16.62	psf	98.045625	plf

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.04583333333	ft
Delta S	L/360	0.04583333333	ft
Delta D+L	L/240	0.06875	ft

Member Lengths and Properties

Variable		Value	Unit
l		16.5	ft
b		7.9	in
d		11.7	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		92.43	in^2
Sxx		180.2	in^3
Ixx		1054.4	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		5.265	
FBe		63	psi

Fire Analysis Calculations – Option 2 Girder Post Fire 1

Member Lengths and Properties

Variable		Value	Unit
l		25	ft
b		11.9	in
d		15.9	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		189.21	in^2
Sxx		501.4	in^3
Ixx		3986.2	in^4
Isupport		6	in

Beam Stability Factor

Variable		Value	Unit
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		4.074	
FBe		105	psi
CL			

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions					
Joist Number		4-1			
Joist b		7.9	in		
joist d		11.7	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		20	psf	773.4375	lbs
Ground snow load (S)		50	psf	1933.59375	lbs
Dead Loads - Total		27.7	psf	1348.127344	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Joist Weight	35	pcf	185.3414063	lbs
	Gyp weight	4	psf	91.575	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	1348.13	lbs
LC2	D+L	27.7	psf	1348.13	lbs
LC3	D+(Lr or S or R)	77.7	psf	3281.72	lbs
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	2798.32	lbs
LC5	D + (0.6W or 0.7E)	27.7	psf	1348.13	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	2798.32	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.'	65.2	psf	2798.32	lbs
LC7	0.6D + 0.6W	16.62	psf	808.88	lbs
LC8	0.6D + 0.7E	16.62	psf	808.88	lbs

Point Load 2 - Middle

Section-Specific Loading and Dimensions					
Joist Number		4-2			
Joist b		7.9	in		
joist d		15.7	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		15.625	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		18.84375	psf	2429.077148	lbs
Ground snow load (S)		50	psf	6445.3125	lbs
Dead Loads - Total		27.7	psf	3932.984115	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Joist Weight	35	pcf	248.7059896	lbs
	Gyp weight	4	psf	113.575	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	3932.98	lbs
LC2	D+L	27.7	psf	3932.98	lbs
LC3	D+(Lr or S or R)	77.7	psf	10378.30	lbs
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	8766.97	lbs
LC5	D + (0.6W or 0.7E)	27.7	psf	3932.98	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	8766.97	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	65.2	psf	8766.97	lbs
LC7	0.6D + 0.6W	16.62	psf	2359.79	lbs
LC8	0.6D + 0.7E	16.62	psf	2359.79	lbs

Point Load 3 - Right

Section-Specific Loading and Dimensions					
Joist Number		4-3			
Joist b		7.9	in		
joist d		13.7	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		20	psf	773.4375	lbs
Ground snow load (S)		50	psf	1933.59375	lbs
Dead Loads - Total		29.7	psf	1468.153385	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*13.1*	*psf*		
	Joist Weight	35	pcf	217.0236979	lbs
	Gyp weight	4	psf	102.575	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	29.7	psf	1468.15	lbs
LC2	D+L	29.7	psf	1468.15	lbs
LC3	D+(Lr or S or R)	79.7	psf	3401.75	lbs
LC4	D + 0.75L + 0.75(Lr or S or	67.2	psf	2918.35	lbs
LC5	D + (0.6W or 0.7E)	29.7	psf	1468.15	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	67.2	psf	2918.35	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	67.2	psf	2918.35	lbs
LC7	0.6D + 0.6W	17.82	psf	880.89	lbs
LC8	0.6D + 0.7E	17.82	psf	880.89	lbs

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Dead Load - from Glulam self weight +gyp		35	pcf	65.85520833	plf
	Gyp weight	4	psf	19.86666667	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		

