Re-Imagining WPI's Gordon Library

A Major Qualifying Project (MQP) Report
Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements
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Architectural Engineering
Civil Engineering

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Abstract

The Gordon Library Reimagination project at Worcester Polytechnic Institute (WPI) involved a comprehensive analysis of the current state of the WPI library and its site location. The project team proposed multiple remodeling concepts aimed at aligning the library with the contemporary needs of the WPI campus while preserving its rich academic history and distinctive personality. The architectural design concepts were coupled with an in-depth examination of the structural system and building energy analysis to formulate plans that are both innovative and economically feasible. The proposed solution advocates for key features such as the incorporation of an atrium, abundant natural lighting, and versatile open spaces, with the overarching goal of creating a conducive and enriching educational environment. This endeavor reflects a commitment to balancing modern functionality with the timeless essence of academic tradition in the revitalization of the Gordon Library.

Acknowledgments

As a team, we would like to thank everyone who supported our efforts during this project. We could not have completed it without the help of the following people. Our greatest thanks to our project advisors, Professor Tahar El-Korchi and Professor Steven Van-Dessel for challenging us and supporting us through our work. Our thanks to the WPI Gordon Library and University Librarian Anna Gold for allowing us to provide our input into the future of the library on this campus. Our thanks to WPI Facilities and Nick Palumbo for allowing us to view the library plans, mechanic rooms, and rooftop. Our thanks to Professor Nima Rahbar for providing guidance and input regarding the structural calculations and concepts we are working with. Our thanks to Professor Shichao Liu for providing guidance and input to our team regarding the energy systems incorporated in our project.

Authorship

Section Number	Author(s)
1.0: Introduction	Team
1.1: Problem Statement	Joseph
1.2: Scope of Work	Team
2.0: Background	Joseph, Kyle
2.1: History of the WPI Library	Joseph, Kyle
2.2: 60's Architecture	Joseph
2.3: Contemporary Library Models for the 21st Century	Emmanuel
2.4: Past Major Qualifying Projects	Kyle
2.5: Case Study/Past Renovation	Kyle
2.6: Existing Library Layout	Joseph
3.0: Methodology	Joseph
3.1: Collecting and Reviewing Plans	Kyle
3.2: Gathering Information on Campus Input	Kyle
3.3: REVIT Modeling	Emmanuel

3.4: Structural Analysis	Emmanuel
3.5: Energy Analysis	Kyle
3.6: Code Review	Kyle
4.0: Architectural Design Proposals	Joseph
4.1: Atrium Design Space	Kyle
4.2: Rooftop Addition	Joseph, Emmanuel
4.2.1: Design Process	Joseph
4.2.2: Final Design	Joseph
4.3: Remove and Redesign of First Floor Stack Space and Floor Plan	Kyle
4.4: Removal of The Drop Ceiling	Joseph
5:0: Code Review	Kyle
5.1: Existing Building Code Analysis	Kyle
5.2: Code Implications of Atrium Design	Kyle
5.3: Code Implications of Rooftop Addition	Kyle
5.4: Code Implications of Removal and Redesign of First Floor Stack Space and Floor Plan	Kyle
5.5: Code Implications of Removal of The Drop Ceiling and Updated Lighting System	Kyle
6.0: Structural Analysis	Joseph
6.1: Explanation of Gordon Library Building Plans	Kyle
6.2: Foundation and Soil Analysis	Emmanuel
6.3: Waffle Slab Analysis	Emmanuel
6.3.1: Rankine-Grashoff Analysis	Emmanuel, Kyle
6.3.2: Removal of Waffle Slab	Emmanuel
6.3.3: Dead Load Calculation	Joseph
6.4: Tributary Area	Joseph
6.5: Column Analysis	Joseph

6.5.1: Allowable Load	Joseph
6.5.2: Original Design Load	Joseph
6.5.3: Current Design Load	Joseph
6.5.4: Allowable Additional Load	Joseph, Emmanuel
6.6: Additional Structural Analysis	Joseph
6.6.1: Voided Concrete Slab Design	Joseph
6.6.2: Space Frame Design	Joseph, Kyle
6.6.3: Addition Column Placement	Joseph, Kyle
6.6.4: Updated Tributary Area	Joseph
6.6.5: Addition Load Analysis	Joseph
7.0: Energy Analysis	Kyle
7.1: Energy Baseline	Kyle
7.2: Design Builder Model Set-up	Kyle
7.3: Design Builder Simulations and Results	Kyle
7.4: Design Builder Results	Kyle
8.0: Conclusion	Joseph
References	Team
Appendix A: Existing Structural Spreadsheets	Joseph, Emmanuel
Appendix B: Allowable Load Structural Spreadsheets	Joseph, Emmanuel
Appendix C: Proposed Load Structural Spreadsheets	Joseph, Emmanuel
Appendix D: Architectural Design	Joseph
Appendix E: Rankine-Grashoff Method Calculation	Emmanuel
Appendix F: 2D Truss Analysis of Proposed Addition	Emmanuel
Appendix G: Energy Simulation Results	Kyle

Professional Licensure Statement

Professional licensure is a formal recognition granted by a regulatory body or authority, affirming an individual's competence and qualification to practice within a specific profession. Licensure ensures that practitioners meet predetermined standards of education, experience, and ethical conduct, thereby safeguarding the interests of the public and upholding the integrity of the profession.

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For aspiring engineers seeking licensure as a Professional Engineer (PE), the journey typically begins with the successful completion of the Fundamentals of Engineering (FE) exam. This foundational step is followed by acquiring relevant work experience under the supervision of a licensed professional engineer. Subsequently, candidates must pass the Principles and Practice of Engineering (PE) exam, demonstrating their comprehensive understanding of engineering principles and their ability to apply them competently.

To maintain licensure, engineers are often required to fulfill continuing education requirements, staying abreast of technological advancements, evolving regulations, and best practices within their respective fields. Additionally, adherence to a strict code of ethics and professional conduct is paramount for maintaining licensure, ensuring accountability, and fostering trust within the profession and among the public.

The importance of obtaining and holding this licensure can be related to three different stakeholders. The profession in which the licensure is obtained, the individual obtaining the licensure, and the public. The benefits each of these groups experience from an individual who pursues and later obtains their licensure are discussed further.

Professional licensure serves as a hallmark of excellence within the engineering profession, distinguishing licensed engineers as individuals who have met rigorous standards of education, experience, and proficiency. By upholding these standards, licensure elevates the credibility and reputation of the engineering profession, instilling confidence in clients, employers, and stakeholders regarding the competence and reliability of licensed practitioners.

For individual engineers, licensure opens doors to diverse career opportunities, enhances professional credibility, and facilitates mobility across jurisdictions and industries. Licensure empowers engineers to take on greater responsibilities, pursue leadership roles, and contribute meaningfully to projects of significant public interest and societal impact.

Perhaps most importantly, licensure serves the interests of the public by ensuring the safety, health, and welfare of communities. Licensed engineers are held to stringent standards of ethical conduct and professional accountability, mitigating risks associated with engineering projects and safeguarding against potential harm. Through licensure, the public can trust that engineering endeavors are executed with integrity, expertise, and a steadfast commitment to public safety and well-being.

In conclusion, licensure is a cornerstone of the engineering profession, embodying the values of competence, integrity, and accountability. It serves as a testament to the commitment of engineers to uphold the highest standards of practice, thereby advancing innovation, safeguarding public welfare, and fostering trust in the transformative potential of engineering solutions.

Capstone Design Statement

This Major Qualifying Project (MQP) endeavors to enhance the user experience of the Gordon Library by implementing designs that focus on creating open spaces, reorganizing floor plans to foster interaction, and maximizing natural light. Central to the project is the creation of an atrium intended to facilitate connectivity between floors, allowing sunlight to permeate throughout the upper levels. Complementing the atrium is a rooftop addition designed to cultivate collaborative spaces while offering panoramic views encompassing the WPI Campus Center and the city of Worcester. Leveraging knowledge gained from architectural and structural coursework, the team aims to satisfy the requirements of the capstone design. In alignment with the project's objectives, considerations are given to systems and processes from various architectural engineering disciplines, ensuring a comprehensive approach that addresses structural integrity, environmental sustainability, and user functionality.

The project integrates within the broader architectural design of the Gordon Library, harmonizing new elements with existing structures while enhancing the overall aesthetic and functional coherence of the space. Effective communication and collaboration with other design and construction team members are prioritized throughout the project lifecycle, fostering interdisciplinary cooperation, and ensuring the seamless integration of diverse expertise. Utilization of CAD was integral to the design process, facilitating visualization, simulation, and analysis to optimize spatial arrangements, structural integrity, and environmental performance. Furthermore, compliance with relevant codes and standards is diligently observed to ensure the safety, legality, and regulatory adherence of the project. Building performance and sustainability are rigorously considered throughout the design process, with a focus on maximizing energy efficiency, minimizing environmental impact, and promoting occupant well-being for the Gordon Library.

Through the application of knowledge gleaned from architectural and structural coursework, the team endeavors to meet the rigorous requirements of the capstone design, ensuring a holistic approach that addresses structural integrity, sustainability, and user-centric design principles.

Executive Summary

This project addresses the current challenges and drawbacks of the current WPI Gordon Library and creates new opportunities and solutions for improvement. Within the project scope the following objectives were achieved:

1.) Conducted a thorough analysis of applicable building, fire, and life safety codes to ensure compliance and guarantee the safety of all occupants within the library.
2.) Engaged in contemporary research to explore the configurations and functionalities of existing libraries, informing our design decisions and strategies.
3.) Performed a comprehensive structural engineering assessment to evaluate the feasibility and structural integrity of proposed additions, such as the rooftop addition and atrium.
4.) Enhanced the library's exterior connectivity with the surrounding site and campus to foster a sense of cohesion and belonging within the community.
5.) Created physical models that vividly depict the proposed design, providing stakeholders with a tangible representation of the envisioned changes.

By analyzing the current building, the group argues the possibility of adding a rooftop, a multistory atrium, a new floorplan layout, and the possibility for better energy-efficient construction. With the current configuration of the building, and our group's proposal to further reduce bookstacks, the building is ultimately overdesigned, allowing for such alterations to take place.

It was imperative to conduct such exploration to more closely align the library with the present and future requirements of the WPI community. By tackling these challenges and seizing opportunities for enhancement, our goal is to guarantee that the Gordon Library remains an indispensable asset and center of knowledge for generations to follow.

Table of Contents

Table of Figures

Table of Tables

1.0: Introduction

Libraries, once revered as bastions of printed knowledge, have experienced a profound transformation in recent decades. Traditionally, they served as havens for reading, community connection, and housing countless books to nourish the mind's thirst for knowledge and growth. However, the modern library has transcended its conventional role, evolving into a multifaceted institution that reflects the dynamic needs of society.

As we navigate the digital age, this evolution becomes both intriguing and crucial to study. Influenced by advances in technology, evolving user needs, and shifting educational values, contemporary libraries have become vibrant hubs of intellectual exploration, group collaboration, and innovation. They no longer merely store information; instead, they serve as dynamic spaces where individuals converge to engage in a myriad of activities, from research and study to creative endeavors and community events.

This metamorphosis underscores the resilience and adaptability of libraries in the face of societal change. By embracing innovation and catering to the diverse needs of their patrons, modern libraries stand as beacons of knowledge, creativity, and connection in an ever-evolving world.

1.1: Problem Statement

As the landscape of quality education continues to evolve, academic buildings must adapt to meet the changing needs, working patterns, and preferences of university communities. In this context, libraries play a pivotal role as dynamic hubs of knowledge and collaboration. Therefore, the design considerations for libraries must encompass updated mechanical, electrical, and plumbing systems, as well as structural and HVAC upgrades, to ensure they remain relevant and functional in today's context.

The Gordon Library, constructed in a bygone era, stands as a testament to the evolution of construction and information technology over time. Our research has uncovered significant transformations since its inception in 1967. These alterations, occurring over various intervals, necessitate a thorough exploration of alternative layouts, structural systems, and building designs. Such exploration is essential to better align the library with the current and future needs of the WPI community. By addressing these challenges and opportunities for improvement, we aim to ensure that the Gordon Library continues to serve as a vital resource and hub of learning for generations to come.

1.2: Scope of Work

The project scope was diligently focused on various critical components of the Gordon Library, aiming to bring about a comprehensive transformation marked by innovative elements and enhancements. The scope of the ambitious endeavor includes:

1.) Conduct a thorough analysis of applicable building, fire, and life safety codes to ensure compliance and guarantee the safety of all occupants within the library.
2.) Engaging in contemporary research to explore the configurations and functionalities of existing libraries, informing our design decisions and strategies.
3.) Performing a comprehensive structural engineering assessment to evaluate the feasibility and structural integrity of proposed additions, such as the rooftop addition and atrium.
4.) Enhancing the library's exterior connectivity with the surrounding site and campus to foster a sense of cohesion and belonging within the community.
5.) Creating physical models that vividly depict the proposed design, providing stakeholders with a tangible representation of the envisioned changes.

Our team has conducted a thorough analysis of applicable building, fire, and life safety codes to ensure compliance and guarantee the safety of all occupants within the library. Additionally, we have engaged in contemporary research to explore the configurations and functionalities of existing libraries, informing our design decisions and strategies. Furthermore, we have performed a comprehensive structural engineering assessment to evaluate the feasibility and structural integrity of proposed additions, such as the rooftop addition and atrium. Additionally, we have enhanced the library's exterior connectivity with the surrounding site and campus to foster a sense of cohesion and belonging within the community. Lastly, we have created physical models that vividly depict our team's proposed design, providing stakeholders with a tangible representation of the envisioned changes.

Our vision for the Gordon Library is rooted in the integration of functionality, aesthetics, and safety. By undertaking these critical assessments and enhancements, our team aims to rejuvenate this cherished institution, ensuring it remains a beacon of knowledge and inspiration for generations to come. The suggested alteration aims to increase visual transparency, enhance the flow, improve student productivity, and create an inviting space for the community to come together and grow.

2.0: Background

This chapter offers a detailed exploration of the fascinating history and development of the Gordon Library at WPI. We will delve into the library's journey from its inception, tracing its evolution over time and its adaptation to the ever-changing landscape of education and technology. By examining the library's origins, we will uncover the societal and architectural influences that have shaped its current form and functionality. Furthermore, we will conduct a thorough analysis of the dynamic shifts in library design across different periods, providing valuable insights into the need for modernizing the Gordon Library to better serve the diverse and evolving needs of students at WPI.

Through this comprehensive examination, we aim to provide readers with a deeper understanding of the library's significance and the rationale behind proposed updates and enhancements. By aligning the library's infrastructure and resources with contemporary educational requirements and technological advancements, we endeavor to create a dynamic and inclusive learning environment that fosters academic excellence and innovation for generations to come.

2.1: History of the WPI Library

Worcester Polytechnic Institute (WPI) has a distinguished history of growth and achievement in the fields of science and engineering (George C. Gordon Library | Worcester Polytechnic Institute, n.d.). A surge in enrollment during the early 1960s, fueled by a national emphasis on enhancing science and engineering education in the United States (Trends in United States Higher Education from Massification to Post Massification, 1997), led to a remarkable 44 percent increase over the preceding seven years. At the time, WPI recognized a critical challenge in delivering high-quality education: the absence of a university library capable of housing all its archival sources and providing a functional space to serve its diverse student body and academic programs. Boynton Hall served as a small general library with a broad collection of literature, economics, history, and art volumes. Other academic resources were scattered across various departments, each maintaining its own library To address this challenge and fulfill its objectives of expanding its book collection, centralizing resources, creating a conducive study environment, and embracing emerging audio-visual and microfilm technologies, WPI initiated the design and construction of a new library facility located on the east side of the campus near Boynton Street seen in Figure 1 (George C. Gordon Library | Worcester Polytechnic Institute, n.d.).

This ambitious project required a substantial capital investment from George C. Gordon, a distinguished WPI alumnus for a donation of $5 million (*George C. Gordon Library | Worcester Polytechnic Institute*, n.d.). This significant donation enabled the university to embark on the design and construction of a state-of-the-art library seen in Figure 2 capable of accommodating 600 students and housing an impressive collection of 200,000 volumes (*George C. Gordon Library | Worcester Polytechnic Institute*, n.d.). The library's design included various amenities such as individual reading tables, group study rooms, smoking areas, music rooms, and lounges on each floor, enhancing the overall student experience.

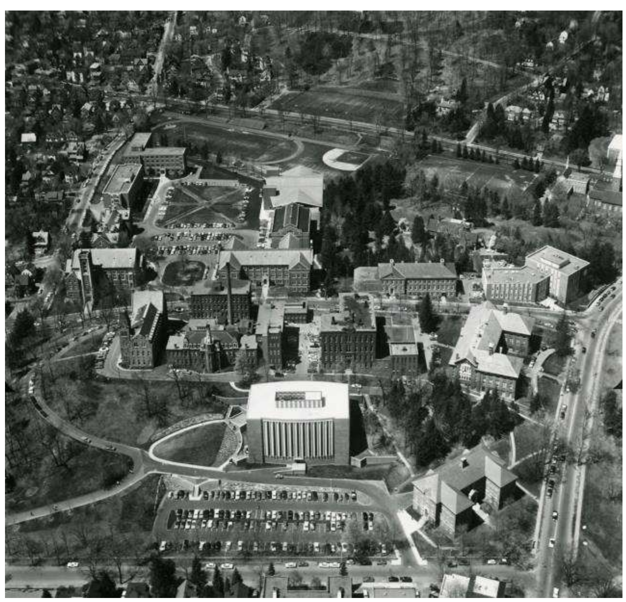


Figure 1: Aerial image of the Gordon Library taken in the mid-1970s (Library Archives).

Figure 2: Proposed rendering of the Gordon Library in 1963 from O.E. Nault & Sons (Library Archives).

Architecturally, the Gordon Library stands as a four-story, reinforced concrete structure adorned with a brick and precast concrete panel facade (George C. Gordon Library | Worcester Polytechnic Institute, n.d.). O.E. Nault & Sons, based in Worcester, Massachusetts, were the architects behind the design, while Harvey and Tracey Consulting Engineers handled the structural engineering aspects. The structural design of the building was based on a voided slab system that allowed for a two-way dispersion of forces down to the columns. This system is commonly known as a waffle slab system for each floor and is used in reinforced concrete designs to efficiently distribute the expected loads of the building. Figure 3 depicts the library's structural concrete during the installation of precast concrete fins, providing a visual insight into its construction process.

Figure 3: Construction photo of the Gordon Library showing the precast concrete fins being installed (Library Archives).

Over time, the library's interior layout has transformed to accommodate the evolving use of technology and collaborative workspaces. However, aesthetic concerns have arisen, with some perceiving the Gordon Library as resembling a bunker rather than a welcoming and inviting space. The library's primary entrance from the campus is located on the "Second" floor, boasting an expansive open area tailored for computer use and group collaboration, complemented by conference rooms equipped with computers and flat-screen TVs, known as "tech suites." Additionally, a café caters to the needs of both students and faculty. Progressing to the third floor, one encounters additional flexible tables for group work, individual cubbies, and administrative offices. The first floor primarily comprises quiet study areas, tech suites, handbook stacks, and a computer lab. Finally, the ground floor houses compact book shelving, tables for group work, and the recently renovated university archives and special collections department. Presently, WPI's library boasts an extensive collection comprising over 270,000 books, more than 4,000 archival materials, and rare books, and provides students with access to over 70,000 electronic journals, books, and databases, enriching their academic pursuits (Jones, 2015).

Nevertheless, the WPI environment today markedly differs from the time of the library's construction, with undergraduate enrollment having surged to approximately 6,500 students. A common challenge students face is the difficulty in finding adequate working areas for group and individual work, prompting multiple small renovations over the years to ensure that the library continues to meet the evolving needs of its users.

2.2: 60's Architecture

During the 1960s, architecture experienced a dynamic period marked by various influential movements and styles. Among the notable trends were Brutalism, Modernism, and Counter-culturalism, each championed by prominent architects such as Le Corbusier, Paul Rudolph, and Oscar Niemeyer (Smith, 1965; Brown, 1968).

Modernism, characterized by clean lines, functional design, and minimal ornamentation, continued to dominate architectural discourse. Concurrently, Brutalism emerged as a significant movement, often featuring untreated concrete and bold geometric configurations. Counter-cultural architecture also gained traction, advocating for experimental and unconventional designs that challenged traditional norms (Jones, 1970).

The architecture of the WPI Gordon Library predominantly reflects the Brutalist movement prevalent during the era. Elements such as the raw concrete aesthetic, geometric forms, and monumental scale are indicative of this stylistic expression. The library's prominent use of exposed concrete, particularly evident in its façades adjacent to the windows spanning multiple floors, underscores its Brutalist influence. Moreover, the mixture of sharp angles and curves, rugged edges, and a sense of monumentality seen further characterize the Brutalist design ethos, as seen throughout the library's exterior form. The New York TWA Terminal included a brutalist-designed building as seen in Figure 4. The building incorporated sharp curves while allowing for abundant natural lighting *(architect-staff, 2010).*

Figure 4: The New York TWA Terminal, a concrete brutalist building in the 1960s showing the primary use of concrete to create large intimidating buildings (architect-staff, 2010).

Despite being a significant example of Brutalist design from the 1960s, the Gordon Library stands as a potential canvas for future renovations. Brutalism was renowned for its structural expression and spatial innovations, which integrated structure and function seamlessly. However, the current library conceals its structural system under column covers and a drop ceiling, obscuring the intricate waffle-slab system above and diminishing the sense of scale within the building. Thus, future renovations present an opportunity to enhance the building's architectural integrity by revealing and celebrating its structural elements (Brown, 1972).

2.3: Contemporary Library Models for the 21st Century

Although the WPI Gordon Library has been a campus landmark since its construction, the usage and design of the space have evolved to meet the changing needs and requirements of a modern university library (Smith, 2019). Today, libraries are more than just repositories for books; they have transformed into dynamic learning hubs that prioritize flexibility, technology integration, and community engagement (Pierce, n.d.).

There has been a noticeable shift towards creating open, flexible layouts that can easily adapt to accommodate various activities and events (*Universal Design: A Guide For Architects and Designers*, n.d.). This includes the incorporation of movable furniture, modular shelving, and multipurpose rooms, allowing libraries to serve diverse functions ranging from collaborative workspaces to quiet reading areas (Designing Libraries for the 21st Century, 2022).

At WPI, spaces that encourage collaboration and interdisciplinary learning are particularly emphasized, featuring comfortable seating, writable surfaces, and multimedia resources to facilitate teamwork and creativity. While the typical seating arrangement accommodates groups of 4-6 people, individual workspaces can also be booked as needed (George C. Gordon Library | Worcester Polytechnic Institute, n.d.). Furthermore, libraries have embraced advancements in technology, offering access to e-books, online databases, and virtual reality experiences alongside traditional print resources (Prepare, 2023).

In line with the broader trend of sustainable construction, many 21st-century library designs prioritize sustainability and aim for a Net Zero carbon footprint (Designing Libraries for the 21st Century, 2022). Incorporating energy-efficient lighting, recycled materials, and eco-friendly construction methods not only reduces environmental impact but also lowers operating costs in due time (Nail, 2023).

By integrating these modern features and sustainable practices, libraries like the WPI Gordon Library continue to evolve to meet the ever-changing needs of their users while also contributing to a greener future.

2.4: Past Major Qualifying Projects

Despite the ongoing renovations and adaptations, it's imperative to acknowledge the invaluable contributions of previous student projects aimed at enhancing the Gordon Library. Over the years, numerous Major Qualifying Projects (MQPs) have explored various facets of the library's functionality and design, offering insights and recommendations that can significantly benefit our current project.

One notable MQP, completed in 2015, centered on investigating the lighting system of the Gordon Library. This endeavor focused on evaluating the energy efficiency of the library's lighting systems and proposing measures to enhance sustainability and user comfort (Varrichione, Jarvis, 2015). Through meticulous measurements and analysis, the team identified areas ripe for improvement, suggesting solutions ranging from the adoption of more efficient light bulbs to initiatives promoting energy conservation awareness among students.

Similarly, a significant MQP titled "The Academic Library Design: A Case Study of the George C. Gordon Library," undertaken in 2016 examined the library's architecture within the framework of contemporary design standards (Attalla, Connors, 2016). This study shed light on the evolving role of libraries in the digital era, where traditional functions have evolved to accommodate emerging services and technologies. The project proposed structural renovations, including the incorporation of an atrium to augment natural lighting and foster a more welcoming ambiance throughout the building.

Integrating insights gleaned from these past MQPs into our current project is paramount as we endeavor to build upon existing knowledge and leverage innovative ideas to further enhance the Gordon Library. By tapping into the expertise and research findings of previous student initiatives, we can develop comprehensive solutions that address the evolving needs of our university community and contribute to the continued evolution of the library.

2.5: Case Study/Past Renovation

In the summer of 2000, Worcester Polytechnic Institute (WPI) engaged Shepley Bulfinch Richardson and Abbot (SBRA) to develop a master plan defining the Gordon

Library's role in the future of the Institute. The team that developed this plan reviewed WPI's strategic vision at the time, assessed existing facilities, and identified needs that were not currently provided. This background research allowed the team to develop a summary program detailing the amount of space required for the ideal facility, which was then further developed into a diagrammatic floor plan identifying the allocation of space throughout the building. In conjunction with the development of the space, SBRA, along with a team of consulting engineers, assessed the existing building envelope (Master Planning Study for Gordon Library, 2000).

The study under the master plan resulted in the identification of three distinct work components. These work components included a base scheme for renovating the existing building and two other design options for additions to the library. The Base scheme involved the full renovation of the existing building including the mechanical systems. Option 1 involved the infill of the current entrance on the second and third floors to create a common entry space to provide the building with an inviting feel and updating the west facade to a glass curtain wall to increase transparency and draw people to the facility's interior spaces. Option 2 involved the addition to the south side of the building on every floor, providing the library with an additional 12,250 sq. ft. of space for the addition of new spaces and student seating.

Other significant renovations to the library include the addition of the Café and expansion of the Service Desk in 2009, and a Mechanical/Plumbing Renovation in 2016 focused on the Ground floor and archive services. The 2009 renovation was focused on the 2nd floor of the building adding a Café where students could gather and take a break from studying and socialize. In addition, the service desk and IT services were expanded to be able to serve the increasing demand of the library and the campus's digital needs better. The mechanical/plumbing renovation in 2016 provided the ground floor and archive services with an updated HVAC system designed specifically for the archive. As part of this renovation, the ground floor was also provided with sprinkler system protection. Most recently the entrance to the first floor shown in Figure 5 was removed and converted into an interview room to accommodate the construction and site work necessary for Unity Hall.

Figure 5: South side first-floor entrance before its removal for the construction of Unity Hall (Library Archives)

2.6: Existing Library Layout

The existing Gordon Library was constructed in 1967 as a Type II-A protected, non-combustible construction building with its primary use being group A-3 Assembly (2021, IBC). The building also contains support spaces associated with the operation of libraries including offices for library staff, IT and circulation desks, and student study spaces. The building is not currently equipped with an automatic sprinkler system throughout.

The current library has four floors that are accessible to the student population, and the idea is that the lower floors in the building are quieter and the less collaborative the spaces become. This is done to create an environment where a user can study in the library and have the option to have discussions and speak freely amongst a project group or to sit at a table or cubicle and work independently.

The sub-ground level of the basement shown in Figure 6 is designated facilities access only and the only rooms on this floor include the electrical, mechanical, and elevator control rooms as well as a large storage space.

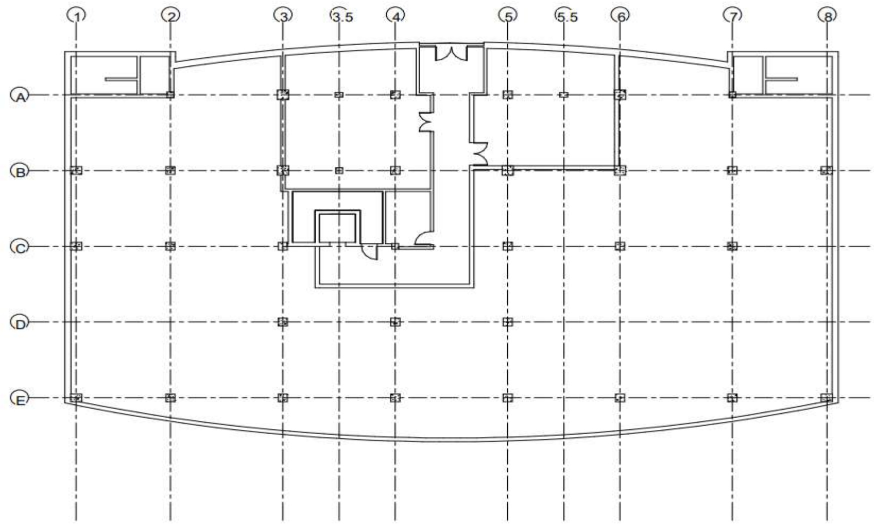


Figure 6: Existing Ground-level floorplan of the library containing the mechanical room on the left and the electrical and storage spaces on the right.

The Ground level of the library shown in Figure 7 is home to the archives, stack space, and student seating. There is also currently a temporary classroom on this level sectioned off on the west wall to accommodate the decrease of classroom space due to the ongoing Stratton Hall renovation.

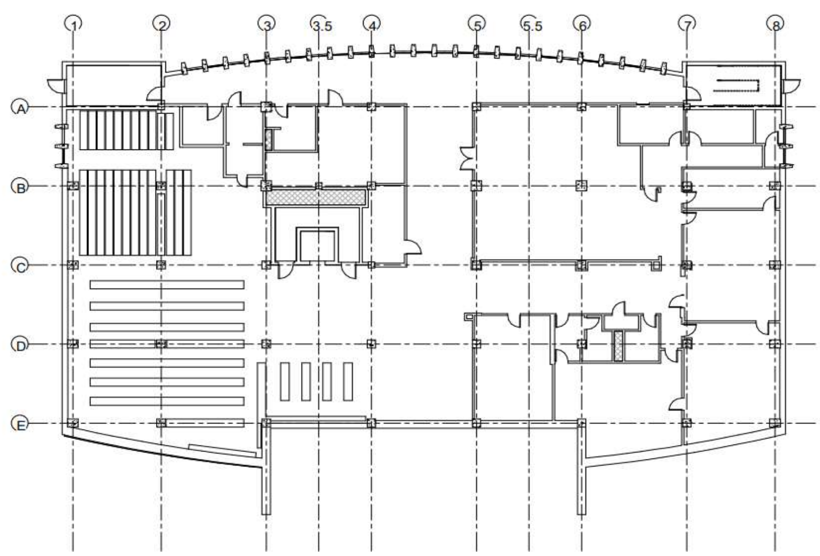


Figure 7: Existing Ground Level floorplan of the library containing the moveable stack space on the left and the dedicated archive space on the right.

The first floor of the library shown in Figure 8 is where the majority of the library's tech suites are located, as well as most of the remaining bookstacks, and individual working cubbies along the east wall.

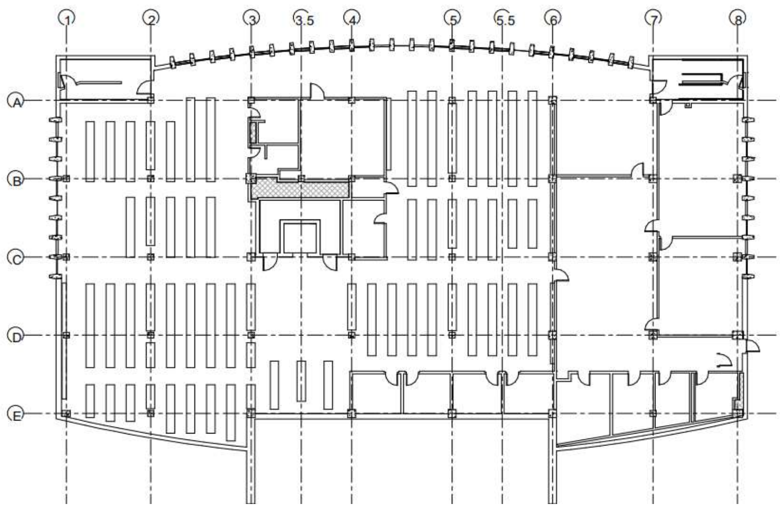


Figure 8: Existing First Floor floorplan of the library which contains the majority of the stack space on the left of the building and tech suites on the bottom.

The second floor shown in Figure 9 serves as the main entrance to the building and has a cafe, help desks for IT and Library services, staff offices, and student working spaces.

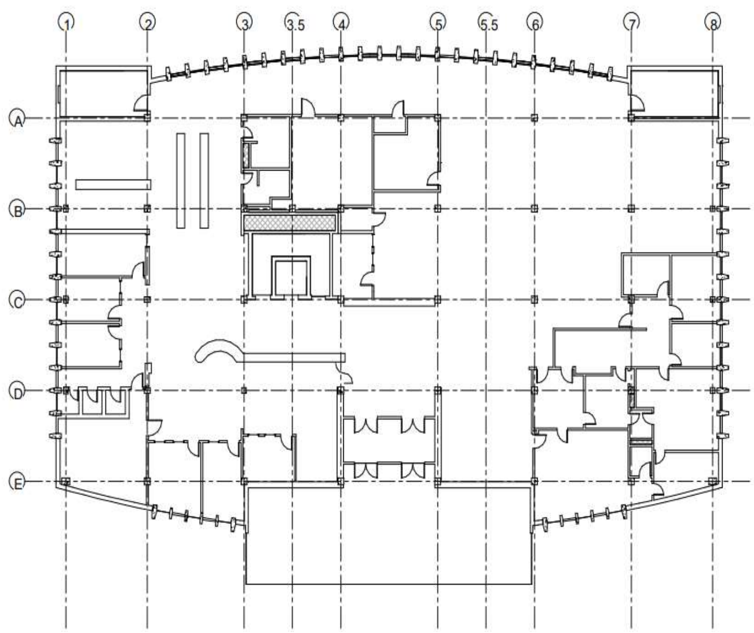


Figure 9: Existing Second Floor floorplan of the library containing the library services desk to the left of the main entrance and the café and IT-related spaces to the right of the building.

The third floor shown in Figure 10 features open student working space furnished with larger tables for group work and some individual cubbies, as well as a few staff offices on this floor.

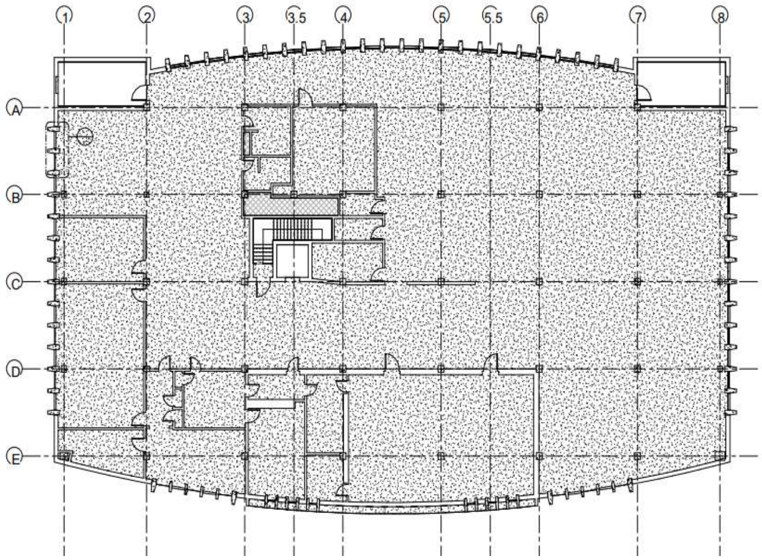


Figure 10: Existing Third Floor floorplan of the library contains mainly open space used for group work by students, and some library administrative offices.

3.0: Methodology

This project required a significant amount of information and data-gathering aimed at obtaining all available plans of the Gordon Library, and the campus communities needs and wants from the library. This endeavor involved close collaboration with the facilities department and library staff at WPI, navigating paperwork procedures, coordinating efforts to retrieve the necessary documents, and planning meetings to discuss different design options. Along with various analyses outlined below the group will propose renovations to the existing Gordon Library.

3.1: Collecting and Reviewing Plans

Within the initial weeks of the project term, we successfully obtained a diverse array of plans, spanning from the library's original construction in 1967 to subsequent renovations, including the 1996 chiller replacement, the 2009 Café/Service Desk renovation, and the 2016 mechanical/plumbing overhaul. This meticulous organization of files by discipline and renovation phase served as a foundational step, ensuring that we had a robust reference point for the subsequent design process. Additionally, gaining access to mechanical rooms and rooftop spaces allowed us to glean insights into equipment layout and spatial considerations essential for our analysis and recommendations.

3.2: Gathering Information on Campus Input

Throughout the project, regular meetings were held with Librarian Anna Gold to gather input on our design and to understand the staff's priorities for library improvements. Engaging with the library staff was crucial, as they are significant stakeholders in the project and have valuable insights into the space's functionality and needs. These meetings served as opportunities to receive Anna's feedback on our evolving concepts and models. Topics discussed during these sessions included, among others, the potential removal of the drop ceiling to reveal the raw concrete waffle slab and the possibility of dividing the computer lab on the first floor, which is sometimes utilized as a meeting room.

3.3: REVIT Modeling

Revit stands out as a powerful Building Information Modeling (BIM) software, developed by Autodesk, tailored specifically for the architecture, engineering, and construction (AEC) industry. This comprehensive toolset facilitates building design, documentation, and collaboration with unparalleled efficiency. One of its key features is the ability to model existing building structures and floor plans accurately. Through Revit, structural elements, site layouts, building designs, and floorplans can be intricately detailed, providing a holistic view of the project.

Parametric software applications like Revit offer significant advantages to firms, notably in streamlining the process of making changes and coordinating with various disciplines. By storing computable graphic and data attributes, Revit enables swift adjustments while minimizing errors and ensuring seamless collaboration across teams.

Moreover, Revit fosters collaboration and coordination by centralizing crucial project information within a single model. This includes key dimensions, load paths, and other essential data points. Beyond its collaborative capabilities, Revit boasts an intuitive interface that enhances user experience and accessibility. Additionally, its extensive object libraries, curated by Autodesk and end-users alike, offer a vast array of resources to support diverse project needs.

A notable strength of Revit lies in its bidirectional drawing support, facilitating seamless information updates and management across drawing and model views, including schedules (Wang, 2012). This feature further enhances efficiency and accuracy in project execution, making Revit an indispensable tool for modern AEC professionals. The team used Revit to develop a model showcasing the current state of the building as shown in Figure 11.

Figure 11: REVIT model of the existing library from the northeast side of the building looking up from ground level.

3.4: Structural Analysis

This section elucidates the structural design methodology employed in this MQP report, offering insights into the meticulous process undertaken to analyze and evaluate the structural integrity of the library.

To conduct a comprehensive structural analysis of the library, it was imperative to establish a thorough understanding of the load distribution across its structural elements. This served as a foundational step in evaluating the feasibility and implications of proposed design alterations compared to existing conditions. To achieve this goal, tributary areas were meticulously delineated for each column, and corresponding loads were calculated or estimated following state building codes.

These loads encompassed both dead loads and live loads, representing the permanent and temporary forces acting upon the structure, respectively. The live loads do not include wind, snow, and seismic loads. These loads are separately identified as seen in the LRFD equations used from the Massachusetts State Building Code. Through a meticulous load and resistance factor (LRFD) analysis, the team delved into the intricate dynamics of load-bearing elements, shedding light on the distribution of forces and their transmission through the building's foundation.

It's worth emphasizing that while the library was initially designed using allowable stress design principles, adopting an LRFD approach offered a conservative perspective on the structural integrity of the building. This method, widely acknowledged and accepted within the engineering community, provided a pragmatic framework for assessing the library's capacity to withstand various loads and stresses.

The following LRFD equations were used from the Massachusetts State Building Code to determine loads from each floor (*780 CMR Ninth Edition, Chapter 16*, 2018).

- $1.4(D+F)$ *Equation 16-1*
- $1.2(D+F) + 1.6(L+H) + 0.5(L_r \text{ or } S \text{ or } R)$ *Equation 16-2*
- $1.2(D+F) + 1.6(L_r \text{ or } S \text{ or } R) + 1.6(H) + (f_1L \text{ or } 0.5W)$ *Equation 16-3*
- $1.2(D+F) + 1.0(W) + f_1L + 1.6H + 0.5(L_r \text{ or } S \text{ or } R)$ *Equation 16-4*
- $1.2(D+F) + 1.0(E) + f_1L + 1.6H + f_2S$ *Equation 16-5*
- $0.9D + 1.0W + 1.6H$ *Equation 16-6*
- $0.9(D+F) + 1.0E + 1.6H$ *Equation 16-7*

An Excel sheet was developed to automate the calculation of these equations accompanied by various hand-calculations to verify the results from the spreadsheet.

To determine the structural capability of the library, the loads must be calculated, and the load path must be determined for each column. Figure 12 illustrates an example of a 2 x 2 bay in the library and the floor slabs connected to it. The loads being distributed vertically down through the columns, and the tributary area of each column must be found and then the loads on the floor must be calculated. By comprehensively understanding and quantitatively analyzing the loads carried throughout the building, insights to propose alterations to the facility can be revealed. These alterations may involve additions or removals of walls and floor systems; however, it is imperative to first grasp the existing structural conditions before implementing any modifications to the building.

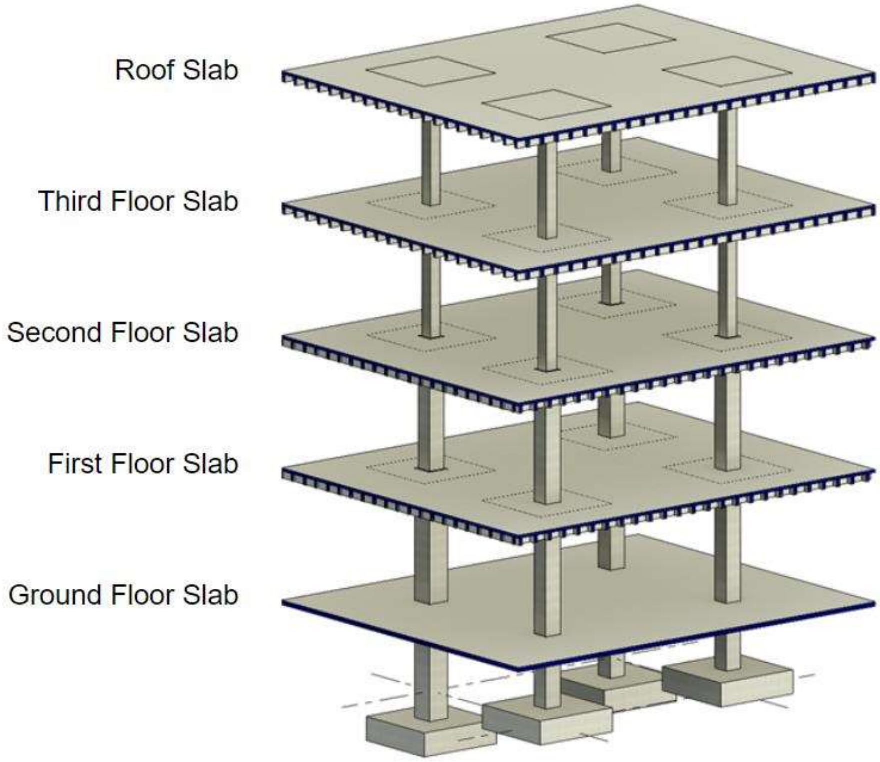


Figure 12: Column diagram representing the unknown load path.

In addition to assessing the loads carried throughout the column, it was important to analyze the bending moments and shear forces acting upon the waffle slab system. This was achieved through the Rankine-Grashoff method, which achieves an approximation based on calculating deflection in either direction at the junctions of ribs (Halkude & Mahamuni, 2014). In order to conduct a more thorough analysis of a partial removal from a waffle slab system, a finite element modeling program or deep dive into the theory of plates and shells is required. These various approaches are further discussed in Section 6.3: Waffle Slab Analysis.

3.5: Energy Analysis

Conducting an energy analysis of the Gordon Library is essential for pinpointing areas where enhancements can be made to the building's envelope and mechanical systems. This analysis will be carried out using a blend of Design Builder software and manual calculations to validate the R-values and U-factors of the walls. Design Builder facilitates the simulation of the building environment over a defined period, producing comprehensive results in the form of tables and graphs. These results depict various metrics such as total site energy, energy consumption by end-use, as well as comfort and set point data. Preliminary hand calculations were also performed to understand the R-values and U-factors of the windows, concrete panels, and brick wall that make up the facade.

3.6: Code Review

As an integral part of our project, we will conduct a thorough code review, commencing once our design concepts are finalized. This review is crucial to understanding the necessary modifications to the building and the implications introduced by current building codes compared to those in place at the time of construction. Presently, Massachusetts adopts the 9th edition of 780 CMR, which amends the 2015 International Building Code (IBC). However, it is anticipated that by 2024, the 10th edition will be adopted, amending from the 2021 IBC. Following the adoption, there will be a 6-month concurrency period during which buildings designed to meet the standards of the 9th edition code will still be acceptable. Given the timeline for a project of this magnitude, our team will adhere to the 10th edition of 780 CMR, as we do not anticipate the project being permitted within the concurrency period of the 9th edition.

In addition to the 780 CMR, other codes integral to our review includes the 521 CMR Massachusetts Accessibility Code, the 2021 International Existing Building Code (IEBC), NFPA 1 (Fire Code), and NFPA 101 (Life Safety Code). To conduct the code review effectively, we first identified the key elements undergoing changes in each design concept. We then delved into the codes to ascertain the specific requirements for each element. It's worth noting that certain code sections may reference more specific applications where certain requirements are no longer necessary. Exceptions also play a role in determining whether a requirement is needed under specific circumstances.

One of the significant implications uncovered during our review is that the building is not fully sprinkler protected throughout, raising concerns regarding the current accessibility of the building. This is a critical consideration, as the building code mandates that if the cost of renovations exceeds 30% of the full and fair cash value of the building, the entire building must be brought up to the current accessibility code. Such an undertaking would pose significant challenges for the university and must be carefully evaluated in our design proposals.

4.0: Architectural Design Proposals

To improve the functionality of the Gordon Library to meet today's standards of what is expected for a college library and what is needed by its students, we decided upon multiple design changes for a better environment. Some of these are a more significant undertaking than others, but all are designed to improve the library environment and give users more space. Our proposal includes:

1. The removal of a section of the 3rd floor waffle slab and roof slab to form an atrium.
2. A new lightweight addition to the library rooftop.
3. The relocation of stack book storage spaces and removal of select non-structural walls allows for more usable space for students.
4. Removals of the drop ceiling throughout.