Actual Loading						
Variable	Description	Calculation	Units	Total DL (lbs)	Total LL (lbs)	Total Roof SL (lbs)
LC1	D	8395.65	lbs	0	0	0
LC2	D+L	8395.65	lbs	0	0	0
LC3	D+(Lr or S or R)	18708.15	lbs	8395.645052	0	3975.952148
LC4	D + 0.75L + 0.75(Lr or S or R)	16130.02	lbs	0	0	0
LC5	D + (0.6W or 0.7E)	8395.65	lbs	0	0	0
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(L	16130.02	lbs	0	0	0
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	16130.02	lbs	0	0	0
LC7	0.6D + 0.6W	5037.39	lbs	0	0	0
LC8	0.6D + 0.7E	5037.39	lbs	0	0	0

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	300	
Le	1.63Lu+3D	536.7	
Rb	sqrt((le*d)/b^2)	7.762782147	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	18925.74032	
Cfu		1	
CL	look at nds	0.9936451077	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		1	0.86
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*C	1749.6	psi
Ultimate F'b	x2.85	4986.36	psi
Allowable Moment		73105.07	ft-lb
Ultimate Allowable Moment		208349.44	ft-lb
Moment		70009.29	ft-lb
Adjusted Shear Parallel to Grain Design Value (F			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	6012.338411	lb
Actual fv	3V/2bd	6863.617657	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	6012.338411	lb
Fc actual		84.20642033	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column	0.01586912554	ft
Delta S	See next column	0.04210713243	ft
Delta D+L	See next column	0.02259149812	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.06944444444	ft
Delta S	L/360	0.06944444444	ft
Delta D+L	L/240	0.1041666667	ft

Fire Analysis Calculations – Option 2 Girder Post Fire 2

Member Lengths and Properties			
Variable		**Value**	**Unit**
l		25	ft
b		8.3	in
d		12.3	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		102.09	in^2
Sxx		209.3	in^3
Ixx		1287.1	in^4
Isupport		6	in

Beam Stability Factor			
Variable		**Value**	**Unit**
Fbx+*		2760	psi
lu		96	in
le		148	in
RB		5.138	
FBe		66	psi
CL			

Loading

Point Load 1 - left

Section-Specific Loading and Dimensions					
Joist Number		4-1			
Joist b		7.9	in		
joist d		11.7	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		20	psf	773.4375	lbs
Ground snow load (S)		50	psf	1933.59375	lbs
Dead Loads - Total		27.7	psf	1348.127344	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Joist Weight	35	pcf	185.3414063	lbs
	Gyp weight	4	psf	91.575	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs
Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	1348.13	lbs
LC2	D+L	27.7	psf	1348.13	lbs
LC3	D+(Lr or S or R)	77.7	psf	3281.72	lbs
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	2798.32	lbs
LC5	D + (0.6W or 0.7E)	27.7	psf	1348.13	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	2798.32	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.7	65.2	psf	2798.32	lbs
LC7	0.6D + 0.6W	16.62	psf	808.88	lbs
LC8	0.6D + 0.7E	16.62	psf	808.88	lbs

Point Load 2 - Middle

Section-Specific Loading and Dimensions					
Joist Number		4-2			
Joist b		7.9	in		
joist d		15.7	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		15.625	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		18.84375	psf	2429.077148	lbs
Ground snow load (S)		50	psf	6445.3125	lbs
Dead Loads - Total		27.7	psf	3932.984115	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*11.1*	*psf*		
	Joist Weight	35	pcf	248.7059896	lbs
	Gyp weight	4	psf	113.575	lbs
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	27.7	psf	3932.98	lbs
LC2	D+L	27.7	psf	3932.98	lbs
LC3	D+(Lr or S or R)	77.7	psf	10378.30	lbs
LC4	D + 0.75L + 0.75(Lr or S or	65.2	psf	8766.97	lbs
LC5	D + (0.6W or 0.7E)	27.7	psf	3932.98	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	65.2	psf	8766.97	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	65.2	psf	8766.97	lbs
LC7	0.6D + 0.6W	16.62	psf	2359.79	lbs
LC8	0.6D + 0.7E	16.62	psf	2359.79	lbs

Point Load 3 - Right

Section-Specific Loading and Dimensions					
Joist Number		4-3			
Joist b		7.9	in		
joist d		13.7	in		
Girder Tributary Width		8.25	ft		
CLT Tributary Area		4.6875	ft		
Roof Live Load (Lr) (enter reduced load if reduced)		20	psf	773.4375	lbs
Ground snow load (S)		50	psf	1933.59375	lbs
Dead Loads - Total		29.7	psf	1468.153385	lbs
	Insulation on CLT (D)	*9*	*psf*		
	MEP Allowance (D)	*5*	*psf*		
	Roofing Membrane	*1*	*psf*		
	Misc. Hung Ceiling	*1.6*	*psf*		
	CLT Weight (D)	*13.1*	*psf*		
	Joist Weight	35	pcf	217.0236979	lbs
	Gyp weight	4	psf	102.575	plf
Wind (W)		0	mph		
Earthquake (E)		0	psf		
Live Load (L) (enter reduced load if reduced)		0	psf	0	lbs

Actual Loading					
Variable	Description	Calculation	Units		
LC1	D	29.7	psf	1468.15	lbs
LC2	D+L	29.7	psf	1468.15	lbs
LC3	D+(Lr or S or R)	79.7	psf	3401.75	lbs
LC4	D + 0.75L + 0.75(Lr or S or	67.2	psf	2918.35	lbs
LC5	D + (0.6W or 0.7E)	29.7	psf	1468.15	lbs
LC6a	D + 0.75L + 0.75(0.6W) + 0.	67.2	psf	2918.35	lbs
LC6b	D + 0.75L + 0.75(0.7E) + 0.	67.2	psf	2918.35	lbs
LC7	0.6D + 0.6W	17.82	psf	880.89	lbs
LC8	0.6D + 0.7E	17.82	psf	880.89	lbs

Uniform Load from Glulam Self weight

Section-Specific Loading and Dimensions					
Floor		4			
Section:		1A - 1			
Dead Load - from Glulam self weight +gyp	35	pcf	39.88020833	plf	
	Gyp weight 4	psf	15.06666667	plf	
Wind (W)	0	mph			
Earthquake (E)	0	psf			

Actual Loading						
Variable	Description	Calculation	Units	Total DL (lbs)	Total LL (lbs)	Total Roof SL (lbs)
LC1	D	7746.27	lbs	0	0	0
LC2	D+L	7746.27	lbs	0	0	0
LC3	D+(Lr or S or R)	18058.77	lbs	7746.270052	0	3975.952148
LC4	D + 0.75L + 0.75(Lr or S or R)	15480.65	lbs	0	0	0
LC5	D + (0.6W or 0.7E)	7746.27	lbs	0	0	0
LC6a	D + 0.75L + 0.75(0.6W) + 0.75(L	15480.65	lbs	0	0	0
LC6b	D + 0.75L + 0.75(0.7E) + 0.75S	15480.65	lbs	0	0	0
LC7	0.6D + 0.6W	4647.76	lbs	0	0	0
LC8	0.6D + 0.7E	4647.76	lbs	0	0	0

Cd	Load Duration Factor	0.9	
Cm	Wet Service Factor	1	
Ct	Temperature Factor	1	
Cc	Curvature Factor	1	
Ci	Incising Factor	1	
Fb*	Fb*Cd*Cm*Ct*Cc*Ci	2160	
CL			
Lu	length (inches)	300	
Le	1.63Lu+3D	525.9	
Rb	sqrt((le*d)/b^2)	9.690050686	
Emin'	Emin*Cm*Ct	950400	
Fbe	(1.2*Emin')/(Rb^2)	12146.06431	
Cfu		1	
CL	look at nds	0.989436352	
CV	look at nds	0.81	
Fire Resistance Adjustment Factor		1	0.86
F'b	Fb*Cd*CM*Ct*(CL or Cv)*Cc*(	1749.6	psi
Ultimate F'b	x2.85	4986.36	psi
Allowable Moment		30513.68	ft-lb
Ultimate Allowable Moment		86963.99	ft-lb
Moment		67980.00	ft-lb