These alterations will increase visual transparency, enhance the flow, improve student productivity, and create an inviting space for the community to come together and grow.

4.1: Atrium Design Space

The group's design recommendations entail the removal of a section of the 3rd-floor waffle slab and the roof of the library, facilitating a connection to the second floor of the existing library and the proposed rooftop addition. This innovative approach introduces an atrium into the space, enhancing the library's modernity and allowing natural light to penetrate deeper into the building's core.

Figure 13 illustrates how the introduction of an atrium could significantly augment the influx of natural light into the library's core, while also showcasing the connectivity facilitated by the inclusion of a staircase. To ensure the atrium aligns with the library's existing function, careful consideration was given to noise levels on different floors. It was imperative to introduce the atrium between two floors with comparable noise levels to minimize disruptions to students.

In the original library design, the main staircase was offset to the north side of the floorplans, leaving the south side open for working space. This spatial arrangement provides ample room to introduce the atrium without compromising floor area. Additionally, the atrium will feature an open stair to serve the 3rd floor and rooftop addition, improving accessibility and flow within the building. Introducing another staircase in a more central location with increased natural light aims to enhance the functionality and aesthetics of the library's core.

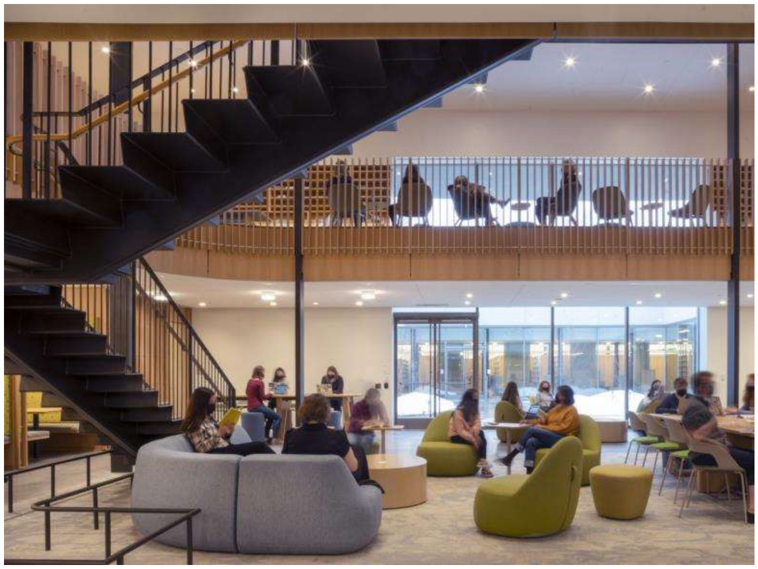


Figure 13: Example atrium in a library being used as a study space bringing natural light further into the building and connecting the spaces (Neilson Library Giving, n.d.).

The proposed atrium will be 20’ by 25’ on both floors corresponding to the size of the bays of the waffle slab. The structural analysis and the group's recommendations for the removal of this section of waffle slab can be found in 6.3: Waffle Slab Analysis. As shown in Figure 14, the atriums are offset in the N-S direction with the intention of allowing more sunlight from the rooftop and adding large windows to reach further into the building.

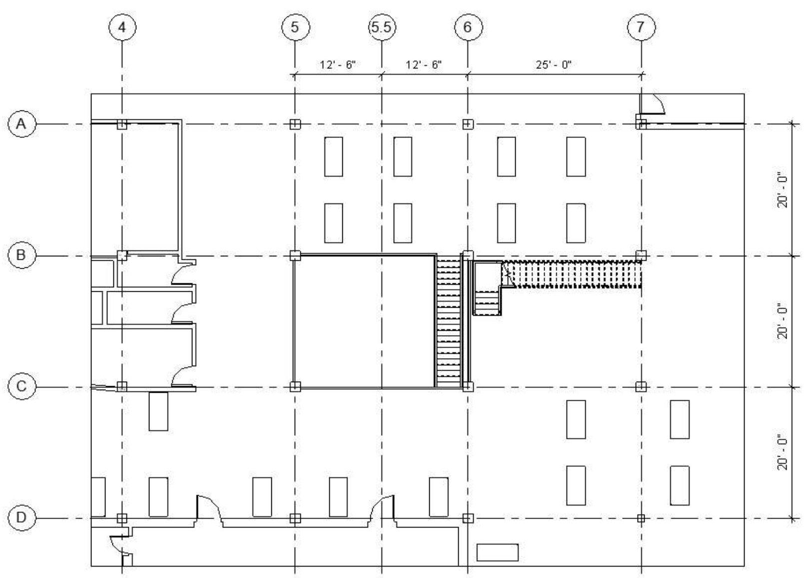


Figure 14: 3rd Floorplan showing the proposed atriums between column lines 5-6 on the 2nd-3rd floor and shifting to 6 and 7 between the 3^{rd} floor and rooftop addition.

Figure 15 depicts a similar view of the example atrium looking at the new staircase from the second floor to the third floor in the main entrance of the library. The staircase leading to the third floor is oriented so that when you reach the top you are faced with the view of the city, and the staircase to the addition has a landing and makes a turn so that the view at the top is a direct sightline through campus. The space under the stairs will be filled with bookcases to make up for the stack space that is being removed from the first floor, and will also serve a purpose by restricting peoples access to an area with low headroom per 521 CMR which is discussed later in Section 5.2: Code Implications of Atrium Design.

Figure 15: Second Floor Looking South up at atriums to the large southern facing windows, showing the orientation of the staircases leading to the third floor and rooftop addition.

4.2: Rooftop Addition

Preliminary research for the new roof addition revealed changes in the prescribed live loads for sections of the library compared to its original design. Initially, most of the library was designated for stack storage, with a prescribed live load of 150 psf. However, over time, the library's usage has evolved to accommodate more student workspace, resulting in some areas now being classified as assembly areas with a reduced prescribed live load of only 80 psf. This shift in live load suggests that the building may be over-engineered for its current use, with calculations indicating a 15% decrease in the building load compared to its initial design. Further details and explanations of these calculations will be provided in

6.0: Structural Analysis.

This surplus load capacity presents an opportunity for a new lightweight addition to the top of the library, aiming to increase the usable space for WPI students and take advantage of the opportunity to expand the campus view of the city. While the building's structural capacity appears sufficient to accommodate the expected added loads of a rooftop addition, several structures on the roof pose limitations to these proposed design changes. Notably, the roof houses multiple HVAC units and ductwork essential for the building's heating and cooling, along with the elevator headhouse, as illustrated in Figure 16 and Figure 17.

Figure 16: Google Earth screenshot of the library showing the current rooftop HVAC layout (Google Maps).

Figure 17: Picture taken from Washburn 3rd floor of Gordon Library Roof showing the current view people have of the library roof.

While these units occupy most of the roof area, it would be necessary for the relocation of mechanical equipment towards the northern side of the building to leave space on the southern side for the proposed addition. This relocation appears feasible as there is unused space within the existing mechanical penthouse as shown in Figure 18.

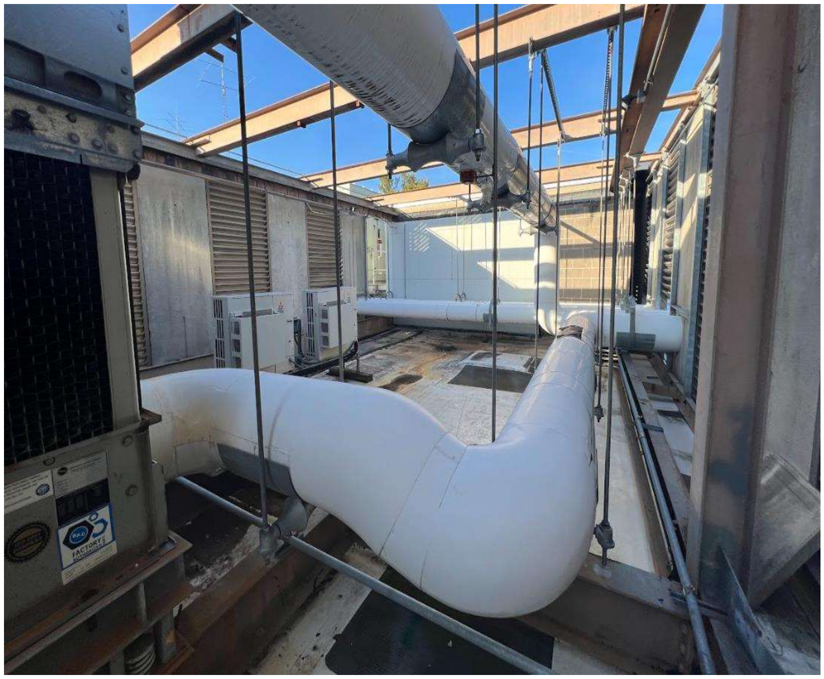


Figure 18: Interior of the mechanical penthouse screen wall showing unused space left over after the 2016 renovation.

4.2.1: Design Process

During the initial phases of the design process, the proposed addition was envisioned to occupy half of the existing rooftop footprint, totaling 8000 sq. ft., featuring architecture distinct from the existing Brutalist style. This space was intended to serve as a versatile area, combining table space and lounge areas, complemented by a deck for outdoor use during warmer months. Beyond providing functional workspace, the deck would offer panoramic views of the surrounding campus and cityscape, enhancing the overall experience for students.

However, upon further design exploration, it became evident that the original concept, depicted in Figure 19 with its corresponding floor plan in Figure 20, failed to present a compelling and visually appealing view when observed from ground level. Moreover, additional challenges emerged regarding the accessibility of the space, particularly due to the absence of an elevator. While the possibility of installing an accessibility lift through the atrium was considered, this solution was deemed impractical as it would introduce visual disruptions for occupants and obstruct sightlines from various parts of both the third floor and the proposed design addition.

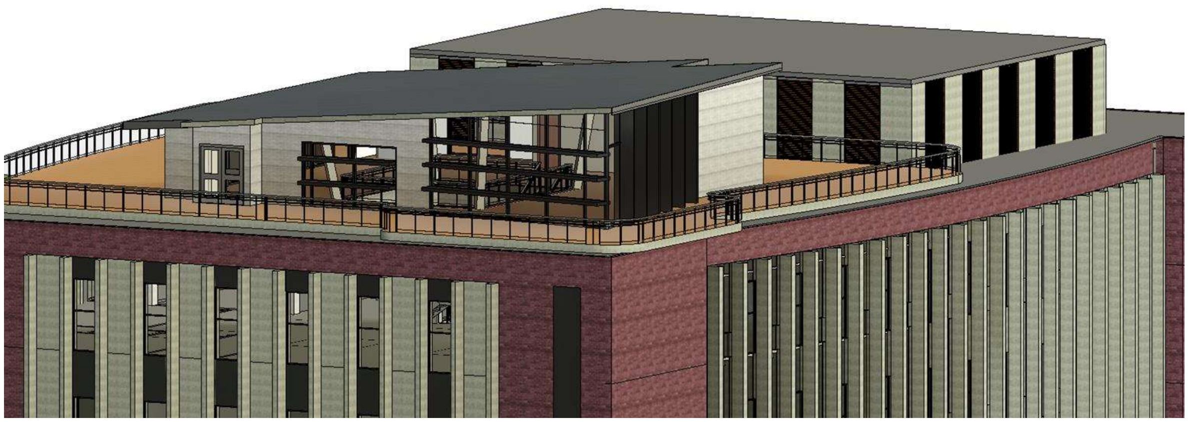


Figure 19: Arial view of the original design of the rooftop addition from the southeast corner of the building.

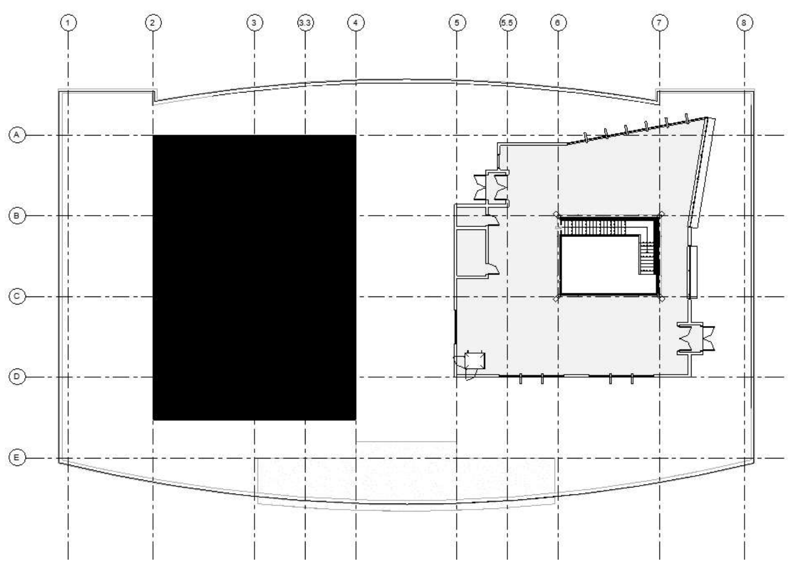


Figure 20: Original design of the smaller interior floorplan for the rooftop addition and a larger exterior deck space.

The design process necessitated a reevaluation, requiring a return to the initial form stage. The revised design aimed to harmonize with the existing Brutalist structure while enhancing the distinctive geometry of the current library. The new rooftop design sought to incorporate interior space exclusively, while offering access to three primary sightlines, enriching the experience of occupants with the surrounding vistas. These sightlines include:

1. Western view, oriented towards the school and campus walkway.
2. Southern view, overlooking Unity and downtown Worcester.
3. Eastern view, facing Boynton Street with slight angles towards the park.

Figure 21 provides an example of the exceptional views achievable with this new addition, fostering a connection between students and the city of Worcester while offering breathtaking scenery for all to enjoy. Furthermore, as illustrated in Figure 22, the walkway linking the Gordon Library to the rest of the campus can be observed from above, facilitating a sightline encompassing Washburn, Salisbury, the CDC, and the Campus center.

Figure 21: Eastern view from library roof highlighting views of Institute Park and Downtown Worcester in the distance.

Figure 22: Western view from the library roof highlighting the main walkway to the library from the center of campus that could be seen from the windows of the addition.

After committing to pursue the concept of the three-sightline design and incorporating Brutalist design elements into our new design, we proceeded to develop three distinct models for testing. These models were meticulously crafted, and 3D printed, as depicted in Figure 23, to facilitate a thorough comparison. Following extensive deliberation and analysis, Form 1 emerged as the clear choice to advance, primarily owing to its striking exterior curves.

Figure 23: Three 3D printed experimental forms of rooftop addition from left to right Form 1, Form 2, and Form 3.

4.2.2: Final Design

The ultimate design selected successfully incorporates the three primary sightlines available from the rooftop, facing east, south, and west directions. These facets will feature expansive curtain walls, maximizing the entry of natural sunlight. Embracing a curved geometric design, reminiscent of 1960s architecture and harmonious with the existing building's curves, the structure's shape exudes a sense of continuity. As illustrated in Figure 24, the prominent curtain wall is prominently displayed to observers from Boynton Street, epitomizing a modern identity reflective of the interior's functional enhancements.

Figure 24: View of the library from Kaven parking lot highlighting the proposed addition curtain wall on the east façade.

From the hilltop perspective, onlookers can better understand and clearly see the broad curvature of the building, with its sweeping edge going from the bottom of the southern wall to the top of the western wall shown in Figure 25.

Figure 25: View highlighting the broad curvature and vast windows of the proposed addition seen from campus in-front of Unity Hall.

The floor plan of the addition features expansive open areas designated for tables and cozy lounges, fostering an environment conducive to group work and collaborative endeavors. This layout encourages students to engage in discussions and exchange ideas more fluidly, promoting an active style of learning. Such a space has the potential to cultivate a keen sense of community and serve as a hallmark of the university's contemporary identity. Figure 26 showcases the envisioned floorplan design, accentuated by the integrated atrium system facilitating access to the third floor.

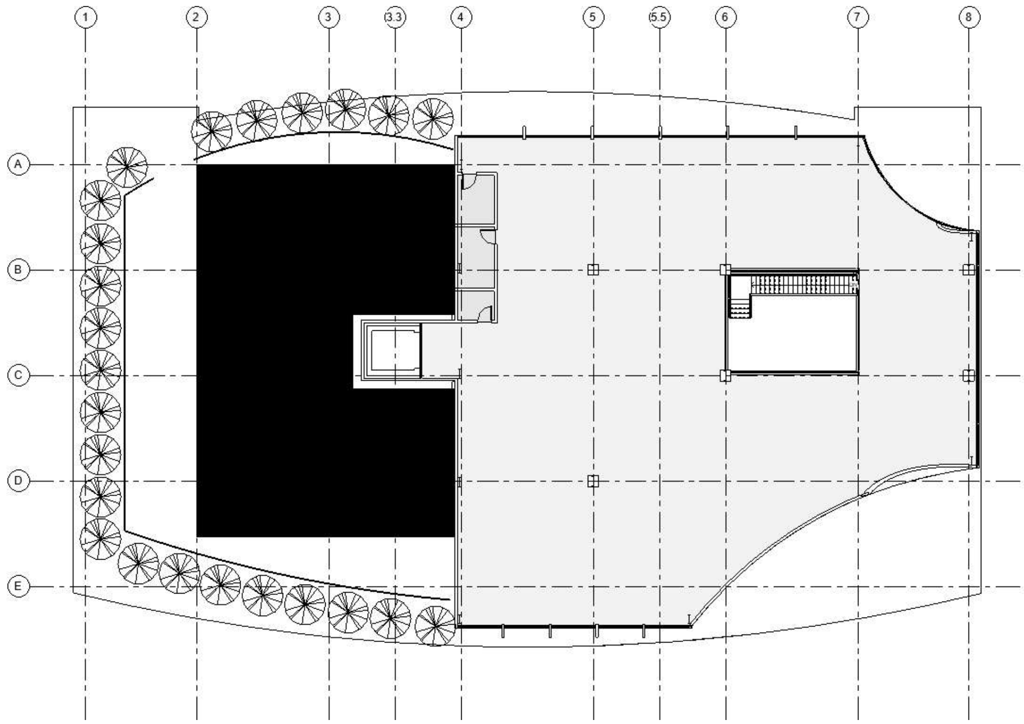


Figure 26: Proposed addition floor plan with atrium and connectivity to the existing elevator shaft.

The new total floor plan encompasses an area of approximately 7,770 square feet. In addition to facilitating collaboration through its open layout, the design offers exceptional adaptability and flexibility for the space. Various furnishing arrangements can be employed to accommodate different learning activities, allowing users to customize the environment to meet their specific needs. This promotes a dynamic and responsive atmosphere conducive to creativity and productivity. Figure 27 presents an initial rendering of the addition, highlighting its expansive vertical scale and inviting ambiance.


Figure 27: Interior render to showcase column placement with interior trusses of space frame covered.

To ensure accessibility for all occupants, modifications must be made to the existing elevator system. The elevator shaft needs to be extended upwards to reach the proposed addition, while the elevator itself must be altered to incorporate a dual door system opening to the southern direction. Currently, the elevator opens only to the western side, but due to space constraints caused by rooftop HVAC units, a new configuration is necessary to provide access to the addition.

4.3: Removal and Redesign of First Floor Stack Space and Floor Plan

In addition to an atrium, the team proposes the removal and relocation of stack space and the removal of non-structural in-fill walls throughout the building but primarily focused on the first floor. The existing arrangement of stacks on the first floor can be seen in Figure 28*: Current 1st Floor Stack Arrangement which takes up the majority of the floor and significantly decreases the flow within the space.*.

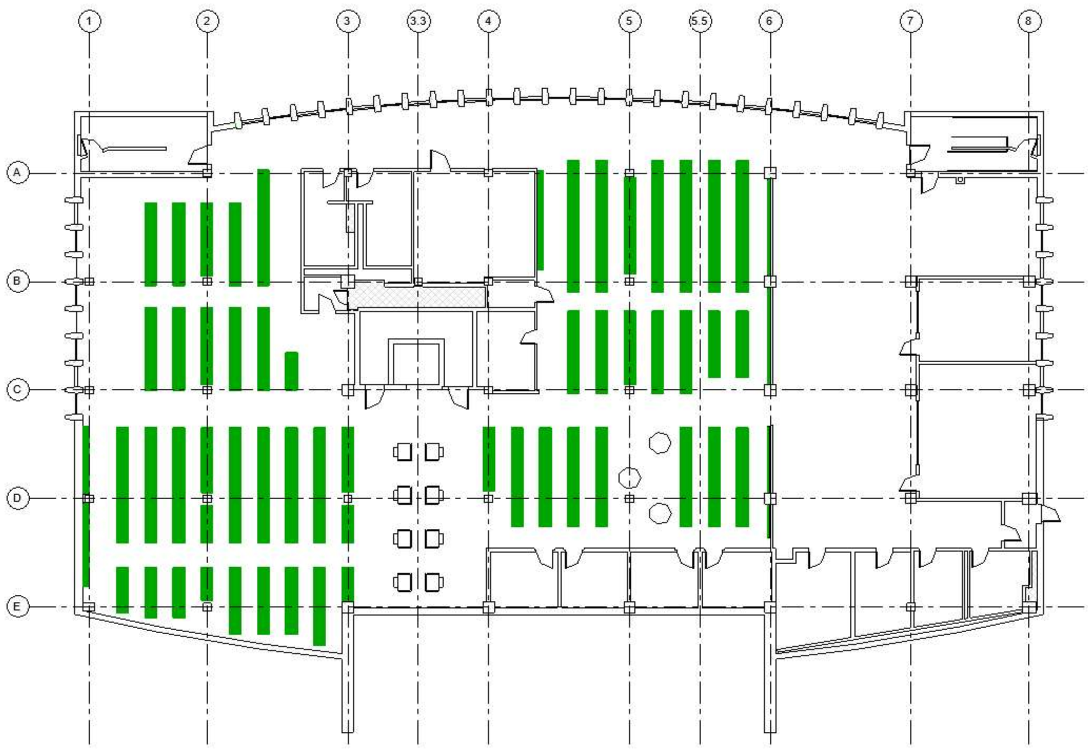


Figure 28: Current 1st Floor Stack Arrangement which takes up the majority of the floor and significantly decreases the flow within the space.

The intent of this proposal is to provide the students and staff using the library with a more open collaborative working space that flows through the building as well as the addition of more tech suites. As seen in Figure 29 we are proposing that the first-floor book stacks be removed and relocated to create space for more tables and individual cubbies. We understand the first floor is an active quiet space, so we are also proposing the addition of new tech suites on the Western wall to allow for engaged conversations for group work.

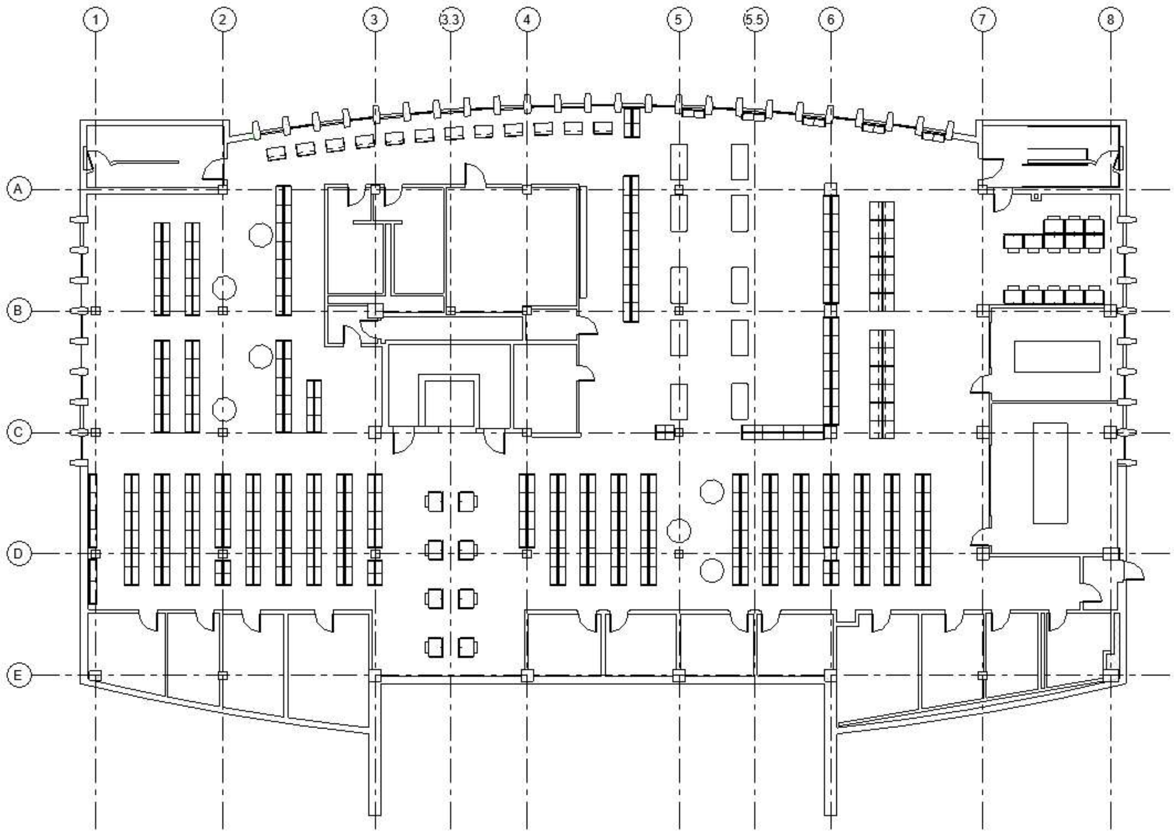


Figure 29: Proposed 1st floor plan showing rearranged stacks creating a designated working space as well as relocating some of the computers into their own room on the right (southern) wall, and new tech suites along the bottom (west) wall.

4.4: Removal of The Drop Ceiling

In addition to the new layout for the first floor, we have decided to take out the old drop ceiling panels and lighting to add to the openness of the space. The old drop ceiling currently sits 10' off the floor, however the height from floor to bottom of the slab is 13' 4", meaning that there is around 3' 4" available above the drop ceiling that can be utilized to give the space a more open feel. In Figure 30 you can see a render of the existing drop ceiling with the new 1st floor design.

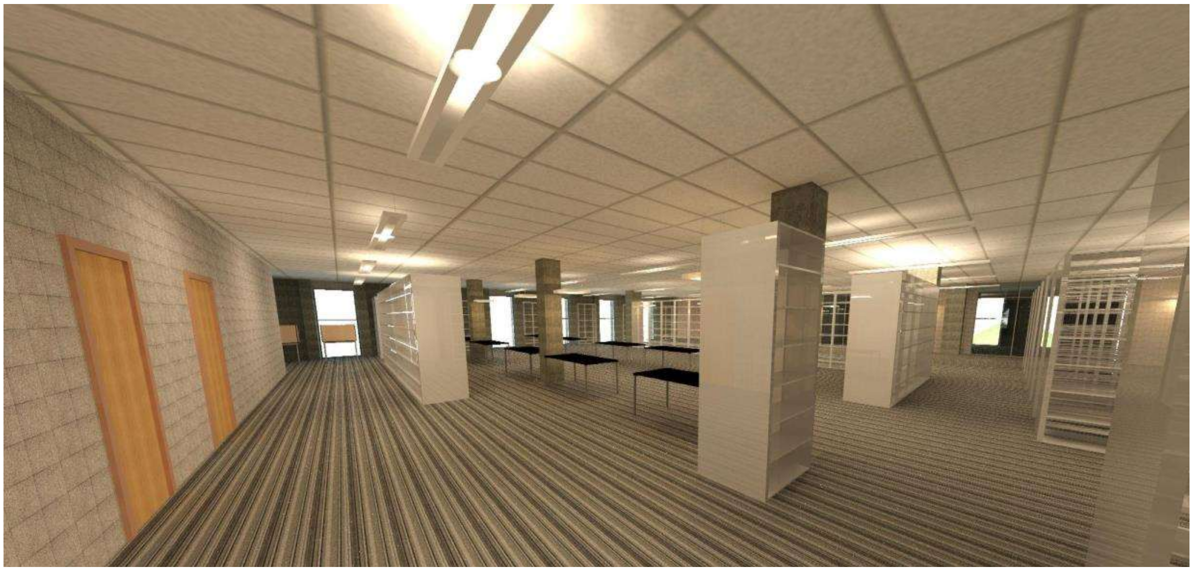


Figure 30: Proposed 1st floor render with current drop ceiling which represents the current finish of the existing Library ceiling.

By opening the existing space, the building can utilize the large vertical space at its disposal and increase the sense of openness and allow the rooms to feel larger and grander, enhancing the overall visual experience. The taller ceilings also allow for better distribution of natural light throughout the room. This can reduce the levels of artificial lighting during the day, leading to energy savings and a more pleasant atmosphere. In Figure 31, the drop ceiling is removed, and the room is open to the bottom of the slab adding more than 3’ giving the space a much grander and open feeling.

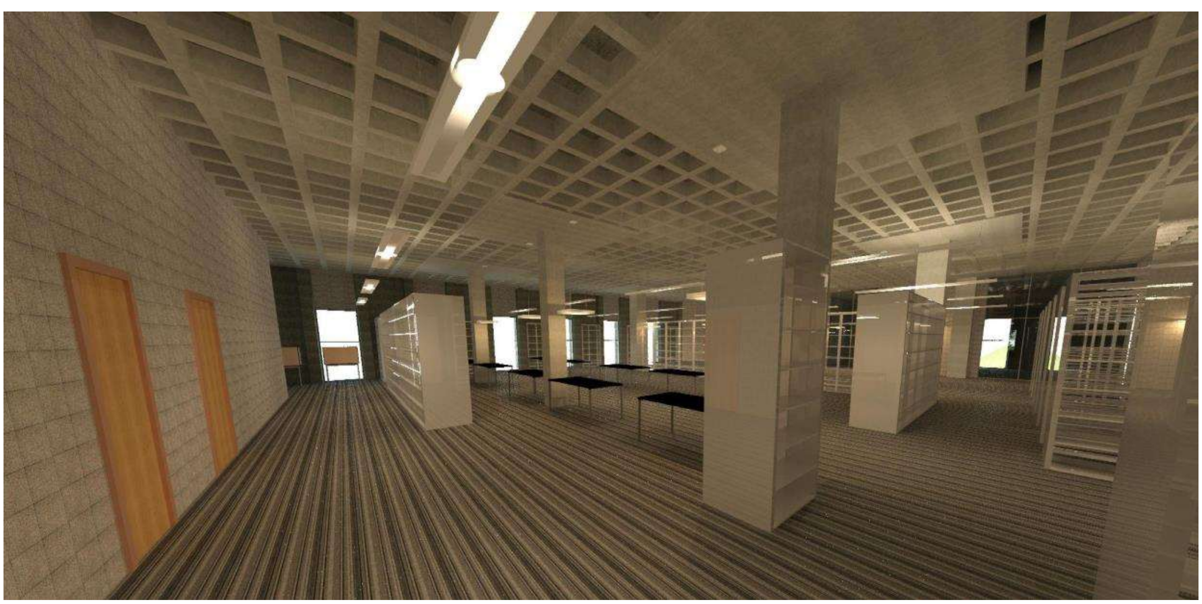


Figure 31: Proposed 1st floor render with the drop ceiling removed to expose the raw concrete of the waffle slab form. The removal of the drop ceiling would add close to 3’ to the height and give the space a much larger feel.

Since a key component of the building is its intricate waffle slab design, by removing the drop ceiling the library is able to showcase its unique structural features and add to the charm of the space. On top of visual and spatial benefits, increasing the ceiling height may allow for a more comfortable experience when it comes to auditory and HVAC performance. The raised ceilings can contribute to better air circulation and ventilation. The increased volume of air in the room allows for a more efficient exchange of fresh air, creating a healthier indoor environment. In addition to air circulation, taller ceilings allow for better temperature regulation as heat tends to rise. Overall, the psychological impact of higher ceilings can contribute to a positive atmosphere. People often associate lofty spaces with freedom, creativity, and a sense of liberation, leading to a more uplifting and inspiring environment.

5.0: Code Review

This section will begin by introducing the applicable codes to the existing building and then move into the code implications of each design proposal. This section aims to ensure the design proposals meet all code requirements and, where applicable, propose methods to achieve design goals. This section will also address the work-level classification of each design proposal using the Work Area Method in Chapter 6 of the International Existing Building Code (IEBC). This breaks projects up into Levels 1, 2, and 3 alterations and change of occupancy, which only occurs when the occupancy type of a space is changed as part of the renovation, and the requirements of each are detailed in the succeeding sections.

5.1: Existing Building Code Analysis

The existing Gordon Library was constructed in 1967, and from original construction documents, it can be estimated to be a Type IB under the current code, protected non-combustible construction with its primary use being group A-3 Assembly. The construction type was previously stated to be Type 2A in previous studies of the library, like the 2000 masterplan; however, code updates have resulted in different “definitions” of each type. This can be seen in *Figure 32*, which shows that under the BOCA National Building Code, a Type 2A construction is now considered a Type IB construction. Further, the similarities can be seen in the code when looking at the required fire-resistance rating of the building elements.

Evolution of Construction Types

Code Name	Editions	NC* Protected	NC* Protected	NC* Protected	NC* Protected	NC* Unprotected	NC/C* Protected	NC/C* Unprotected	NC/C* Heavy Timber	Combustible Protected	Combustible Unprotected
ICC International Building Code	2000 - Present	IA	IA	IB	IIA	IIB	IIIA	IIIB	IV	VA	VB
BOCA National Building Code	1984 - 1996	1A	1B	2A	2B	2C	3A	3B	4	5A	5B
BOCA Basic Building Code	1960 - 1981	1A	1B	2A	2B	2C	3B	3C	3A	4A	5B

* NC = Noncombustible
** C = Combustible

Figure 32 in building types have varied by code.

The current building is four (4) stories above grade with a basement (a service floor for access only to facilities) and is 50' tall (measured from the grade plane, which can be seen as the red line at an elevation of 533'-8" in Figure 33).

Figure 33: Section view of library showing grade plane (red).

When determining a building's height limitations, the IBC defines building height in Chapter 2 as "the vertical distance from grade plane to the average height of the highest roof surface." The grade plane is defined in chapter 2 of the IBC as "a reference plane representing the average of finished ground level adjoining the building at exterior walls." In the case of the library, this imaginary plane is the average between the second floor and the floor of the sub ground basement.

Table 1: Reproduction of Table 504.3 from 2021 International Building Code.

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION												
	See Footnotes	Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	270	180	85	85	70	60

Table 2: Reproduction of Table 504.4 from 2021 International Building Code.

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION												
	See Footnotes	Type I		Type II		Type III		Type IV				Type V	
		A	B	A	B	A	B	A	B	C	HT	A	B
A-1	NS	UL	5	3	2	3	2	3	3	3	3	2	1
	S	UL	6	4	3	4	3	9	6	4	4	3	2
A-2	NS	UL	11	3	2	3	2	3	3	3	3	2	1
	S	UL	12	4	3	4	3	18	12	6	4	3	2
A-3	NS	UL	11	3	2	3	2	3	3	3	3	2	1
	S	UL	12	4	3	4	3	18	12	6	4	3	2

Table 1 shows Table 504.3 from the 2021 IBC depicting a building of our type (Type IB, Non-sprinklered, Type-A Occupancy) can be 180' tall, and Table 2 shows Table 504.4, which says a building of our type can be up to 11 stories.

The building has a current occupancy capacity of 55 people in the basement, 210 on the first floor, 125 on the second (Main) floor, and 245 on the third floor for a total of 635 people which is noted on its certificate of occupancy. These values were calculated by multiplying the square footage of the floor by the occupant load factor designated in the building code for the respective use of each space.

When evaluating the building for means of egress, Sections 1005.3.1 and 1005.3.2 of the 2021 IBC shown in Figure 34 are used to determine the capacity factors for stairs and other egress components (doors) respectively.

1005.3.1 Stairways.

The capacity, in inches, of means of egress *stairways* shall be calculated by multiplying the *occupant load* served by such *stairways* by a *means of egress* capacity factor of 0.3 inch (7.6 mm) per occupant. Where *stairways* serve more than one *story*, only the *occupant load* of each *story* considered individually shall be used in calculating the required capacity of the *stairways* serving that *story*.

Exceptions:

1. For other than Group H and I-2 occupancies, the capacity, in inches, of means of egress *stairways* shall be calculated by multiplying the *occupant load* served by such *stairways* by a means of egress capacity factor of 0.2 inch (5.1 mm) per occupant in buildings equipped throughout with an *automatic sprinkler system* installed in accordance with Section 903.3.1.1 or 903.3.1.2 and an *emergency voice/alarm communication system* in accordance with Section 907.5.2.2.
2. Facilities with *smoke-protected assembly seating* shall be permitted to use the capacity factors in Table 1030.6.2 indicated for stepped *aisles* for *exit access* or exit *stairways* where the entire path for *means of egress* from the seating to the *exit discharge* is provided with a smoke control system complying with Section 909.
3. Facilities with *open-air assembly seating* shall be permitted to the capacity factors in Section 1030.6.3 indicated for stepped *aisles* for *exit access* or *exit stairways* where the entire path for *means of egress* from the seating to the *exit discharge* is open to the outdoors.

1005.3.2 Other egress components.

The capacity, in inches, of *means of egress* components other than *stairways* shall be calculated by multiplying the *occupant load* served by such component by a means of egress capacity factor of 0.2 inch (5.1 mm) per occupant.

Exceptions:

1. For other than Group H and I-2 occupancies, the capacity, in inches, of *means of egress* components other than *stairways* shall be calculated by multiplying the *occupant load* served by such component by a means of egress capacity factor of 0.15 inch (3.8 mm) per occupant in buildings equipped throughout with an *automatic sprinkler system* installed in accordance with Section 903.3.1.1 or 903.3.1.2 and an emergency voice/alarm communication system in accordance with Section 907.5.2.2.
2. Facilities with *smoke-protected assembly seating* shall be permitted to use the capacity factors in Table 1030.6.2 indicated for level or ramped *aisles* for *means of egress* components other than *stairways* where the entire path for *means of egress* from the seating to the *exit discharge* is provided with a smoke control system complying with Section 909.
3. Facilities with *open-air assembly seating* shall be permitted to the capacity factors in Section 1030.6.3 indicated for level or ramped *aisles* for *means of egress* components other than *stairways* where the entire path for *means of egress* from the seating to the *exit discharge* is open to the outdoors.

Figure 34: Image showing a reproduction of IBC 2021 Sections 1005.3.1 and 1005.3.2 2021 detailing the capacity factors used in calculating the egress of stairs and doors.

The stair exit capacity factor for a building without automatic sprinkler protection is .3" per occupant, and for other egress components is .2" per occupant. When measuring the building elements, we measured the stairs from the inside of one riser to the inside of the other, and the door itself was measured, from which we subtracted 3" to account for hardware. It is essential to consider that when egress components are in series (ex: a door into a stairwell), they are limited by the most restrictive factor. The building has one (1) main central staircase and two (2) stairs used for egress, which are only located in the back corners of the building. The main central stair has a consistent stair width of 60" and a door width of 39" on each floor. When divided by their respective exit capacity factors, the stairs are limited to 200 people, and the door is limited to 195, limiting the stairwell to 195 people. Both egress stairs located in the back corners of the building have consistent stair widths of 54" and door widths of 33". This results in the stairs being limited to 180 people and the door being limited to 165, limiting the stairwell to 165 people. The main central staircase and the two stairs used for egress are sized so 525 people can egress from each floor. The front entrance to the library also must be sized accordingly, which has 2 sets of 33" double doors, allowing a maximum of 330 people to pass through each set of entrance and exit doors.

Since the building has occupiable floors above and below the main entrance, the idea of egress convergence in section 1005.6 shown in Figure 35 also applies to this project. Egress convergence is the idea that when people exit a building from above and below an intermediate exit floor the egress components along the exit route must accommodate the number of both floors. In this case, the convergent floors are the third and first floors since the exit is on the second Floor. From our earlier calculation, we determined that 525 people can exit each floor using all the staircases, and the occupant loads of the first and third floors are 210 and 245 respectively. 455 is less than the 525 that is permitted based on the calculations, which confirms the sizing of egress components in the library is adequate.

1005.6 Egress convergence.

Where the *means of egress* from stories above and below converge at an intermediate level, the capacity of the *means of egress* from the point of convergence shall be not less than the largest minimum width or the sum of the required capacities for the *stairways* or *ramps* serving the two adjacent stories, whichever is larger.

Figure 35: Image showing a reproduction of IBC 2021 Section 1005.6 detailing the concept of egress convergence.

5.2: Code Implications of Atrium Design

Among the structural implications of introducing an atrium, discussed later in the paper, various code considerations must also be addressed during the project's design to accommodate the addition of an atrium in the space. The first would be to provide the building with a sprinkler system throughout the building. This would be a significant undertaking; however, it offers various benefits, including adding to the number of updated buildings on campus. Section 404 of the IBC is dedicated to atriums, and section 404.3 shown in Figure 36 explicitly requires the building to be equipped with a fully automatic sprinkler system.

[F] 404.3 Automatic sprinkler protection.

An *approved automatic sprinkler system* shall be installed throughout the entire building.

Exceptions:

1. That area of a building adjacent to or above the *atrium* need not be sprinklered provided that portion of the building is separated from the *atrium* portion by not less than 2-hour *fire barriers* constructed in accordance with Section 707 or *horizontal assemblies* constructed in accordance with Section 711, or both.
2. Where the ceiling of the *atrium* is more than 55 feet (16 764 mm) above the floor, sprinkler protection at the ceiling of the *atrium* is not required.

Figure 36: Image showing a reproduction of IBC 2021 Section 404.3 detailing where an automatic sprinkler system shall be installed.

The current design for the atrium space involves opening the second floor to the third floor by removing a section of the floor slab resulting in the connection of only 2 stories. Per section 404.5 in Figure 37, exception 1 excludes our project from needing to install a smoke control system to have an atrium.

404.5 Smoke control. P

A smoke control system shall be installed in accordance with Section 909.

Exceptions:

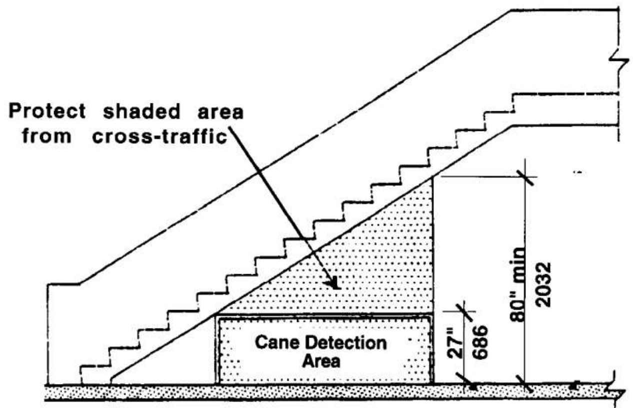
1. In other than Group I-2, and Group I-1, Condition 2, smoke control is not required for *atriums* that connect only two *stories*.
2. A smoke control system is not required for *atriums* connecting more than two *stories* when all of the following are met:
   2.1. Only the two lowest *stories* shall be permitted to be open to the *atrium* .
   2.2. All *stories* above the lowest two *stories* shall be separated from the *atrium* in accordance with the provisions for a *shaft* in Section 713.4.

Figure 37: Image capturing Section 404.5 of 521 CMR (Code of Massachusetts Regulations) describing smoke control system requirements.

The current design of the atrium includes open stairs that are open to the floor below. Section 20.7 of 521 CMR shown in Figure 38 requires that hallways, passageways, aisles, or other circulation spaces must have a minimum of 80" of clear headroom, where 80" of headroom is not achieved a cane detection area is required. A cane detection area is a raised surface which warns blind or visibly impaired people of the reduced headroom. By filling in the bottom of the stairs with bookcases it is no longer considered a circulation space and does not have to be marked.

20.7 HEADROOM

Walks, halls, corridors, passageways, aisles, or other circulation *spaces* shall have a minimum of 80 inches (80" = 2032mm) *clear* headroom. *See* **Fig. 20d**. If vertical clearance of an area adjoining an *accessible route* is reduced to less than 80 inches (80" = 2032mm), a barrier shall be provided to warn blind or visually-impaired persons of the reduced headroom. *See* **Fig. 20g**.



Minumum Clear Headroom
Figure 20g

Figure 38: Image capturing Section 20.7 of 521 CMR (Code of Massachusetts Regulations), providing a visual reference of where a cane detection area is required.

5.3: Code Implications of Rooftop Addition

As previously mentioned in the above section regarding the code implications of the atrium design, a smoke control system would need to be installed in the building if the atrium were to extend up into the new rooftop edition and exceed the 2-story maximum for no smoke control system. In addition, the extensions of the existing shafts and through floor penetrations must be protected from the third floor to the roof addition in accordance with the codes shown in Figure 39. Per section 713.4 the shafts shall have a fire resistance rating of 2 hours as they connect more than four stories. Section 713.5 expands upon the standard set in 713.4 to ensure that the wall fire resistance ratings are consistent from wall to ceiling to prevent fire from traveling over the walls where applicable.

713.4 Fire-resistance rating.

Shaft enclosures shall have a *fire-resistance rating* of not less than 2 hours where connecting four *stories* or more, and not less than 1 hour where connecting less than four *stories*. The number of *stories* connected by the *shaft enclosure* shall include any *basements* but not any *mezzanines*. *Shaft enclosures* shall have a *fire-resistance rating* not less than the floor assembly penetrated, but need not exceed 2 hours. *Shaft enclosures* shall meet the requirements of Section 703.2.1.1.

713.5 Continuity.

Shaft enclosures shall be constructed as *fire barriers* in accordance with Section 707 or *horizontal assemblies* constructed in accordance with Section 711, or both, and shall have continuity in accordance with Section 707.5 for *fire barriers* or Section 711.2.2 for *horizontal assemblies*, as applicable.

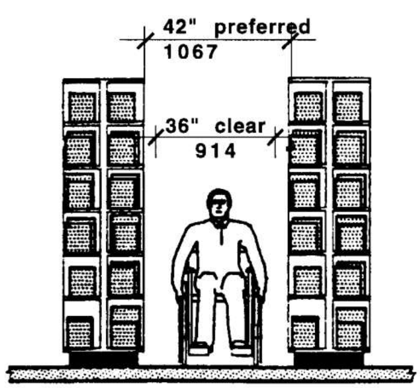
Figure 39: Image capturing Section 713.4 and 713.5 of 521 CMR (Code of Massachusetts Regulations), providing requirements pertaining to the Fire resistance ratings of shafts.

Another code implication that will have to be taken into consideration is convergence. Earlier, we looked at the 3rd and 1st floors; now we are considering a level 2 floor above the exit, and we must compare it to the level 2 floors below the exit (basement).

5.4: Code Implications of Removal and Redesign of First Floor Stack Space and Floor Plan

With the removal of non-structural infill walls, and rearrangement of the stack space, the most influential code implications include the spacing and accessibility of the stacks and ensuring that a clear path of travel is maintained between working tables. Figure 40 shows that the minimum distance between stacks must be 36” however 42” is preferred with no limitation on the height of the stacks.

12.2.6 Stacks: Aisles between stacks shall have a minimum *clear* width of 36 inches (36" = 914mm) and preferably 42 inches (42" = 1067mm), where possible, as shown in **Fig. 12c**. Shelf height in stack areas is unrestricted.



Stacks
Figure 12c

Figure 40: Image capturing Section 12.2.6 of 521 CMR (Code of Massachusetts Regulations), providing a visual reference to the required spacing of book stacks.

Similarly to between the bookstacks the tables and chairs must also be spaced to allow for unobstructed passage through the space. Figure 41 details the major requirements for spacing of elements in libraries. Section 12.2.2 is important as it addresses the percentage of each component within the library that must be accessible, this percentage is set at 5%. However, if 5% of the elements results in a number less than 1 there shall be at least 1 accessible component.

12.2 LIBRARIES
Shall comply with the following and **Figure 12a**.

12.2.1 General: All public areas of a library, including but not limited to, reading and study areas, stacks, reference rooms, reserve areas, and special *facilities* or collections, shall comply with **521 CMR 12.00.**

12.2.2 Reading Areas, Study Areas and Computer Workstations: Where tables, study carrels, computer workstations, or fixed seating are provided, at least 5% with a minimum of one of each *element* shall be *accessible*, be on an *accessible route*, and comply with the following:

a. *Access aisles*: A 36 inch (36" = 914mm) *access aisle* shall be provided between tables and between study carrels. No seating shall overlap the *access aisle*. **See Fig. 12a**.
b. *Clear floor space* as defined in **521 CMR 5.00: DEFINITIONS** shall be provided at each seating space. Such *clear floor* space shall not overlap knee space by more than 19 inches (19" = 483 mm). **See Fig. 12a**.
c. Knee Clearances: If seating for disabled persons is provided at tables or counters, kneespaces at least 27 inches (27" = 686mm) high, 30 inches (30" = 762mm) wide, and 19 inches (19" = 483mm) deep shall be provided. **See Fig. 12a**.
d. Height of Tables or Counters: The tops of *accessible* tables and counters shall be from 28 inches to 34 inches (28" to 34" = 711mm to 864mm) above the finished floor or ground.

Figure 41: Image showing a reproduction of Section 12.2 of 521 CMR detailing the major requirements for spacing of elements in libraries.

5.5: Code Implications of Removal of The Drop Ceiling and Updated Lighting System

For the removal of the drop ceiling and updating the lighting systems, there aren't as many code requirements compared to the other design proposals. Changes to the drop ceiling and lighting systems are more "cosmetic" and changes to them will have minimal impact on the safety of the building. Code considerations for this renovation include the interior finish materials, emergency lighting, as well as the total cost of the project.

Chapter 8 of the 2021 International Building Code governs the use of materials used for interior finishes. These materials are denoted by Class A, Class B, and Class C which are the most flammable and likely to contribute to a fire. This chapter references various other standards that are responsible for the classification of materials like NFPA 286. NFPA 286 describes methods for determining the contribution of interior finish materials to room fire growth during specified fire exposure conditions. Section 802.1 seen in Figure 42 refers you to Table 803.13 shown in Table 3 which details the finish requirement by occupancy.

802.1 Interior wall and ceiling finish.

The provisions of Section 803 shall limit the allowable fire performance and smoke development of *interior wall and ceiling finish* materials based on occupancy classification.

Figure 42: Image showing a reproduction of IBC 2021 Section 802.1 which describes how the fire rating of finishes are determined within a building.

Table 3: Reproduction of table 803.13 2021 IBC detailing interior wall and ceiling finish requirements by occupancy.

TABLE 803.13 INTERIOR WALL AND CEILING FINISH REQUIREMENTS BY OCCUPANCY[k]

GROUP	SPRINKLERED[l]			NONSPRINKLERED		
	Interior exit stairways and ramps and exit passageways[a, b]	Corridors and enclosure for exit access stairways and ramps	Rooms and enclosed spaces[c]	Interior exit stairways and ramps and exit passageways[a, b]	Corridors and enclosure for exit access stairways and ramps	Rooms and enclosed spaces[c]
A-1 & A-2	B	B	C	A	A[d]	B[e]
A-3[f], A-4, A-5	B	B	C	A	A[d]	C
B, E, M, R-1	B	C[m]	C	A	B	C
R-4	B	C	C	A	B	B
F	C	C	C	B	C	C
H	B	B	C[g]	A	A	B
I-1	B	C	C	A	B	B
I-2	B	B	B[h, i]	A	A	B
I-3	A	A[j]	C	A	A	B
I-4	B	B	B[h, i]	A	A	B
R-2	C	C	C	B	B	C
R-3	C	C	C	C	C	C
S	C	C	C	B	B	C
U	No restrictions			No restrictions		

For SI: 1 inch = 25.4 mm, 1 square foot = 0.0929 m^2.

a. Class C interior finish materials shall be permitted for wainscotting or paneling of not more than 1,000 square feet of applied surface area in the grade lobby where applied directly to a noncombustible base or over furring strips applied to a noncombustible base and fireblocked as required by Section 803.15.1.
b. In other than Group I-3 occupancies in buildings less than three stories above grade plane, Class B interior finish for nonsprinklered buildings and Class C interior finish for sprinklered buildings shall be permitted in interior exit stairways and ramps.
c. Requirements for rooms and enclosed spaces shall be based on spaces enclosed by partitions. Where a fire-resistance rating is required for structural elements, the enclosing partitions shall extend from the floor to the ceiling. Partitions that do not comply with this shall be considered to be enclosing spaces and the rooms or spaces on both sides shall be considered to be one room or space. In determining the applicable requirements for rooms and enclosed spaces, the specific occupancy thereof shall be the governing factor regardless of the group classification of the building or structure.
d. Lobby areas in Group A-1, A-2 and A-3 occupancies shall be not less than Class B materials.
e. Class C interior finish materials shall be permitted in places of assembly with an occupant load of 300 persons or less.
f. For places of religious worship, wood used for ornamental purposes, trusses, paneling or chancel furnishing shall be permitted.
g. Class B material is required where the building exceeds two stories.
h. Class C interior finish materials shall be permitted in administrative spaces.
i. Class C interior finish materials shall be permitted in rooms with a capacity of four persons or less.
j. Class B materials shall be permitted as wainscotting extending not more than 48 inches above the finished floor in corridors and exit access stairways and ramps.
k. Finish materials as provided for in other sections of this code.
l. Applies when protected by an automatic sprinkler system installed in accordance with Section 903.3.1.1 or 903.3.1.2.
m. Corridors in ambulatory care facilities shall be provided with Class A or B materials.

The library is classified as use group A-3, and no exceptions apply to the Gordon Library. From the table, the building is not protected by a sprinkler system under Section 903.3.1.1 or 903.3.1.2 therefore we reference to the rightmost half of the table. Interior exit stairways and ramps and exit passageways are required to be finished with class A materials, corridors and enclosures for exit access stairways and ramps are required to be finished with class A materials, however, exception d specifies lobby areas in group A-1, A-2, and A-3 spaces shall not be less than class B materials which is less restrictive than what the table denotes. Rooms and enclosed spaces are to be constructed with class C materials.

The lighting requirements shown in Figure 43 describe the minimum amount of light (in footcandles) that must be in a space, and stairways for it to be adequately lit for egress. Section 1008.2.1 specifically addresses the lighting under normal power which states that the lighting must be at least 1 footcandle at the walking surface inside the building, and 10 footcandles in exit stairways and landings. The stairways must provide sufficient illumination in the event of an emergency, the occupants will be using these stairs in unknown conditions so it is important to ensure the lighting does not impair their egress.

1008.2 Illumination required.

The *means of egress* serving a room or space shall be illuminated at all times that the room or space is occupied.

Exceptions:

1. Occupancies in Group U.
2. *Aisle accessways* in Group A.
3. *Dwelling units* and *sleeping units* in Groups R-1, R-2 and R-3.
4. *Sleeping units* of Group I occupancies.

1008.2.1 Illumination level under normal power. P

The *means of egress* illumination level shall be not less than 1 footcandle (11 lux) at the walking surface. Along *exit access stairways*, exit stairways and at their required landings, the illumination level shall not be less than 10 footcandles (108 lux) at the walking surface when the *stairway* is in use.

Exception: For auditoriums, theaters, concert or opera halls and similar assembly occupancies, the illumination at the walking surface is permitted to be reduced during performances by one of the following methods provided that the required illumination is automatically restored upon activation of a premises' *fire alarm system*:

1. Externally illuminated walking surfaces shall be permitted to be illuminated to not less than 0.2 footcandle (2.15 lux).
2. Steps, landings and the sides of *ramps* shall be permitted to be marked with *self-luminous* materials in accordance with Sections 1025.2.1, 1025.2.2 and 1025.2.4 by systems *listed* in accordance with UL 1994.

Figure 43: Image showing a reproduction of IBC 2021 Sections 1008.2 and 1008.2.1 providing the requirements associated with egress lighting under normal power.

Another implication of removing the drop ceiling is the potential for the presence of asbestos. Asbestos was used in a lot in construction as a form of insulation and fire retardant between the 1940's and 1977 when it was banned from being used as it was found to be a carcinogen and prolonged exposure could lead to lung cancer. If during any point in a construction project asbestos is found or disturbed it must be removed from the building. This is a long process that could delay the construction as well as significantly drive the cost of the project up.

6.0: Structural Analysis

To be able to comply with the required code sections, the waffle slab and the columns must undergo structural analysis to be able to withstand the rooftop addition and the removal of the grid of waffle slabs. In this project, a grid can be defined as a 20’ by 25’ area. To accomplish this, the group analyzed original design conditions, current conditions, then compared them to the proposed library changes.

6.1: Explanation of Gordon Library Building Plans

The Gordon Library is a complete reinforced concrete design that contains a concrete column grid system leading the load down to the footings into the soil. The grids for the building run from grid Line A to Line E from east to west and from grid Line 1 to Line 8 from north to south shown in Figure 44.

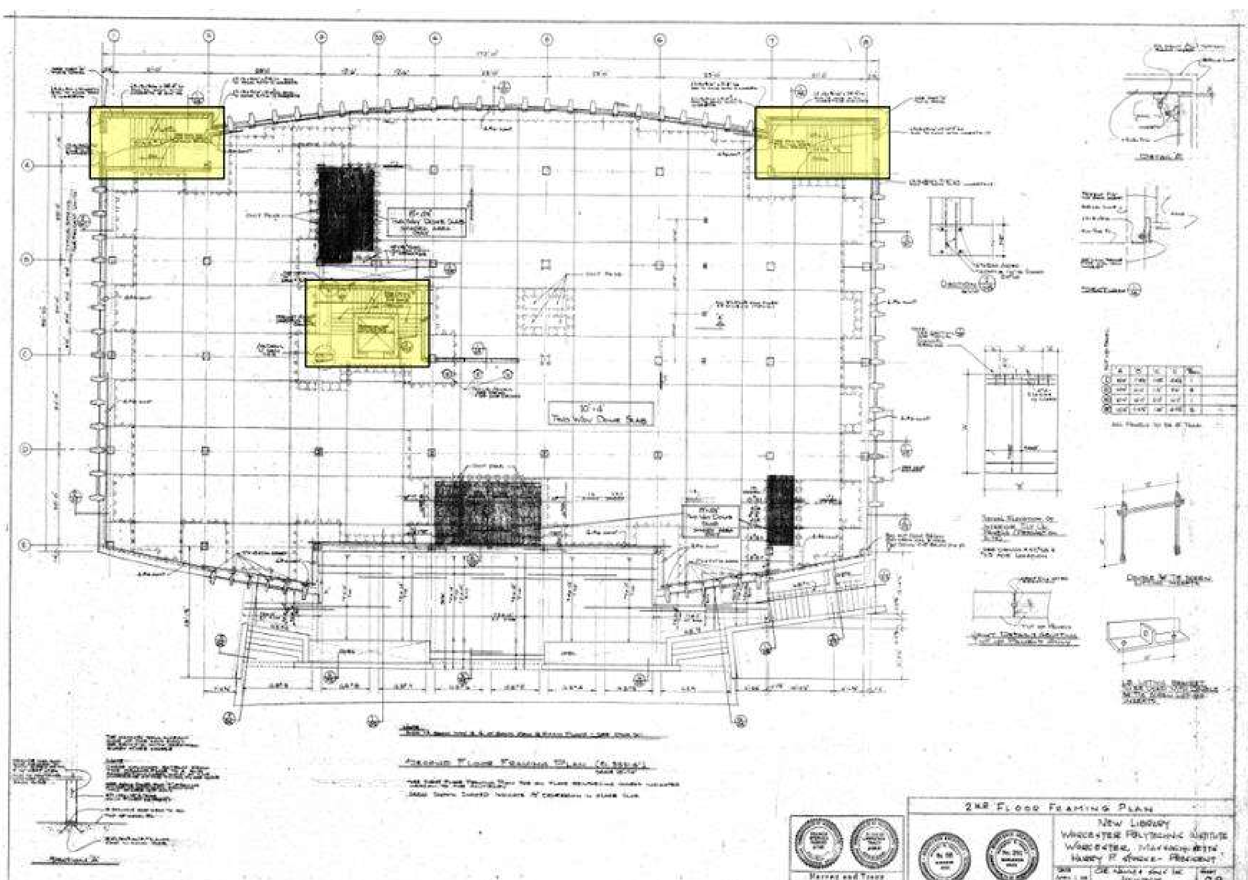


Figure 44: Original 1965 structural plan of a floor with the waffle slab system with 3 concrete cores highlighted.

Columns are located on the intersections of these grid lines and are continuous across all the floors shown in Figure 45. In addition to the columns, the building contains 3 concrete cores that also carry their tributary areas down to footings. These concrete cores are used for both the staircases and the elevator shaft. In addition to carrying the loads, these cores help stabilize the building with their resistance to lateral forces.

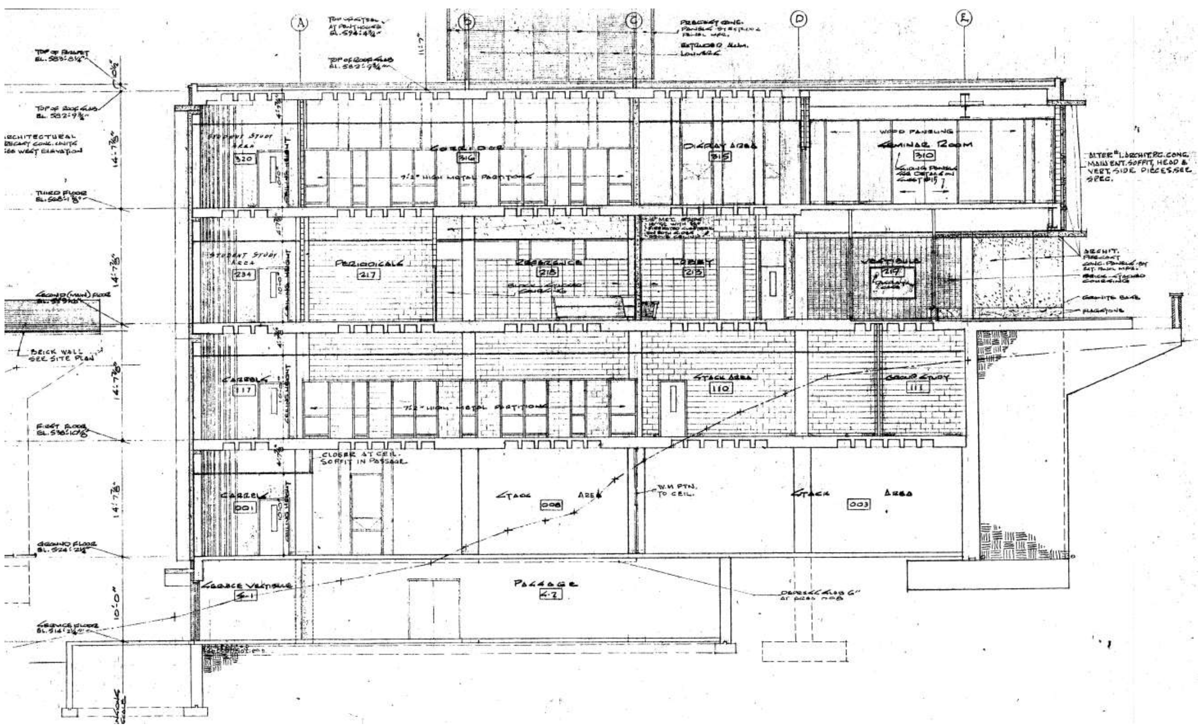


Figure 45: Section of the building showing the Column Layout and Sizing from floor to floor.

Figure 46 shows a zoomed in portion of the third floor depicting the sizes of the third-floor columns. The dimensions of these columns increase as they move down the building to accommodate the additional load each floor adds.

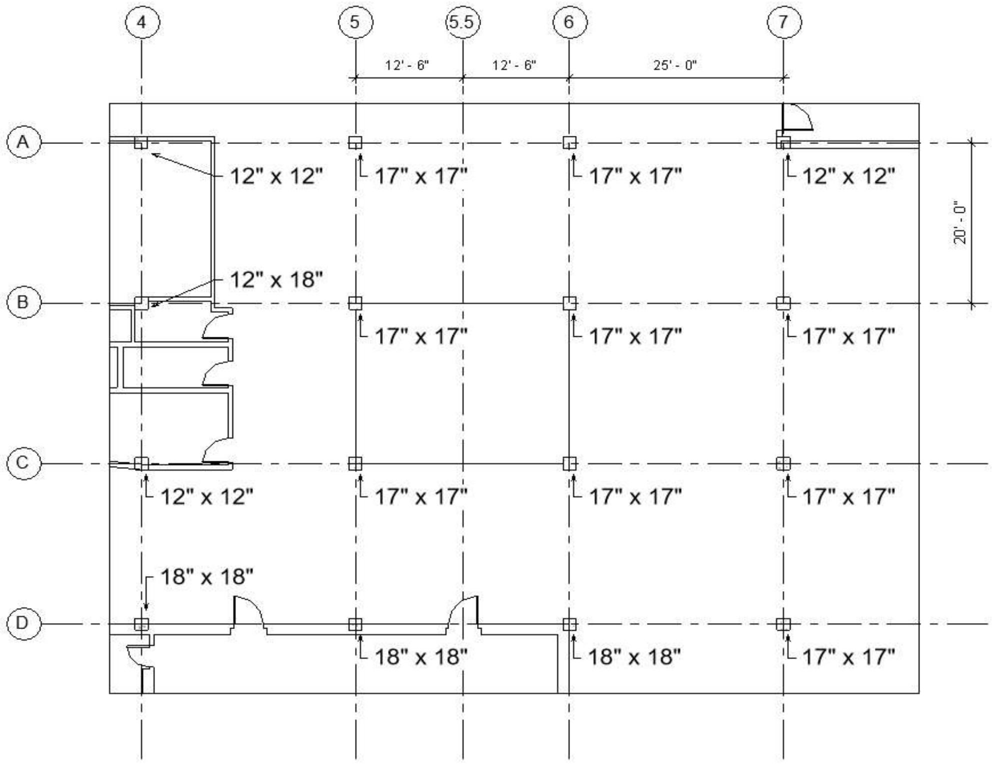


Figure 46: Example of third floor column layout and sizing

The structural system for the building was designed for a building of entirely stack space with a live load of 150 psf across every floor. This live load is applied to the waffle slabs and then transferred to the nearest column based off of the tributary area and then brought down to the base of the building onto the building footings. The multiple levels of the building create additional loads that lead to columns below receiving a higher load than the columns above due to the additional weight of the floor slab of the floor above. This requires that the strength of the columns be able to withstand the additional demand of the live load and dead load. For most of the column paths, the size of the column below increases to have the capacity to withstand the additional load.

6.2: Foundation and Soil Analysis

In reference to the Master Planning Study for the Gordon Library and original construction drawings, the Gordon Library is supported on isolated footings that transfer loads from columns and shear walls to the earth. The footings, which distribute the building loads to the underlying soil or bedrock, are a key element in the structural system. Engineers examine the existing foundation to ensure it can accommodate the increased loads resulting from rooftop additions. Soil testing and analysis are crucial to understand the soil's bearing capacity and its response to additional loads.

In accordance with Massachusetts building codes, the load of each column was determined using a load and resistance factor design method. It is important to note that the original design employed an allowable stress design approach. The method used utilizes various combinations of equations, but ultimately designed to a conservative approach. Through calculations as seen in the Appendix, it was found various bearing pressures on each isolated footing. In addition, the typical stress on footings is approximately 8,622 psf. This is consistent with the Gordon Library structural report that references “footings were proportioned for an allowable bearing pressure of approximately 8,000 psf.” (Shepley, 2000)

In addition to the structural report, the Massachusetts State Building Code (780 CMR) provides presumptive load-bearing values based on soil classification. As shown in Table 4 and compared to the existing soil conditions of not as strong as bedrock and not as weak as sedimentary and foiled rock, the bearing pressure should fall somewhere in between 4,000 psf and 12,000 psf. This analysis serves as an additional verification that calculations made are within acceptable range. For a more detailed analysis, a geotechnical report would have to be requested from WPI facilities.

Table 4: Reproduction of Table 1806.2 from 2021 International Building Code

TABLE 1806.2 PRESUMPTIVE LOAD-BEARING VALUES

CLASS OF MATERIALS	VERTICAL FOUNDATION PRESSURE (psf)	LATERAL BEARING PRESSURE (psf/ft below natural grade)	LATERAL SLIDING RESISTANCE	
			Coefficient of friction[a]	Cohesion (psf)[b]
1. Crystalline bedrock	12,000	1,200	0.70	—
2. Sedimentary and foliated rock	4,000	400	0.35	—
3. Sandy gravel and gravel (GW and GP)	3,000	200	0.35	—
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	—
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	1,500	100	—	130

For SI: 1 pound per square foot = 0.0479kPa, 1 pound per square foot per foot = 0.157 kPa/m.

a. Coefficient to be multiplied by the dead load.

b. Cohesion value to be multiplied by the contact area, as limited by Section 1806.3.2.

6.3: Waffle Slab Analysis

There are various two-way slabs that can be constructed within reinforced concrete - flat plate, waffle slab, flat slab, and two-way slab with beams depicted in Figure *47*. Apartments and similar buildings that carry relatively light loads frequently utilize flat plates as they are most economical for spans from 15 to 20 ft. “For longer spans, the thickness required for the shear transfer of vertical loads to the columns exceeds that required for flexural strength. As a result, the concrete at the middle of the panel is not used efficiently.” (Wight, 2012) In order to combat the high bending moments and heavy concrete slab, pans are set in place before the pouring of concrete in order to create a waffle slab system. Typically waffle slab systems are utilized for spans that span from 25 to 40 ft (Wight, 2012). Flat slab systems are used in which heavy loads that exceed 100 psf are across spans from 20 to 30 ft. In this system “the shear transfer to the column is accomplished by thickening the slab near the column with drop panels or by flaring the top of the column to form a column capital (Wight, 2012).” Lastly in a two-way slab with beams, each beam is connected to the columns in both directions forming a square shape.

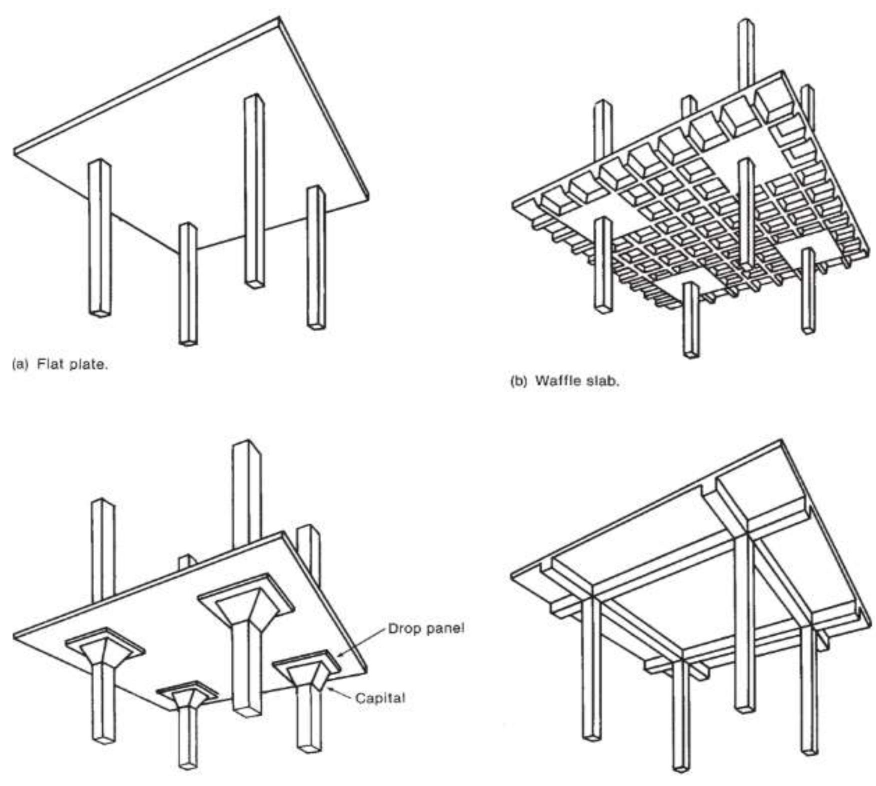


Figure 47: Various two-way slab systems schematic. (Wight, 2012)

To analyze the current existing configuration, the Direct Design Method (DDM) was utilized. In order to use this method, seven various checks must be made for such analysis to be viable (Wight, 2012). The following include the seven limitations:

1. There must be a minimum of three continuous spans in each direction. Thus, a nine-panel structure (3 by 3) is the smallest that can be considered. If there are fewer than three panels, the interior negative moments from the direct-design method tend to be too small.
2. Rectangular panels must have a long-span/short-span ratio that is not greater than 2. One-way action predominates as the span ratio reaches and exceeds 2.
3. Successive span lengths in each direction shall not differ by more than one-third of the longer span. This limit is imposed so that certain standard reinforcement cut-off details can be used.
4. Columns may be offset from the basic rectangular grid of the building by up to 0.1 times the span parallel to the offset. In a building laid out in this way, the actual column locations are used in determining the spans of the slab to be used in calculating the design moments.
5. All loads must be due to gravity only and uniformly distributed over an entire panel. The direct-design method cannot be used for unbraced, laterally loaded frames, foundation mats, or prestressed slabs.
6. The service (unfactored) live load shall not exceed two times the service dead load. Strip or checkerboard loadings with large ratios of live load to dead load may lead to moments larger than those assumed in this method of analysis.
7. For a panel with beams between supports on all sides, the relative stiffness of the beams in the two perpendicular directions given by shall not be less than 0.2 or greater than 5. The term was defined in the prior section, and are the spans in the two directions.

Once these checks are made, bending moment calculations are made in which "for interior spans, 65 percent of M_o is assigned to the negative-moment region and 35 percent to the positive-moment regions." (Wight, 2012) This approach was abandoned as bending moment calculations were based under a simply supported beam. This would not allow for a comprehensive analysis of the waffle slab and its surrounding effects on partial removals.

6.3.1: Rankine-Grashoff Analysis

In conducting research on the structural analysis of two-way waffle slabs, the group discovered the Rankine-Grashoff Method. The International Journal of Engineering Science Invention describes this method as an approximate method based on equating deflections in either direction at the junctions of ribs, suitable for small span grids with the spacing of ribs not exceeding 1.50 m (4.92') (Halkude & Mahamuni, 2014). It was shortly determined that this method would give us a rudimentary understanding of the moment and shear force per unit width of the slab. The spacing of the ribs in the library is 2' 0" on center and 1' 7" within the cavity, both of which are less than 4.92'. This method indicated a suitable analysis for calculating the moment and shear force of structural members.

The Rankine-Grashoff method includes the following pivotal formulas, where a = width, b = length, a_1 / b_1 = spacing of ribs in x/y direction, and q = load per unit area.

Using load intensity given in (1), the design bending moments and shears are calculated as follows:

Load intensity in the x-direction. $(q_1) = q \times \frac{b^4}{a^4+b^4} =$

Load intensity in the x-direction. $(q_2) = q \times \frac{a^4}{a^4+b^4} =$

Moment Calculations

Moment in beams running in the x-direction. $(M_x) = \frac{q_1 \times b_1 \times a^2}{2}$

Moment in beams running in the y-direction. $(M_y) = \frac{q_1 \times a_1 \times b^2}{2}$

Shear Force Calculations

Shear force in beams running in x-direction. $Q_x = \frac{q_1 \times a \times b_1}{2}$

Shear force in beams running in y-direction. $Q_x = \frac{q_1 \times b \times a_1}{2}$

By following this method for original design conditions, the moment in the x and y direction was found to be 26.19 kip-ft and 16.75 kip-ft respectively. The shear forces in the x and y direction were found to be 5.238 kips and 2.681 kips respectively. The calculations of bending moments and shear forces can be seen in Appendix E: Rankine-Grashoff Method Calculation. Although this provided insight into a 20’ x 25’ area, it did not reflect how conditions in other areas would be affected.

6.3.2: Removal of Waffle Slab

To encapsulate the complex geometry and understand the relationship amongst various grids when a puncture is made, the use of a finite element model (FEM) was made to accurately model the structure. “In a finite element model, the structures with complex geometry are divided into a finite number of elements, which in turn are simple in their geometry. The elements are reconnected at nodes and the results are calculated in each node using mathematical interpolation. The results are presented as a set of simultaneous algebraic equations.” (Vedenoja, n.d.). Autodesk Robot Structural Analysis was chosen as a tool to analyze the floor system due to its built implementation of designing a waffle slab system, and its free availability to students. In order to model existing conditions, a work in progress 3x3 grid that is supported by columns on fixed supports was created. Beams measuring 5x14 inches were linked between adjacent columns, and then later copied and moved at an interval of 2’ 0”. Once beams were placed in both the x and y direction, modifications were made within each property setting to convert a 5x14 inch beam to a T-beam that matches the existing slab conditions. Figure 48 shows a 3D view of the model, it is important to note that shear reinforcement is not modeled, and reinforcement within ribs is automatically provided by the program through default settings. Figure 49 shows the 3D view of the model with the proposed bay opening in the middle.

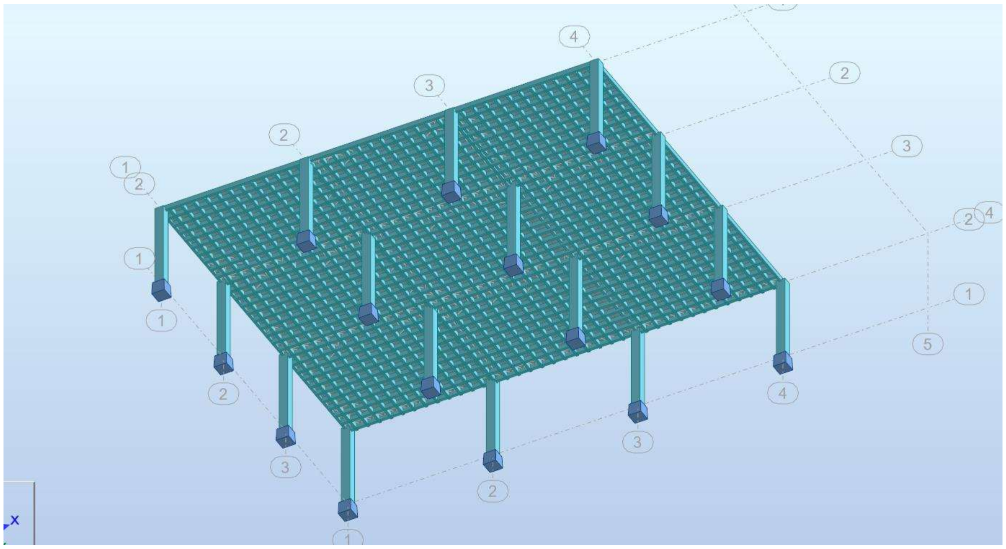


Figure 48: 3D visual of the underside of the waffle slab configuration for a 60’ x 75’ section.

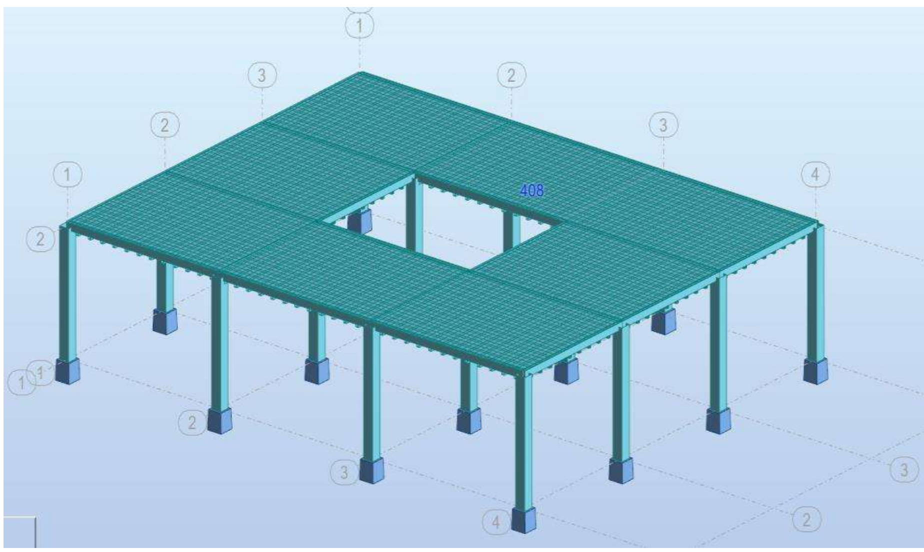


Figure 49: 3D visual of 60’ x 75’ section of waffle slab showing how the creation of the atrium removes one bay of the slab.

To better understand the building’s structural components, preliminary simulations were conducted. This included an iteration of what the building was originally designed to carry - 150 psf throughout all floors; and a secondary iteration of reducing the live load to 80 psf to floors that no longer support heavy bookstacks. Once simulations were completed the program was able to offer pivotal information such as moment diagrams, shear diagrams, deflection within members, etc. Despite the efforts made to depict the system, connections, and loads, it was decided that the model was not in the best of our interest to move forward with. It was recognized and understood that this model is only as effective as the input parameters given.

Therefore, any results resulting from the model would not have been with high confidence which is why those outputs have been omitted from this report.

Although the model was unable to quantify whether the removal of a small portion of the waffle slab would still provide sufficient strength, it is still argued that it is structurally feasible. The building was originally designed to 150 psf and has undergone multiple renovations that include removal of bookstacks and creation of more open spaces, ultimately reducing the stress on footings ranging from 15 to 20%. The current configuration of the building is overdesigned allowing for such punctures to be possible. In addition, relative to the entirety of the library spanning 4 stories above grade, with a typical 92' x 172' floor area, a 20' x 25' puncture on a single floor with sufficient reinforcement is feasible as long as it is entirely within a column bay.

6.3.3: Dead Load Calculation

To calculate the dead load of the existing building's waffle slab, the geometry and volume of the current waffle slab shown in Figure 50. A density of 150 pcf was used to calculate the weight of the slab.

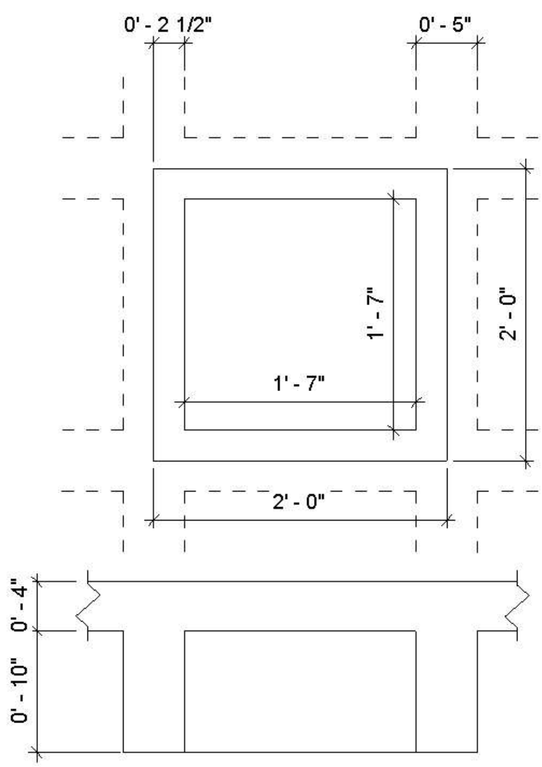


Figure 50: Detail of waffle slab grid.

The waffle slab is made up of shells separated by 2’ 0” O.C. with 5” thick webs with a separation of 1’ 7” on the interior. The volume of the 10” high 2’ x 2’ unit square that contained both the webs and the voided gap was calculated to be 3.333 cubic feet. Subsequently the volume of the 1’ 7” x 1’ 7” gap was 2.089 cubic feet. The void space subtracted from the unit square volume resulted in a web volume of 1.244 cubic feet. The volume of the 4” high continuous concrete on top of the waffle system by multiplying it by the unit square and then adding it to the web volume (1.244) for a total volume of 2.578 cubic feet.

Multiplying this volume by the assumed concrete density of 150 pcf provided the weight across the 2’ x 2’ unit square. To determine the weight per square foot, the weight was divided by 4 square feet to receive a final dead load of 96.66 psf. Although this value does not consider the shear reinforcement, this value was used for every floor’s dead load due to the inconsistent shear reinforcement across each floor.

To calculate the dead load for the roof waffle slab, the previous calculation was utilized but replaced the 10” + 4” with new dimensions of 10” + 3”. The calculations for the 10” + 3” slab resulted in a dead load of 84.15 psf.

6.4: Tributary Area

To evaluate the structural integrity of the building, the loads on each column had to be analyzed based on the tributary area that is attributed to it. To calculate this, the midpoints between columns had to be found to form rectangles that would be used to calculate the tributary area of the column. The loads that apply to the floor slab will go down each respective column that is nearest within its tributary area. Figure 51 shows an example of the mapping done on for the third-floor columns.

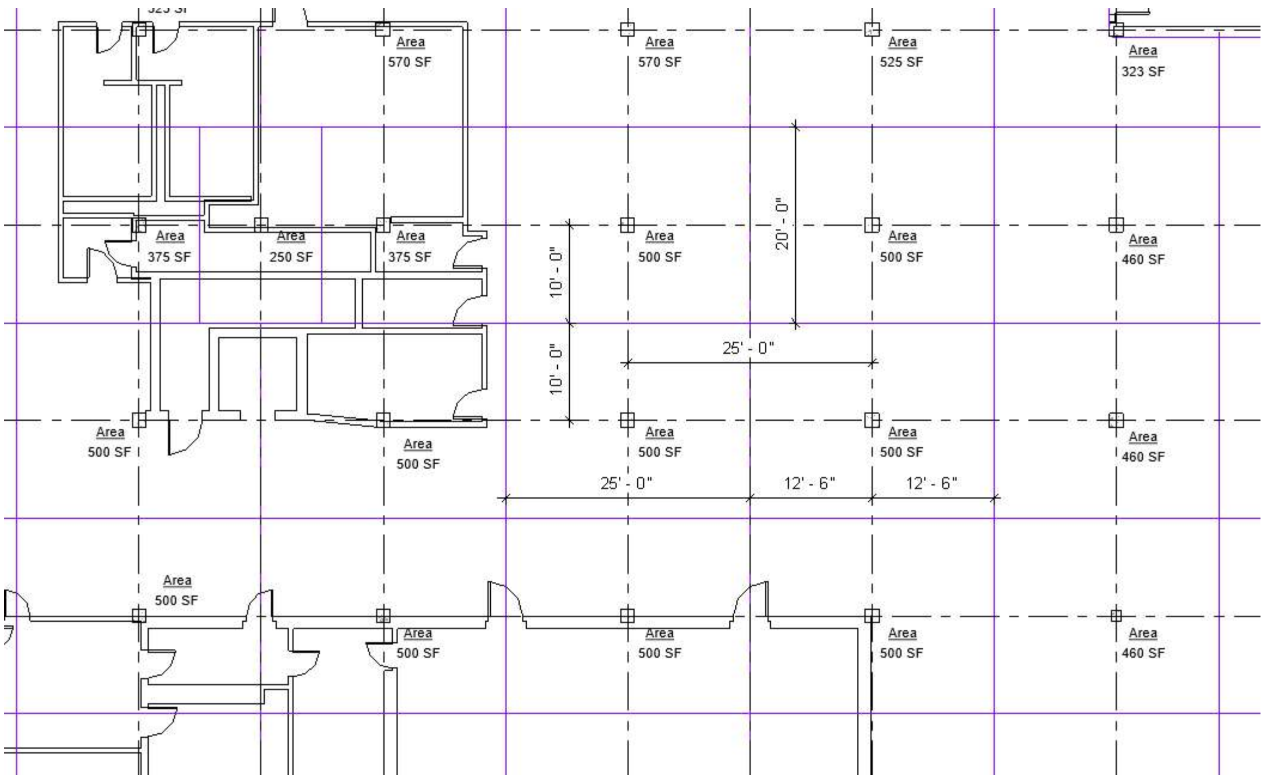


Figure 51: Plan view of 3rd floor tributary area.

6.5: Column Analysis

To be able to accurately evaluate if any rooftop additions could be structurally possible, we must analyze the loads that are carried by the columns down into the library's footings. Engineers need to identify and quantify the various loads exerted on the building, including dead loads (permanent and fixed), live loads (temporary and variable), and environmental loads (such as wind and seismic forces). This involves calculating the weight of the building itself, as well as any occupants, furniture, and equipment. Since columns play a critical role in supporting the building's weight and distributing it to the footings, engineers must assess the load-bearing capacity of the columns by considering factors. These factors include material strength, dimensions, and the structural configuration of each column. This helps determine how much additional load the columns can support without compromising structural integrity. If the initial analysis reveals that the existing structure may be insufficient to support rooftop additions, structural modifications may be considered. This could involve reinforcing columns, upgrading footings, or introducing additional structural elements to enhance the overall load-carrying capacity. To walk through the process used, the case of column C6 will be used.

6.5.1: Allowable Load

To analyze the maximum load axial load that any column can withstand in pure compression and assuming that there is no moment being applied to the column by the following equation:

$$\phi P_{o,max} = 0.8\phi[0.85f_c'(A_g - A_s) + A_s f_y]$$

Some notable constants in the equation are f_c' being the compressive strength of concrete, f_y being the yielding strength of steel, A_g being the total area of the column, A_s being the area of rebar within the column and using $\phi = 0.65$ since the shear reinforcements are tied and not spiraled. The geometry of the concrete column is what completely controls the allowable load that it can withstand. P_o is the symbol for the maximum load and by multiplying the maximum by the safety factor of ϕ reveals the allowable maximum compression for the column.

Looking at the column C6, it is known that the f_c' or the compressive strength of the concrete used in the library is determined or assumed to be 3500 psi or 3.5 ksi. Since the concrete is much older than 28 days now and could be anywhere from 10-15% larger in strength, the f_y was assumed to be 60 ksi. The C6 column on the third floor has a geometry that is 17" x 17". Assuming a 1.5" cover and using 8 #9 steel bars for internal reinforcement, an assumed cross section is given as seen in Figure 52.

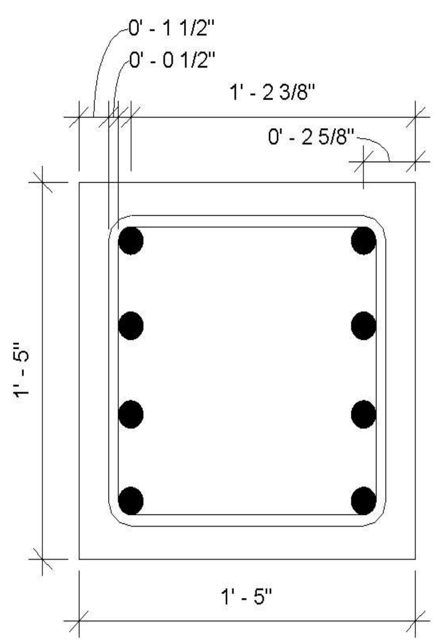


Figure 52: Cross section of column C6 showing geometric and reinforcement details.