Adjusted Shear Parallel to Grain Design Value (F			
Cd	Load Duration Factor	0.9	NDS Table 2.3.2
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Ci	Incising Factor	1	NDS Table 4.3.8
F'v	Fvx*Cd*CMV*Ct*Ci	270	psi
F'v		38880	psf
Actual V	wL/2	5687.650911	lb
Actual fv	3V/2bd	12033.81915	psf

Fc perp			
Cb	Bearing Area Factor	1	
CMV	Wet Service Factor	1	NDS Supplement Table 4A
Ct	Temperature Factor	1	NDS Table 2.3.2
Fc perp		600	psi
Reaction forces	1/2 * wl	5687.650911	lb
Fc actual		114.2098577	psi

Adjusted Modulus of Elasticity (E')			
CME	Wet Service Factor	1	NDS Supplement Table 4A
CtE	Temperature Factor	1	NDS Table 2.3.3
CiE	Incising Factor	1	NDS Table 4.3.8
E'	E*CME*CtE*CiE	1800000	

Manual pg 72

Actual Deflection			
Variable	Description	Calculation	Units
Delta L	See next column	0.04914710075	ft
Delta S	See next column	0.1304069008	ft
Delta D+L	See next column	0.06175478309	ft

Allowable Deflection			
Variable	Description	Calculation	Units
Delta L	L/360	0.06944444444	ft
Delta S	L/360	0.06944444444	ft
Delta D+L	L/240	0.1041666667	ft

Fire Analysis Calculations – Option 2 Column

Variable	Name	Value	Unit
Axial Loading			
Fc	Compression parallel to grain	2300	psi
Ft	Tension parallel to grain	1600	psi
Ea	modulus of elasticity	1900000	psi
Emin	Modulus of elasticity (min) = 0.528Exapp	1003200	**psi**
	Member Lengths and Properties		
Variable	**Initial**	**final Value**	**Unit**
l		12	ft
b	11.5	7.9	in
d	11.5	7.9	in
p	density	35	pcf
SG	Specific gravity	0.46	
Ag		62.41	in^2
Sxx		82.2	in^3
Ixx		5128.4	in^4
Isupport		6	in

Loading				
Point Load 1 - left				
Section-Specific Loading and Dimensions				
Load from girder to the left		0	lbs	
Load from girder to the right		9,930.59	lbs	LC 3 Governs
Self-weight of column		385.73	lbs	LC 3 Governs

Cp Calculations!				
Fc*	adjusted compression parallel to grain			
Table 2.3	Cd	Load Duration Factor	1.15	
	Cm	Wet Service Factor	1	
	Ct	Temperature Factor	1	
	CF	Size Factor	1	
	Ci - Fc	Incising Factor	0.8	
Fc*	(Fc)*Cd*Cm*Ct*CF*Ci		2116	psi

E'min	Minimum Modulus of elasticity			
	CT	Buckling Stiffness Factor	1	
	Ci - Emin	Incising Factor	0.95	
E'min	Emin*Cm*Ci*Ct*CT		953040	

le	Effective Length			
	Ke	Effective length factor	1	
le	Length*Ke		12	ft
le/d	**Must be less than 50**		18.2278481	in/in

FcE	critical buckling design value			
FcE	((0.822)*E'min)/((le/d)^2)		2357.82813	psi