Using the equation:

$$\phi P_{o,max} = 0.8\phi[0.85 f_c'(A_g - A_s) + A_s f_y]$$

and substituting in the known variables, the resulting equation becomes:

$$\phi P_{o,max} = 0.8 * 0.65 * [0.85 * 3 * (289 - 2.45) + 2.45 * 60]$$

$$\phi P_{o,max} = 456\ kips$$

This equation is looking strictly at the compressive strength of the column and does not include any applied moments to the equation. As the moment of the column increases, the maximum load that the column can hold decreases. Due to the complexity of the waffle slab building, the scope of the project did not include analyzing the column to slab moment connection. Thus, the assumption that the column will withstand another safety factor of 70% due to the moment connection. This means that the allowable load will become $0.7\phi P_{o,max}$ resulting in the third floor C6 column to be able to withstand $\phi P_{o,max} = 320\ kips$. The calculations can be repeated for each column on each floor by inserting the corresponding column geometry into the equation. The spreadsheets showing the structural calculations can be found in Appendix B: Allowable Load Structural Spreadsheets. The final allowable compression values for the C6 column are depicted in Table 5:

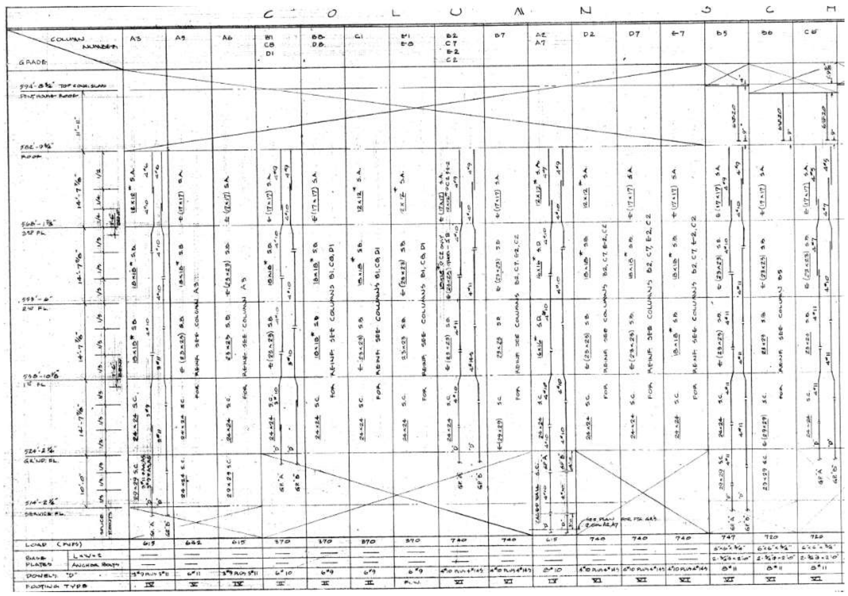
Table 5: Allowable load per floor for column C6.

Level	Allowable Load
Third Floor	319.6 kips
Second Floor	591.6 kips
First Floor	696.3 kips
Ground Floor	739.9 kips

The total allowable load on base of the C6 column was projected to be 740 kips. Looking at the 1965 structural blueprints of the building, a column chart was included to describe the rebar, the dimensions, and the calculated load for the time. The column chart can be seen in Table 6 and by finding column C6, the load was expected to be 720 kips for the entire column section. This 720 kip is only 20 kips less than the 740 kip calculation and the

1965 design load could have been a conservative number and the actual allowable load is assumed to have been a larger value.

Table 6: Original construction column schedule.



6.5.2: Original Design Load

To determine the actual load that each column experiences for each floor, the tributary area on the slab must be multiplied by the load factors that it is subjected to and then be added to the column as the total load experienced. The process can be shown by continuing the assessment of column C6. The tributary area that the third-floor column C6 experiences is 500 sq ft as found by the process explained in 6.4: Tributary Area. The column carries the tributary area of the floor above thus for the roof loads are the loads that attribute to the third floor. The controlling LFRD equation for the roof ends up being $1.2\text{D} + 1.6\text{S} + 0.5L_r$. The dead load of the roof slab is 84.15 psf as calculated from Section 6.3.3: Dead Load Calculation, the roof live load is 20 psf, and the snow load for the Worcester area is 50 psf. Combing these together:

$$W_u = 1.2 * 84.15 + 1.6 * 50 + 0.5 * 20$$
$$W_u = 191.0 \text{ psf}$$

Multiplying the load by the tributary area of 500 sf, the total load becomes 95.5 kips for the third floor C7 column. The process is repeated for each subsequent floor. The controlling LFRD equation for the ground floor up to the second floor ends up becoming $1.2\text{D} + 1.6\text{L}$. The dead load of the floor slabs become 96.66 psf as calculated from Section 6.3.3: Dead Load Calculation. The original design was engineered for a live load of 150 psf for every floor, no matter the occupancy type. The loads become:

$$W_u = 1.2 * 96.66 + 1.6 * 150$$
$$W_u = 356.0 \text{ psf}$$

Multiplying the load by the tributary area of 500 sf, the load of the third floor slab becomes 178.0 kips. In addition to the load from the third floor column, the weight of the column itself must be added into the calculation. To calculate this the density of the concrete must be multiplied by the height and cross section of the column. For the C6 column on the third floor, the column has a cross section of 17" x 17" and a height of 13' 6" from base to bottom of slab. The assumed density of concrete was 150 pcf. Multiplying these resulted in:

$$L = 150 * \left(\frac{17}{12} * \frac{17}{12}\right) * (13.5)$$
$$L = 4.06 \text{ kips}$$

Because the column is a dead load it must be multiplied by the 1.2 load factor resulting in a load of 4.872 kips. The total load expired by the second floor C6 column is the combined load from the third floor column, the weight of the third floor column, and the load experienced by the second floor slab. The total load is calculated to be:

$$W = 95.5 + 178.0 + 4.9$$
$$W = 278.4 \text{ kips}$$

The calculation process for the first floor and ground floor are the same, however the geometry of the columns differed as they got closer to the grade seen in Table 7.

Table 7: Original total load on C6 column.

Column Floor	**Marginal Load**	**Total Load**
Third	95.5 kips	95.5 kips
Second	182.9 kips	278.4 kips
First	186.9 kips	465.3 kips

Ground	186.9 kips	652.2 kips

6.5.3: Current Design Load

As mentioned earlier, the usage of the library has changed since its original design intentions. Most of the space on the upper floors are now used as workspaces and collaboration areas. This new usage opens the library and allows for more capacity for potential load. The original live load for the entire building was 150 psf, however a more practical live load of 80 psf was decided for the second and third floors due to the new usage of the library with abundant table spaces and limited book stacks. Following the same process used in Section 6.5.2: Original Design Load, the current design load can be calculated using the 80 psf live load for the C6 columns. The C6 column on the ground floor had a portion of the tributary area of the first floor being used for book stacks. This required that the original 150 psf live load had to be kept. The total calculated load can be found in Table 8.

Table 8: Current total load on C6 column.

Column Floor	Marginal Load	Total Load
Third	95.5 kips	95.4 kips
Second	126.9 kips	222.4 kips
First	130.9 kips	353.3 kips
Ground	186.9 kips	540.2 kips

There is a clear decrease in the total load after changing the occupancy of the floors to better fit its usage today and can be compared as such in Table 9. The third-floor columns experience no change due to the fact that they are supporting only the roof slab and there has been no change in roof loads.

Table 9: Load change on C6 column.

Column Floor	Original Total Load	Current Total Load	% Change
Third	95.5 kips	95.5 kips	0%
Second	278.4 kips	222.4 kips	-20.1%
First	465.3 kips	353.3 kips	-24.1%
Ground	652.2 kips	540.2 kips	-17.2%

6.5.4: Allowable Additional Load

To calculate the allowable additional load that can be added to the building requires knowing the load capacity and the actual load for each column. Continuing with the case study of column C6, Section 6.5.1: Allowable Load tells us the column load capacity based on the geometry of the column. Because the load capacity is the maximum load that can be allowed, the total load must be subtracted from the capacity to calculate the allowable additional load per column.

$$Allowable\ Additional\ Load = Load\ Capacity - Total\ Load$$

Without changing the usage of the building and keeping the live load at a value of 150 psf, the allowable additional load looks as such in Table 10:

Table 10: Original allowable additional load on C6 column.

Column Floor	Load Capacity	Original Total Load	Allowable Additional Load
Third	319.6 kips	95.5 kips	224.1 kips
Second	591.6 kips	278.4 kips	313.2 kips
First	696.3 kips	465.3 kips	231.0 kips

Ground	739.9 kips	652.2 kips	87.7 kips

Although there are multiple floors that can withstand over 200 kips of additional load to their columns, the minimum allowable value is the governing allowable load that can be added. If 100 kips of loaded is added to C6, the column will fail due to the ground column since it can only withstand 87.7 additional kips.

However, after altering the occupancy and live loads to match the building usage as it currently stands, there is more allowance on the allowable additional loads shown in Table 11.

Table 11: Current allowable additional load on C6 column.

Column Floor	**Load Capacity**	**Current Total Load**	**Allowable Additional Load**
Third	319.6 kips	95.5 kips	224.1 kips
Second	591.6 kips	222.4 kips	369.2 kips
First	696.3 kips	353.3 kips	343.0 kips
Ground	739.9 kips	540.2 kips	199.7 kips

The C6 column has increased the allowable load of its governing value from 87.7 kips to 199.7 kips. The additional value is not constant throughout every column on each floor, but the pattern does continue.

Through the created spreadsheets, entire calculations can be automatically created to show the allowable load differences for each scenario. Using the original design loads intended with 150 psf as the live load, a complete analysis for every column has been completed as seen in Table 12. The governing additional load has been highlighted in orange for each column.

Table 12: Calculation results for original design allowable additional load.

Column	**Original Design Allowable Additional Load (kips)**			
	Ground Floor	**First Floor**	**Second Floor**	**Third Floor**

A3	63.01	22.20	215.31	106.91
A5	12.51	178.06	193.49	234.73
A6	53.64	206.58	403.14	241.50
B1	405.93	460.23	364.42	386.80
C8	405.93	460.23	364.42	386.80
D1	405.93	460.23	364.42	386.80
B8	409.39	269.95	364.42	386.80
D8	409.39	269.95	364.42	386.80
C1	408.38	462.68	366.86	252.21
E1	515.71	538.68	605.28	269.02
E8	515.71	538.68	605.28	269.02
B2	138.09	267.15	439.83	346.69
C7	138.09	267.15	439.83	346.69
E2	278.08	368.25	502.04	232.97
C2	187.11	316.17	252.00	212.10
B7	138.09	267.15	439.83	346.69
A2	319.27	142.39	262.53	237.82
A7	319.27	142.39	262.53	237.82
D2	144.00	273.06	252.00	212.10
D7	141.55	270.61	249.55	346.69
E7	282.55	178.98	309.31	367.56
B5	130.85	274.15	417.96	339.05
B6	376.82	274.15	417.96	339.05
C6	87.74	231.03	313.25	224.09
C5	87.74	231.03	313.25	224.09
A4	18.42	-9.78	91.23	77.56
D3	N/A	N/A	N/A	N/A

D6	N/A	N/A	N/A	N/A
D4	N/A	N/A	N/A	N/A
D5	N/A	N/A	N/A	N/A
E3	N/A	N/A	N/A	N/A
E4	N/A	N/A	N/A	N/A
E6	N/A	N/A	N/A	N/A
E5	N/A	N/A	N/A	N/A
C3	50.38	238.10	346.49	169.56
C4	50.38	238.10	346.49	169.56
B3	167.16	309.59	223.37	260.27
B4	167.16	309.59	223.37	260.27
B3.3	236.13	332.42	291.74	152.75
A3.3	0.00	0.00	0.00	0.00
A5.5	0.00	0.00	0.00	0.00

The allowable loads for Columns D3 through to E5 could not accurately be determined within the scope. The columns in question are composite columns which is a steel column with a concrete column cast around it. The equations used throughout the rest of the structure and the methods of allowable load analysis could not be used for these columns.

Additionally, there may be some columns with the additional load value being skewed to a lesser amount than in practicality. This is due to the complications in determining the tributary area for columns that are nearby other load carrying elements such as concrete cores like the stairwells and elevator. We took the building loads to be carried by only the concrete columns to their isolated footings and ignored the concrete cores and its wall footing for simplicity.

A new table outlining the additional allowable loads using the new current design standards outlined by Section 6.5.3: Current Design Load can be seen in Table 13.

Table 13: Calculation results for current design allowable additional load.

Column	Current Design Allowable Additional Load (kips)			
	Ground Floor	**First Floor**	**Second Floor**	**Third Floor**

A3	240.10	140.27	274.34	106.91
A5	201.51	304.06	256.49	234.73
A6	230.74	324.64	462.18	241.50
B1	489.93	516.23	392.42	386.80
C8	461.93	516.23	392.42	386.80
D1	461.93	516.23	392.42	386.80
B8	493.39	325.95	392.42	386.80
D8	465.39	325.95	392.42	386.80
C1	464.38	518.68	394.86	252.21
E1	552.00	574.97	623.42	269.02
E8	552.00	574.97	623.42	269.02
B2	292.65	370.19	491.35	346.69
C7	241.13	370.19	491.35	346.69
E2	356.65	446.82	541.32	232.97
C2	290.15	419.21	303.52	212.10
B7	292.65	370.19	491.35	346.69
A2	428.59	215.27	298.97	237.82
A7	428.59	215.27	298.97	237.82
D2	247.04	376.10	303.52	212.10
D7	244.59	373.65	301.07	346.69
E7	361.12	257.55	348.59	367.56
B5	298.85	386.15	473.96	339.05
B6	544.82	386.15	473.96	339.05
C6	199.74	343.03	369.25	224.09
C5	199.74	343.03	369.25	224.09
A4	207.42	116.22	154.23	77.56
D3	N/A	N/A	N/A	N/A

D6	N/A	N/A	N/A	N/A
D4	N/A	N/A	N/A	N/A
D5	N/A	N/A	N/A	N/A
E3	N/A	N/A	N/A	N/A
E4	N/A	N/A	N/A	N/A
E6	N/A	N/A	N/A	N/A
E5	N/A	N/A	N/A	N/A
[redacted]				
C3	162.38	350.10	402.49	169.56
C4	162.38	350.10	402.49	169.56
B3	293.16	393.59	265.37	260.27
B4	293.16	393.59	265.37	260.27
[redacted]				
B3.3	320.13	388.42	319.74	152.75
A3.3	0.00	0.00	0.00	0.00
A5.5	0.00	0.00	0.00	0.00

Table 14 shows the comparison in the increase of the allowable load from the original design to the current design.

Table 14: Allowable load increase.

Column	Original Allowable	Current Allowable	Allowable Load Increase
A3	22.20	106.91	84.70
A5	12.51	201.51	189.00
A6	53.64	230.74	177.10
[redacted]			
B1	364.42	386.80	22.38
C8	364.42	386.80	22.38
D1	364.42	386.80	22.38
B8	269.95	325.95	56.00
D8	269.95	325.95	56.00
C1	252.21	252.21	0.00
E1	269.02	269.02	0.00

E8	269.02	269.02	0.00
B2	138.09	292.65	154.56
C7	138.09	241.13	103.04
E2	232.97	232.97	0.00
C2	187.11	212.10	24.99
B7	138.09	292.65	154.56
A2	142.39	215.27	72.88
A7	142.39	215.27	72.88
D2	144.00	212.10	68.10
D7	141.55	244.59	103.04
E7	178.98	257.55	78.57
B5	130.85	298.85	168.00
B6	274.15	339.05	64.91
C6	87.74	199.74	112.00
C5	87.74	199.74	112.00
A4	-9.78	77.56	87.34
D3	N/A	N/A	N/A
D6	N/A	N/A	N/A
D4	N/A	N/A	N/A
D5	N/A	N/A	N/A
E3	N/A	N/A	N/A
E4	N/A	N/A	N/A
E6	N/A	N/A	N/A
E5	N/A	N/A	N/A
C3	50.38	162.38	112.00
C4	50.38	162.38	112.00
B3	167.16	260.27	93.10

B4	167.16	260.27	93.10
[redacted]			
B3.3	152.75	152.75	0.00
A3.3	0.00	0.00	0.00
A5.5	0.00	0.00	0.00

For the columns that carry loads on the floors that have changed occupancy use have a clear noticeable additional load capacity for their column. These values jump from a range of 22 kips to almost 170 kips. In total, most of the columns have a capacity for over 200 kips which can withstand a new lightweight structure onto the roof.

6.6: Addition Structural Analysis

After calculating the additional allowable load for the columns throughout the building, the structural analysis for a rooftop addition could begin. The design of the new rooftop slab, space frame, interior column placement, updated tributary area, and load analysis shall be seen throughout the section. The challenge of this rooftop addition was to be able to structurally design a space to carry the loads down properly to the footings with a unique curved wall design as seen in Figure 53. The design required that no columns be placed beneath the curved wall area and thus the number of usable column gridlines were numbered.

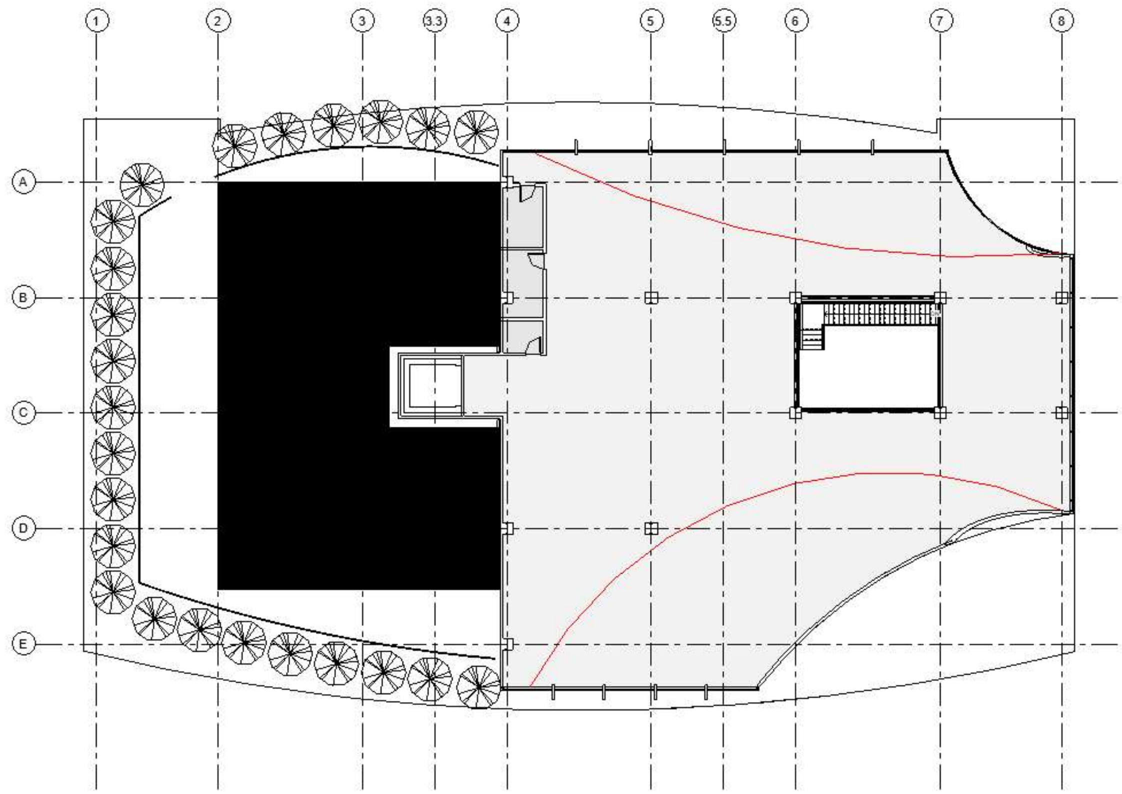


Figure 53: Plan view of rooftop addition with the projected red lines representing the curvature of the wall.

6.6.1: Voided Concrete Slab Design

Because the proposed rooftop addition floor sits 3 feet above the existing roof slab, as seen in Figure 54, there must be an additional floor slab to properly carry the expected loads of the addition. The best option in this case to do so would be to design a voided concrete slab system to be set cast in place over the roof. The existing building columns can be extended upwards using more cast in place concrete and reinforced steel to meet the new slab system.

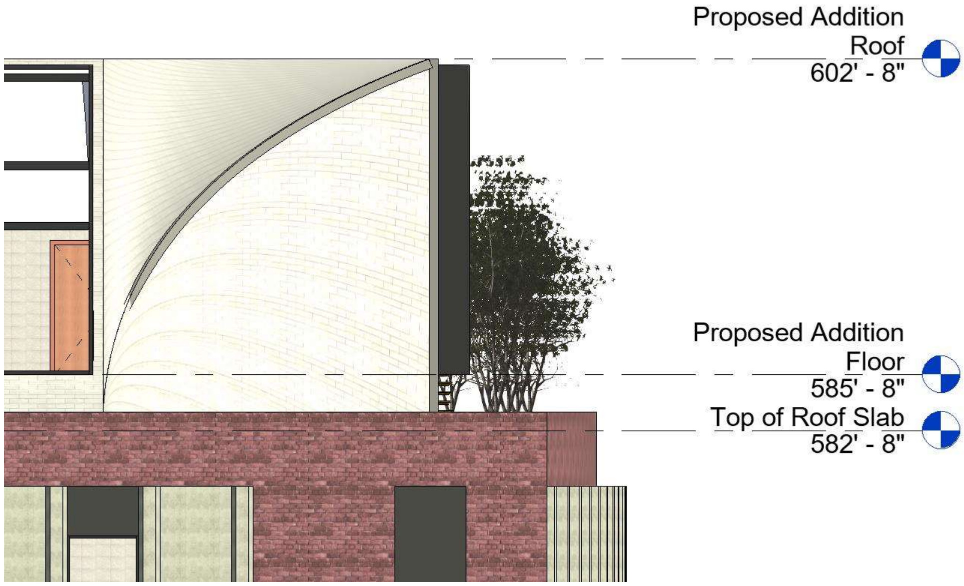


Figure 54: Elevation of proposed addition floor in comparison showing the space between the existing roof slab and the proposed addition floor.

Voided concrete slabs are structurally slabs that are designed with empty gaps and spaces in the cross-section to allow for a relatively lighter and more efficient design compared to solid slabs (*Voided Concrete Slab System*, 2020). There are different types of shapes for the voids that can be used, and each may serve a different purpose in the design. The existing waffle slab system of the library is an example of one of the types of voided slab systems with its deep grid system of ribs and the voided air gaps between.

For this proposal, the bubble deck voided slab system was the preferred design. An example of the bubble-deck slab system precast can be seen in Figure 55. The design of the slab system allows for a more flexible design enabling architects and engineers to create the desired addition without compromising any structural integrity.

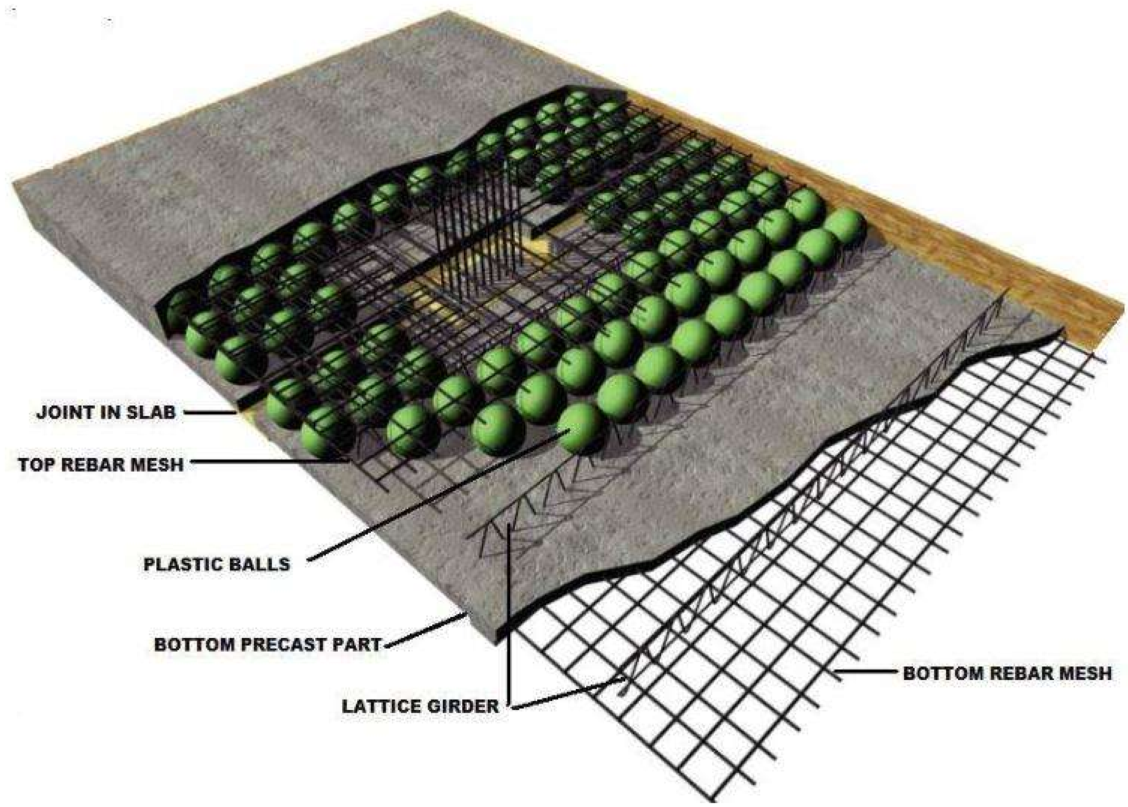


Figure 55: Diagram of a voided slab system (Voided Concrete Slab System, 2020)

The voided slab carries similar strength to that of the waffle slabs on the floors below. Because of this, the assumed dead load for the new voided slab was to be the exact same value as the waffle slab as the floors below with a value of 96.66 psf. This will allow for a light structure to be placed on top without exceeding the maximum allowable load for columns as mentioned previously.

6.6.2: Space Frame Design

For the design of the rooftop on the new lightweight addition, a space frame design was proposed and ultimately chosen for the design to be based upon. Space frame roofs are structurally designed roofs often used throughout architectural projects to create large open spans with minimal roof materials and reduced number of columns. These roofs are made of a grid system with lattice framework using rigid components such as steel or aluminum struts. Combined, these elements create a 3-D structure that can support and distribute loads effectively across the frame. These spaceframes can be constructed with lightweight designs that have the strength and structural capacity to support the necessary loads. Figure 56 shows the proposed spaceframe grid for the roof with the major and minor axis highlighted in red and blue respectively. The green highlighted lines are to represent the curve of the sloped wall. The sloped wall itself is not meant to fully rely on the space frame to carry its loads.

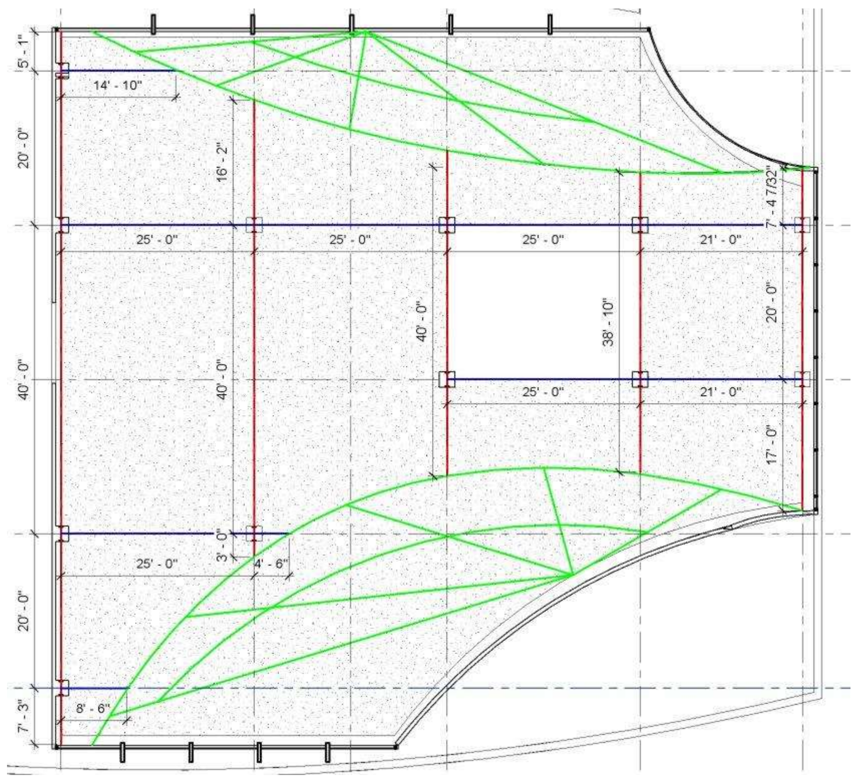


Figure 56: Major (red) and minor (blue) axis of proposed space frame showing the largest spans in each direction.

The weight of space frames tended to range based on the size of the span required and the design of the truss layout. These values can range from 40 psf to 150 psf based on the size of the span (“Space Frames - Space Frames Design & Fabrication”, 2023).To ensure the columns could carry the loads of the space frame, we decided to estimate the dead load of the space frame to be 65 psf since there is only a 40 ft maximum gap between columns. A preliminary two-dimensional analysis which includes calculated design forces of each member can be seen in Appendix E. Further analysis of trusses should include spans in both major and minor axes to determine appropriate member sizes.

6.6.3: Addition Column Placement

To carry the roof loads efficiently down to the footing, the rooftop columns would be placed on top of the existing column grid. However, to accomplish having an open floorplan on the addition floor while proving the necessary columns to carry the roof loads, we used a spacing guide of a maximum of 40’ for our space frame design. Figure *57* shows the proposed roof addition layout with the new column spacing that are within the 40’ maximum.

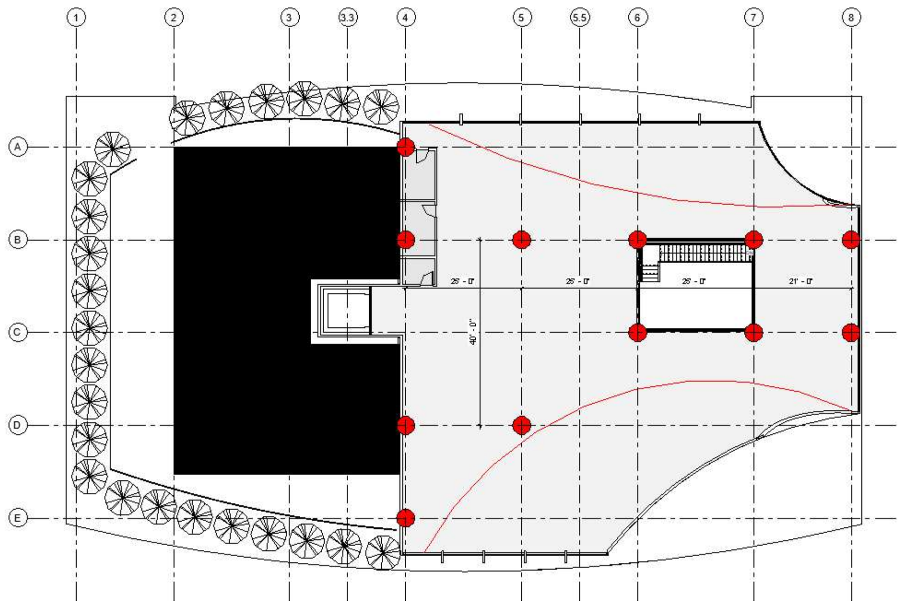


Figure 57: Roof addition column layout showing where the roof will be curved due to the shave of the addition.

These interior columns are only designed to carry the loads of the rooftop space frame and are not expected to carry any large load bearing elements. The tributary area of the rooftops loads that are carried by these interior columns can be seen within Figure 58.

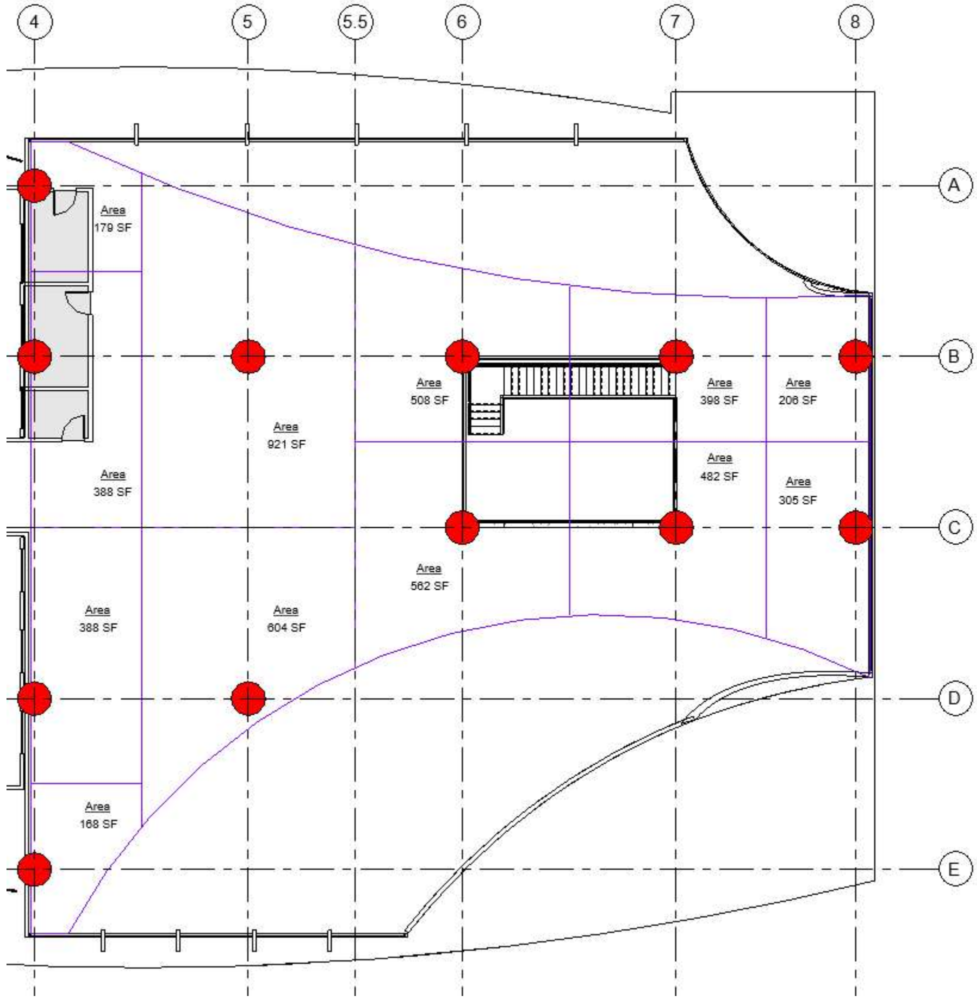


Figure 58: Addition interior columns tributary area on rooftop.

6.6.4: Updated Tributary Area

Once the new rooftop addition is added there will be a change of usage for portions of the existing roof slab. On the exterior of the new addition, some columns will have mixed rooftop usage since one part of the roof is still exposed and another part is covered by the addition. Looking at the case for Column A5 can help describe and explain how an area is broken down. Column A5 is circled in Figure 59. Area 1 with 186 sf is still under the roof usage and thus must apply LRFD load equation $1.2\text{D} + 1.6\text{S} + 0.5L_r$. Area 2 of the roof slab with 383 square feet can apply the LRFD equation 1.4D since the slab will be underneath the new addition and become inaccessible.

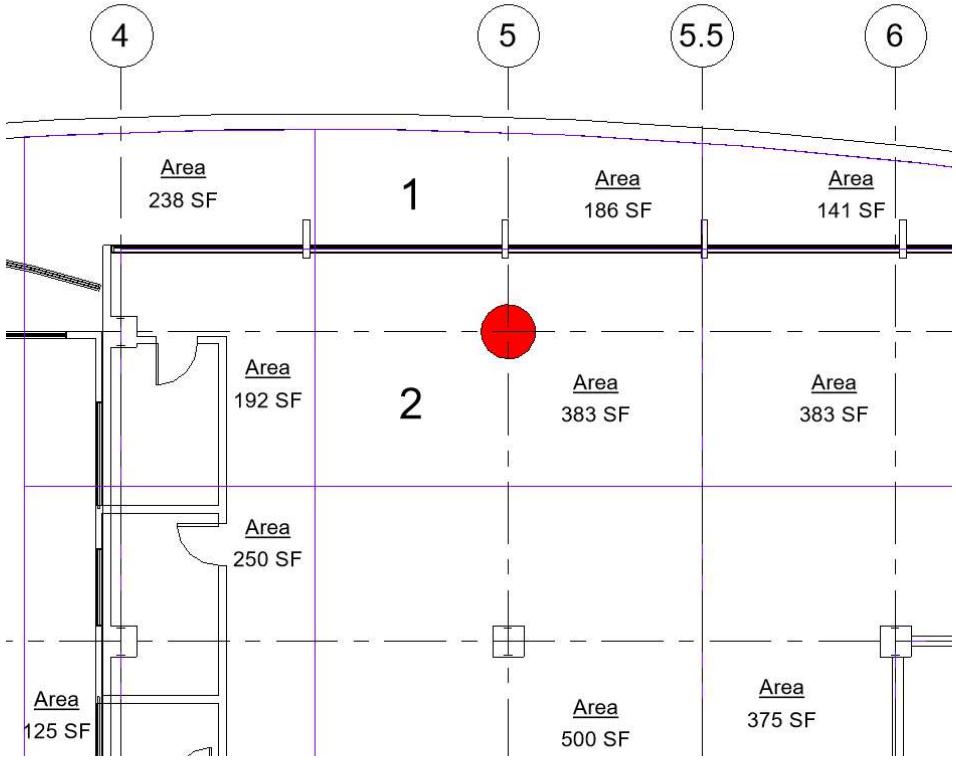


Figure 59: Updated roof slab tributary area.

In addition to column A5, columns A4, A6, A7, B8, D8, D7, E6, E5, E4, D4, C4, and B4 all experience factored tributary loads. Additionally, the new atriums will take away from the tributary area of their respective columns they are nearest to. For the third floor atrium that connects into the new rooftop addition, the affected columns are B6, B7, C6, and C7. The tributary area for columns B7 and C7 go from 460 sq. ft. to 335 sq. ft and columns B6 and C6 go from 500 sq ft to 375 sq ft.

6.6.5: Addition Load Analysis

The expected roof load for the addition can be calculated using the column placement from Section 6.6.3: Addition Column Placement and the load calculation method as used in Section 6.5: Column Analysis. The controlling LRFD equation for the roof remains being $1.2D + 1.6S + 0.5L_r$. The dead of the space frame system was set to be 65 psf as stated in Section 6.6.2: Space Frame Design. The snow load and roof live load was set to 50 psf and 20 psf respectively. After plugging in the values to the excel calculation sheet, the expected roof load was determined for each interior column through Table 16.

Table 15: Simplified table representing roof load on the interior columns.

Column	Tributary Area (sf)	Roof Load (kips)
C8	305.00	51.24
B8	206.00	34.61
C7	482.00	80.98
B7	398.00	66.86
B5	921.00	154.73
B6	508.00	85.34
C6	562.00	94.42
A4	179.00	30.07
D4	388.00	65.18
D5	604.00	101.47
E4	168.00	28.22
B4	388.00	65.18

Next, the floor loads of the addition floor had to be calculated for the extension of the columns underneath to carry the loads down to the footings. The controlling LRFD equation for the floors was 1.2D + 1.6L with the dead load of the floor set to 96.66 psf and the expected live load of 80 psf. The resulting loads can be seen in Table 16.

Table 16: Roof addition floor loads

Column	Load Above (Roof Load)	Tributary Area (sf)	Floor Load (1.2D + 1.6L) (k)	Total Load
A3	N/A	N/A	N/A	
A5	N/A	383.00	93.45	93.45
A6	N/A	383.00	93.45	93.45
[redacted]				
B1	N/A	N/A	N/A	N/A
C8	51.24	239.00	58.31	109.55
D1	N/A	N/A	N/A	N/A
B8	34.61	224.00	54.65	89.26
D8	N/A	101.00	24.64	24.64
C1	N/A	N/A	N/A	N/A
E1	N/A	N/A	N/A	N/A

E8	N/A	N/A	N/A	N/A
B2	N/A	N/A	N/A	N/A
C7	80.98	335.00	81.74	162.71
E2	N/A	N/A	N/A	N/A
C2	N/A	N/A	N/A	N/A
B7	66.86	335.00	81.74	148.60
A2	N/A	N/A	N/A	N/A
A7	N/A	274.00	66.85	66.85
D2	N/A	N/A	N/A	N/A
D7	N/A	326.00	79.54	79.54
E7	N/A	N/A	N/A	N/A
B5	154.73	500.00	122.00	276.72
B6	85.34	375.00	91.50	176.84
C6	94.42	375.00	91.50	185.91
C5	N/A	500.00	122.00	122.00
A4	30.07	192.00	46.85	76.92
D3	N/A	N/A	N/A	N/A
D6	N/A	500.00	122.00	122.00
D4	65.18	247.00	60.27	125.45
D5	101.47	500.00	122.00	223.47
E3	N/A	N/A	N/A	N/A
E4	28.22	221.00	53.92	82.15
E6	N/A	255.00	62.22	62.22
E5	N/A	442.00	107.84	107.84
C3	N/A	N/A	N/A	N/A
C4	N/A	250.00	61.00	61.00
B3	N/A	N/A	N/A	N/A

B4	65.18	250.00	61.00	126.18
B3.3	N/A	N/A	N/A	N/A
A3.3	N/A	N/A	N/A	N/A
A5.5	N/A	N/A	N/A	N/A

After the calculation of the new voided slab floor and its floors loads were complete, the new loads for the existing roof slab had to be updated. The existing roof slab loads had changed from the previous use of the building due to the new rooftop addition. As previously stated in Section 6.6.4: Updated Tributary Area, the new loads must be factored based on the tributary area of the existing roof and the covered roof. The calculations can be seen in Table 17 for the factored loads for the effected columns of A4, A6, A7, B8, D8, D7, E6, E5, E4, D4, C4, and B4.

Table 17: Factored loads for effected edge columns.

Column	Load Above (kips)	Covered Slab Area (sf)	Roof Area (sf)	Covered Slab LFRD 1.4(D+F) (kips)	Roof LFRD 1.2D+1.6S+0.5LR (kips)	Factored Slab Load (kips)	Total Load (kips)
A5	85.89	383.00	186.00	45.12	35.52	80.64	166.53
A6	85.89	383.00	141.00	45.12	26.93	72.05	157.93
D8	10.49	82.00	117.00	9.66	22.34	32.01	42.50
A7	48.55	277.00	210.00	32.63	40.11	72.74	121.29
D7	69.29	344.00	156.00	40.53	29.79	70.32	139.61
A4	72.53	192.00	238.00	22.62	45.45	68.07	140.60
D4	125.45	250.00	250.00	29.45	47.75	77.20	202.65
E4	80.68	221.00	288.00	26.04	55.00	81.04	161.72
E6	45.87	255.00	211.00	30.04	40.30	70.34	116.21
E5	106.14	442.00	67.00	52.07	12.80	64.87	171.00
C4	60.27	250.00	250.00	29.45	47.75	77.20	137.46
B4	125.45	125.00	250.00	14.73	47.75	62.47	187.92

Using the new loads calculated, the total load experienced on the third-floor columns by the new rooftop addition can be seen in Table 18. The table shows the maximum allowable load with the 0.7ϕPo (k), the total load experienced (k), and the expected load difference (k).

Table 18: Third floor column loads experienced with new rooftop addition.

Column	**$0.7\phi P_o$ (k)**	**Total Load (k)**	**Difference**
A3	207.57	100.66	106.91
A5	342.16	174.09	168.07
A6	342.16	165.50	176.66
B1	434.54	47.75	386.80
C8	434.54	139.01	295.54
D1	434.54	47.75	386.80
B8	434.54	114.38	320.17
D8	434.54	56.65	377.90
C1	299.95	47.75	252.21
E1	299.95	30.94	269.02
E8	299.95	30.94	269.02
B2	434.54	87.85	346.69
C7	434.54	202.18	232.36
E2	299.95	66.99	232.97
C2	299.95	87.85	212.10
B7	434.54	188.07	246.48
A2	299.95	62.14	237.82
A7	299.95	139.59	160.36
D2	299.95	87.85	212.10
D7	434.54	149.86	284.68
E7	434.54	66.99	367.56
B5	434.54	320.90	113.64
B6	434.54	221.02	213.52
C6	319.58	230.09	89.48
C5	319.58	166.17	153.40
A4	184.99	144.99	39.99

[redacted]			
D3	N/A	N/A	N/A
D6	N/A	N/A	N/A
D4	N/A	N/A	N/A
D5	N/A	N/A	N/A
E3	N/A	N/A	N/A
E4	N/A	N/A	N/A
E6	N/A	N/A	N/A
E5	N/A	N/A	N/A
[redacted]			
C3	265.05	95.49	169.56
C4	265.05	174.09	90.96
B3	331.88	71.62	260.27
B4	331.88	188.65	143.23
[redacted]			
B3.3	200.49	47.75	152.75
A3.3	0.00	0.00	0.00
A5.5	0.00	0.00	0.00

Table 18 however is not enough to show whether the rooftop addition is structurally feasible. To prove this, we must once again use the governing addition load throughout the rest of the building as used in Section 6.5: Column Analysis. The resulting additional loads throughout the rest of the building can be seen in Table 19 after subtracting the actual load from the maximum load to end with the remaining load for the column. The smallest of the values for each column shall be the governing remaining allowable load for the column. The highlighted value within the column row shall designate the governing value.

Table 19: Remaining additional load after addition.

	Remaining Additional Load After Addition (kips)			
Column	**Ground Floor**	**First Floor**	**Second Floor**	**Third Floor**
A3	198.46	101.76	235.83	92.70
A5	100.77	203.90	158.88	159.62
A6	131.83	226.32	363.85	168.22
[redacted]				

B1	448.29	475.18	353.91	355.28
C8	340.26	395.15	273.88	275.25
D1	420.29	475.18	353.91	355.28
B8	393.48	229.17	295.63	297.00
D8	429.00	292.69	359.16	360.52
C1	422.74	477.62	356.36	222.49
E1	510.36	533.91	582.37	239.30
E8	510.36	533.91	582.37	239.30
B2	251.01	329.13	450.30	315.17
C7	70.98	200.62	321.78	158.49
E2	315.01	405.76	500.27	203.25
C2	241.27	370.91	265.01	182.38
B7	135.15	213.27	334.43	171.13
A2	386.95	177.60	261.31	208.10
A7	327.79	118.45	202.15	148.94
D2	205.40	335.04	265.01	182.38
D7	151.19	280.83	210.80	263.41
E7	319.48	219.04	310.09	336.04
B5	85.55	173.43	268.48	85.18
B6	397.61	242.82	337.87	154.56
C6	53.99	197.87	241.68	49.83
C5	148.41	292.29	336.09	144.25
A4	132.60	44.54	100.14	33.98
D3	N/A	N/A	N/A	N/A
D6	N/A	N/A	N/A	N/A
D4	N/A	N/A	N/A	N/A
D5	N/A	N/A	N/A	N/A
E3	N/A	N/A	N/A	N/A

E4	N/A	N/A	N/A	N/A
E6	N/A	N/A	N/A	N/A
E5	N/A	N/A	N/A	N/A
C3	127.29	315.01	373.85	145.71
C4	85.32	273.03	331.88	74.67
B3	258.66	359.08	239.27	235.51
B4	142.35	242.78	122.97	119.21
B3.3	286.83	355.12	293.65	150.06
A3.3	0.00	0.00	0.00	0.00
A5.5	0.00	0.00	0.00	0.00

All of the governing values have a positive number meaning that there is still some remaining load that can be added to each column. The magnitude of the load will vary depending on which column is analyzed but the proposition for a rooftop addition would be feasible based off the load analysis for each individual column line due to the expected loads.

7.0: Energy Analysis

When the library was constructed in 1963 the codes and construction standards were drastically different. Throughout the years understanding of building envelopes and construction standards have increased. Recently there has been a shift in the construction industry focusing on the efficiency and sustainability of buildings. The library has not had any major renovations to its exterior envelope since its construction in 1963 making it outdated and not up to the current codes.

7.1: Energy Baseline

To fully understand the current energy usage of the Gordon Library we first had to establish a baseline to compare to. We used the building performance database provided by Lawrence Berkeley National Laboratory. The Lawrence Berkeley National Laboratory is the most extensive publicly available collection of measured energy performance data for buildings in the United States. The website allows the user to select filters that refine the data generated to create histograms shown in Figure 60 and Figure 61, showing the average Source and Site Energy Use Intensity (EUI) of buildings similar to the Gordon Library. Filters for libraries in Climate Zone 5A were applied to the search, using these filters resulted in an average Source EUI of 164 kBtu/sf per year and a site EUI of 89. These parameters must be set as the climate a building is in directly affects its efficiency and output.

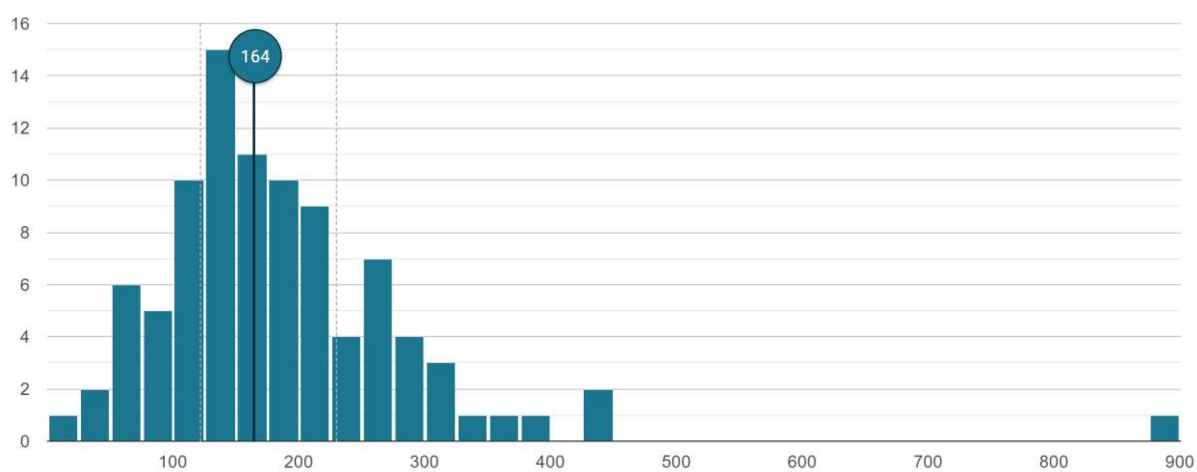


Figure 60: Histogram showing the average source EUI of libraries in the same climate zone (5-A).

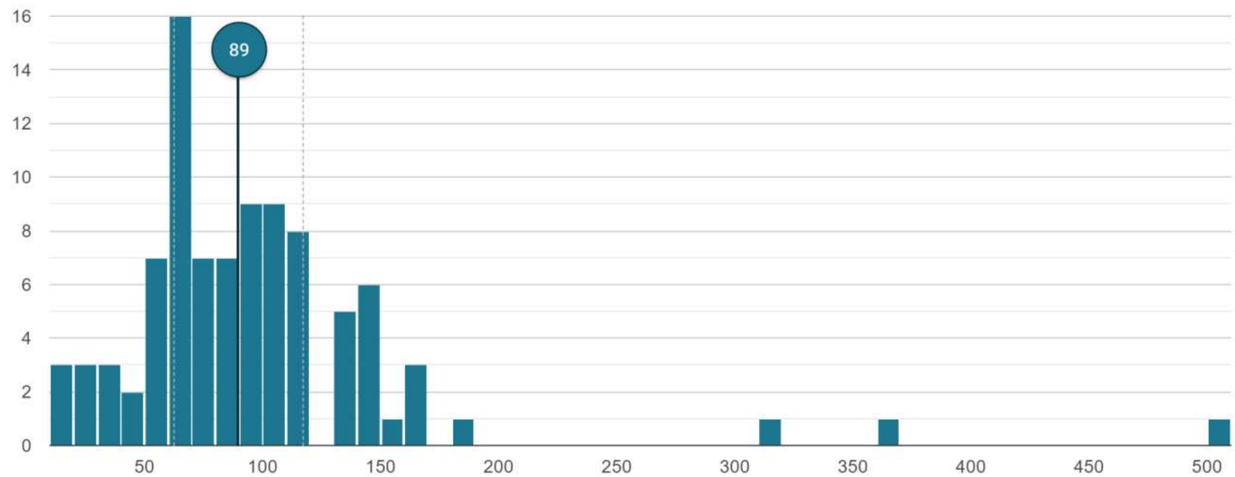


Figure 61: Histogram showing average site EUI of libraries in the same climate zone (5-A).

7.2: Design Builder Model Set-up

After understanding the EUI of libraries in the surrounding area the next step was to develop a model of the library within Design Builder. First a weather file must be selected which is available in Design Builder or can be downloaded to better reflect the location of the building, weather data from Worcester Regional Airport was used for these simulations. Worcester Regional Airport (ORH) is 4.8 miles away from Gordon library which is a reasonable distance as the weather doesn't drastically change over that distance. The building geometry is created next by modeling building blocks. These building blocks and their surface can be modified to reflect the shape of the building further. Using component blocks, the next step is to model the concrete mullions on the facade of the building. It is important to use component blocks rather than building blocks because they are treated differently when it comes time to simulate. Once the mullions were set, the surface of the building block was modified to correctly represent whether that section was a concrete panel or a single pane window in the alternating pattern. This was done on all four building facades, with the front entrance-oriented east as does the library. The orientation and surroundings of the building are also factored into the simulation, so it is important to model the slope of the site as well as any surrounding buildings. The east to west slope of the library was modeled using component blocks set to the ground type. Unity Hall, Boynton Hall, and Salisbury Hall were modeled using component blocks to account for sun shading. Once the exterior and site of the building is modeled, zones can be created using partition walls to separate the interior spaces. We obtained the zoning map of each floor of the library from the WPI facilities department, which can be seen in figures 62 - 66. These zoning maps were taken from the Facilities department’s Building Information Modeling System (BIM) which provides them with real time information regarding each system's status within the library.

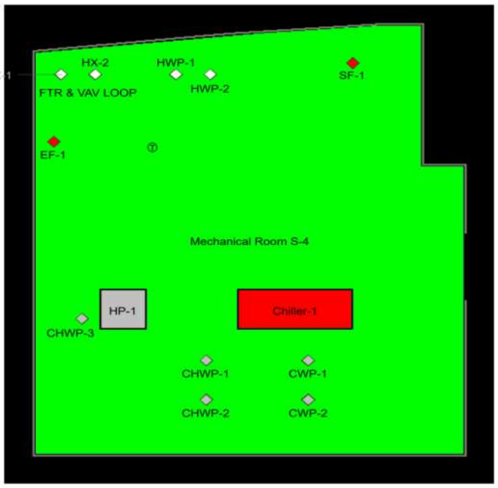


Figure 62: Service floor zoning layout from facilities Building information monitoring system.

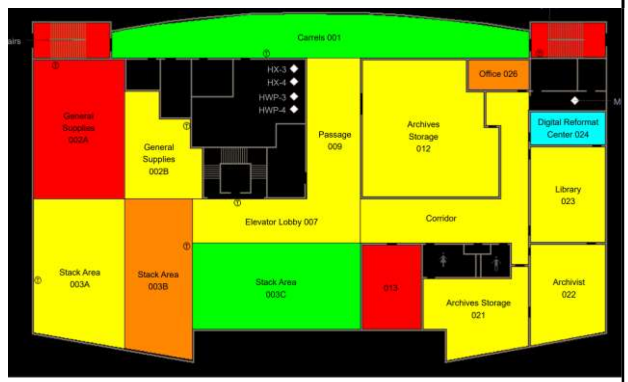


Figure 63: Ground floor zoning layout from facilities Building information monitoring system.

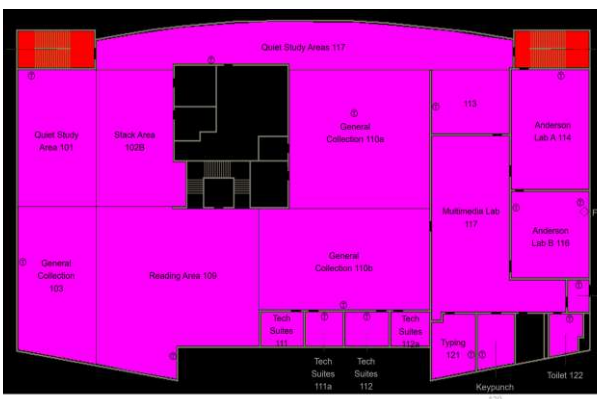


Figure 64: 1st floor zoning layout from facilities Building information monitoring system.

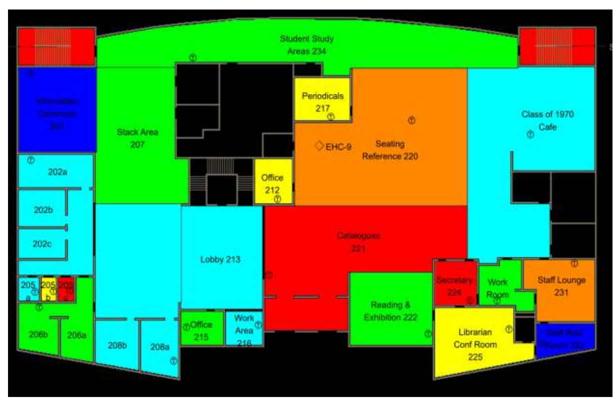


Figure 65: 2nd floor zoning layout from facilities Building information monitoring system.

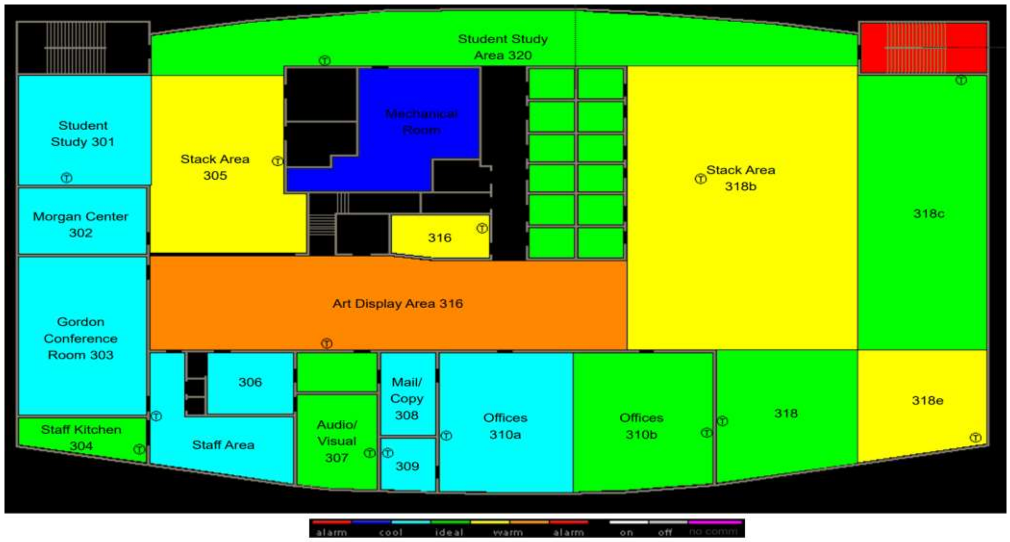


Figure 66: 3rd floor zoning layout from facilities Building information monitoring system.

Once all the zones were determined using partition walls, the HVAC system must be set in the simulation to resemble the system currently in use. For this, the system most representative of that in the library was selected using the spec sheets and plans from the 2016 update of the mechanical systems. Each HVAC system then has to be assigned zones in order to run the simulation. For this the zones in the archives were split from the rest of the building to represent the different systems currently in place in the library. Design builder also allows the user to edit different aspects of the construction of the building, like the wall construction and type of window, the lighting systems can also be altered.

7.3: Design Builder Simulations and Results

The total U-factor of the wall/window system was calculated to be 0.56 Btu/h·ft^2·F. This is larger than the current code requirement of 0.45 Btu/h·ft^2·F for an operable window that is currently required by the 2021 IECC (International Energy Conservation Code).

Four simulations were carried out to represent different renovation options. The first simulation represents the existing construction of the library. The Second simulation maintains the existing walls of the library and improves the windows. The Third maintains the existing windows of the library and improves the wall construction by adding insulation to the concrete panels between windows. The final simulation represents improvements to both the windows and the concrete panels between the windows.

The first simulation represents the existing conditions of the library. The exterior walls were constructed with standard brick backed with continuous flashing and then 12” of concrete. The concrete panels between the windows are 6” and the windows are single pane. For this simulation the R-value of the wall construction was 3.79 ft^2 °F h/BTU, and the U-factor of the single pane window was 1.038 BTU/ft^2 °F h. This simulation resulted in a source EUI of 183.88 kBtu/ft^2 and a site EUI of 103.18 kBtu/ft^2. These values are around what we expected to see compared to the data from Lawrence Berkeley National Laboratory considering the age and construction of the library.

The second simulation represents the existing walls of the library and improves the windows. The windows were improved from single pane to double pane with a U-Factor of .345 BTU/ft^2 °F h, and the R-value of the wall stayed the same without any alterations at 3.79 ft^2 °F h/BTU. This simulation resulted in a source EUI of 178 kBtu/ft^2 and a site EUI of 99 kBtu/ft^2. Compared to the existing condition simulation, updating the windows to double pane improves the source and site EUI by 2.82% and 3.66% respectively. This small decrease in EUI makes sense when considering the window to wall ratio, since there is more wall area than window it is expected to see a smaller decrease by changing the window type.

The third simulation represents the existing windows of the library and improves the wall construction. For this improvement insulation was added to the interior of the concrete panels between the windows and then covered with an interior finish. The U-factor of the windows was the same as simulation 1 at 1.038 BTU/ft^2 °F h, and the R-value of the walls was improved to be 16.2 ft^2 °F h/BTU. This simulation resulted in a source EUI of 120 kBtu/ft^2 and a site EUI of 57 kBtu/ft^2. Compared to the existing condition simulation, adding insulation to the interior of the concrete panels improves the source and site EUI by 34.38% and 44.69% respectively. As previously mentioned, the wall to window ratio has a large effect on why this improvement has a much larger effect on the total EUI of the building.

The fourth simulation combines simulations two and three and represents the improvement of both the windows and the wall construction of the library. The windows were changed from single pane to double pane with a U-Factor of .345 BTU/ft^2 °F h, and the R-value of the wall was improved to be 16.2 ft^2 °F h/BTU by adding insulation to the interior of the concrete panels between the windows and then covered with an interior finish. This simulation resulted in a source EUI of 114 kBtu/ft^2 and a site EUI of 52 kBtu/ft^2. Compared to the existing condition simulation, adding insulation to the interior of the concrete panels improves the source and site EUI by 38% and 49% respectively. Combining simulations two and three result in the lowest calculated EUI and represent the most efficient design of the building.

7.4: Design Builder Results

Upon completing the simulations outlined above the following charts were developed in order to effectively visualize the effects the changes made have on the building. Figure 67 shows resulting source and site EUI of the respective simulations. Looking at the chart from left to right it is evident that the proposed changes decrease the EUI of the building, however some changes have a larger effect on the EUI. This can be seen in Figure 68 which shows the percent change in EUI compared to the first simulation which represents the existing conditions of the building.

When considering which changes to apply to the library multiple factors must be considered including the cost of the project, as well as the scope of the project. Replacing all the windows in the library would be a large undertaking for a relatively small improvement on the building's performance, while adding insulation to the interior of the walls has a much larger effect on the EUI of the building and can be done relatively easily without having to demo any of the existing exterior envelope. Completing both improvements makes sense if there are any other plans at the time to change or update the exterior envelope and the scope of the project already includes the exterior walls. It is recommended the insulation is added to the interior of the walls to improve the buildings' performance.

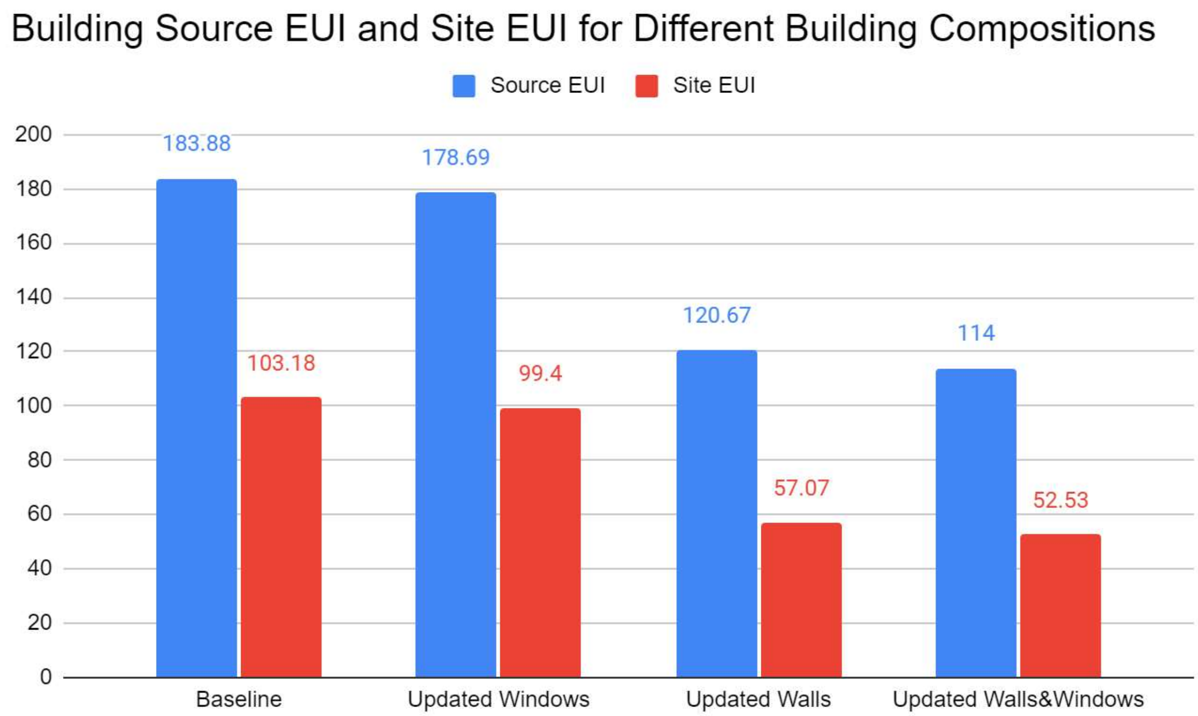


Figure 67: Comparison of simulations Energy Use Intensity (EUI).

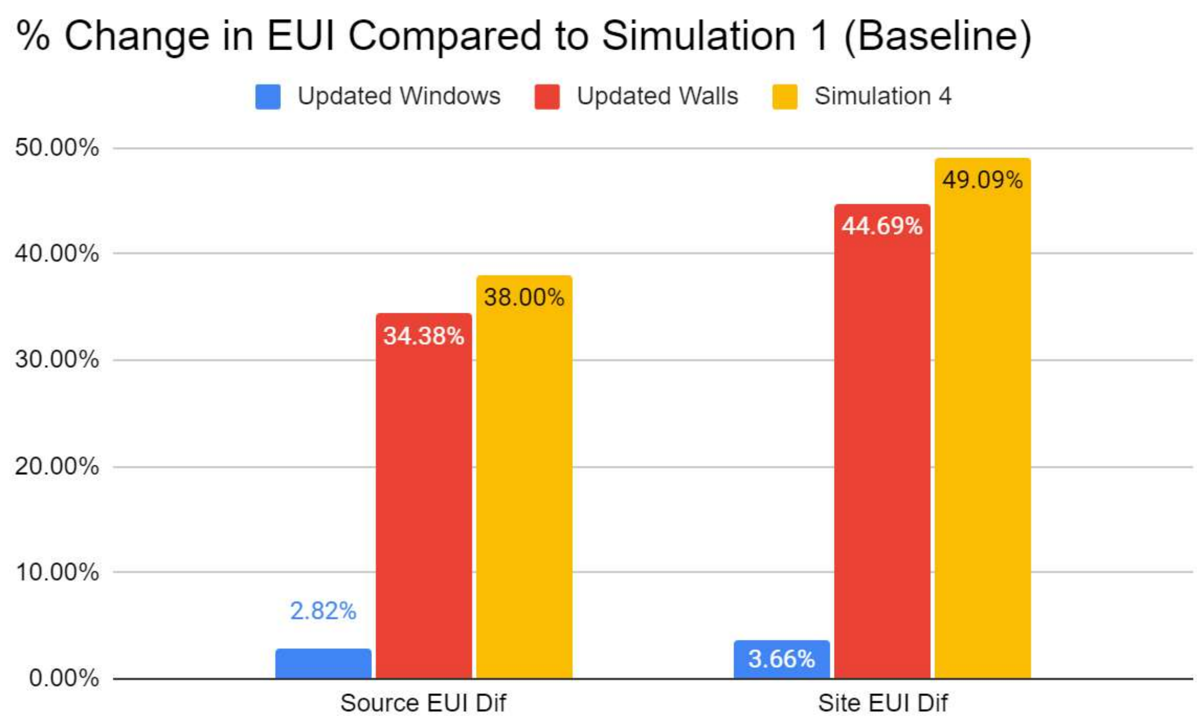


Figure 68: Percent change in Energy Use Intensity (EUI) compared to simulation 1 (baseline).

8.0: Conclusion

Due to the new usage of libraries in today's age and the growing need for more group space on the WPI campus, there is a clear need for a change with the WPI library. The plans proposed can be recalled:

1.) The removal of the drop ceiling within the library
2.) The removal and redesign of the first floor bookstacks for more table space
3.) The addition of multiple tech suites on the north-west side of the first floor
4.) The possible addition of a rooftop addition with the movement of roof HVAC equipment.

The drop ceiling only caused a more cramped feeling in the library floors and by its removal, students will be able to experience the true scale of the library and connect to the structure for an iconic environment. The first floor bookstacks should not stay within the library as it takes away potential working space for the ever-growing number of WPI students. There is a clear need for more table space made for group and individual work for all students to benefit from.

After much work on the structural loads experienced by the building, it does seem plausible that a rooftop addition can be constructed on top the existing roof of the current library. The original library design was overdesigned and because of the new projected usage of the building, there is an excess amount of additional load that the structural columns can withstand. After going through the calculations of a proposed addition, there was only one column that had less than 50 addition kips of allowance after the addition with that column being A4. The governing remaining additional load value for the columns ranged from 100 kips all the way up to 300 kips depending on the column. Moving forward, the study of the footings and the soil should be built upon to further defend the claim that the existing building can withstand the additional load proposed upon it. Although there was much difficulty with going about the structural analysis of cutting a hole through the waffle slab, it should theoretically only decrease the load of the affected columns. To further develop the structural capacity of this idea, a 3D structural system of the entire library should be made to ensure that the removal of any slab does not affect different part of the library in such a way that it degrades the structurally integrity of the building. Another focus of this should be the effect on the columns below the hole to analyze the system and ensure that the column does not suffer from any buckling failure due to the offset load that is now upon the column.

The energy analysis done also shows that the building envelope is outdated when compared to newer buildings of the same size and usage. Upgrading just the windows alone leads to a decrease of the EUI by about 5 (2.82% decrease). Although this would be a costly endeavor, it can lead to better heat and cooling insulation resulting in a more efficient and cost-effective HVAC system.

Overall, to move forward in the upcoming years and to allow WPI to continue its growth and status among other notable universities, the Gordon Library must undergo changes. These changes must put the students first by ensuring that their academic needs are met, and that the library's infrastructure supports their learning and collaboration effectively. This includes not only structural improvements such as the removal of the drop ceiling and potential rooftop additions but also energy-efficient upgrades to modernize the building's envelope. By prioritizing these enhancements, the Gordon Library can better serve the evolving needs of the WPI community, fostering a dynamic and innovative environment for academic excellence to thrive.

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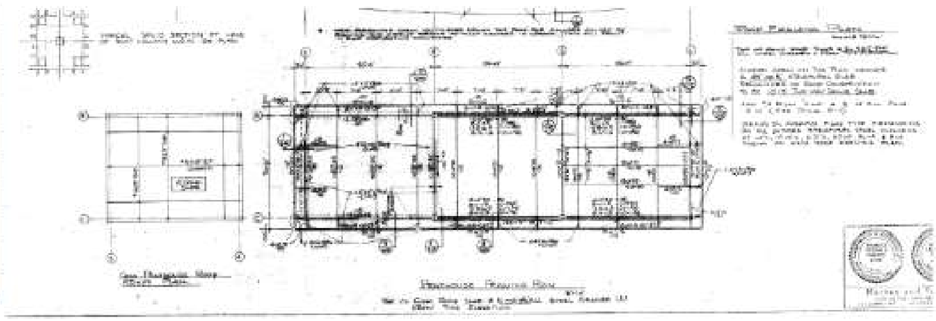
Appendices

A: Existing Structural Spreadsheets

Penthouse		
Name	1.4(DL)	Total Load (k)
B3	3.12	3.12
C3	3.12	3.12
B4	4.38	4.38
C4	4.38	4.38
B5	3.66	3.66
C5	3.66	3.66
B6	2.40	2.40
C6	2.40	2.40



Load Combination Eq: 1.4DL

		B:C , 3:4			C:D , 3:4			D:E , 3:4		
W Shape	lb/ft	Length (ft)	#	Weight (k)	Length (ft)	#	Weight (k)	Length (ft)	#	Weight (k)
10x25 Beam	25	20	5	2.5						
10x21 Beam	21				20	5	2.1	2		
14x48 Beam	48	25	2	2.4						
14x30 Beam	30				25	2	1.5	25	2	1.5
12x31 Beam	31							20	2	1.24
12x31 Beam	31							25	1	0.775
12x27 Beam	27							25	2	1.35
MEP				4						2

	B:C , 3:4	C:D , 3:4	D:E , 3:4
Total Weight	8.9	3.6	6.865

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	150
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

Existing Penthouse Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	ϕPo (k)	0.7ϕPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6LR	Total Load (k)	1.2D+1.6S+0.5LR (k)	Total Load (k)	0.7ϕPo (k)	Total Load (k)	Difference
A3	12" x 12"	144	527.08	0.00	0.00	6	3.53	456.2	296.53	207.57	62.10	62.10	70.09	70.09	100.66	100.66	207.57	100.66	106.91
A5	17" x 17"	289	562.50	0.00	0.00	6	3.53	752.0	488.80	342.16	66.27	66.27	74.80	74.80	107.43	107.43	342.16	107.43	234.73
A6	17" x 17"	289	527.08	0.00	0.00	6	3.53	752.0	488.80	342.16	62.10	62.10	70.09	70.09	100.66	100.66	342.16	100.66	241.50
B1	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
C8	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
D1	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
B8	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
D8	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
C1	12" x 12"	144	250.00	0.00	0.00	9	7.95	659.2	428.51	299.95	29.45	29.45	33.25	33.25	47.75	47.75	299.95	47.75	252.21
E1	12" x12"	144	162.00	0.00	0.00	9	7.95	659.2	428.51	299.95	19.09	19.09	21.54	21.54	30.94	30.94	299.95	30.94	269.02
E8	12" x12"	144	162.00	0.00	0.00	9	7.95	659.2	428.51	299.95	19.09	19.09	21.54	21.54	30.94	30.94	299.95	30.94	269.02
B2	17" x 17"	289	460.00	0.00	0.00	9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85	434.54	87.85	346.69
C7	17" x 17"	289	460.00	0.00	0.00	9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85	434.54	87.85	346.69
E2	12" x 12"	144	350.75	0.00	0.00	9	7.95	659.2	428.51	299.95	41.32	41.32	46.64	46.64	66.99	66.99	299.95	66.99	232.97
C2	12" x 12"	144	460.00	0.00	0.00	9	7.95	659.2	428.51	299.95	54.19	54.19	61.17	61.17	87.85	87.85	299.95	87.85	212.10
B7	17" x 17"	289	460.00	0.00	0.00	9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85	434.54	87.85	346.69
A2	12" x 12"	144	325.35	0.00	0.00	9	7.95	659.2	428.51	299.95	38.33	38.33	43.27	43.27	62.14	62.14	299.95	62.14	237.82
A7	12" x 12"	144	325.35	0.00	0.00	9	7.95	659.2	428.51	299.95	38.33	38.33	43.27	43.27	62.14	62.14	299.95	62.14	237.82
D2	12" x 12"	144	460.00	0.00	0.00	9	7.95	659.2	428.51	299.95	54.19	54.19	61.17	61.17	87.85	87.85	299.95	87.85	212.10
D7	17" x 17"	289	460.00	0.00	0.00	9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85	434.54	87.85	346.69
E7	17" x 17"	289	350.75	0.00	0.00	9	7.95	955.0	620.78	434.54	41.32	41.32	46.64	46.64	66.99	66.99	434.54	66.99	367.56
B5	17" x 17"	289	500.00	0.00		9	7.95	955.0	620.78	434.54	58.91	58.91	66.49	66.49	95.49	95.49	434.54	95.49	339.05
B6	17" x 17"	289	500.00	0.00		9	7.95	955.0	620.78	434.54	58.91	58.91	66.49	66.49	95.49	95.49	434.54	95.49	339.05
C6	17" x 17"	289	500.00	0.00		5	2.45	702.4	456.54	319.58	58.91	58.91	66.49	66.49	95.49	95.49	319.58	95.49	224.09
C5	17" x 17"	289	500.00	0.00		5	2.45	702.4	456.54	319.58	58.91	58.91	66.49	66.49	95.49	95.49	319.58	95.49	224.09
A4	12" x 12"	144	562.50	0.00	0.00	5	2.45	406.6	264.27	184.99	66.27	66.27	74.80	74.80	107.43	107.43	184.99	107.43	77.56
D3	18" x 18"	324	500.00	0.00	0.00		0.00				58.91	58.91	66.49	66.49	95.49	95.49			
D6	18" x 18"	324	500.00	0.00	0.00		0.00				58.91	58.91	66.49	66.49	95.49	95.49			
D4	18" x 18"	324	500.00	0.00	0.00		0.00				58.91	58.91	66.49	66.49	95.49	95.49			
D5	18" x 18"	324	500.00	0.00	0.00		0.00				58.91	58.91	66.49	66.49	95.49	95.49			
E3	12" x 12"	144	468.75	0.00	0.00		0.00				55.22	55.22	62.33	62.33	89.52	89.52			
E4	12" x 12"	144	516.67	0.00	0.00		0.00				60.87	60.87	68.71	68.71	98.67	98.67			
E6	12" x 12"	144	468.75	0.00	0.00		0.00				55.22	55.22	62.33	62.33	89.52	89.52			
E5				0.00	0.00		0.00				0.00	0.00	0.00	0.00	0.00	0.00			
C3	12" x 12"	144	500.00	0.00		8	6.28	582.5	378.65	265.05	58.91	58.91	66.49	66.49	95.49	95.49	265.05	95.49	169.56
C4	12" x 12"	144	500.00	0.00		8	6.28	582.5	378.65	265.05	58.91	58.91	66.49	66.49	95.49	95.49	265.05	95.49	169.56
B3	12" x 18"	216	375.00	0.00		8	6.28	729.4	474.12	331.88	44.18	44.18	49.87	49.87	71.62	71.62	331.88	71.62	260.27
B4	12" x 18"	216	375.00	0.00		8	6.28	729.4	474.12	331.88	44.18	44.18	49.87	49.87	71.62	71.62	331.88	71.62	260.27
B3.3	12" x 18"	216	250.00	0.00	0.00		0.00	440.6	286.42	200.49	29.45	29.45	33.25	33.25	47.75	47.75	200.49	47.75	152.75
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11

Seismic Load	0.24
Slab Dead Load	96.66
Live Load	150
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

ϕ	0.65

Existing Third Floor Column Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7φPo (k)	Total Load (k)	Difference (k)
A3	18" x 18"	324	527.08	2.03	100.66	10	9.82	1,112.2	722.91	506.04	74.16	174.82	190.07	290.73	506.04	290.73	215.31
A5	18" x 18"	324	562.50	4.06	107.43	10	9.82	1,112.2	722.91	506.04	81.81	189.24	205.12	312.55	506.04	312.55	193.49
A6	23" x 23"	529	527.08	4.06	100.66	10	9.82	1,530.4	994.74	696.32	77.02	177.68	192.51	293.18	696.32	293.18	403.14
B1	18" x 18"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	93.87	141.62	506.04	141.62	364.42
C8	18" x 18"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	93.87	141.62	506.04	141.62	364.42
D1	18" x 18"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	93.87	141.62	506.04	141.62	364.42
B8	18" x 18"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	93.87	141.62	506.04	141.62	364.42
D8	18" x 18"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	93.87	141.62	506.04	141.62	364.42
C1	18" x 18"	324	250.00	2.03	47.75	10	9.82	1,112.2	722.91	506.04	36.67	84.41	91.43	139.17	506.04	139.17	366.86
E1	23" x 23"	529	162.00	2.03	30.94	10	9.82	1,530.4	994.74	696.32	24.76	55.70	60.10	91.04	696.32	91.04	605.28
E8	23" x 23"	529	162.00	2.03	30.94	10	9.82	1,530.4	994.74	696.32	24.76	55.70	60.10	91.04	696.32	91.04	605.28
B2	23" x 23"	529	460.00	4.06	87.85	10	9.82	1,530.4	994.74	696.32	67.94	155.79	168.63	256.48	696.32	256.48	439.83
C7	23" x 23"	529	460.00	4.06	87.85	10	9.82	1,530.4	994.74	696.32	67.94	155.79	168.63	256.48	696.32	256.48	439.83
E2	23" x 23"	529	350.75	2.03	66.99	10	9.82	1,530.4	994.74	696.32	50.30	117.29	127.29	194.28	696.32	194.28	502.04
C2	18" x 18"	324	460.00	2.03	87.85	10	9.82	1,112.2	722.91	506.04	65.08	152.93	166.19	254.04	506.04	254.04	252.00
B7	23" x 23"	529	460.00	4.06	87.85	10	9.82	1,530.4	994.74	696.32	67.94	155.79	168.63	256.48	696.32	256.48	439.83
A2	16" x 16"	256	325.35	2.03	62.14	10	9.82	973.5	632.74	442.92	46.86	109.00	118.25	180.39	442.92	180.39	262.53
A7	16" x 16"	256	325.35	2.03	62.14	10	9.82	973.5	632.74	442.92	46.86	109.00	118.25	180.39	442.92	180.39	262.53
D2	18" x 18"	324	460.00	2.03	87.85	10	9.82	1,112.2	722.91	506.04	65.08	152.93	166.19	254.04	506.04	254.04	252.00
D7	18" x 18"	324	460.00	4.06	87.85	10	9.82	1,112.2	722.91	506.04	67.94	155.79	168.63	256.48	506.04	256.48	249.55
E7	18" x 18"	324	350.75	4.06	66.99	10	9.82	1,112.2	722.91	506.04	53.15	120.14	129.74	196.73	506.04	196.73	309.31
B5	23" x 23"	529	500.00	4.06	95.49	10	9.82	1,530.4	994.74	696.32	73.35	168.84	182.87	278.36	696.32	278.36	417.96
B6	23" x 23"	529	500.00	4.06	95.49	10	9.82	1,530.4	994.74	696.32	73.35	168.84	182.87	278.36	696.32	278.36	417.96
								0.0	0.00	0.00					0.00		
C6	23" x 23"	529	500.00	4.06	95.49	7	4.81	1,300.3	845.16	591.62	73.35	168.84	182.87	278.36	591.62	278.36	313.25
C5	23" x 23"	529	500.00	4.06	95.49	7	4.81	1,300.3	845.16	591.62	73.35	168.84	182.87	278.36	591.62	278.36	313.25
A4	18" x 18"	324	562.50	2.03	107.43	7	4.81	882.1	573.33	401.33	78.95	186.38	202.68	310.10	401.33	310.10	91.23
D3	18" x 18"	324	500.00	4.56	95.49		0.00				74.04	169.53	183.46	278.95			
D6	18" x 18"	324	500.00	4.56	95.49		0.00				74.04	169.53	183.46	278.95			
D4	23" x 23"	529	500.00	4.56	95.49		0.00				74.04	169.53	183.46	278.95			
D5	18" x 18"	324	500.00	4.56	95.49		0.00				74.04	169.53	183.46	278.95			
E3	18" x 18"	324	468.75	2.03	89.52		0.00				66.27	155.79	169.30	258.82			
E4	18" x 18"	324	516.67	2.03	98.67		0.00				72.75	171.43	186.36	285.03			
E6	18" x 18"	324	468.75	2.03	89.52		0.00				66.27	155.79	169.30	258.82			
E5	18" x 18"	324	516.67	0.00	0.00		0.00				69.92	69.92	183.93	183.93			
C3	23" x 23"	529	500.00	2.03	95.49	8	6.28	1,367.9	889.16	622.41	70.50	165.99	180.43	275.92	622.41	275.92	346.49
C4	23" x 23"	529	500.00	2.03	95.49	8	6.28	1,367.9	889.16	622.41	70.50	165.99	180.43	275.92	622.41	275.92	346.49
B3	18" x 18"	324	375.00	3.04	71.62	8	6.28	949.7	617.33	432.13	55.00	126.62	137.14	208.76	432.13	208.76	223.37
B4	18" x 18"	324	375.00	3.04	71.62	8	6.28	949.7	617.33	432.13	55.00	126.62	137.14	208.76	432.13	208.76	223.37
B3.3	18" x 18"	324	250.00	3.04	47.75	8	6.28	949.7	617.33	432.13	38.08	85.83	92.64	140.39	432.13	140.39	291.74
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	7
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	150
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

Existing Second Floor Column Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7φPo (k)	Total Load (k)	Difference
A3	18" x 18"	324	527.08	4.56	290.73	10	9.82	1,112.2	722.91	506.04	77.71	368.44	193.10	483.83	506.04	483.83	22.20
A5	23" x 23"	529	562.50	4.56	312.55	10	9.82	1,530.4	994.74	696.32	82.50	395.05	205.71	518.26	696.32	518.26	178.06
A6	23" x 23"	529	527.08	7.44	293.18	10	9.82	1,530.4	994.74	696.32	81.74	374.92	196.56	489.74	696.32	489.74	206.58
B1	23" x 23"	529	250.00	4.56	141.62	10	9.82	1,530.4	994.74	696.32	40.21	181.83	94.47	236.09	696.32	236.09	460.23
C8	23" x 23"	529	250.00	4.56	141.62	10	9.82	1,530.4	994.74	696.32	40.21	181.83	94.47	236.09	696.32	236.09	460.23
D1	23" x 23"	529	250.00	4.56	141.62	10	9.82	1,530.4	994.74	696.32	40.21	181.83	94.47	236.09	696.32	236.09	460.23
B8	18" x 18"	324	250.00	4.56	141.62	10	9.82	1,112.2	722.91	506.04	40.21	181.83	94.47	236.09	506.04	236.09	269.95
D8	18" x 18"	324	250.00	4.56	141.62	10	9.82	1,112.2	722.91	506.04	40.21	181.83	94.47	236.09	506.04	236.09	269.95
C1	23" x 23"	529	250.00	4.56	139.17	10	9.82	1,530.4	994.74	696.32	40.21	179.38	94.47	233.64	696.32	233.64	462.68
E1	23" x 23"	529	162.00	7.44	91.04	10	9.82	1,530.4	994.74	696.32	32.34	123.38	66.60	157.64	696.32	157.64	538.68
E8	23" x 23"	529	162.00	7.44	91.04	10	9.82	1,530.4	994.74	696.32	32.34	123.38	66.60	157.64	696.32	157.64	538.68
B2	23" x 23"	529	460.00	7.44	256.48	10	9.82	1,530.4	994.74	696.32	72.66	329.15	172.68	429.17	696.32	429.17	267.15
C7	23" x 23"	529	460.00	7.44	256.48	10	9.82	1,530.4	994.74	696.32	72.66	329.15	172.68	429.17	696.32	429.17	267.15
E2	23" x 23"	529	350.75	7.44	194.28	10	9.82	1,530.4	994.74	696.32	57.88	252.16	133.79	328.07	696.32	328.07	368.25
C2	23" x 23"	529	460.00	4.56	254.04	11	11.88	1,625.1	1,056.33	739.43	68.63	322.66	169.22	423.26	739.43	423.26	316.17
B7	23" x 23"	529	460.00	7.44	256.48	10	9.82	1,530.4	994.74	696.32	72.66	329.15	172.68	429.17	696.32	429.17	267.15
A2	16" x 16"	256	325.35	3.60	180.39	10	9.82	973.5	632.74	442.92	49.07	229.46	120.14	300.53	442.92	300.53	142.39
A7	16" x 16"	256	325.35	3.60	180.39	10	9.82	973.5	632.74	442.92	49.07	229.46	120.14	300.53	442.92	300.53	142.39
D2	23" x 23"	529	460.00	4.56	254.04	10	9.82	1,530.4	994.74	696.32	68.63	322.66	169.22	423.26	696.32	423.26	273.06
D7	23" x 23"	529	460.00	4.56	256.48	10	9.82	1,530.4	994.74	696.32	68.63	325.11	169.22	425.71	696.32	425.71	270.61
E7	18" x 18"	324	350.75	4.56	196.73	10	9.82	1,112.2	722.91	506.04	53.84	250.57	130.33	327.06	506.04	327.06	178.98
B5	23" x 23"	529	500.00	7.44	278.36	11	11.88	1,625.1	1,056.33	739.43	78.08	356.44	186.92	465.29	739.43	465.29	274.15
B6	23" x 23"	529	500.00	7.44	278.36	11	11.88	1,625.1	1,056.33	739.43	78.08	356.44	186.92	465.29	739.43	465.29	274.15
C6	23" x 23"	529	500.00	7.44	278.36	10	9.82	1,530.4	994.74	696.32	78.08	356.44	186.92	465.29	696.32	465.29	231.03
C5	23" x 23"	529	500.00	7.44	278.36	10	9.82	1,530.4	994.74	696.32	78.08	356.44	186.92	465.29	696.32	465.29	231.03
A4	18" x 18"	324	562.50	4.56	310.10	10	9.82	1,112.2	722.91	506.04	82.50	392.60	205.71	515.81	506.04	515.81	-9.78
D3	23" x 23"	529	500.00	4.56	278.95		0.00				74.04	352.99	183.46	462.42			
D6	18" x 18"	324	500.00	4.56	278.95		0.00				74.04	352.99	183.46	462.42			
D4	23" x 23"	529	500.00	7.44	278.95		0.00				78.08	357.03	186.92	465.88			
D5	23" x 23"	529	500.00	4.56	278.95		0.00				74.04	352.99	183.46	462.42			
E3			468.75	4.56	258.82		0.00				69.81	328.64	172.34	431.16			
E4			516.67	4.56	285.03		0.00				76.30	361.33	189.40	474.43			
E6			468.75	4.56	258.82		0.00				69.81	328.64	172.34	431.16			
E5			516.67	4.56	183.93		0.00				76.30	260.23	189.40	373.33			
C3	24" x 24'	576	500.00	7.44	275.92	9	7.95	1,540.5	1,001.34	700.94	78.08	353.99	186.92	462.84	700.94	462.84	238.10
C4	24" x 24'	576	500.00	7.44	275.92	9	7.95	1,540.5	1,001.34	700.94	78.08	353.99	186.92	462.84	700.94	462.84	238.10
B3	23" x 23"	529	375.00	4.56	208.76	9	7.95	1,444.6	939.02	657.31	57.13	265.88	138.96	347.72	657.31	347.72	309.59
B4	23" x 23"	529	375.00	4.56	208.76	9	7.95	1,444.6	939.02	657.31	57.13	265.88	138.96	347.72	657.31	347.72	309.59
B3.3	24" x 18"	432	250.00	4.56	140.39	9	7.95	1,246.8	810.39	567.28	40.21	190.60	94.47	234.85	567.28	234.85	332.42
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	7
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	150
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