Cp	Column Stability Factor			
	c_glulam	a constant for glulam	0.9	
	FcE/Fc*		1.114285506	
Cp	$C_P := \frac{\left(1+\frac{F_{cE}}{F_{c*}}\right)}{2c_{sawn}} - \sqrt{\left[\frac{\left(1+\frac{F_{cE}}{F_{c*}}\right)}{2c_{sawn}}\right]^2 - \frac{\left(\frac{F_{cE}}{F_{c*}}\right)}{c_{sawn}}}$		0.7983088397	

F'c	Axial Buckling Capacity			
F'c	Fc*Cd*Cm*Ct*Cf*Ci*Cp		1,689.22	psi
Ultimate F'c			4,358.19	psi
Overall Tributary Area			62.41	in2
Allowable Load			105,424.31	lbs
Allowable Load for 2h fire (1 hr + 2 gyp)			13,150.00	lbs
Total Actual Load on column			9,930.59	lbs
Total Actual Load including column			10,316.32	lbs

Appendix E: Inventory and Cost Estimate

Inventory – Option 1 Building

CLT Inventory					
Purpose	Location	Ply Type	Area		Quantity
			Length (ft)	Width (ft)	
Roofing	Roof	105-3s	12.5	5	72
			12.5	6	76
			13	5	6
			13	6	6
			62	107	1
Roof/Penthouse Floor	Roof/Penthouse Floor	175-5s	12.5	5	48
			12.5	6	44
			13	5	24
			13	6	22
Flooring	Floors 3-2-1	175-5s	12.5	5	330
			12.5	6	328
			13	5	72
			13	6	70
	Atrium		16	5	6
			16	6	7

Simplified Holistic Inventory (not by location/purpose)

CLT			
Ply Type	Area		Quantity
	Length (ft)	Width (ft)	
105-3s	12.5	5	72
	12.5	6	76
	13	5	6
	13	6	6
	62	107	1
175-5s	12.5	5	378
	12.5	6	372
	13	5	96
	13	6	92
	16	5	6
	16	6	7

GLT Vertical Members			
Area			Quantity
b (in)	d (in)	Length (ft)	
15.5	15.5	12	24
13.625	13.625	12	149
11.5	11.5	12	111
9.5	9.5	12	9

GLT Horizontal Members			
Area			Quantity
b (in)	d (in)	Length (ft)	
17.625	29.5	26	1
17.625	27.5	26	1
15.5	27.5	26	1
15.5	23.5	26	6
11.5	29.5	26	2
11.5	27.5	32	2
11.5	27.5	26	4
11.5	25.5	26	4
11.5	23.5	26	3
11.5	23.5	25	18
11.5	23.5	16.5	6
11.5	21.5	32	1
11.5	21.5	26	9
11.5	21.5	25	1
11.5	19.5	32	1
11.5	19.5	26	3
11.5	19.5	25	18
11.5	19.5	16.5	8
11.5	17.5	32	1
11.5	17.5	26	13
11.5	17.5	25	8
11.5	17.5	16.5	133
11.5	15.5	16.5	140
11.5	15.5	10.5	1
11.5	15.5	8	8
11.5	13.5	16.5	97
11.5	13.5	16.5	7
11.5	13.5	10.5	3
11.5	13.5	8.25	1
11.5	11.5	26	4
11.5	11.5	16.5	3
11.5	11.5	10.5	8
11.5	11.5	8.25	5
11.5	11.5	6	8
9.5	11.5	32	1
9.5	11.5	25	1
9.5	11.5	16.5	11
9.5	11.5	15	4
9.5	11.5	10.5	8
9.5	11.5	10	4
9.5	11.5	8.25	14
9.5	11.5	6	10