Existing First Floor Column Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	ϕPo (k)	0.7ϕPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7ϕPo (k)	Total Load (k)	Difference
A3	24" x 24"	576	527.08	4.56	483.83	10	9.82	1,626.3	1,057.06	739.94	77.71	561.54	193.10	676.94	739.94	676.94	63.01
A5	24" x 24"	576	562.50	7.44	518.26	10	9.82	1,626.3	1,057.06	739.94	86.53	604.80	209.17	727.43	739.94	727.43	12.51
A6	24" x 24"	576	527.08	7.44	489.74	10	9.82	1,626.3	1,057.06	739.94	81.74	571.48	196.56	686.30	739.94	686.30	53.64
B1	24" x 24"	576	250.00	7.44	236.09	10	9.82	1,626.3	1,057.06	739.94	44.25	280.33	97.92	334.01	739.94	334.01	405.93
C8	24" x 24"	576	250.00	7.44	236.09	10	9.82	1,626.3	1,057.06	739.94	44.25	280.33	97.92	334.01	739.94	334.01	405.93
D1	24" x 24"	576	250.00	7.44	236.09	10	9.82	1,626.3	1,057.06	739.94	44.25	280.33	97.92	334.01	739.94	334.01	405.93
B8	24" x 24"	576	250.00	4.56	236.09	10	9.82	1,626.3	1,057.06	739.94	40.21	276.30	94.47	330.55	739.94	330.55	409.39
D8	24" x 24"	576	250.00	4.56	236.09	10	9.82	1,626.3	1,057.06	739.94	40.21	276.30	94.47	330.55	739.94	330.55	409.39
C1	24" x 24"	576	250.00	7.44	233.64	10	9.82	1,626.3	1,057.06	739.94	44.25	277.88	97.92	331.56	739.94	331.56	408.38
E1	24" x 24"	576	162.00	7.44	157.64	10	9.82	1,626.3	1,057.06	739.94	32.34	189.97	66.60	224.23	739.94	224.23	515.71
E8	24" x 24"	576	162.00	7.44	157.64	10	9.82	1,626.3	1,057.06	739.94	32.34	189.97	66.60	224.23	739.94	224.23	515.71
B2	24" x 24"	576	460.00	7.44	429.17	10	9.82	1,626.3	1,057.06	739.94	72.66	501.83	172.68	601.85	739.94	601.85	138.09
C7	24" x 24"	576	460.00	7.44	429.17	10	9.82	1,626.3	1,057.06	739.94	72.66	501.83	172.68	601.85	739.94	601.85	138.09
E2	24" x 24"	576	350.75	7.44	328.07	10	9.82	1,626.3	1,057.06	739.94	57.88	385.95	133.79	461.86	739.94	461.86	278.08
C2	24" x 24"	576	460.00	7.44	423.26	11	11.88	1,721.0	1,118.65	783.06	72.66	495.92	172.68	595.94	783.06	595.94	187.11
B7	29" x 29"	576	460.00	7.44	429.17	10	9.82	1,626.3	1,057.06	739.94	72.66	501.83	172.68	601.85	739.94	601.85	138.09
A2	24" x 24"	576	325.35	3.60	300.53	10	9.82	1,626.3	1,057.06	739.94	49.07	349.60	120.14	420.68	739.94	420.68	319.27
A7	24" x 24"	576	325.35	3.60	300.53	10	9.82	1,626.3	1,057.06	739.94	49.07	349.60	120.14	420.68	739.94	420.68	319.27
D2	24" x 24"	576	460.00	7.44	423.26	10	9.82	1,626.3	1,057.06	739.94	72.66	495.92	172.68	595.94	739.94	595.94	144.00
D7	24" x 24"	576	460.00	7.44	425.71	10	9.82	1,626.3	1,057.06	739.94	72.66	498.37	172.68	598.39	739.94	598.39	141.55
E7	24" x 24"	576	350.75	4.56	327.06	10	9.82	1,626.3	1,057.06	739.94	53.84	380.90	130.33	457.39	739.94	457.39	282.55
B5	24" x 24"	576	500.00	7.44	465.29	11	11.88	1,721.0	1,118.65	783.06	78.08	543.36	186.92	652.21	783.06	652.21	130.85
B6	29" x 29"	841	500.00	7.44	465.29	11	11.88	2,261.6	1,470.04	1,029.03	78.08	543.36	186.92	652.21	1,029.03	652.21	376.82
C6	24" x 24"	576	500.00	7.44	465.29	10	9.82	1,626.3	1,057.06	739.94	78.08	543.36	186.92	652.21	739.94	652.21	87.74
C5	24" x 24"	576	500.00	7.44	465.29	10	9.82	1,626.3	1,057.06	739.94	78.08	543.36	186.92	652.21	739.94	652.21	87.74
A4	24" x 24"	576	562.50	4.56	515.81	10	9.82	1,626.3	1,057.06	739.94	82.50	598.31	205.71	721.53	739.94	721.53	18.42
D3	23" x 23"	529	500.00	7.44	462.42		0.00				78.08	540.49	186.92	649.34			
D6	18" x 18"	324	500.00	4.56	462.42		0.00				74.04	536.46	183.46	645.88			
D4	23" x 23"	529	500.00	7.44	465.88		0.00				78.08	543.95	186.92	652.88			
D5	23" x 23"	529	500.00	7.44	462.42		0.00				78.08	540.49	186.92	649.34			
E3			468.75	0.00	431.16		0.00				63.43	494.60	166.87	598.03			
E4			516.67	0.00	474.43		0.00				69.92	544.35	183.93	658.36			
E6			468.75	0.00	431.16		0.00				63.43	494.60	166.87	598.03			
E5			516.67	0.00	373.33		0.00				69.92	443.24	183.93	557.25			
C3	24" x 24'	576	500.00	8.10	462.84	9	7.95	1,540.5	1,001.34	700.94	79.00	541.84	187.72	650.55	700.94	650.55	50.38
C4	24" x 24'	576	500.00	8.10	462.84	9	7.95	1,540.5	1,001.34	700.94	79.00	541.84	187.72	650.55	700.94	650.55	50.38
B3	23" x 23"	529	375.00	7.44	347.72	9	7.95	1,444.6	939.02	657.31	61.16	408.89	142.42	490.15	657.31	490.15	167.16
B4	23" x 23"	529	375.00	7.44	347.72	9	7.95	1,444.6	939.02	657.31	61.16	408.89	142.42	490.15	657.31	490.15	167.16
B3.3	24" x 18"	432	250.00	6.08	234.85	9	7.95	1,246.8	810.39	567.28	42.34	277.19	96.29	331.14	567.28	331.14	236.13
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	150
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

ϕ	0.65

Existing Ground Floor Column Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.8φPo (k)	Total Load (k)	Difference
A3	29" x 29"	841	527.08	3.38	676.94	10	9.82	2,166.9	1,408.45	985.92	76.05	752.99	191.69	868.63	1,408.45	868.63	539.83
A5	24" x 24"	576	562.50	5.51	727.43	10	9.82	1,626.3	1,057.06	739.94	83.83	811.27	206.86	934.29	1,057.06	934.29	122.77
A6	29" x 29"	841	527.08	5.51	686.30	10	9.82	2,166.9	1,408.45	985.92	79.04	765.35	194.25	880.55	1,408.45	880.55	527.90
								0.0	0.00	0.00					0.00		
B1				5.51	334.01		0.00	0.0	0.00	0.00	7.71	341.72	6.61	340.62			
C8				5.51	334.01		0.00	0.0	0.00	0.00	7.71	341.72	6.61	340.62			
D1				5.51	334.01		0.00	0.0	0.00	0.00	7.71	341.72	6.61	340.62			
B8				3.38	330.55		0.00	0.0	0.00	0.00	4.73	335.28	4.05	334.60			
D8				3.38	330.55		0.00	0.0	0.00	0.00	4.73	335.28	4.05	334.60			
C1				5.51	331.56		0.00	0.0	0.00	0.00	7.71	339.28	6.61	338.18			
E1				5.51	224.23		0.00	0.0	0.00	0.00	7.71	231.95	6.61	230.85			
E8				5.51	224.23		0.00	0.0	0.00	0.00	7.71	231.95	6.61	230.85			
								0.0	0.00	0.00							
B2				5.51	601.85		0.00	0.0	0.00	0.00	7.71	609.56	6.61	608.46			
C7				5.51	601.85		0.00	0.0	0.00	0.00	7.71	609.56	6.61	608.46			
E2				5.51	461.86		0.00	0.0	0.00	0.00	7.71	469.58	6.61	468.48			
C2				5.51	595.94		0.00	0.0	0.00	0.00	7.71	603.66	6.61	602.56			
B7				5.51	601.85		0.00	0.0	0.00	0.00	7.71	609.56	6.61	608.46			
								0.0	0.00	0.00							
A2				2.67	420.68		0.00	0.0	0.00	0.00	3.73	424.41	3.20	423.88			
A7				2.67	420.68		0.00	0.0	0.00	0.00	3.73	424.41	3.20	423.88			
D2				5.51	595.94		0.00	0.0	0.00	0.00	7.71	603.66	6.61	602.56			
D7				5.51	598.39		0.00	0.0	0.00	0.00	7.71	606.11	6.61	605.00			
E7				3.38	457.39		0.00	0.0	0.00	0.00	4.73	462.12	4.05	461.44			
								0.0	0.00	0.00					0.00		
B5	29" x 29"	841	500.00	5.51	652.21	11	11.88	2,261.6	1,470.04	1,029.03	75.38	727.59	184.61	836.82	1,470.04	836.82	633.23
B6	29" x 29"	841	500.00	5.51	652.21	11	11.88	2,261.6	1,470.04	1,029.03	75.38	727.59	184.61	836.82	1,470.04	836.82	633.23
								0.0	0.00	0.00					0.00		
C6				5.51	652.21		0.00	0.0	0.00	0.00	7.71	659.92	6.61	658.82			
C5				5.51	652.21		0.00	0.0	0.00	0.00	7.71	659.92	6.61	658.82			
A4				3.38	721.53		0.00	0.0	0.00	0.00	4.73	726.25	4.05	725.58			
								0.0	0.00	0.00							
D3				5.51	649.34		0.00	0.0	0.00	0.00	7.71	657.05	6.61	655.95			
D6				3.38	645.88		0.00	0.0	0.00	0.00	4.73	650.61	4.05	649.93			
D4				5.51	652.80		0.00	0.0	0.00	0.00	7.71	660.51	6.61	659.41			
D5				5.51	649.34		0.00	0.0	0.00	0.00	7.71	657.05	6.61	655.95			
E3				0.00	598.03		0.00	0.0	0.00	0.00	0.00	598.03	0.00	598.03			
E4				0.00	658.36		0.00	0.0	0.00	0.00	0.00	658.36	0.00	658.36			
E6				0.00	598.03		0.00	0.0	0.00	0.00	0.00	598.03	0.00	598.03			
E5				0.00	557.25		0.00	0.0	0.00	0.00	0.00	557.25	0.00	557.25			
								0.0	0.00	0.00					0.00		
C3	29" x 29"	841	500.00	6.00	650.55	9	7.95	2,081.1	1,352.73	946.91	76.06	726.62	185.20	835.75	1,352.73	835.75	516.98
C4	24" x 24"	576	500.00	6.00	650.55	9	7.95	1,540.5	1,001.34	700.94	76.06	726.62	185.20	835.75	1,001.34	835.75	165.59
B3	29" x 29"	841	375.00	5.51	490.15	9	7.95	2,081.1	1,352.73	946.91	58.46	548.61	140.11	630.26	1,352.73	630.26	722.47
B4	24" x 24"	576	375.00	5.51	490.15	9	7.95	1,540.5	1,001.34	700.94	58.46	548.61	140.11	630.26	1,001.34	630.26	371.08
								0.0	0.00	0.00					0.00		
B3.3	24" x 18"	432	250.00	4.50	331.14	9	7.95	1,246.8	810.39	567.28	40.13	371.27	94.40	425.54	810.39	425.54	384.86
A3.3	12" x 24"	288	283.33	0.00	0.00	9	7.95	953.0	619.45	433.62	38.34	38.34	100.86	100.86	619.45	100.86	518.59
A5.5	12" x 24"	288	283.33	0.00	0.00	9	7.95	953.0	619.45	433.62	38.34	38.34	100.86	100.86	619.45	100.86	518.59

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	7
Seismic Load	0.24
Slab Dead Load	86.66
Live Load	150
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	10.0

φ	0.65

Existing Sub-Ground Floor Column Sheet

Name	Max Column Size	Max Column Size (sq. in.)	Footing Type	Footing Area (sf)	Footing Height (ft)	Footing Self Weight (k)	Load Above (k)	Total Load (k)	Bearing Pressure (psf)
A3	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	868.63	909.62	11,229.9
A5	24" x 24"	576	9.5' x 9.5' x 2.5' (V)	90.25	2.50	47.4	934.29	981.67	10,877.3
A6	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	880.55	921.55	11,377.1
B1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	340.62	360.28	7,352.6
C8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	340.62	360.28	7,352.6
D1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	340.62	360.28	7,352.6
B8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	334.60	354.25	7,229.7
D8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	334.60	354.25	7,229.7
C1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	338.18	357.83	7,302.6
E1	24" x 24"	576	Bot Footing?			0.0	230.85	230.85	#DIV/0!
E8	24" x 24"	576	Bot Footing?			0.0	230.85	230.85	#DIV/0!
B2	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	608.46	664.32	6,643.2
C7	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	608.46	664.32	6,643.2
E2	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	468.48	524.34	5,243.4
C2	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	602.56	658.42	6,584.2
B7	29" x 29"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	608.46	664.32	6,643.2
A2	24" x 24"	576	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	423.88	464.87	5,739.1
A7	24" x 24"	576	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	423.88	464.87	5,739.1
D2	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	602.56	658.42	6,584.2
D7	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	605.00	660.86	6,608.6
E7	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	461.44	517.30	5,173.0
B5	29" x 29"	841	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	836.82	892.68	8,926.8
B6	29" x 29"	841	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	836.82	892.68	8,926.8
C6	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	658.82	714.68	7,146.8
C5	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	658.82	714.68	7,146.8
A4	24" x 24"	576	9.5' x 9.5' x 2.5' (V)	90.25	2.50	47.4	725.58	772.98	8,564.6
D3	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	655.95	688.25	10,428.0
D6	18" x 18"	324	8.5' x 8.5' x 2.33' (III)	72.25	2.33	35.4	649.93	685.28	9,484.9
D4	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	659.41	691.71	10,480.4
D5	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	655.95	688.25	10,428.0
E3			Bot Footing?			0.0	598.03	598.03	#DIV/0!
E4			Bot Footing?			0.0	658.36	658.36	#DIV/0!
E6			Bot Footing?			0.0	598.03	598.03	#DIV/0!
E5			Bot Footing?			0.0	557.25	557.25	#DIV/0!
C3	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	835.75	876.74	10,824.0
C4	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	835.75	855.40	17,457.2
B3	29" x 29"	841	7' x 7' x 1.91' (II)	49.00	1.91	19.7	630.26	649.91	13,263.5
B4	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	630.26	649.91	13,263.5
B3.3	24" x 18"	432	7' x 7' x 1.91' (II)	49.00	1.91	19.7	425.54	445.19	9,085.6
A3.3	12" x 24"	288	3.5' x 3.5' x 1.33' (I)	12.25	1.33	3.4	100.86	104.28	8,513.0
A5.5	12" x 24"	288	3.5' x 3.5' x 1.33' (I)	12.25	1.33	3.4	100.86	104.28	8,513.0

	(psf)
Roof Dead Load	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	150
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

Existing Footing Sheet

B: Allowable Load Structural Spreadsheets

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6LR	Total Load (k)	1.2D+1.6S+0.5LR (k)	Total Load (k)	0.7φPo (k)	Total Load (k)	Difference
A3	12" x 12"	144	527.08	0.00	0.00	6	3.53	456.2	296.53	207.57	62.10	62.10	70.09	70.09	100.66	100.66	207.57	100.66	106.91
A5	17" x 17"	289	562.50	0.00	0.00	6	3.53	752.0	488.80	342.16	66.27	66.27	74.80	74.80	107.43	107.43	342.16	107.43	234.73
A6	17" x 17"	289	527.08	0.00	0.00	6	3.53	752.0	488.80	342.16	62.10	62.10	70.09	70.09	100.66	100.66	342.16	100.66	241.50
B1	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
C8	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
D1	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
B8	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
D8	17" x 17"	289	250.00	0.00	0.00	9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75	434.54	47.75	386.80
C1	12" x 12"	144	250.00	0.00	0.00	9	7.95	659.2	428.51	299.95	29.45	29.45	33.25	33.25	47.75	47.75	299.95	47.75	252.21
E1	12" x12"	144	162.00	0.00	0.00	9	7.95	659.2	428.51	299.95	19.09	19.09	21.54	21.54	30.94	30.94	299.95	30.94	269.02
E8	12" x12"	144	162.00	0.00	0.00	9	7.95	659.2	428.51	299.95	19.09	19.09	21.54	21.54	30.94	30.94	299.95	30.94	269.02
B2	17" x 17"	289	460.00	0.00	0.00	9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85	434.54	87.85	346.69
C7	17" x 17"	289	460.00	0.00	0.00	9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85	434.54	87.85	346.69
E2	12" x 12"	144	350.75	0.00	0.00	9	7.95	659.2	428.51	299.95	41.32	41.32	46.64	46.64	66.99	66.99	299.95	66.99	232.97
C2	12" x 12"	144	460.00	0.00	0.00	9	7.95	659.2	428.51	299.95	54.19	54.19	61.17	61.17	87.85	87.85	299.95	87.85	212.10
B7	17" x 17"	289	460.00	0.00	0.00	9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85	434.54	87.85	346.69
A2	12" x 12"	144	325.35	0.00	0.00	9	7.95	659.2	428.51	299.95	38.33	38.33	43.27	43.27	62.14	62.14	299.95	62.14	237.82
A7	12" x 12"	144	325.35	0.00	0.00	9	7.95	659.2	428.51	299.95	38.33	38.33	43.27	43.27	62.14	62.14	299.95	62.14	237.82
D2	12" x 12"	144	460.00	0.00	0.00	9	7.95	659.2	428.51	299.95	54.19	54.19	61.17	61.17	87.85	87.85	299.95	87.85	212.10
D7	17" x 17"	289	460.00	0.00	0.00	9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85	434.54	87.85	346.69
E7	17" x 17"	289	350.75	0.00	0.00	9	7.95	955.0	620.78	434.54	41.32	41.32	46.64	46.64	66.99	66.99	434.54	66.99	367.56
B5	17" x 17"	289	500.00	0.00	0.00	9	7.95	955.0	620.78	434.54	58.91	58.91	66.49	66.49	95.49	95.49	434.54	95.49	339.05
B6	17" x 17"	289	500.00	0.00	0.00	9	7.95	955.0	620.78	434.54	58.91	58.91	66.49	66.49	95.49	95.49	434.54	95.49	339.05
C6	17" x 17"	289	500.00	0.00	0.00	5	2.45	702.4	456.54	319.58	58.91	58.91	66.49	66.49	95.49	95.49	319.58	95.49	224.09
C5	17" x 17"	289	500.00	0.00	0.00	5	2.45	702.4	456.54	319.58	58.91	58.91	66.49	66.49	95.49	95.49	319.58	95.49	224.09
A4	12" x 12"	144	562.50	0.00	0.00	5	2.45	406.6	264.27	184.99	66.27	66.27	74.80	74.80	107.43	107.43	184.99	107.43	77.56
D3	18" x 18"	324	500.00	0.00	0.00		0.00				58.91	58.91	66.49	66.49	95.49	95.49		95.49	-95.49
D6	18" x 18"	324	500.00	0.00	0.00		0.00				58.91	58.91	66.49	66.49	95.49	95.49		95.49	-95.49
D4	18" x 18"	324	500.00	0.00	0.00		0.00				58.91	58.91	66.49	66.49	95.49	95.49		95.49	-95.49
D5	18" x 18"	324	500.00	0.00	0.00		0.00				58.91	58.91	66.49	66.49	95.49	95.49		95.49	-95.49
E3	12" x 12"	144	468.75	0.00	0.00		0.00				55.22	55.22	62.33	62.33	89.52	89.52		89.52	-89.52
E4	12" x 12"	144	516.67	0.00	0.00		0.00				60.87	60.87	68.71	68.71	98.67	98.67		98.67	-98.67
E6	12" x 12"	144	468.75	0.00	0.00		0.00				55.22	55.22	62.33	62.33	89.52	89.52		89.52	-89.52
E5			525.00	0.00	0.00		0.00				61.85	61.85	69.81	69.81	100.26	100.26			
C3	12" x 12"	144	500.00	0.00	0.00	8	6.28	582.5	378.65	265.05	58.91	58.91	66.49	66.49	95.49	95.49	265.05	95.49	169.56
C4	12" x 12"	144	500.00	0.00	0.00	8	6.28	582.5	378.65	265.05	58.91	58.91	66.49	66.49	95.49	95.49	265.05	95.49	169.56
B3	12" x 18"	216	375.00	0.00	0.00	8	6.28	729.4	474.12	331.88	44.18	44.18	49.87	49.87	71.62	71.62	331.88	71.62	260.27
B4	12" x 18"	216	375.00	0.00	0.00	8	6.28	729.4	474.12	331.88	44.18	44.18	49.87	49.87	71.62	71.62	331.88	71.62	260.27
B3.3	12" x 18"	216	250.00	0.00	0.00		0.00	440.6	286.42	200.49	29.45	29.45	33.25	33.25	47.75	47.75	200.49	47.75	152.75
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150
	ksi
f'c	3
fy	60
	ft
Column Height	13.5
ϕ	0.65

Changed Occupancy Third Floor Column Sheet

Name	Column Size	Column Size (sq. In.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	ϕPo (k)	0.7ϕPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7ϕPo (k)	Total Load (k)	Difference (k)
A3	16" x 16"	324	527.06	2.03	100.66	10	9.82	1,112.2	722.91	506.04	74.16	174.82	131.03	231.70	506.04	231.70	274.34
A5	16" x 16"	324	562.50	4.06	107.43	10	9.82	1,112.2	722.91	506.04	81.81	189.24	142.12	249.55	506.04	249.55	256.49
A6	23" x 23"	529	527.06	4.06	100.66	10	9.82	1,530.4	994.74	696.32	77.02	177.68	133.48	234.14	696.32	234.14	462.18
B1	16" x 16"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	65.87	113.62	506.04	113.62	392.42
C8	16" x 16"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	65.87	113.62	506.04	113.62	392.42
D1	16" x 16"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	65.87	113.62	506.04	113.62	392.42
B8	16" x 16"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	65.87	113.62	506.04	113.62	392.42
D8	16" x 16"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	65.87	113.62	506.04	113.62	392.42
C1	16" x 16"	324	250.00	2.03	47.75	10	9.82	1,112.2	722.91	506.04	36.67	84.41	63.43	111.17	506.04	111.17	394.86
E1	23" x 23"	529	162.00	2.03	30.94	10	9.82	1,530.4	994.74	696.32	24.76	55.70	41.96	72.90	696.32	72.90	623.42
E8	23" x 23"	529	162.00	2.03	30.94	10	9.82	1,530.4	994.74	696.32	24.76	55.70	41.96	72.90	696.32	72.90	623.42
B2	23" x 23"	529	460.00	4.06	87.85	10	9.82	1,530.4	994.74	696.32	67.94	155.79	117.11	204.96	696.32	204.96	491.35
C7	23" x 23"	529	460.00	4.06	87.85	10	9.82	1,530.4	994.74	696.32	67.94	155.79	117.11	204.96	696.32	204.96	491.35
E2	23" x 23"	529	350.75	2.03	66.99	10	9.82	1,530.4	994.74	696.32	50.30	117.29	88.01	155.00	696.32	155.00	541.32
C2	16" x 16"	324	460.00	2.03	87.85	10	9.82	1,112.2	722.91	506.04	65.08	152.93	114.67	202.52	506.04	202.52	303.52
B7	23" x 23"	529	460.00	4.06	87.85	10	9.82	1,530.4	994.74	696.32	67.94	155.79	117.11	204.96	696.32	204.96	491.35
A2	16" x 16"	256	325.35	2.03	62.14	10	9.82	973.5	632.74	442.92	46.86	109.00	81.81	143.95	442.92	143.95	298.97
A7	16" x 16"	256	325.35	2.03	62.14	10	9.82	973.5	632.74	442.92	46.86	109.00	81.81	143.95	442.92	143.95	298.97
D2	16" x 16"	324	460.00	2.03	87.85	10	9.82	1,112.2	722.91	506.04	65.08	152.93	114.67	202.52	506.04	202.52	303.52
D7	16" x 16"	324	460.00	4.06	87.85	10	9.82	1,112.2	722.91	506.04	67.94	155.79	117.11	204.96	506.04	204.96	301.07
E7	16" x 16"	324	350.75	4.06	66.99	10	9.82	1,112.2	722.91	506.04	53.15	120.14	90.46	157.44	506.04	157.44	348.59
B5	23" x 23"	529	500.00	4.06	95.49	10	9.82	1,530.4	994.74	696.32	73.35	168.84	126.87	222.36	696.32	222.36	473.96
B6	23" x 23"	529	500.00	4.06	95.49	10	9.82	1,530.4	994.74	696.32	73.35	168.84	126.87	222.36	696.32	222.36	473.96
C6	23" x 23"	529	500.00	4.06	95.49	7	4.81	1,300.3	845.16	591.62	73.35	168.84	126.87	222.36	591.62	222.36	369.25
C5	23" x 23"	529	500.00	4.06	95.49	7	4.81	1,300.3	845.16	591.62	73.35	168.84	126.87	222.36	591.62	222.36	369.25
A4	16" x 16"	324	562.50	2.03	107.43	7	4.81	882.1	573.33	401.33	78.95	186.38	139.68	247.10	401.33	247.10	154.23
D3	16" x 16"	324	500.00	4.56	95.49		0.00				74.04	169.53	127.46	222.95		222.95	-222.95
D6	16" x 16"	324	500.00	4.56	95.49		0.00				74.04	169.53	127.46	222.95		222.95	-222.95
D4	23" x 23"	529	500.00	4.56	95.49		0.00				74.04	169.53	127.46	222.95		222.95	-222.95
D5	16" x 16"	324	500.00	4.56	95.49		0.00				74.04	169.53	127.46	222.95		222.95	-222.95
E3	16" x 16"	324	468.75	2.03	89.52		0.00				66.27	155.79	116.80	206.32		206.32	-206.32
E4	16" x 16"	324	516.67	2.03	98.67		0.00				72.75	171.43	128.49	227.17		227.17	-227.17
E6	16" x 16"	324	468.75	2.03	89.52		0.00				66.27	155.79	116.80	206.32		206.32	-206.32
E5	16" x 16"	324	516.67	0.00	100.26		0.00				69.92	170.18	126.06	226.33		226.33	-226.33
C3	23" x 23"	529	500.00	2.03	95.49	8	6.28	1,367.9	889.16	622.41	70.50	165.99	124.43	219.92	622.41	219.92	402.49
C4	23" x 23"	529	500.00	2.03	95.49	8	6.28	1,367.9	889.16	622.41	70.50	165.99	124.43	219.92	622.41	219.92	402.49
B3	16" x 16"	324	375.00	3.04	71.62	8	6.28	949.7	617.33	432.13	55.00	126.62	95.14	166.76	432.13	166.76	265.37
B4	16" x 16"	324	375.00	3.04	71.62	8	6.28	949.7	617.33	432.13	55.00	126.62	95.14	166.76	432.13	166.76	265.37
B3.3	16" x 16"	324	250.00	3.04	47.75	8	6.28	949.7	617.33	432.13	36.08	85.83	64.64	112.39	432.13	112.39	319.74
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

ϕ	0.65

Changed Occupancy Second Floor Column Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7φPo (k)	Total Load (k)	Difference
A3	18" x 18"	324	527.08	4.56	231.70	10	9.82	1,112.2	722.91	506.04	77.71	309.40	134.07	365.77	506.04	365.77	140.27
A5	23" x 23"	529	562.50	4.56	249.55	10	9.82	1,530.4	994.74	696.32	82.50	332.05	142.71	392.26	696.32	392.26	304.06
A6	23" x 23"	529	527.08	7.44	234.14	10	9.82	1,530.4	994.74	696.32	81.74	315.88	137.53	371.67	696.32	371.67	324.64
B1	23" x 23"	529	250.00	4.56	113.62	10	9.82	1,530.4	994.74	696.32	40.21	153.83	66.47	180.09	696.32	180.09	516.23
C8	23" x 23"	529	250.00	4.56	113.62	10	9.82	1,530.4	994.74	696.32	40.21	153.83	66.47	180.09	696.32	180.09	516.23
D1	23" x 23"	529	250.00	4.56	113.62	10	9.82	1,530.4	994.74	696.32	40.21	153.83	66.47	180.09	696.32	180.09	516.23
B8	18" x 18"	324	250.00	4.56	113.62	10	9.82	1,112.2	722.91	506.04	40.21	153.83	66.47	180.09	506.04	180.09	325.95
D8	18" x 18"	324	250.00	4.56	113.62	10	9.82	1,112.2	722.91	506.04	40.21	153.83	66.47	180.09	506.04	180.09	325.95
C1	23" x 23"	529	250.00	4.56	111.17	10	9.82	1,530.4	994.74	696.32	40.21	151.38	66.47	177.64	696.32	177.64	518.68
E1	23" x 23"	529	162.00	7.44	72.90	10	9.82	1,530.4	994.74	696.32	32.34	105.23	48.45	121.35	696.32	121.35	574.97
E8	23" x 23"	529	162.00	7.44	72.90	10	9.82	1,530.4	994.74	696.32	32.34	105.23	48.45	121.35	696.32	121.35	574.97
B2	23" x 23"	529	460.00	7.44	204.96	10	9.82	1,530.4	994.74	696.32	72.66	277.63	121.16	326.13	696.32	326.13	370.19
C7	23" x 23"	529	460.00	7.44	204.96	10	9.82	1,530.4	994.74	696.32	72.66	277.63	121.16	326.13	696.32	326.13	370.19
E2	23" x 23"	529	350.75	7.44	155.00	10	9.82	1,530.4	994.74	696.32	57.88	212.88	94.51	249.50	696.32	249.50	446.82
C2	23" x 23"	529	460.00	4.56	202.52	11	11.88	1,625.1	1,056.33	739.43	68.63	271.14	117.70	320.22	739.43	320.22	419.21
B7	23" x 23"	529	460.00	7.44	204.96	10	9.82	1,530.4	994.74	696.32	72.66	277.63	121.16	326.13	696.32	326.13	370.19
A2	16" x 16"	256	325.35	3.60	143.95	10	9.82	973.5	632.74	442.92	49.07	193.02	83.70	227.65	442.92	227.65	215.27
A7	16" x 16"	256	325.35	3.60	143.95	10	9.82	973.5	632.74	442.92	49.07	193.02	83.70	227.65	442.92	227.65	215.27
D2	23" x 23"	529	460.00	4.56	202.52	10	9.82	1,530.4	994.74	696.32	68.63	271.14	117.70	320.22	696.32	320.22	376.10
D7	23" x 23"	529	460.00	4.56	204.96	10	9.82	1,530.4	994.74	696.32	68.63	273.59	117.70	322.67	696.32	322.67	373.65
E7	18" x 18"	324	350.75	4.56	157.44	10	9.82	1,112.2	722.91	506.04	53.84	211.29	91.05	248.49	506.04	248.49	257.55
B5	23" x 23"	529	500.00	7.44	222.36	11	11.88	1,625.1	1,056.33	739.43	78.08	300.44	130.92	353.29	739.43	353.29	386.15
B6	23" x 23"	529	500.00	7.44	222.36	11	11.88	1,625.1	1,056.33	739.43	78.08	300.44	130.92	353.29	739.43	353.29	386.15
C6	23" x 23"	529	500.00	7.44	222.36	10	9.82	1,530.4	994.74	696.32	78.08	300.44	130.92	353.29	696.32	353.29	343.03
C5	23" x 23"	529	500.00	7.44	222.36	10	9.82	1,530.4	994.74	696.32	78.08	300.44	130.92	353.29	696.32	353.29	343.03
A4	18" x 18"	324	562.50	4.56	247.10	10	9.82	1,112.2	722.91	506.04	82.50	329.80	142.71	389.81	506.04	389.81	116.22
D3	23" x 23"	529	500.00	4.56	222.95		0.00				74.04	296.99	127.46	350.42			
D6	18" x 18"	324	500.00	4.56	222.95		0.00				74.04	296.99	127.46	350.42			
D4	23" x 23"	529	500.00	7.44	222.95		0.00				78.08	301.03	130.92	353.88			
D5	23" x 23"	529	500.00	4.56	222.95		0.00				74.04	296.99	127.46	350.42			
E3			468.75	4.56	206.32		0.00				69.81	276.14	119.84	326.16			
E4			516.67	4.56	227.17		0.00				76.30	303.46	131.53	358.70			
E6			468.75	4.56	206.32		0.00				69.81	276.14	119.84	326.16			
E5			516.67	4.56	226.33		0.00				76.30	302.62	131.53	357.86			
C3	24" x 24'	576	500.00	7.44	219.92	9	7.95	1,540.5	1,001.34	700.94	78.08	297.99	130.92	350.84	700.94	350.84	350.10
C4	24" x 24'	576	500.00	7.44	219.92	9	7.95	1,540.5	1,001.34	700.94	78.08	297.99	130.92	350.84	700.94	350.84	350.10
B3	23" x 23"	529	375.00	4.56	166.76	9	7.95	1,444.6	939.02	657.31	57.13	223.88	96.96	263.72	657.31	263.72	393.59
B4	23" x 23"	529	375.00	4.56	166.76	9	7.95	1,444.6	939.02	657.31	57.13	223.88	96.96	263.72	657.31	263.72	393.59
B3.3	24" x 18"	432	250.00	4.56	112.39	9	7.95	1,246.8	810.39	567.28	40.21	152.60	66.47	178.85	567.28	178.85	388.42
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

ϕ	0.65

Changed Occupancy First Floor Column Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7φPo (k)	Total Load (k)	Difference
A3	24" x 24"	576	527.08	4.56	365.77	10	9.82	1,626.3	1,057.06	739.94	77.71	443.47	134.07	499.84	739.94	499.84	240.10
A5	24" x 24"	576	562.50	7.44	392.26	10	9.82	1,626.3	1,057.06	739.94	86.53	478.80	146.17	538.43	739.94	538.43	201.51
A6	24" x 24"	576	527.08	7.44	371.67	10	9.82	1,626.3	1,057.06	739.94	81.74	453.42	137.53	509.21	739.94	509.21	230.74
B1	24" x 24"	576	250.00	7.44	180.09	10	9.82	1,626.3	1,057.06	739.94	44.25	224.33	89.92	250.01	739.94	250.01	489.93
C8	24" x 24"	576	250.00	7.44	180.09	10	9.82	1,626.3	1,057.06	739.94	44.25	224.33	97.92	278.01	739.94	278.01	461.93
D1	24" x 24"	576	250.00	7.44	180.09	10	9.82	1,626.3	1,057.06	739.94	44.25	224.33	97.92	278.01	739.94	278.01	461.93
B8	24" x 24"	576	250.00	4.56	180.09	10	9.82	1,626.3	1,057.06	739.94	40.21	220.30	66.47	246.55	739.94	246.55	493.39
D8	24" x 24"	576	250.00	4.56	180.09	10	9.82	1,626.3	1,057.06	739.94	40.21	220.30	94.47	274.55	739.94	274.55	465.39
C1	24" x 24"	576	250.00	7.44	177.64	10	9.82	1,626.3	1,057.06	739.94	44.25	221.88	97.92	275.56	739.94	275.56	464.38
E1	24" x 24"	576	162.00	7.44	121.35	10	9.82	1,626.3	1,057.06	739.94	32.34	153.69	66.60	187.95	739.94	187.95	552.00
E8	24" x 24"	576	162.00	7.44	121.35	10	9.82	1,626.3	1,057.06	739.94	32.34	153.69	66.60	187.95	739.94	187.95	552.00
B2	24" x 24"	576	460.00	7.44	326.13	10	9.82	1,626.3	1,057.06	739.94	72.66	398.79	121.16	447.29	739.94	447.29	292.65
C7	24" x 24"	576	460.00	7.44	326.13	10	9.82	1,626.3	1,057.06	739.94	72.66	398.79	172.68	498.81	739.94	498.81	241.13
E2	24" x 24"	576	350.75	7.44	249.50	10	9.82	1,626.3	1,057.06	739.94	57.88	307.38	133.79	383.29	739.94	383.29	356.65
C2	24" x 24"	576	460.00	7.44	320.22	11	11.88	1,721.0	1,118.65	783.06	72.66	392.88	172.68	492.90	783.06	492.90	290.15
B7	29" x 29"	576	460.00	7.44	326.13	10	9.82	1,626.3	1,057.06	739.94	72.66	398.79	121.16	447.29	739.94	447.29	292.65
A2	24" x 24"	576	325.35	3.60	227.65	10	9.82	1,626.3	1,057.06	739.94	49.07	276.72	83.70	311.36	739.94	311.36	428.59
A7	24" x 24"	576	325.35	3.60	227.65	10	9.82	1,626.3	1,057.06	739.94	49.07	276.72	83.70	311.36	739.94	311.36	428.59
D2	24" x 24"	576	460.00	7.44	320.22	10	9.82	1,626.3	1,057.06	739.94	72.66	392.88	172.68	492.90	739.94	492.90	247.04
D7	24" x 24"	576	460.00	7.44	322.67	10	9.82	1,626.3	1,057.06	739.94	72.66	395.33	172.68	495.35	739.94	495.35	244.59
E7	24" x 24"	576	350.75	4.56	248.49	10	9.82	1,626.3	1,057.06	739.94	53.84	302.33	130.33	378.82	739.94	378.82	361.12
B5	24" x 24"	576	500.00	7.44	353.29	11	11.88	1,721.0	1,118.65	783.06	78.08	431.36	130.92	484.21	783.06	484.21	298.85
B6	29" x 29"	841	500.00	7.44	353.29	11	11.88	2,261.6	1,470.04	1,029.03	78.08	431.36	130.92	484.21	1,029.03	484.21	544.82
								0.0	0.00								
C6	24" x 24"	576	500.00	7.44	353.29	10	9.82	1,626.3	1,057.06	739.94	78.08	431.36	186.92	540.21	739.94	540.21	199.74
C5	24" x 24"	576	500.00	7.44	353.29	10	9.82	1,626.3	1,057.06	739.94	78.08	431.36	186.92	540.21	739.94	540.21	199.74
A4	24" x 24"	576	562.50	4.56	389.81	10	9.82	1,626.3	1,057.06	739.94	82.50	472.31	142.71	532.53	739.94	532.53	207.42
D3	23" x 23"	529	500.00	7.44	350.42		0.00				78.08	428.49	186.92	537.34			
D6	18" x 18"	324	500.00	4.56	350.42		0.00				74.04	424.46	183.46	533.88			
D4	23" x 23"	529	500.00	7.44	353.88		0.00				78.08	431.95	186.92	540.80			
D5	23" x 23"	529	500.00	7.44	350.42		0.00				78.08	428.49	186.92	537.34			
E3			468.75	0.00	326.16		0.00				63.43	389.60	166.87	493.03			
E4			516.67	0.00	358.70		0.00				69.92	428.61	183.93	542.62			
E6			468.75	0.00	326.16		0.00				63.43	389.60	166.87	493.03			
E5			516.67	0.00	357.86		0.00				69.92	427.77	183.93	541.79			
C3	24" x 24'	576	500.00	8.10	350.84	9	7.95	1,540.5	1,001.34	700.94	79.00	429.84	187.72	538.55	700.94	538.55	162.38
C4	24" x 24'	576	500.00	8.10	350.84	9	7.95	1,540.5	1,001.34	700.94	79.00	429.84	187.72	538.55	700.94	538.55	162.38
B3	23" x 23"	529	375.00	7.44	263.72	9	7.95	1,444.6	939.02	657.31	61.16	324.89	100.42	364.15	657.31	364.15	293.16
B4	23" x 23"	529	375.00	7.44	263.72	9	7.95	1,444.6	909.02	657.31	61.16	324.89	100.42	364.15	657.31	364.15	293.16
B3.3	24" x 18"	432	250.00	6.08	178.85	9	7.95	1,246.8	810.39	567.28	42.34	221.19	68.29	247.14	567.28	247.14	320.13
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

φ	0.65

Changed Occupancy Ground Floor Column Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7φPo (k)	Total Load (k)	Difference
A3	29" x 29"	841	527.08	3.38	499.84	10	9.82	2,166.9	1,408.45	985.92	76.05	575.89	191.69	691.53	985.92	691.53	294.39
A5	24" x 24"	576	562.50	5.51	538.43	10	9.82	1,626.3	1,057.06	739.94	83.83	622.27	206.86	745.29	739.94	745.29	-5.35
A6	29" x 29"	841	527.08	5.51	509.21	10	9.82	2,166.9	1,408.45	985.92	79.04	588.25	194.25	703.45	985.92	703.45	282.46
B1				5.51	250.01		0.00	0.0	0.00	0.00	7.71	257.72	6.61	256.62	0.00		
C8				5.51	278.01		0.00	0.0	0.00	0.00	7.71	285.72	6.61	284.62	0.00		
D1				5.51	278.01		0.00	0.0	0.00	0.00	7.71	285.72	6.61	284.62	0.00		
B8				3.38	246.55		0.00	0.0	0.00	0.00	4.73	251.28	4.05	250.60	0.00		
D8				3.38	274.55		0.00	0.0	0.00	0.00	4.73	279.28	4.05	278.60	0.00		
C1				5.51	275.56		0.00	0.0	0.00	0.00	7.71	283.28	6.61	282.18	0.00		
E1				5.51	187.95		0.00	0.0	0.00	0.00	7.71	195.66	6.61	194.56	0.00		
E8				5.51	187.95		0.00	0.0	0.00	0.00	7.71	195.66	6.61	194.56	0.00		
B2				5.51	447.29		0.00	0.0	0.00	0.00	7.71	455.00	6.61	453.90	0.00		
C7				5.51	498.81		0.00	0.0	0.00	0.00	7.71	506.52	6.61	505.42	0.00		
E2				5.51	383.29		0.00	0.0	0.00	0.00	7.71	391.01	6.61	389.91	0.00		
C2				5.51	492.90		0.00	0.0	0.00	0.00	7.71	500.62	6.61	499.52	0.00		
B7				5.51	447.29		0.00	0.0	0.00	0.00	7.71	455.00	6.61	453.90	0.00		
A2				2.67	311.36		0.00	0.0	0.00	0.00	3.73	315.09	3.20	314.56	0.00		
A7				2.67	311.36		0.00	0.0	0.00	0.00	3.73	315.09	3.20	314.56	0.00		
D2				5.51	492.90		0.00	0.0	0.00	0.00	7.71	500.82	6.61	499.52	0.00		
D7				5.51	495.35		0.00	0.0	0.00	0.00	7.71	503.07	6.61	501.96	0.00		
E7				3.38	378.82		0.00	0.0	0.00	0.00	4.73	383.55	4.05	382.87	0.00		
B5	29" x 29"	841	500.00	5.51	484.21	11	11.88	2,261.6	1,470.04	1,029.03	75.38	559.59	184.61	668.82	1,029.03	668.82	360.21
B6	29" x 29"	841	500.00	5.51	484.21	11	11.88	2,261.6	1,470.04	1,029.03	75.38	559.59	184.61	668.82	1,029.03	668.82	360.21
C6				5.51	540.21		0.00	0.0	0.00	0.00	7.71	547.92	6.61	546.82	0.00		
C5				5.51	540.21		0.00	0.0	0.00	0.00	7.71	547.92	6.61	546.82	0.00		
A4				3.38	532.53		0.00	0.0	0.00	0.00	4.73	537.25	4.05	536.58	0.00		
D3				5.51	537.34		0.00	0.0	0.00	0.00	7.71	545.05	6.61	543.95	0.00		
D6				3.38	533.88		0.00	0.0	0.00	0.00	4.73	538.61	4.05	537.93	0.00		
D4				5.51	540.80		0.00	0.0	0.00	0.00	7.71	548.51	6.61	547.41	0.00		
D5				5.51	537.34		0.00	0.0	0.00	0.00	7.71	545.05	6.61	543.95	0.00		
E3				0.00	493.03		0.00	0.0	0.00	0.00	0.00	493.03	0.00	493.03	0.00		
E4				0.00	542.62		0.00	0.0	0.00	0.00	0.00	542.62	0.00	542.62	0.00		
E6				0.00	493.03		0.00	0.0	0.00	0.00	0.00	493.03	0.00	493.03	0.00		
E5				0.00	541.79		0.00	0.0	0.00	0.00	0.00	541.79	0.00	541.79	0.00		
C3	29" x 29"	841	500.00	6.00	538.55	9	7.95	2,081.1	1,352.73	946.91	76.06	614.62	185.20	723.75	946.91	723.75	223.16
C4	24" x 24"	576	500.00	6.00	538.55	9	7.95	1,540.5	1,001.34	700.94	76.06	614.62	185.20	723.75	700.94	723.75	-22.81
B3	29" x 29"	841	375.00	5.51	364.15	9	7.95	2,081.1	1,352.73	946.91	58.46	422.61	140.11	504.26	946.91	504.26	442.65
B4	24" x 24"	576	375.00	5.51	364.15	9	7.95	1,540.5	1,001.34	700.94	58.46	422.61	140.11	504.26	700.94	504.26	196.68
B3.3	24" x 18"	432	250.00	4.50	247.14	9	7.95	1,246.8	810.39	567.28	40.13	287.27	94.40	341.54	567.28	341.54	225.74
A3.3	12" x 24"	288	283.33	0.00	0.00	9	7.95	953.0	619.45	433.62	38.34	38.34	100.86	100.86	433.62	100.86	332.75
A5.5	12" x 24"	288	283.33	0.00	0.00	9	7.95	953.0	619.45	433.62	38.34	38.34	100.86	100.86	433.62	100.86	332.75

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150
	ksi
f'c	3
fy	60
	ft
Column Height	10.0
φ	0.65

Changed Occupancy Sub-Ground Floor Column Sheet

Name	Max Column Size	Max Column Size (sq. in.)	Footing Type	Footing Area (sf)	Footing Height (ft)	Footing Self Weight (k)	Load Above (k)	Total Load (k)	Bearing Pressure (psi)
A3	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	691.53	732.52	9,043.5
A5	24" x 24"	576	9.5' x 9.5' x 2.5' (V)	90.25	2.50	47.4	745.29	792.67	8,783.1
A6	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	703.45	744.45	9,190.7
B1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	256.62	276.28	5,638.3
C8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	284.62	304.28	6,209.7
D1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	284.62	304.28	6,209.7
B8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	250.60	270.25	5,515.4
D8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	278.60	298.25	6,086.8
C1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	282.18	301.83	6,159.8
E1	24" x 24"	576	Bat Footing?			0.0	194.56	194.56	#DIV/0!
E8	24" x 24"	576	Bat Footing?			0.0	194.56	194.56	#DIV/0!
B2	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	453.90	509.76	5,097.6
C7	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	505.42	561.28	5,612.8
E2	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	389.91	445.77	4,457.7
C2	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	499.52	555.38	5,553.8
B7	29" x 29"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	453.90	509.76	5,097.6
A2	24" x 24"	576	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	314.56	355.55	4,389.5
A7	24" x 24"	576	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	314.56	355.55	4,389.5
D2	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	499.52	555.38	5,553.8
D7	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	501.96	557.82	5,578.2
E7	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	382.87	438.73	4,387.3
B5	29" x 29"	841	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	668.82	724.68	7,246.8
B6	29" x 29"	841	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	668.82	724.68	7,246.8
C6	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	546.82	602.68	6,026.8
C5	24" x 24"	576	10' x 10' x 2.68' (VI)	100.00	2.68	55.9	546.82	602.68	6,026.8
A4	24" x 24"	576	9.5' x 9.5' x 2.5' (V)	90.25	2.50	47.4	536.56	583.96	6,470.5
D3	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	543.95	576.25	8,731.0
D6	18" x 18"	324	8.5' x 8.5' x 2.33' (III)	72.25	2.33	35.4	537.93	573.28	7,934.7
D4	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	547.41	579.71	8,783.4
D5	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	543.95	576.25	8,731.0
E3			Bat Footing?			0.0	493.03	493.03	#DIV/0!
E4			Bat Footing?			0.0	542.62	542.62	#DIV/0!
E6			Bat Footing?			0.0	493.03	493.03	#DIV/0!
E5			Bat Footing?			0.0	541.79	541.79	#DIV/0!
C3	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	723.75	764.74	9,441.3
C4	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	723.75	743.40	15,171.5
B3	29" x 29"	841	7' x 7' x 1.91' (II)	49.00	1.91	19.7	504.26	523.91	10,692.1
B4	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	504.26	523.91	10,692.1
B3.3	24" x 18"	432	7' x 7' x 1.91' (II)	49.00	1.91	19.7	341.54	361.19	7,371.3
A3.3	12" x 24"	288	3.5' x 3.5' x 1.33' (I)	12.25	1.33	3.4	100.86	104.28	8,513.0
A5.5	12" x 24"	288	3.5' x 3.5' x 1.33' (I)	12.25	1.33	3.4	100.86	104.28	8,513.0

Name	Existing Bearing Pressure (psi)	Proposed Bearing Pressure (psi)	Change (psi)	% Change
A3	11,229.9	9,043.5	-2,186.42	-19.5%
A5	10,877.3	8,783.1	-2,094.18	-19.3%
A6	11,377.1	9,190.7	-2,186.42	-19.2%
B1	7,352.6	5,638.3	-1,714.29	-23.3%
C8	7,352.6	6,209.7	-1,142.86	-15.5%
D1	7,352.6	6,209.7	-1,142.86	-15.5%
B8	7,229.7	5,515.4	-1,714.29	-23.7%
D8	7,229.7	6,086.8	-1,142.86	-15.8%
C1	7,302.6	6,159.8	-1,142.86	-15.6%
E1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
E8	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
B2	6,643.2	5,097.6	-1,545.60	-23.3%
C7	6,643.2	5,612.8	-1,030.40	-15.5%
E2	5,243.4	4,457.7	-785.68	-15.0%
C2	6,584.2	5,553.8	-1,030.40	-15.6%
B7	6,643.2	5,097.6	-1,545.60	-23.3%
A2	5,739.1	4,389.5	-1,349.62	-23.5%
A7	5,739.1	4,389.5	-1,349.62	-23.5%
D2	6,584.2	5,553.8	-1,030.40	-15.6%
D7	6,608.6	5,578.2	-1,030.40	-15.6%
E7	5,173.0	4,387.3	-785.68	-15.2%
B5	8,963.4	7,246.8	-1,716.63	-19.2%
B6	8,950.8	7,246.8	-1,704.03	-19.0%
C6	7,170.8	6,026.8	-1,144.03	-16.0%
C5	7,183.4	6,026.8	-1,156.63	-16.1%
A4	8,564.6	6,470.5	-2,094.18	-24.5%
D3	10,428.0	8,731.0	-1,696.97	-16.3%
D6	9,484.9	7,934.7	-1,550.17	-16.3%
D4	10,480.4	8,783.4	-1,696.97	-16.2%
D5	10,428.0	8,731.0	-1,696.97	-16.3%
E3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
E4	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
E6	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
E5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
C3	10,862.5	9,441.3	-1,421.17	-13.1%
C4	17,546.5	15,171.5	-2,375.00	-13.5%
B3	13,327.1	10,692.1	-2,635.00	-19.8%
B4	13,352.8	10,692.1	-2,660.71	-19.9%
B3.3	9,085.6	7,371.3	-1,714.29	-18.9%
A3.3	8,513.0	8,513.0	0.00	0.0%
A5.5	8,513.0	8,513.0	0.00	0.0%

Name	Existing Load (k)	Proposed Load (k)	Change (k)	% Change
A3	909.62	732.52	-177.10	-19.5%
A5	981.67	792.67	-189.00	-19.3%
A6	921.55	744.45	-177.10	-19.2%
B1	360.28	276.28	-84.00	-23.3%
C8	360.28	304.28	-56.00	-15.5%
D1	360.28	304.28	-56.00	-15.5%
B8	354.25	270.25	-84.00	-23.7%
D8	354.25	298.25	-56.00	-15.8%
C1	357.83	301.83	-56.00	-15.6%
E1	230.85	194.56	-36.29	-15.7%
E8	230.85	194.56	-36.29	-15.7%
B2	664.32	509.76	-154.56	-23.3%
C7	664.32	561.28	-103.04	-15.5%
E2	524.34	445.77	-78.57	-15.0%
C2	658.42	555.38	-103.04	-15.6%
B7	664.32	509.76	-154.56	-23.3%
A2	464.87	355.55	-109.32	-23.5%
A7	464.87	355.55	-109.32	-23.5%
D2	658.42	555.38	-103.04	-15.6%
D7	660.86	557.82	-103.04	-15.6%
E7	517.30	438.73	-78.57	-15.2%
B5	896.34	724.68	-171.66	-19.2%
B6	895.08	724.68	-170.40	-19.0%
C6	717.08	602.68	-114.40	-16.0%
C5	718.34	602.68	-115.66	-16.1%
A4	772.96	583.96	-189.00	-24.5%
D3	688.25	576.25	-112.00	-16.3%
D6	685.28	573.28	-112.00	-16.3%
D4	691.71	579.71	-112.00	-16.2%
D5	688.25	576.25	-112.00	-16.3%
E3	598.03	493.03	-105.00	-17.6%
E4	658.36	542.62	-115.73	-17.6%
E6	598.03	493.03	-105.00	-17.6%
E5	557.25	541.79	-15.47	-2.8%
C3	879.86	764.74	-115.12	-13.1%
C4	859.78	743.40	-116.38	-13.5%
B3	653.03	523.91	-129.12	-19.8%
B4	654.29	523.91	-130.38	-19.9%
B3.3	445.19	361.19	-84.00	-18.9%
A3.3	104.28	104.28	0.00	0.0%
A5.5	104.28	104.28	0.00	0.0%

	(psf)
Roof Dead Load	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.68
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

Existing Bearing Pressure (psi)	Proposed Bearing Pressure (psi)	Change (psi)	% Change
6,643.2	5,612.8	-1,030.40	-15.5%

Existing Load (k)	Proposed Load (k)	Change (k)	% Change
664.32	561.28	-103.04	-15.5%

Changed Occupancy Footing Sheet

	Current Design Allowable additional Load (kips)								
Column	Ground Floor	First Floor	Second Floor	Third Floor	Governing (Min Value)	Column	Original	Current	Increase
A3	240.10	140.27	274.34	106.91	106.91	A3	22.20	106.91	84.70
A5	201.51	304.06	256.49	234.73	201.51	A5	12.51	201.51	189.00
A6	230.74	324.64	462.18	241.50	230.74	A6	53.64	230.74	177.10
B1	489.93	516.23	392.42	386.80	386.80	B1	364.42	386.80	22.38
C8	461.93	516.23	392.42	386.80	386.80	C8	364.42	386.80	22.38
D1	461.93	516.23	392.42	386.80	386.80	D1	364.42	386.80	22.38
B8	493.39	325.95	392.42	386.80	325.95	B8	269.95	325.95	56.00
D8	465.39	325.95	392.42	386.80	325.95	D8	269.95	325.95	56.00
C1	464.38	518.68	394.86	252.21	252.21	C1	252.21	252.21	0.00
E1	552.00	574.97	623.42	269.02	269.02	E1	269.02	269.02	0.00
E8	552.00	574.97	623.42	269.02	269.02	E8	269.02	269.02	0.00
B2	292.65	370.19	491.35	346.69	292.65	B2	138.09	292.65	154.56
C7	241.13	370.19	491.35	346.69	241.13	C7	138.09	241.13	103.04
E2	356.65	446.82	541.32	232.97	232.97	E2	232.97	232.97	0.00
C2	290.15	419.21	303.52	212.10	212.10	C2	187.11	212.10	24.99
B7	292.65	370.19	491.35	346.69	292.65	B7	138.09	292.65	154.56
A2	428.59	215.27	298.97	237.82	215.27	A2	142.39	215.27	72.88
A7	428.59	215.27	298.97	237.82	215.27	A7	142.39	215.27	72.88
D2	247.04	376.10	303.52	212.10	212.10	D2	144.00	212.10	68.10
D7	244.59	373.65	301.07	346.69	244.59	D7	141.55	244.59	103.04
E7	361.12	257.55	348.59	367.56	257.55	E7	178.98	257.55	78.57
B5	298.85	386.15	473.96	339.05	298.85	B5	130.85	298.85	168.00
B6	544.82	386.15	473.96	339.05	339.05	B6	274.15	339.05	64.91
C6	199.74	343.03	369.25	224.09	199.74	C6	87.74	199.74	112.00
C5	199.74	343.03	369.25	224.09	199.74	C5	87.74	199.74	112.00
A4	207.42	116.22	154.23	77.56	77.56	A4	-9.78	77.56	87.34
D3	N/A	N/A	N/A	N/A		D3	N/A	N/A	N/A
D6	N/A	N/A	N/A	N/A		D6	N/A	N/A	N/A
D4	N/A	N/A	N/A	N/A		D4	N/A	N/A	N/A
D5	N/A	N/A	N/A	N/A		D5	N/A	N/A	N/A
E3	N/A	N/A	N/A	N/A		E3	N/A	N/A	N/A
E4	N/A	N/A	N/A	N/A		E4	N/A	N/A	N/A
E6	N/A	N/A	N/A	N/A		E6	N/A	N/A	N/A
E5	N/A	N/A	N/A	N/A		E5	N/A	N/A	N/A
C3	162.38	350.10	402.49	169.56	162.38	C3	50.38	162.38	112.00
C4	162.38	350.10	402.49	169.56	162.38	C4	50.38	162.38	112.00
B3	293.16	393.59	265.37	260.27	260.27	B3	167.16	260.27	93.10
B4	293.16	393.59	265.37	260.27	260.27	B4	167.16	260.27	93.10
B3.3	320.13	388.42	319.74	152.75	152.75	B3.3	152.75	152.75	0.00
A3.3	0.00	0.00	0.00	0.00	0.00	A3.3	0.00	0.00	0.00
A5.5	0.00	0.00	0.00	0.00	0.00	A5.5	0.00	0.00	0.00

Changed Occupancy Allowable Load Difference Sheet

C: Proposed Load Structural Spreadsheets

New Addition Columns

Column	Trib Area (Roof Above) (sf)	1.4(D) (kips)	1.2D+1.6LR (kips)	1.2D+1.6S+0.5LR (kips)
A3				
A5				
A6				
B1				
C8	305.00	27.76	33.55	51.24
D1				
B8	206.00	18.75	22.66	34.61
D8				
C1				
E1				
E8				
B2				
C7	482.00	43.86	53.02	80.98
E2				
C2				
B7	398.00	36.22	43.78	66.86
A2				
A7				
D2				
D7				
E7				
B5	921.00	83.81	101.31	154.73
B6	508.00	46.23	55.88	85.34
C6	562.00	51.14	61.82	94.42
C5				
A4	179.00	16.29	19.69	30.07
D3				
D6				
D4	388.00	35.31	42.68	65.18
D5	604.00	54.96	66.44	101.47
E3				
E4	168.00	15.29	18.48	28.22
E6				
E5				
C3				
C4				
B3				
B4	388.00	35.31	42.68	65.18
B3.3				
A3.3				
A5.5				

Column	Tributary Area (sf)	Roof Load (kips)
C8	305.00	51.24
B8	206.00	34.61
C7	482.00	80.98
B7	398.00	66.86
B5	921.00	154.73
B6	508.00	85.34
C6	562.00	94.42
A4	179.00	30.07
D4	388.00	65.18
D5	604.00	101.47
E4	168.00	28.22
B4	388.00	65.18

	(psf)
space frame dead	65.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

kg/m^2	50.00
lb/ft	10.24

	(pcf)
Concrete Weight	150

	(ksi)
f'c	3
fy	60

	(ft)
Column Height	13.5

ϕ	0.65

Proposed Addition Interior Columns Sheet

New Undershell Columns

Column	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)
A3	12" x 12"	144		0.00		6	3.53	456.2	296.53	207.57				
A5	17" x 17"	289	383.00	0.00		6	3.53	752.0	488.80	342.16	51.83	51.83	93.45	93.45
A6	17" x 17"	289	383.00	0.00		6	3.53	752.0	488.80	342.16	51.83	51.83	93.45	93.45
B1	17" x 17"	289		0.00		9	7.95	955.0	620.78	434.54				
C8	17" x 17"	289	239.00	0.00	51.24	9	7.95	955.0	620.78	434.54	32.34	83.58	58.31	109.55
D1	17" x 17"	289		0.00		9	7.95	955.0	620.78	434.54				
B8	17" x 17"	289	224.00	0.00	34.61	9	7.95	955.0	620.78	434.54	30.31	64.92	54.65	89.26
D8	17" x 17"	289	101.00	0.00		9	7.95	955.0	620.78	434.54	13.67	13.67	24.64	24.64
C1	12" x 12"	144		0.00		9	7.95	659.2	428.51	299.95				
E1	12" x12"	144		0.00		9	7.95	659.2	428.51	299.95				
E8	12" x12"	144		0.00		9	7.95	659.2	428.51	299.95				
B2	17" x 17"	289		0.00		9	7.95	955.0	620.78	434.54				
C7	17" x 17"	289	335.00	0.00	80.98	9	7.95	955.0	620.78	434.54	45.33	126.31	81.74	162.71
E2	12" x 12"	144		0.00		9	7.95	659.2	428.51	299.95				
C2	12" x 12"	144		0.00		9	7.95	659.2	428.51	299.95				
B7	17" x 17"	289	335.00	0.00	66.86	9	7.95	955.0	620.78	434.54	45.33	112.20	81.74	148.60
A2	12" x 12"	144		0.00		9	7.95	659.2	428.51	299.95				
A7	12" x 12"	144	274.00	0.00		9	7.95	659.2	428.51	299.95	37.08	37.08	66.85	66.85
D2	12" x 12"	144		0.00		9	7.95	659.2	428.51	299.95				
D7	17" x 17"	289	326.00	0.00		9	7.95	955.0	620.78	434.54	44.12	44.12	79.54	79.54
E7	17" x 17"	289		0.00		9	7.95	955.0	620.78	434.54				
B5	17" x 17"	289	500.00	0.00	154.73	9	7.95	955.0	620.78	434.54	67.66	222.39	122.00	276.72
B6	17" x 17"	289	375.00	0.00	85.34	9	7.95	955.0	620.78	434.54	50.75	136.09	91.50	176.84
C6	17" x 17"	289	375.00	0.00	94.42	5	2.45	702.4	456.54	319.58	50.75	145.16	91.50	185.91
C5	17" x 17"	289	500.00	0.00		5	2.45	702.4	456.54	319.58	67.66	67.66	122.00	122.00
A4	12" x 12"	144	192.00	0.00	30.07	5	2.45	406.6	264.27	184.99	25.96	56.05	46.85	76.92
D3	18" x 18"	324		0.00			0.00							
D6	18" x 18"	324	500.00	0.00			0.00				67.66	67.66	122.00	122.00
D4	18" x 18"	324	247.00	0.00	65.18		0.00				33.43	98.61	60.27	125.45
D5	18" x 18"	324	500.00	0.00	101.47		0.00				67.66	169.13	122.00	223.47
E3	12" x 12"	144		0.00			0.00							
E4	12" x 12"	144	221.00	0.00	28.22		0.00				29.91	58.13	53.92	82.15
E6	12" x 12"	144	255.00	0.00			0.00				34.51	34.51	62.22	62.22
E5			442.00	0.00			0.00				59.81	59.81	107.84	107.84
C3	12" x 12"	144		0.00		8	6.28	582.5	378.65	265.05				
C4	12" x 12"	144	250.00	0.00		8	6.28	582.5	378.65	265.05	33.83	33.83	61.00	61.00
B3	12" x 18"	216		0.00		8	6.28	729.4	474.12	331.88				
B4	12" x 18"	216	250.00	0.00	65.18	8	6.28	729.4	474.12	331.88	33.83	99.02	61.00	126.18
B3.3	12" x 18"	216		0.00			0.00	440.6	286.42	200.49				
A3.3				0.00			0.00	0.0	0.00	0.00				
A5.5				0.00			0.00	0.0	0.00	0.00				

Column	Load Above (Roof Load)	Tributary Area (sf)	Floor Load (1.2D + 1.6L) (k)	Total Load
A3				
A5		383.00	93.45	93.45
A6		383.00	93.45	93.45
B1				
C8	51.24	239.00	58.31	109.55
D1				
B8	34.61	224.00	54.65	89.26
D8		101.00	24.64	24.64
C1				
E1				
E8				
B2				
C7	80.98	335.00	81.74	162.71
E2				
C2				
B7	66.86	335.00	81.74	148.60
A2				
A7		274.00	66.85	66.85
D2				
D7		326.00	79.54	79.54
E7				
B5	154.73	500.00	122.00	276.72
B6	85.34	375.00	91.50	176.84
C6	94.42	375.00	91.50	185.91
C5		500.00	122.00	122.00
A4	30.07	192.00	46.85	76.92
D3				
D6		500.00	122.00	122.00
D4	65.18	247.00	60.27	125.45
D5	101.47	500.00	122.00	223.47
E3				
E4	28.22	221.00	53.92	82.15
E6		255.00	62.22	62.22
E5		442.00	107.84	107.84
C3				
C4		250.00	61.00	61.00
B3				
B4	65.18	250.00	61.00	126.18
B3.3				
A3.3				
A5.5				

	(psf)
Addition Slab	96.66
Live Load	80
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

ϕ	0.65

Proposed Addition Under Slab Column Sheet

Column	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6LR	Total Load (k)	1.2D+1.6S+0.5LR (k)	Total Load (k)
A3	12" x 12"	144	527.08	0.00		6	3.53	456.2	296.53	207.57	62.10	62.10	70.09	70.09	100.66	100.66
A5	17" x 17"	289	562.50	0.00	93.45	6	3.53	752.0	488.80	342.16						
A6	17" x 17"	289	527.08	0.00	93.45	6	3.53	752.0	488.80	342.16						
B1	17" x 17"	289	250.00	0.00		9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75
C8	17" x 17"	289	250.00	0.00	109.55	9	7.95	955.0	620.78	434.54	29.45	139.01				
D1	17" x 17"	289	250.00	0.00		9	7.95	955.0	620.78	434.54	29.45	29.45	33.25	33.25	47.75	47.75
B8	17" x 17"	289	250.00	0.00	89.26	9	7.95	955.0	620.78	434.54						
D8	17" x 17"	289	250.00	0.00	24.64	9	7.95	955.0	620.78	434.54						
C1	12" x 12"	144	250.00	0.00		9	7.95	659.2	428.51	299.95	29.45	29.45	33.25	33.25	47.75	47.75
E1	12" x12"	144	162.00	0.00		9	7.95	659.2	428.51	299.95	19.09	19.09	21.54	21.54	30.94	30.94
E8	12" x12"	144	162.00	0.00		9	7.95	659.2	428.51	299.95	19.09	19.09	21.54	21.54	30.94	30.94
B2	17" x 17"	289	460.00	0.00		9	7.95	955.0	620.78	434.54	54.19	54.19	61.17	61.17	87.85	87.85
C7	17" x 17"	289	335.00	0.00	162.71	9	7.95	955.0	620.78	434.54	39.47	202.18				
E2	12" x 12"	144	350.75	0.00		9	7.95	659.2	428.51	299.95	41.32	41.32	46.64	46.64	66.99	66.99
C2	12" x 12"	144	460.00	0.00		9	7.95	659.2	428.51	299.95	54.19	54.19	61.17	61.17	87.85	87.85
B7	17" x 17"	289	335.00	0.00	148.60	9	7.95	955.0	620.78	434.54	39.47	188.07				
A2	12" x 12"	144	325.35	0.00		9	7.95	659.2	428.51	299.95	38.33	38.33	43.27	43.27	62.14	62.14
A7	12" x 12"	144	325.35	0.00	66.85	9	7.95	659.2	428.51	299.95						
D2	12" x 12"	144	460.00	0.00		9	7.95	659.2	428.51	299.95	54.19	54.19	61.17	61.17	87.85	87.85
D7	17" x 17"	289	460.00	0.00	79.54	9	7.95	955.0	620.78	434.54						
E7	17" x 17"	289	350.75	0.00		9	7.95	955.0	620.78	434.54	41.32	41.32	46.64	46.64	66.99	66.99
B5	17" x 17"	289	375.00	0.00	276.72	9	7.95	955.0	620.78	434.54	44.18	320.90				
B6	17" x 17"	289	375.00	0.00	176.84	9	7.95	955.0	620.78	434.54	44.18	221.02				
C6	17" x 17"	289	375.00	0.00	185.91	5	2.45	702.4	456.54	319.58	44.18	230.09				
C5	17" x 17"	289	375.00	0.00	122.00	5	2.45	702.4	456.54	319.58	44.18	166.17				
A4	12" x 12"	144	562.50	0.00	76.92	5	2.45	406.6	264.27	184.99						
D3	18" x 18"	324	500.00	0.00			0.00				58.91	58.91	66.49	66.49	95.49	95.49
D6	18" x 18"	324	500.00	0.00	122.00		0.00				56.91	180.90				
D4	18" x 18"	324	500.00	0.00	125.45		0.00									
D5	18" x 18"	324	500.00	0.00	223.47		0.00				56.91	282.37				
E3	12" x 12"	144	468.75	0.00			0.00				55.22	55.22	62.33	62.33	89.52	89.52
E4	12" x 12"	144	516.67	0.00	82.15		0.00									
E6	12" x 12"	144	468.75	0.00	62.22		0.00									
E5			525.00	0.00	107.84		0.00									
C3	12" x 12"	144	500.00	0.00		8	6.28	582.5	378.65	265.05	58.91	58.91	66.49	66.49	95.49	95.49
C4	12" x 12"	144	500.00	0.00	61.00	8	6.28	582.5	378.65	265.05						
B3	12" x 18"	216	375.00	0.00		8	6.28	729.4	474.12	331.88	44.18	44.18	49.87	49.87	71.62	71.62
B4	12" x 18"	216	375.00	0.00	126.18	8	6.28	729.4	474.12	331.88						
B3.3	12" x 18"	216	250.00	0.00			0.00	440.6	286.42	200.49	29.45	29.45	33.25	33.25	47.75	47.75
A3.3				0.00			0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00			0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Column	Covered Slab Area (sf)	Load Above (kips)	Roof Area (sf)	1.4(D+F) (k)	1.2D+1.6S+0.5LR (k)	Factored Load (k)	Total Load (k)
A3							
A5	383.00	93.45	186.00	45.12	35.52	80.64	174.09
A6	383.00	93.45	141.00	45.12	26.93	72.05	165.50
B1							
C8							
D1							
B8	184.00	89.26	18.00	21.68	3.44	25.11	114.38
D8	82.00	24.64	117.00	9.66	22.34	32.01	56.65
C1							
E1							
E8							
B2							
C7							
E2							
C2							
B7							
A2							
A7	277.00	66.85	210.00	32.63	40.11	72.74	139.59
D2							
D7	344.00	79.54	156.00	40.53	29.79	70.32	149.86
E7							
B5							
B6							
C6							
C5							
A4	192.00	76.92	238.00	22.62	45.45	68.07	144.99
D3							
D6							
D4	250.00	125.45	250.00	29.45	47.75	77.20	202.65
D5							
E3							
E4	221.00	82.15	288.00	26.04	55.00	81.04	163.19
E6	255.00	62.22	211.00	30.04	40.30	70.34	132.56
E5	442.00	107.84	67.00	52.07	12.80	64.87	172.71
C3							
C4	250.00	61.00	250.00	29.45	47.75	77.20	138.20
B3							
B4	125.00	126.18	250.00	14.73	47.75	62.47	188.65
B3.3							47.75
A3.3							0.00
A5.5							0.00

Column	0.7φPo (k)	Total Load (k)	Difference
A3	207.57	100.66	106.91
A5	342.16	174.09	168.07
A6	342.16	165.50	176.66
B1	434.54	47.75	386.80
C8	434.54		434.54
D1	434.54	47.75	386.80
B8	434.54		434.54
D8	434.54	56.65	377.90
C1	299.95	47.75	252.21
E1	299.95	30.94	269.02
E8	299.95	30.94	269.02
B2	434.54	87.85	346.69
C7	434.54		434.54
E2	299.95	66.99	232.97
C2	299.95	87.85	212.10
B7	434.54		434.54
A2	299.95	62.14	237.82
A7	299.95	139.59	160.36
D2	299.95	87.85	212.10
D7	434.54	149.86	284.68
E7	434.54	66.99	367.56
B5	434.54		434.54
B6	434.54		434.54
C6	319.58		319.58
C5	319.58		319.58
A4	184.99	144.99	39.99
D3			
D6			
D4			
D5			
E3			
E4			
E6			
E5			
C3	265.05	95.49	169.56
C4	265.05	174.09	90.96
B3	331.88	71.62	260.27
B4	331.88	188.65	143.23
B3.3	200.49	47.75	152.75
A3.3	0.00	0.00	0.00
A5.5	0.00	0.00	0.00

Column	0.7φPo (k)	Total Load (k)	Difference
A3	193.37	100.66	92.70
A5	326.15	174.09	152.06
A6	326.15	165.50	160.65
B1	403.02	47.75	355.28
C8	403.02	157.30	245.72
D1	403.02	47.75	355.28
B8	403.02	137.01	266.01
D8	403.02	56.65	346.37
C1	270.24	47.75	222.49
E1	270.24	30.94	239.30
E8	270.24	30.94	239.30
B2	403.02	87.85	315.17
C7	403.02	226.69	176.33
E2	270.24	66.99	203.25
C2	270.24	87.85	182.38
B7	403.02	212.58	190.44
A2	270.24	62.14	208.10
A7	270.24	139.59	130.64
D2	270.24	87.85	182.38
D7	403.02	149.86	253.16
E7	403.02	66.99	336.04
B5	403.02	348.34	54.68
B6	403.02	248.46	154.56
C6	307.36	257.53	49.83
C5	307.36	193.61	113.75
A4	174.58	144.99	29.58
D3			
D6			
D4			
D5			
E3			
E4			
E6			
E5			
C3	241.20	95.49	145.71
C4	241.20	174.09	67.10
B3	307.13	71.62	235.51
B4	307.13	188.65	118.48
B3.3	197.81	47.75	150.06
A3.3	0.00	0.00	0.00
A5.5	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	7
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

φ	0.65

Proposed Third Floor Column Sheet

Column	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	ϕPo (k)	0.7ϕPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7ϕPo (k)	Total Load (k)	Difference (k)
A3	18" x 18"	324	527.08	2.03	100.66	10	9.82	1,112.2	722.91	506.04	74.16	174.82	131.03	231.70	506.04	231.70	274.34
A5	18" x 18"	324	562.50	4.06	174.09	10	9.82	1,112.2	722.91	506.04	81.81	255.90	142.12	316.21	506.04	316.21	189.82
A6	23" x 23"	529	527.08	4.06	165.50	10	9.82	1,530.4	994.74	696.32	77.02	242.52	133.48	298.98	696.32	298.98	397.34
B1	18" x 18"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	65.87	113.62	506.04	113.62	392.42
C8	18" x 18"	324	250.00	4.06	139.01	10	9.82	1,112.2	722.91	506.04	39.52	178.53	65.87	204.88	506.04	204.88	301.16
D1	18" x 18"	324	250.00	4.06	47.75	10	9.82	1,112.2	722.91	506.04	39.52	87.27	65.87	113.62	506.04	113.62	392.42
B8	18" x 18"	324	250.00	4.06	114.38	10	9.82	1,112.2	722.91	506.04	39.52	153.90	65.87	180.25	506.04	180.25	325.79
D8	18" x 18"	324	250.00	4.06	56.65	10	9.82	1,112.2	722.91	506.04	39.52	96.17	65.87	122.52	506.04	122.52	383.51
C1	18" x 18"	324	250.00	2.03	47.75	10	9.82	1,112.2	722.91	506.04	36.67	84.41	63.43	111.17	506.04	111.17	394.86
E1	23" x 23"	529	162.00	2.03	30.94	10	9.82	1,530.4	994.74	696.32	24.76	55.70	41.96	72.90	696.32	72.90	623.42
E8	23" x 23"	529	162.00	2.03	30.94	10	9.82	1,530.4	994.74	696.32	24.76	55.70	41.96	72.90	696.32	72.90	623.42
B2	23" x 23"	529	460.00	4.06	87.85	10	9.82	1,530.4	994.74	696.32	67.94	155.79	117.11	204.96	696.32	204.96	491.36
C7	23" x 23"	529	460.00	4.06	202.18	10	9.82	1,530.4	994.74	696.32	67.94	270.12	117.11	319.29	696.32	319.29	377.03
E2	23" x 23"	529	350.75	2.03	66.99	10	9.82	1,530.4	994.74	696.32	50.30	117.29	88.01	155.00	696.32	155.00	541.32
C2	18" x 18"	324	460.00	2.03	87.85	10	9.82	1,112.2	722.91	506.04	65.08	152.93	114.67	202.52	506.04	202.52	303.52
B7	23" x 23"	529	460.00	4.06	188.07	10	9.82	1,530.4	994.74	696.32	67.94	256.01	117.11	305.18	696.32	305.18	391.14
A2	16" x 16"	256	325.35	2.03	62.14	10	9.82	973.5	632.74	442.92	46.86	109.00	81.81	143.95	442.92	143.95	298.97
A7	16" x 16"	256	325.35	2.03	139.59	10	9.82	973.5	632.74	442.92	46.86	186.46	81.81	221.41	442.92	221.41	221.51
D2	18" x 18"	324	460.00	2.03	87.85	10	9.82	1,112.2	722.91	506.04	65.08	152.93	114.67	202.52	506.04	202.52	303.52
D7	18" x 18"	324	460.00	4.06	149.86	10	9.82	1,112.2	722.91	506.04	67.94	217.80	117.11	266.97	506.04	266.97	239.06
E7	18" x 18"	324	350.75	4.06	66.99	10	9.82	1,112.2	722.91	506.04	53.15	120.14	90.46	157.44	506.04	157.44	348.59
B5	23" x 23"	529	375.00	4.06	320.90	10	9.82	1,530.4	994.74	696.32	56.44	377.34	96.37	417.28	696.32	417.28	279.04
B6	23" x 23"	529	375.00	4.06	221.02	10	9.82	1,530.4	994.74	696.32	56.44	277.46	96.37	317.39	696.32	317.39	378.93
C6	23" x 23"	529	375.00	4.06	230.09	7	4.81	1,300.3	845.16	591.62	56.44	286.53	96.37	326.47	591.62	326.47	265.15
C5	23" x 23"	529	375.00	4.06	166.17	7	4.81	1,300.3	845.16	591.62	56.44	222.61	96.37	262.55	591.62	262.55	329.07
A4	18" x 18"	324	562.50	2.03	144.99	7	4.81	882.1	573.33	401.33	78.95	223.95	139.68	284.67	401.33	284.67	116.67
D3	18" x 18"	324	500.00	4.56	95.49		0.00				74.04	169.53	127.46	222.95			
D6	18" x 18"	324	500.00	4.56	180.90		0.00				74.04	254.94	127.46	308.36			
D4	23" x 23"	529	500.00	4.56	202.65		0.00				74.04	276.69	127.46	330.11			
D5	18" x 18"	324	500.00	4.56	282.37		0.00				74.04	356.41	127.46	409.84			
E3	18" x 18"	324	468.75	2.03	89.52		0.00				66.27	155.79	116.80	206.32			
E4	18" x 18"	324	516.67	2.03	163.18		0.00				72.75	235.94	128.49	291.68			
E6	18" x 18"	324	468.75	2.03	132.56		0.00				66.27	198.82	116.80	249.36			
E5	18" x 18"	324	516.67	0.00	172.71		0.00				69.92	242.63	126.06	298.77			
C3	23" x 23"	529	500.00	2.03	95.49	8	6.28	1,367.9	889.16	622.41	70.50	165.99	124.43	219.92	622.41	219.92	402.49
C4	23" x 23"	529	500.00	2.03	138.20	8	6.28	1,367.9	889.16	622.41	70.50	208.69	124.43	262.62	622.41	262.62	359.79
B3	18" x 18"	324	375.00	3.04	71.62	8	6.28	949.7	617.33	432.13	55.00	126.62	95.14	166.76	432.13	166.76	265.37
B4	18" x 18"	324	375.00	3.04	188.65	8	6.28	949.7	617.33	432.13	55.00	243.65	95.14	283.80	432.13	283.80	148.33
B3.3	18" x 18"	324	250.00	3.04	47.75	8	6.28	949.7	617.33	432.13	38.08	85.83	64.64	112.39	432.13	112.39	319.74
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

ϕ	0.65

Proposed Second Floor Column Sheet

Column	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7φPo (k)	Total Load (k)	Difference
A3	18" x 18"	324	527.08	4.56	231.70	10	9.62	1,112.2	722.91	506.04	77.71	309.40	134.07	365.77	506.04	365.77	140.27
A5	23" x 23"	529	562.50	4.56	316.21	10	9.62	1,530.4	994.74	696.32	82.50	398.71	142.71	458.93	696.32	458.93	237.39
A6	23" x 23"	529	527.08	7.44	298.98	10	9.62	1,530.4	994.74	696.32	81.74	380.72	137.53	436.51	696.32	436.51	259.81
B1	23" x 23"	529	250.00	4.56	113.62	10	9.62	1,530.4	994.74	696.32	40.21	153.83	66.47	180.09	696.32	180.09	516.23
C8	23" x 23"	529	250.00	4.56	204.88	10	9.62	1,530.4	994.74	696.32	40.21	245.09	66.47	271.35	696.32	271.35	424.97
D1	23" x 23"	529	250.00	4.56	113.62	10	9.62	1,530.4	994.74	696.32	40.21	153.83	66.47	180.09	696.32	180.09	516.23
B8	18" x 18"	324	250.00	4.56	180.25	10	9.62	1,112.2	722.91	506.04	40.21	220.46	66.47	246.72	506.04	246.72	259.32
D8	18" x 18"	324	250.00	4.56	122.52	10	9.62	1,112.2	722.91	506.04	40.21	162.73	66.47	188.99	506.04	188.99	317.05
C1	23" x 23"	529	250.00	4.56	111.17	10	9.62	1,530.4	994.74	696.32	40.21	151.38	66.47	177.64	696.32	177.64	518.68
E1	23" x 23"	529	162.00	7.44	72.90	10	9.62	1,530.4	994.74	696.32	32.34	105.23	48.45	121.35	696.32	121.35	574.97
E8	23" x 23"	529	162.00	7.44	72.90	10	9.62	1,530.4	994.74	696.32	32.34	105.23	48.45	121.35	696.32	121.35	574.97
B2	23" x 23"	529	460.00	7.44	204.96	10	9.62	1,530.4	994.74	696.32	72.88	277.83	121.16	326.13	696.32	326.13	370.19
C7	23" x 23"	529	460.00	7.44	319.29	10	9.62	1,530.4	994.74	696.32	72.88	391.96	121.16	440.46	696.32	440.46	255.86
E2	23" x 23"	529	350.75	7.44	155.00	10	9.62	1,530.4	994.74	696.32	57.88	212.88	94.51	249.50	696.32	249.50	446.82
C2	23" x 23"	529	460.00	4.56	202.52	11	11.88	1,625.1	1,056.33	739.43	68.63	271.14	117.70	320.22	739.43	320.22	419.21
B7	23" x 23"	529	460.00	7.44	305.18	10	9.62	1,530.4	994.74	696.32	72.88	377.84	121.16	426.34	696.32	426.34	269.97
A2	16" x 16"	256	325.35	3.60	143.95	10	9.62	973.5	632.74	442.92	49.07	193.02	83.70	227.65	442.92	227.65	215.27
A7	16" x 16"	256	325.35	3.60	221.41	10	9.62	973.5	632.74	442.92	49.07	270.47	83.70	305.11	442.92	305.11	137.81
D2	23" x 23"	529	460.00	4.56	202.52	10	9.62	1,530.4	994.74	696.32	68.83	271.14	117.70	320.22	696.32	320.22	376.10
D7	23" x 23"	529	460.00	4.56	266.97	10	9.62	1,530.4	994.74	696.32	68.83	335.80	117.70	384.68	696.32	384.68	311.64
E7	18" x 18"	324	350.75	4.56	157.44	10	9.62	1,112.2	722.91	506.04	53.84	211.29	91.05	246.49	506.04	246.49	257.55
B5	23" x 23"	529	500.00	7.44	417.28	11	11.88	1,625.1	1,056.33	739.43	78.08	495.35	130.92	548.20	739.43	548.20	191.23
B6	23" x 23"	529	500.00	7.44	317.39	11	11.88	1,625.1	1,056.33	739.43	78.08	395.47	130.92	448.32	739.43	448.32	291.12
C6	23" x 23"	529	500.00	7.44	326.47	10	9.62	1,530.4	994.74	696.32	78.08	404.54	130.92	457.39	696.32	457.39	238.93
C5	23" x 23"	529	500.00	7.44	262.55	10	9.62	1,530.4	994.74	696.32	78.08	340.63	130.92	393.47	696.32	393.47	302.85
A4	18" x 18"	324	562.50	4.56	284.67	10	9.62	1,112.2	722.91	506.04	82.50	367.17	142.71	427.38	506.04	427.38	78.66
D3	23" x 23"	529	500.00	4.56	222.95		0.00				74.04	296.99	127.46	350.42			
D6	18" x 18"	324	500.00	4.56	308.38		0.00				74.04	382.41	127.46	435.83			
D4	23" x 23"	529	500.00	7.44	330.11		0.00				78.08	408.19	130.92	461.03			
D5	23" x 23"	529	500.00	4.56	409.84		0.00				74.04	483.88	127.46	537.30			
E3			468.75	4.56	206.32		0.00				69.81	276.14	119.84	326.16			
E4			516.67	4.56	291.68		0.00				76.30	367.97	131.53	423.21			
E6			468.75	4.56	249.36		0.00				69.81	319.17	119.84	369.20			
E5			516.67	4.56	298.77		0.00				76.30	375.07	131.53	430.30			
C3	24" x 24"	576	500.00	7.44	219.92	9	7.95	1,540.5	1,001.34	700.94	78.08	297.99	130.92	350.84	700.94	350.84	350.10
C4	24" x 24"	576	500.00	7.44	262.62	9	7.95	1,540.5	1,001.34	700.94	78.08	340.70	130.92	393.54	700.94	393.54	307.39
B3	23" x 23"	529	375.00	4.56	166.76	9	7.95	1,444.6	939.02	657.31	57.13	223.88	96.96	263.72	657.31	263.72	393.59
B4	23" x 23"	529	375.00	4.56	283.80	9	7.95	1,444.6	939.02	657.31	57.13	340.92	96.96	380.76	657.31	380.76	276.55
B3.3	24" x 18"	432	250.00	4.56	112.39	9	7.95	1,246.8	810.39	567.28	40.21	152.60	66.47	178.85	567.28	178.85	388.42
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

φ	0.65

Proposed First Floor Column Sheet

Column	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (sf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	ϕPo (k)	0.7ϕPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7ϕPo (k)	Total Load (k)	Difference
A3	24" x 24"	576	527.08	4.56	365.77	10	9.82	1,626.3	1,057.06	739.94	77.71	443.47	134.07	499.84	739.94	499.84	240.10
A5	24" x 24"	576	562.50	7.44	458.93	10	9.82	1,626.3	1,057.06	739.94	86.53	545.46	146.17	605.10	739.94	605.10	134.84
A6	24" x 24"	576	527.08	7.44	436.51	10	9.82	1,626.3	1,057.06	739.94	81.74	518.25	137.53	574.04	739.94	574.04	165.90
B1	24" x 24"	576	250.00	7.44	180.09	10	9.82	1,626.3	1,057.06	739.94	44.25	224.33	69.92	250.01	739.94	250.01	489.93
C8	24" x 24"	576	250.00	7.44	271.35	10	9.82	1,626.3	1,057.06	739.94	44.25	315.59	97.92	369.27	739.94	369.27	370.67
D1	24" x 24"	576	250.00	7.44	180.09	10	9.82	1,626.3	1,057.06	739.94	44.25	224.33	97.92	278.01	739.94	278.01	461.93
B8	24" x 24"	576	250.00	4.56	246.72	10	9.82	1,626.3	1,057.06	739.94	40.21	286.93	66.47	313.18	739.94	313.18	426.76
D8	24" x 24"	576	250.00	4.56	188.99	10	9.82	1,626.3	1,057.06	739.94	40.21	229.20	94.47	283.45	739.94	283.45	456.49
C1	24" x 24"	576	250.00	7.44	177.64	10	9.82	1,626.3	1,057.06	739.94	44.25	221.88	97.92	275.56	739.94	275.56	464.38
E1	24" x 24"	576	162.00	7.44	121.35	10	9.82	1,626.3	1,057.06	739.94	32.34	153.69	66.60	187.95	739.94	187.95	552.00
E8	24" x 24"	576	162.00	7.44	121.35	10	9.82	1,626.3	1,057.06	739.94	32.34	153.69	66.60	187.95	739.94	187.95	552.00
B2	24" x 24"	576	460.00	7.44	326.13	10	9.82	1,626.3	1,057.06	739.94	72.66	398.79	121.16	447.29	739.94	447.29	292.65
C7	24" x 24"	576	460.00	7.44	440.46	10	9.82	1,626.3	1,057.06	739.94	72.66	513.12	172.68	613.14	739.94	613.14	126.81
E2	24" x 24"	576	350.75	7.44	249.50	10	9.82	1,626.3	1,057.06	739.94	57.88	307.38	133.79	383.29	739.94	383.29	356.65
C2	24" x 24"	576	460.00	7.44	320.22	11	11.88	1,721.0	1,118.65	783.06	72.66	392.88	172.68	492.90	783.06	492.90	290.15
B7	29" x 29"	576	460.00	7.44	426.34	10	9.82	1,626.3	1,057.06	739.94	72.66	499.01	121.16	547.51	739.94	547.51	192.44
A2	24" x 24"	576	325.35	3.60	227.65	10	9.82	1,626.3	1,057.06	739.94	49.07	276.72	83.70	311.36	739.94	311.36	428.59
A7	24" x 24"	576	325.35	3.60	305.11	10	9.82	1,626.3	1,057.06	739.94	49.07	354.18	83.70	388.81	739.94	388.81	351.13
D2	24" x 24"	576	460.00	7.44	320.22	10	9.82	1,626.3	1,057.06	739.94	72.66	392.88	172.68	492.90	739.94	492.90	247.04
D7	24" x 24"	576	460.00	7.44	384.68	10	9.82	1,626.3	1,057.06	739.94	72.66	457.34	172.68	557.36	739.94	557.36	182.58
E7	24" x 24"	576	350.75	4.56	248.49	10	9.82	1,626.3	1,057.06	739.94	53.84	302.33	130.33	378.82	739.94	378.82	361.12
B5	24" x 24"	576	500.00	7.44	548.20	11	11.88	1,721.0	1,118.65	783.06	78.08	626.28	130.92	679.12	783.06	679.12	103.94
B6	29" x 29"	841	500.00	7.44	448.32	11	11.88	2,261.6	1,470.04	1,029.03	78.08	526.39	130.92	579.24	1,029.03	579.24	449.79
C6	24" x 24"	576	500.00	7.44	457.39	10	9.82	1,626.3	1,057.06	739.94	78.08	535.47	186.92	644.31	739.94	644.31	95.63
C5	24" x 24"	576	500.00	7.44	393.47	10	9.82	1,626.3	1,057.06	739.94	78.08	471.55	186.92	580.39	739.94	580.39	159.55
A4	24" x 24"	576	562.50	4.56	427.38	10	9.82	1,626.3	1,057.06	739.94	82.50	509.88	142.71	570.09	739.94	570.09	169.85
D3	23" x 23"	529	500.00	7.44	350.42		0.00				78.08	428.49	186.92	537.34			
D6	18" x 18"	324	500.00	4.56	435.83		0.00				74.04	509.67	183.46	619.29			
D4	23" x 23"	529	500.00	7.44	461.03		0.00				78.08	539.11	186.92	647.96			
D5	23" x 23"	529	500.00	7.44	537.30		0.00				78.08	615.38	186.92	724.22			
E3			468.75	0.00	326.16		0.00				63.43	389.60	166.87	493.03			
E4			516.67	0.00	423.21		0.00				69.92	493.12	183.93	607.14			
E6			468.75	0.00	369.20		0.00				63.43	432.63	166.87	536.07			
E5			516.67	0.00	430.30		0.00				69.92	500.22	183.93	614.23			
C3	24" x 24'	576	500.00	8.10	350.84	9	7.95	1,540.5	1,001.34	700.94	79.00	429.84	187.72	538.55	700.94	538.55	162.38
C4	24" x 24'	576	500.00	8.10	393.54	9	7.95	1,540.5	1,001.34	700.94	79.00	472.55	187.72	581.26	700.94	581.26	119.68
B3	23" x 23"	529	375.00	7.44	263.72	9	7.95	1,444.6	939.02	657.31	61.16	324.89	100.42	364.15	657.31	364.15	293.16
B4	23" x 23"	529	375.00	7.44	380.76	9	7.95	1,444.6	939.02	657.31	61.16	441.92	100.42	481.18	657.31	481.18	176.13
B3.3	24" x 18"	432	250.00	6.08	178.85	9	7.95	1,246.8	810.39	567.28	42.34	221.19	68.29	247.14	567.28	247.14	320.13
A3.3				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A5.5				0.00	0.00		0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	?
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	13.5