Cost Estimate – Option 1 Building

CLT Cost Estimate							
Ply Type	Area			Quantity	Volume (ft^3)	Cost per ft^3	Total Cost
	Length (ft)	Width (ft)	Thickness (ft)				
105-3s	12.5	5	0.3438	72	21.48	$21.00	$32,484.38
	12.5	6	0.3438	76	25.78	$21.00	$41,146.88
	13	5	0.3438	6	22.34	$21.00	$2,815.31
	13	6	0.3438	6	26.81	$21.00	$3,378.38
	62	107	0.3438	1	2,280.44	$21.00	$47,889.19
175-5s	12.5	5	0.5729	378	35.81	$21.00	$284,238.28
	12.5	6	0.5729	372	42.97	$21.00	$335,671.88
	13	5	0.5729	96	37.24	$21.00	$75,075.00
	13	6	0.5729	92	44.69	$21.00	$86,336.25
	16	5	0.5729	6	45.83	$21.00	$5,775.00
	16	6	0.5729	7	55.00	$21.00	$8,085.00
	14	115.5	0.5729	4	926.41	$21.00	$77,818.13
	14	78	0.5729	4	625.63	$21.00	$52,552.50
						TOTAL	**$1,053,266.16**

GLT Vertical Members Cost Estimate						
Area			Quantity	Volume (in^3)	Cost per in^3	Total Cost
b (in)	d (in)	Length (ft)				
15.5	15.5	12	24	34,596.00	$0.03	$24,909.12
13.625	13.625	12	149	26,732.25	$0.03	$119,493.16
11.5	11.5	12	111	19,044.00	$0.03	$63,416.52
9.5	9.5	12	9	12,996.00	$0.03	$3,508.92
					TOTAL	**$211,327.72**

GLT Horizontal Members Cost Estimate						
Area			Quantity	Volume (in^3)	Cost per in^3	Total Cost
b (in)	d (in)	Length (ft)				
17.625	29.5	26	1	162,220.50	$0.03	$4,866.62
17.625	27.5	26	1	151,222.50	$0.03	$4,536.68
15.5	27.5	26	1	132,990.00	$0.03	$3,989.70
15.5	23.5	26	6	113,646.00	$0.03	$20,456.28
11.5	29.5	26	2	105,846.00	$0.03	$6,350.76
11.5	27.5	32	2	121,440.00	$0.03	$7,286.40
11.5	27.5	26	4	98,670.00	$0.03	$11,840.40
11.5	25.5	26	4	91,494.00	$0.03	$10,979.28
11.5	23.5	26	3	84,318.00	$0.03	$7,588.62
11.5	23.5	25	18	81,075.00	$0.03	$43,780.50
11.5	23.5	16.5	6	53,509.50	$0.03	$9,631.71
11.5	21.5	32	1	94,944.00	$0.03	$2,848.32
11.5	21.5	26	9	77,142.00	$0.03	$20,828.34
11.5	21.5	25	1	74,175.00	$0.03	$2,225.25
11.5	19.5	32	1	86,112.00	$0.03	$2,583.36
11.5	19.5	26	3	69,966.00	$0.03	$6,296.94
11.5	19.5	25	18	67,275.00	$0.03	$36,328.50
11.5	19.5	16.5	8	44,401.50	$0.03	$10,656.36
11.5	17.5	32	1	77,280.00	$0.03	$2,318.40
11.5	17.5	26	13	62,790.00	$0.03	$24,488.10
11.5	17.5	25	8	60,375.00	$0.03	$14,490.00
11.5	17.5	16.5	133	39,847.50	$0.03	$158,991.53
11.5	15.5	16.5	140	35,293.50	$0.03	$148,232.70

11.5	15.5	10.5	1	22,459.50	$0.03	$673.79
11.5	15.5	8	8	17,112.00	$0.03	$4,106.88
11.5	13.5	16.5	97	30,739.50	$0.03	$89,451.95
11.5	13.5	16.5	7	30,739.50	$0.03	$6,455.30
11.5	13.5	10.5	3	19,561.50	$0.03	$1,760.54
11.5	13.5	8.25	1	15,369.75	$0.03	$461.09
11.5	11.5	26	4	41,262.00	$0.03	$4,951.44
11.5	11.5	16.5	3	26,185.50	$0.03	$2,356.70
11.5	11.5	10.5	8	16,663.50	$0.03	$3,999.24
11.5	11.5	8.25	5	13,092.75	$0.03	$1,963.91
11.5	11.5	6	8	9,522.00	$0.03	$2,285.28
9.5	11.5	32	1	41,952.00	$0.03	$1,258.56
9.5	11.5	25	1	32,775.00	$0.03	$983.25
9.5	11.5	16.5	11	21,631.50	$0.03	$7,138.40
9.5	11.5	15	4	19,665.00	$0.03	$2,359.80
9.5	11.5	10.5	8	13,765.50	$0.03	$3,303.72
9.5	11.5	10	4	13,110.00	$0.03	$1,573.20
9.5	11.5	8.25	14	10,815.75	$0.03	$4,542.62
9.5	11.5	6	10	7,866.00	$0.03	$2,359.80
					TOTAL	**$703,580.18**

TOTAL COST OF STRUCTURAL MATERIALS	**$1,968,174.05**

Inventory – Option 2 Building

CLT Inventory					
Purpose	Location	Ply Type	Area		Quantity
			Length (ft)	Width (ft)	
Roofing	Roof	105-3s	12.5	5	72
			12.5	6	76
			13	5	6
			13	6	6
				Penthouse roof	
Roof/Penthouse Floor	Roof/Penthouse Floor	197-7s	12.5	5	48
			12.5	6	44
			13	5	24
			13	6	22
Flooring	Floors 3-2-1	175-5s	12.5	5	330
			12.5	6	328
			13	5	72
			13	6	70
	Atrium		16	5	6
			16	6	7

Simplified Holistic Inventory (not by location/purpose)

CLT			
Ply Type	Area		Quantity
	Length (ft)	Width (ft)	
105-3s	12.5	5	72
	12.5	6	76
	13	5	6
	13	6	6
		Penthouse roof	
197-7s	12.5	5	48
	12.5	6	44
	13	5	24
	13	6	22
175-5s	12.5	5	378
	12.5	6	372
	13	5	96
	13	6	92
	16	5	6
	16	6	7

GLT Columns			
Area			Quantity
b (in)	d (in)	Length (ft)	
11.5	11.5	12	26
13.625	13.625	12	18
15.5	15.5	12	166
17.625	17.625	12	91

GLT			
Area			Quantity
b (in)	d (in)	Length (ft)	
11.5	13.5	16.5	20
11.5	15.5	16.5	20
11.5	17.5	16.5	20
11.5	19.5	16.5	20
15.5	15.5	8.00	8
15.5	15.5	8.25	21
15.5	15.5	10.00	5
15.5	15.5	16.50	185
15.5	15.5	25.00	10
15.5	15.5	39.00	2
15.5	17.5	16.50	4
15.5	19.5	16.50	138
15.5	19.5	25.00	3
15.5	21.5	16.50	6
15.5	21.5	25.00	7
15.5	21.5	26.00	13
15.5	25.5	25.00	41
15.5	25.5	26.00	15
15.5	27.5	25.00	19
15.5	27.5	26.00	3
15.5	29.5	25.00	100
15.5	29.5	26.00	20
19.5	25.5	26	4
17.5	29.5	26	1
19.5	29.5	26	2
19.5	35.625	26	4
19.5	37.625	26	1

Cost Estimate – Option 2 Building

CLT Cost Estimate							
Ply Type	Area			Quantity	Volume (ft^3)	Cost per ft^3	Total Cost
	Length (ft)	Width (ft)	Thickness (ft)				
105-3s	12.5	5	0.3438	72	21.48	$21.00	$32,484.38
	12.5	6	0.3438	76	25.78	$21.00	$41,146.88
	13	5	0.3438	6	22.34	$21.00	$2,815.31
	13	6	0.3438	6	26.81	$21.00	$3,378.38
	62	107	0.3438	1	2,280.44	$21.00	$47,889.19
197-7s	12.5	5	0.6458	48	40.36	$21.00	$40,687.50
	12.5	6	0.6458	44	48.44	$21.00	$44,756.25
	13	5	0.6458	24	41.98	$21.00	$21,157.50
	13	6	0.6458	22	50.38	$21.00	$23,273.25
175-5s	12.5	5	0.5729	378	35.81	$21.00	$284,238.28
	12.5	6	0.5729	372	42.97	$21.00	$335,671.88
	13	5	0.5729	96	37.24	$21.00	$75,075.00
	13	6	0.5729	92	44.69	$21.00	$86,336.25
	16	5	0.5729	6	45.83	$21.00	$5,775.00
	16	6	0.5729	7	55.00	$21.00	$8,085.00
	14	115.5	0.5729	4	926.41	$21.00	$77,818.13
	14	78	0.5729	4	625.63	$21.00	$52,552.50
						TOTAL	**$1,183,140.66**

GLT Horizontal Members Cost Estimate						
Area			Quantity	Volume (in^3)	Cost per in^3	Total Cost
b (in)	d (in)	Length (ft)				
11.5	13.5	16.5	20	30,739.50	$0.03	$18,443.70
11.5	15.5	16.5	20	35,293.50	$0.03	$21,176.10
11.5	17.5	16.5	20	39,847.50	$0.03	$23,908.50
11.5	19.5	16.5	20	44,401.50	$0.03	$26,640.90
15.5	15.5	8.00	8	23,064.00	$0.03	$5,535.36
15.5	15.5	8.25	21	23,784.75	$0.03	$14,984.39
15.5	15.5	10.00	5	28,830.00	$0.03	$4,324.50
15.5	15.5	16.50	185	47,569.50	$0.03	$264,010.73
15.5	15.5	25.00	10	72,075.00	$0.03	$21,622.50
15.5	15.5	39.00	2	112,437.00	$0.03	$6,746.22
15.5	17.5	16.50	4	53,707.50	$0.03	$6,444.90
15.5	19.5	16.50	138	59,845.50	$0.03	$247,760.37
15.5	19.5	25.00	3	90,675.00	$0.03	$8,160.75
15.5	21.5	16.50	6	65,983.50	$0.03	$11,877.03
15.5	21.5	25.00	7	99,975.00	$0.03	$20,994.75
15.5	21.5	26.00	13	103,974.00	$0.03	$40,549.86
15.5	25.5	25.00	41	118,575.00	$0.03	$145,847.25
15.5	25.5	26.00	15	123,318.00	$0.03	$55,493.10
15.5	27.5	25.00	19	127,875.00	$0.03	$72,888.75
15.5	27.5	26.00	3	132,990.00	$0.03	$11,969.10
15.5	29.5	25.00	100	137,175.00	$0.03	$411,525.00
15.5	29.5	26.00	20	142,662.00	$0.03	$85,597.20
19.5	25.5	26	4	155,142.00	$0.03	$18,617.04
17.5	29.5	26	1	161,070.00	$0.03	$4,832.10
19.5	29.5	26	2	179,478.00	$0.03	$10,768.68
19.5	35.625	26	4	216,742.50	$0.03	$26,009.10
19.5	37.625	26	1	228,910.50	$0.03	$6,867.32
					TOTAL	**$1,593,595.19**

GLT Vertical Members Cost Estimate						
Area			Quantity	Volume (in^3)	Cost per in^3	Total Cost
b (in)	d (in)	Length (ft)				
11.5	11.5	12	26	19,044.00	$0.03	$14,854.32
13.625	13.625	12	18	26,732.25	$0.03	$14,435.42
15.5	15.5	12	166	34,596.00	$0.03	$172,288.08
17.625	17.625	12	91	44,732.25	$0.03	$122,119.04
					TOTAL	**$323,696.86**

TOTAL COST OF STRUCTURAL MATERIALS	**$3,100,432.71**