ϕ	0.65

Proposed Ground Floor Column Sheet

Name	Column Size	Column Size (sq. in.)	Trib Area (Floor Above) (cf)	Column Weight Above (k)	Load Above (k)	Rebar #	As+As (sq. in)	Maximum Pure Compression Load Po (k)	φPo (k)	0.7φPo (k)	1.4(D+F) (k)	Total Load (k)	1.2D+1.6L	Total Load (k)	0.7φPo (k)	Total Load (k)	Difference
A3	29" x 29"	841	527.08	3.38	499.84	10	9.82	2,156.9	1,408.45	985.92	76.05	575.89	191.69	691.53	985.92	691.53	294.39
A5	24" x 24"	576	562.50	5.51	605.10	10	9.82	1,263.9	821.53	575.07	83.83	688.93	206.86	811.96	575.07	811.96	-236.89
A6	29" x 29"	841	527.08	5.51	574.04	10	9.82	1,703.1	1,107.04	774.93	79.04	653.08	194.25	768.29	774.93	768.29	6.64
B1				5.51	250.01		0.00				7.71	257.72	6.61	256.62			
C8				5.51	369.27		0.00				7.71	376.99	6.61	375.88			
D1				5.51	278.01		0.00				7.71	285.72	6.61	284.62			
B8				3.38	313.18		0.00				4.73	317.91	4.05	317.23			
D8				3.38	283.45		0.00				4.73	288.18	4.05	287.50			
C1				5.51	275.56		0.00				7.71	283.28	6.61	282.18			
E1				5.51	187.95		0.00				7.71	195.66	6.61	194.56			
E8				5.51	187.95		0.00				7.71	195.66	6.61	194.56			
B2				5.51	447.29		0.00				7.71	455.00	6.61	453.90			
C7				5.51	613.14		0.00				7.71	620.85	6.61	619.75			
E2				5.51	383.29		0.00				7.71	391.01	6.61	389.91			
C2				5.51	492.90		0.00				7.71	500.62	6.61	499.52			
B7				5.51	547.51		0.00				7.71	555.22	6.61	554.12			
A2				2.67	311.36		0.00				3.73	315.09	3.20	314.56			
A7				2.67	388.81		0.00				3.73	392.55	3.20	392.01			
D2				5.51	492.90		0.00				7.71	500.62	6.61	499.52			
D7				5.51	557.36		0.00				7.71	565.08	6.61	563.97			
E7				3.38	378.82		0.00				4.73	383.55	4.05	382.87			
B5	29" x 29"	841	500.00	5.51	679.12	11	11.88	1,768.1	1,149.24	804.47	75.38	754.50	184.61	863.73	804.47	863.73	-59.26
B6	29" x 29"	841	500.00	5.51	579.24	11	11.88	1,768.1	1,149.24	804.47	75.38	654.62	184.61	763.85	804.47	763.85	40.62
C6				5.51	644.31		0.00				7.71	652.03	6.61	650.92			
C5				5.51	580.39		0.00				7.71	588.11	6.61	587.01			
A4				3.38	570.09		0.00				4.73	574.82	4.05	574.14			
D3				5.51	537.34		0.00				7.71	545.05	6.61	543.95			
D6				3.38	619.29		0.00				4.73	624.02	4.05	623.34			
D4				5.51	647.96		0.00				7.71	655.67	6.61	654.57			
D5				5.51	724.22		0.00				7.71	731.94	6.61	730.84			
E3				0.00	493.03		0.00				0.00	493.03	0.00	493.03			
E4				0.00	607.14		0.00				0.00	607.14	0.00	607.14			
E6				0.00	536.07		0.00				0.00	536.07	0.00	536.07			
E5				0.00	614.23		0.00				0.00	614.23	0.00	614.23			
C3	29" x 29"	841	500.00	6.00	538.55	9	7.95	1,644.4	1,068.85	748.20	76.06	614.62	185.20	723.75	748.20	723.75	24.45
C4	24" x 24"	576	500.00	6.00	581.26	9	7.95	1,205.2	783.35	548.34	76.06	657.32	185.20	766.46	548.34	766.46	-218.11
B3	29" x 29"	841	375.00	5.51	364.15	9	7.95	1,644.4	1,068.85	748.20	58.46	422.61	140.11	504.26	748.20	504.26	243.94
B4	24" x 24"	576	375.00	5.51	481.18	9	7.95	1,205.2	783.35	548.34	58.46	539.64	140.11	621.29	548.34	621.29	-72.95
B3.3	24" x 18"	432	250.00	4.50	247.14	9	7.95	966.5	628.21	439.75	40.13	287.27	94.40	341.54	439.75	341.54	98.21
A3.3	12" x 24"	288	283.33	0.00	0.00	9	7.95	727.8	473.07	331.15	38.34	38.34	100.86	100.86	331.15	100.86	230.28
A5.5	12" x 24"	288	283.33	0.00	0.00	9	7.95	727.8	473.07	331.15	38.34	38.34	100.86	100.86	331.15	100.86	230.28

	(psf)
Roof Dead	84.15
Roof Live	20
Snow Load	50
Fluid Load	0
Wind Load	11
Lateral Earth Load	7
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

	ft
Column Height	10.0

φ	0.65

Proposed Sub-Ground Floor Column Sheet

Name	Max Column Size	Max Column Size (sq. in.)	Footing Type	Footing Area (sf)	Footing Height (ft)	Footing Self Weight (k)	Load Above (k)	Total Load (k)	Bearing Pressure (psi)	Existing Bearing Pressure (psi)	Proposed Bearing Pressure (psi)	Change (psi)	% Change	Existing Load (k)	Proposed Load (k)	Change (k)	% Change
A3	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	691.53	732.52	9,043.5	11,229.9	9,043.5	-2,186.42	-19.5%	909.62	732.52	-177.10	-19.5%
A5	24" x 24"	576	9.5' x 9.5' x 2.5' (V)	90.25	2.50	47.4	811.96	859.34	9,521.8	10,877.3	9,521.8	-1,355.50	-12.5%	981.67	859.34	-122.33	-12.5%
A6	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	768.29	809.29	9,991.2	11,377.1	9,991.2	-1,385.97	-12.2%	921.55	809.29	-112.26	-12.2%
B1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	256.62	276.28	5,638.3	7,352.6	5,638.3	-1,714.29	-23.3%	360.28	276.28	-84.00	-23.3%
C8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	375.88	395.54	8,072.2	7,352.6	8,072.2	719.62	9.8%	360.28	395.54	35.26	9.8%
D1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	284.62	304.28	6,209.7	7,352.6	6,209.7	-1,142.88	-15.5%	360.28	304.28	-56.00	-15.5%
B8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	317.23	336.89	6,875.2	7,229.7	6,875.2	-354.45	-4.9%	354.25	336.89	-17.37	-4.9%
D8	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	287.50	307.16	6,268.5	7,229.7	6,268.5	-961.16	-13.3%	354.25	307.16	-47.10	-13.3%
C1	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	282.18	301.83	6,159.8	7,302.6	6,159.8	-1,142.86	-15.6%	357.83	301.83	-56.00	-15.6%
E1	24" x 24"	576	Bot Footing?			0.0	194.56	194.56	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	230.85	194.56	-36.29	-15.7%
E8	24" x 24"	576	Bot Footing?			0.0	194.56	194.56	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	230.85	194.56	-36.29	-15.7%
B2	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	453.90	509.76	5,097.6	6,643.2	5,097.6	-1,545.60	-23.3%	664.32	509.76	-154.56	-23.3%
C7	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	619.75	675.61	6,756.1	6,643.2	6,756.1	112.89	1.7%	664.32	675.61	11.29	1.7%
E2	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	389.91	445.77	4,457.7	5,243.4	4,457.7	-785.68	-15.0%	524.34	445.77	-78.57	-15.0%
C2	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	499.52	555.38	5,553.8	6,584.2	5,553.8	-1,030.40	-15.6%	658.42	555.38	-103.04	-15.6%
B7	29" x 29"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	554.12	609.98	6,099.8	6,643.2	6,099.8	-543.43	-8.2%	664.32	609.98	-54.34	-8.2%
A2	24" x 24"	576	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	314.56	355.55	4,389.5	5,739.1	4,389.5	-1,349.62	-23.5%	464.87	355.55	-109.32	-23.5%
A7	24" x 24"	576	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	392.01	433.01	5,345.8	5,739.1	5,345.8	-393.36	-6.9%	464.87	433.01	-31.86	-6.9%
D2	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	499.52	555.38	5,553.8	6,584.2	5,553.8	-1,030.40	-15.6%	658.42	555.38	-103.04	-15.6%
D7	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	563.97	619.83	6,198.3	6,608.6	6,198.3	-410.30	-6.2%	660.86	619.83	-41.03	-6.2%
E7	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	382.87	438.73	4,387.3	5,173.0	4,387.3	-785.68	-15.2%	517.30	438.73	-78.57	-15.2%
B5	29" x 29"	841	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	863.73	919.59	9,195.9	8,963.4	9,195.9	232.51	2.6%	896.34	919.59	23.25	2.6%
B6	29" x 29"	841	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	763.85	819.71	8,197.1	8,950.8	8,197.1	-753.72	-8.4%	895.08	819.71	-75.37	-8.4%
C6	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	650.92	706.78	7,067.8	7,170.8	7,067.8	-103.00	-1.4%	717.08	706.78	-10.30	-1.4%
C5	24" x 24"	576	10' x 10' x 2.66' (VI)	100.00	2.66	55.9	587.01	642.87	6,428.7	7,183.4	6,428.7	-754.77	-10.5%	718.34	642.87	-75.48	-10.5%
A4	24" x 24"	576	9.5' x 9.5' x 2.5' (V)	90.25	2.50	47.4	574.14	621.52	6,886.7	8,564.6	6,886.7	-1,677.95	-19.6%	772.96	621.52	-151.44	-19.6%
D3	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	543.95	576.25	8,731.0	10,428.0	8,731.0	-1,696.97	-16.3%	688.25	576.25	-112.00	-16.3%
D6	18" x 18"	324	8.5' x 8.5' x 2.33' (III)	72.25	2.33	35.4	623.34	658.69	9,116.9	9,484.9	9,116.9	-368.01	-3.9%	685.28	658.69	-26.59	-3.9%
D4	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	654.57	686.86	10,407.0	10,480.4	10,407.0	-73.37	-0.7%	691.71	686.86	-4.84	-0.7%
D5	23" x 23"	529	6' x '11' x 2.33' (VII)	66.00	2.33	32.3	730.84	763.13	11,562.6	10,428.0	11,562.6	1,134.59	10.9%	688.25	763.13	74.88	10.9%
E3			Bot Footing?			0.0	493.03	493.03	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	598.03	493.03	-105.00	-17.6%
E4			Bot Footing?			0.0	607.14	607.14	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	658.36	607.14	-51.22	-7.8%
E6			Bot Footing?			0.0	536.07	536.07	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	598.03	536.07	-61.97	-10.4%
E5			Bot Footing?			0.0	614.23	614.23	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	557.25	614.23	56.98	10.2%
C3	29" x 29"	841	9' x 9' x 2.41' (IV)	81.00	2.41	41.0	723.75	764.74	9,441.3	10,862.5	9,441.3	-1,421.17	-13.1%	879.86	764.74	-115.12	-13.1%
C4	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	766.46	786.11	16,043.1	17,546.5	16,043.1	-1,503.46	-8.6%	859.78	786.11	-73.67	-8.6%
B3	29" x 29"	841	7' x 7' x 1.91' (II)	49.00	1.91	19.7	504.26	523.91	10,692.1	13,327.1	10,692.1	-2,635.00	-19.8%	653.03	523.91	-129.12	-19.8%
B4	24" x 24"	576	7' x 7' x 1.91' (II)	49.00	1.91	19.7	621.29	640.95	13,080.6	13,352.8	13,080.6	-272.23	-2.0%	654.29	640.95	-13.34	-2.0%
B3.3	24" x 18"	432	7' x 7' x 1.91' (II)	49.00	1.91	19.7	341.54	361.19	7,371.3	9,085.6	7,371.3	-1,714.29	-18.9%	445.19	361.19	-84.00	-18.9%
A3.3	12" x 24"	288	3.5' x 3.5' x 1.33' (I)	12.25	1.33	3.4	100.86	104.28	8,513.0	8,513.0	8,513.0	0.00	0.0%	104.28	104.28	0.00	0.0%
A5.5	12" x 24"	288	3.5' x 3.5' x 1.33' (I)	12.25	1.33	3.4	100.86	104.28	8,513.0	8,513.0	8,513.0	0.00	0.0%	104.28	104.28	0.00	0.0%

	(psf)
Roof Dead Load	84.15
Roof Live	20
Snow Load	50
Fluid Loa	0
Wind Loa	11

	pcf
Concrete Weight	150

	ksi
f'c	3
fy	60

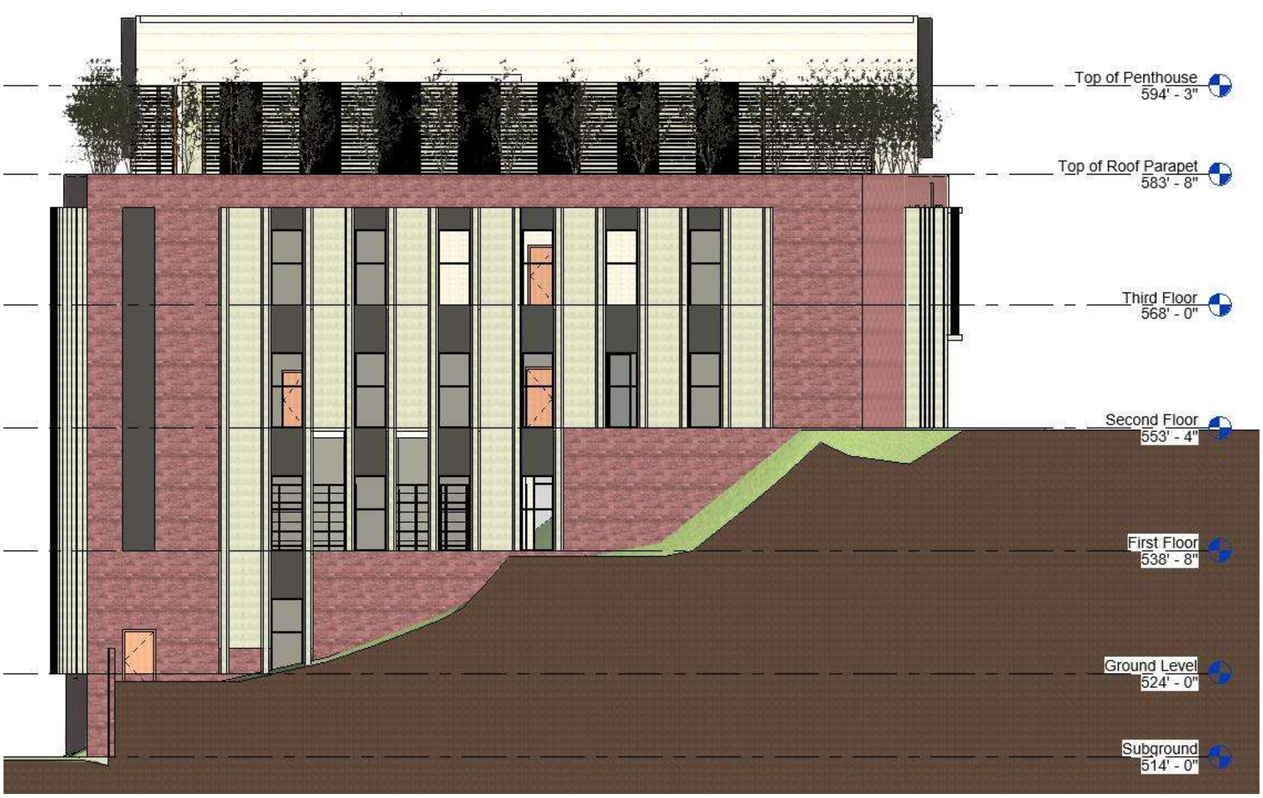
	(psf)
Lateral Earth Load	
Seismic Load	0.24
Slab Dead Load	96.66
Live Load	80
Current LL	150

	ft
Column Height	13.5

Proposed Footing Sheet

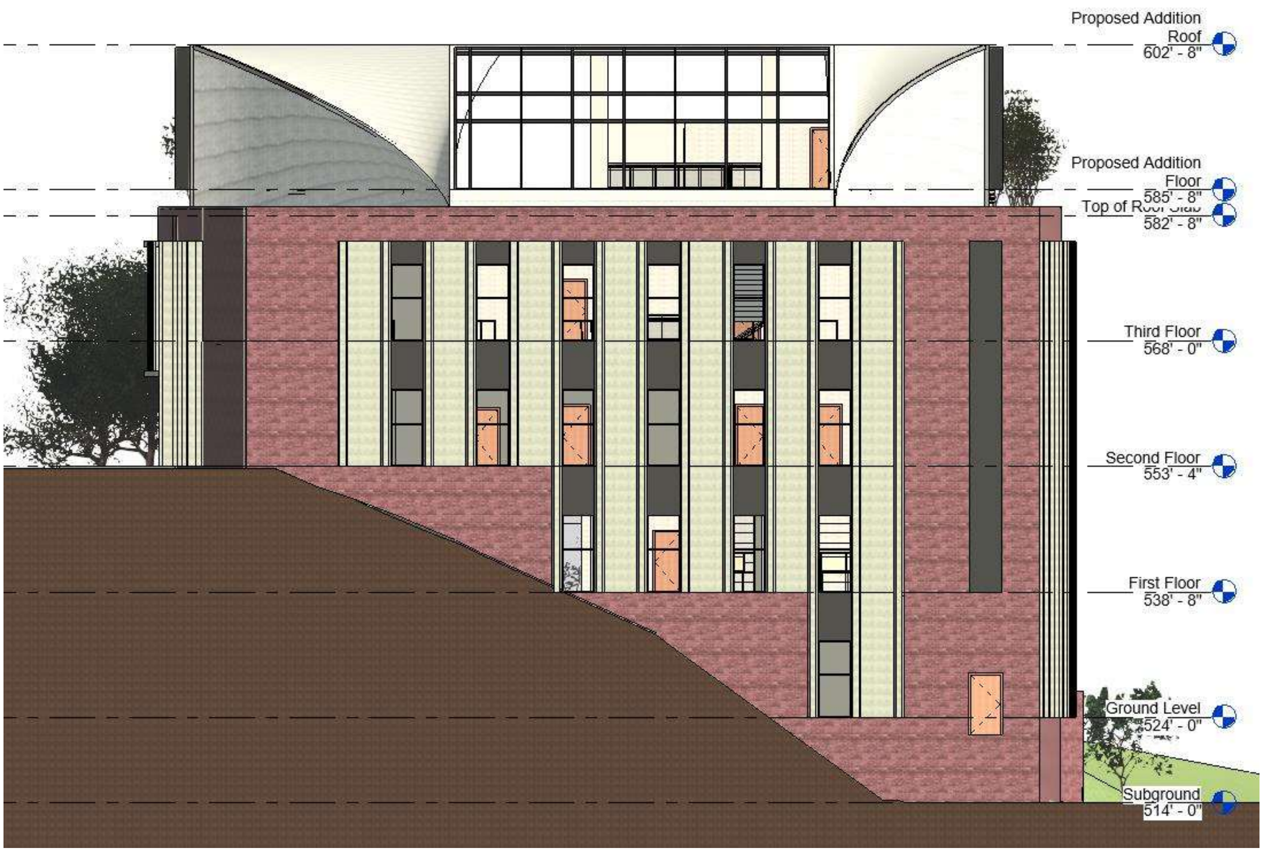
D: Architectural Design

East Elevation



North Elevation

West Elevation



South Elevation

E: Rankine-Grashoff Method Calculation

Rankine - Grashoff Method

Typical Grid Section Analysis (Between Columns)

Moment Calculations

$$M_x = \frac{q_1 \times b_1 \times a^2}{8} = \frac{12.53\ kN/m^2 \times 0.61m \times (6.096\ m)^2}{8} = 35.51\ kN \cdot m$$

$M_x = 35.51\ kN \cdot m = 26.19\ kip \cdot ft$

$$M_y = \frac{q_2 \times b_1 \times a^2}{8} = \frac{5.133\ kN/m^2 \times 0.61m \times (7.62m)^2}{8} = 22.72\ kN \cdot m$$

$M_y = 22.72\ kN \cdot m = 16.75\ kip \cdot ft$

Shear Force Calculations

$$Q_x = \frac{q_1 \times a \times b_1}{2} = \frac{12.53\ kN/m^2 \times 6.096\ m \times 0.61m}{2} = 23.30\ kN$$

$Q_x = 23.30\ kN = 5.238\ kip$

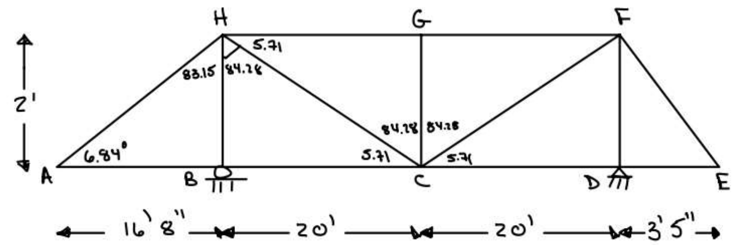
$$Q_y = \frac{q_2 \times b \times a_1}{2} = \frac{5.133\ kN/m^2 \times 7.62m \times 0.61m}{2} = 11.93\ kN$$

$Q_y = 11.93\ kN = 2.68\ kip$

F: 2D Truss Analysis of Proposed Addition

① $\frac{70\,lbs}{Ft^2} \times \frac{1\,Ft^2}{1\,Ft} = \frac{70\,lbs}{Ft}$ Live Load

② $\frac{65\,lbs}{Ft^2} \times \frac{1\,Ft^2}{1\,Ft} = \frac{65\,lbs}{Ft}$ Dead Load



- 13 bars
- 3 reactions
- 8 joints

$b + r = 2j$

$13 + 3 = 2(8)$

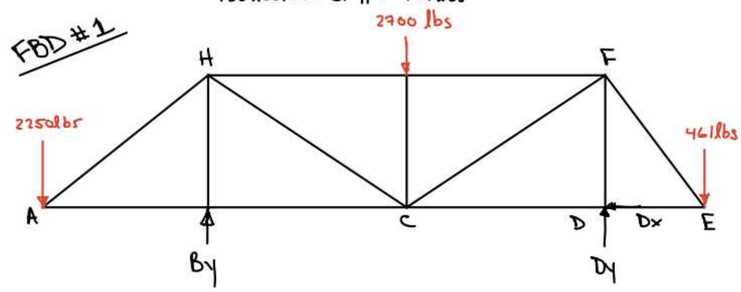
$16 = 16$

∴ Statically determinate and stable

135 lbs/Ft × 20' = 2700 lbs

135 lbs/Ft × 16.67' = 2250 lbs

135 lbs/Ft × 3.41' = 461 lbs



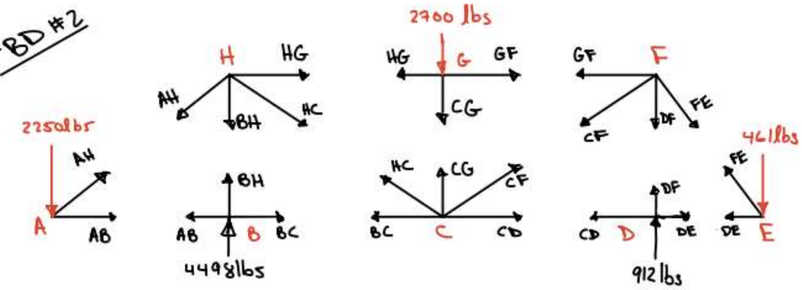
$\Sigma F_x: D_x = 0$

$\Sigma F_y: B_y + D_y - 2250\,lbs - 2700\,lbs - 461\,lbs = 0$

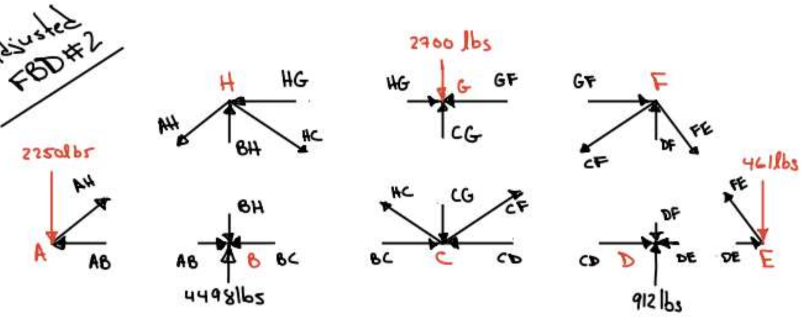
$\circlearrowleft + \Sigma M_B: 2250\,lbs(16.67') - 2700\,lbs(20') + D_y(40') - 461\,lbs(43.41') = 0$

$\therefore D_y = 912\,lbs \rightarrow \therefore B_y = 4498$

FBD #2



Adjusted FBD #2



Members AH & AB

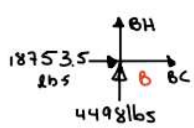
$\Sigma F_y: AH \sin 6.84 - 2250\text{lbs} = 0$ sin 6.84 = 0

$\therefore AH = 18{,}888.24\text{lbs (T)}$

$\Sigma F_x: 18{,}888.24 \cos 6.841 + AB = 0$

$\therefore AB = -18753.5\text{lbs (C)}$

Members BH & BC



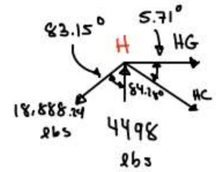
$\Sigma F_y: BH + 4498\text{lbs} = 0$

$\therefore BH = -4498\text{lbs (C)}$

$\Sigma F_x: BC + 18753.5\text{lbs}$

$\therefore BC = -18753.5\text{lbs (C)}$

Members HC & HG



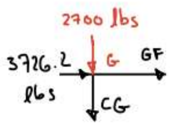
$\sum F_y: -18{,}888.24\cos 83.15° + 4498 - HC\cos 84.28° = 0$

$\therefore HC = 22592.12\ lbs$

$\sum F_x: -18{,}888.24\sin 83.15° + 22592.12\sin 84.28° + HG = 0$

$\therefore HG = -3726.2\ lbs\ (C)$

Members CG & GF



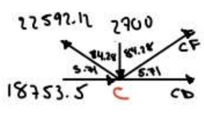
$\sum F_y: -2700 - CG = 0$

$\therefore CG = -2700\ lbs\ (C)$

$\sum F_x: 3726.24 + GF = 0$

$\therefore GF = -3726.24\ lbs\ (C)$

Members CF & CD



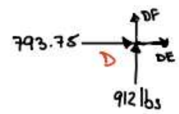
$\sum F_y: 22592.12\cos 84.28 - 2700 + CF\sin 5.71 = 0$

$\therefore CF = 4542.54\ lbs$

$\sum F_x: 18753.5 - 22592.12\cos 5.71 + 4542.54\cos 5.71 + CD$

$\therefore CD = -793.75\ lbs\ (C)$

Members DF & DE



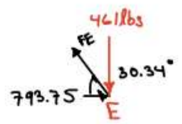
ΣF_y: DF + 912 = 0

∴ DF = -912 lbs (C)

ΣF_x: DE + 793.75 = 0

∴ DE = -793.75 lbs (C)

Member FE



ΣF_y: -461 + FE sin 30.34 = 0

∴ FE = 912.54 lbs

Member	Calculated Design Force
AB	-18753.5 (C)
AH	18,888.24 (T)
BC	-18753.5 (C)
BH	-4498 (C)
HG	-3726.4 (C)
HC	22592.12 (T)
CG	-2700 (C)
CF	4542.54 (T)
CD	-793.75 (C)
GF	-3726.24 (C)
DF	-912 (C)
DE	-793.75 (C)
FE	912.54 (T)

G: Energy Simulation Results

Simulation 1: Existing Building Baseline

Site and Source Energy

	Total Energy [kBtu]	Energy Per Total Building Area [kBtu/ft2]	Energy Per Conditioned Building Area [kBtu/ft2]
Total Site Energy	7308169.83	103.18	103.18
Net Site Energy	7308169.83	103.18	103.18
Total Source Energy	13024038.23	183.88	183.88
Net Source Energy	13024038.23	183.88	183.88

End Uses

	Electricity [kBtu]	Natural Gas [kBtu]	Gasoline [kBtu]	Diesel [kBtu]	Coal [kBtu]	Fuel Oil No 1 [kBtu]	Fuel Oil No 2 [kBtu]	Propane [kBtu]	Other Fuel 1 [kBtu]	Other Fuel 2 [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	286.65	4858826.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	416266.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	927647.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	440544.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	549343.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	20775.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	94479.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	470222.74
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	2449343.32	4858826.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	470222.74

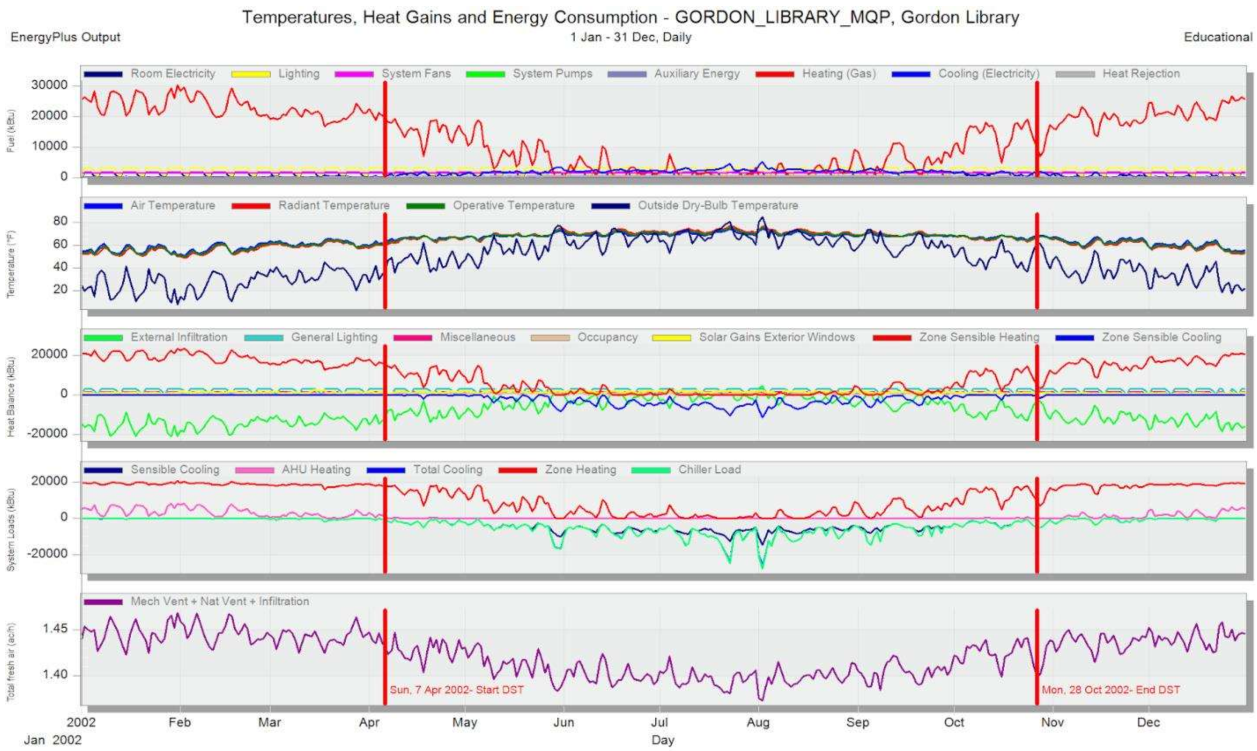
Note: Natural gas appears to be the principal heating source based on energy usage.

End Uses By Subcategory

	Subcategory	Electricity [kBtu]	Natural Gas [kBtu]	Gasoline [kBtu]	Diesel [kBtu]	Coal [kBtu]	Fuel Oil No 1 [kBtu]	Fuel Oil No 2 [kBtu]	Propane [kBtu]	Other Fuel 1 [kBtu]	Other Fuel 2 [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler	0.00	4858826.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler Parasitic	286.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	General	416266.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	General	927647.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	General	440544.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	General	549343.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	General	20775.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	General	94479.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	470222.74
Humidification	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	2957.33
Time Setpoint Not Met During Occupied Cooling	0.00
Time Not Comfortable Based on Simple ASHRAE 55-2004	5453.67



Simulation 2: Existing Walls, Updated Windows

Site and Source Energy

	Total Energy [kBtu]	Energy Per Total Building Area [kBtu/ft2]	Energy Per Conditioned Building Area [kBtu/ft2]
Total Site Energy	7040703.58	99.40	99.40
Net Site Energy	7040703.58	99.40	99.40
Total Source Energy	12656351.07	178.69	178.69
Net Source Energy	12656351.07	178.69	178.69

End Uses

	Electricity [kBtu]	Natural Gas [kBtu]	Gasoline [kBtu]	Diesel [kBtu]	Coal [kBtu]	Fuel Oil No 1 [kBtu]	Fuel Oil No 2 [kBtu]	Propane [kBtu]	Other Fuel 1 [kBtu]	Other Fuel 2 [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	286.69	4628688.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	397357.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	927647.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	440544.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	534809.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	20142.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	91228.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	454629.12
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	2412015.55	4628688.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	454629.12

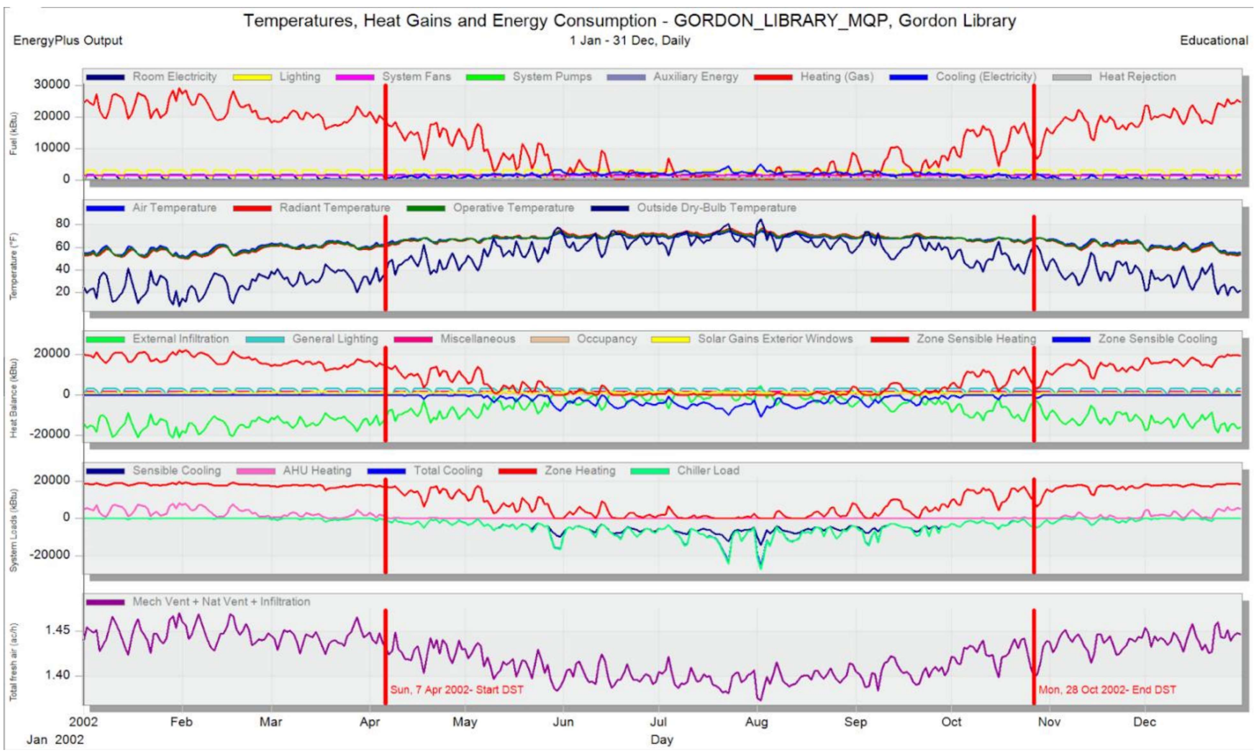
Note: Natural gas appears to be the principal heating source based on energy usage.

End Uses By Subcategory

	Subcategory	Electricity [kBtu]	Natural Gas [kBtu]	Gasoline [kBtu]	Diesel [kBtu]	Coal [kBtu]	Fuel Oil No 1 [kBtu]	Fuel Oil No 2 [kBtu]	Propane [kBtu]	Other Fuel 1 [kBtu]	Other Fuel 2 [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler	0.00	4628688.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler Parasitic	286.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	General	397357.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	General	927647.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	General	440544.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	General	534809.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	General	20142.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	General	91228.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	454629.12
Humidification	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	2909.17
Time Setpoint Not Met During Occupied Cooling	0.00
Time Not Comfortable Based on Simple ASHRAE 55-2004	5447.67



Simulation 3: Updated Walls, Existing Windows

Site and Source Energy

	Total Energy [kBtu]	Energy Per Total Building Area [kBtu/ft2]	Energy Per Conditioned Building Area [kBtu/ft2]
Total Site Energy	4042201.98	57.07	57.07
Net Site Energy	4042201.98	57.07	57.07
Total Source Energy	8547293.77	120.67	120.67
Net Source Energy	8547293.77	120.67	120.67

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	2536.50
Time Setpoint Not Met During Occupied Cooling	0.00
Time Not Comfortable Based on Simple ASHRAE 55-2004	4867.00

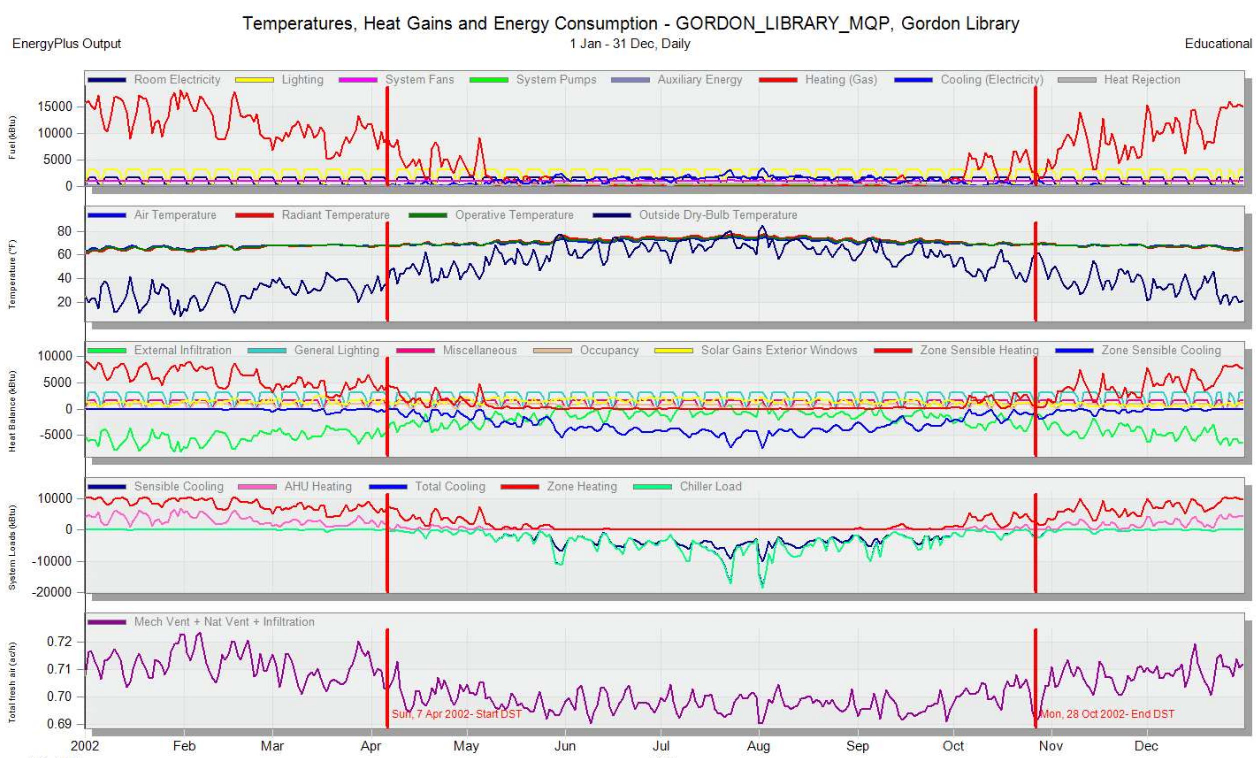
End Uses

	Electricity [kBtu]	Natural Gas [kBtu]	Gasoline [kBtu]	Diesel [kBtu]	Coal [kBtu]	Fuel Oil No 1 [kBtu]	Fuel Oil No 2 [kBtu]	Propane [kBtu]	Other Fuel 1 [kBtu]	Other Fuel 2 [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	177.90	2042419.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	217183.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	927647.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	440544.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	351199.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	10753.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	52276.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	270236.62
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	1999782.44	2042419.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	270236.62

Note: Natural gas appears to be the principal heating source based on energy usage.

End Uses By Subcategory

	Subcategory	Electricity [kBtu]	Natural Gas [kBtu]	Gasoline [kBtu]	Diesel [kBtu]	Coal [kBtu]	Fuel Oil No 1 [kBtu]	Fuel Oil No 2 [kBtu]	Propane [kBtu]	Other Fuel 1 [kBtu]	Other Fuel 2 [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler	0.00	2042419.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler Parasitic	177.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	General	217183.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	General	927647.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	General	440544.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	General	351199.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	General	10753.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	General	52276.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	270236.62
Humidification	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



Simulation 4: Updated Walls, Updated Windows

Site and Source Energy

	Total Energy [kBtu]	Energy Per Total Building Area [kBtu/ft2]	Energy Per Conditioned Building Area [kBtu/ft2]
Total Site Energy	3720575.15	52.53	52.53
Net Site Energy	3720575.15	52.53	52.53
Total Source Energy	8142920.54	114.96	114.96
Net Source Energy	8142920.54	114.96	114.96

End Uses

	Electricity [kBtu]	Natural Gas [kBtu]	Gasoline [kBtu]	Diesel [kBtu]	Coal [kBtu]	Fuel Oil No 1 [kBtu]	Fuel Oil No 2 [kBtu]	Propane [kBtu]	Other Fuel 1 [kBtu]	Other Fuel 2 [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	166.53	1747547.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	207115.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	927647.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	440544.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	337469.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	10128.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	49956.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	259727.39
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	1973027.88	1747547.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	259727.39

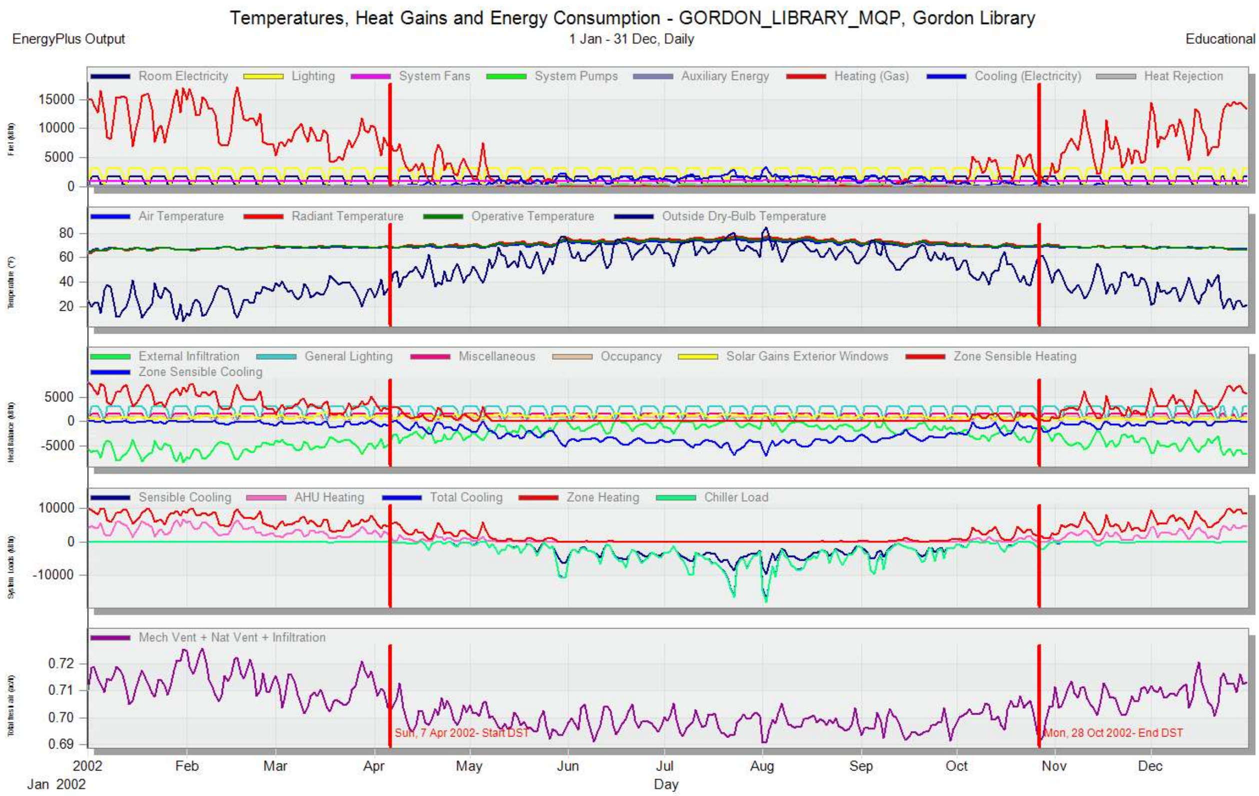
Note: Natural gas appears to be the principal heating source based on energy usage.

End Uses By Subcategory

	Subcategory	Electricity [kBtu]	Natural Gas [kBtu]	Gasoline [kBtu]	Diesel [kBtu]	Coal [kBtu]	Fuel Oil No 1 [kBtu]	Fuel Oil No 2 [kBtu]	Propane [kBtu]	Other Fuel 1 [kBtu]	Other Fuel 2 [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler	0.00	1747547.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Boiler Parasitic	166.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling	General	207115.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	General	927647.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	General	440544.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	General	337469.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	General	10128.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	General	49956.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	259727.39
Humidification	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	General	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	1415.17
Time Setpoint Not Met During Occupied Cooling	0.00
Time Not Comfortable Based on Simple ASHRAE 55-2004	4579.67


Temperatures, Heat Gains and Energy Consumption - GORDON_LIBRARY_MQP, Gordon Library
EnergyPlus Output
1 Jan - 31 Dec, Daily
Educational
Room Electricity
Lighting
System Fans
System Pumps
Auxiliary Energy
Heating (Gas)
Cooling (Electricity)
Heat Rejection
Air Temperature
Radiant Temperature
Operative Temperature
Outside Dry-Bulb Temperature
External Infiltration
General Lighting
Miscellaneous
Occupancy
Solar Gains Exterior Windows
Zone Sensible Heating
Zone Sensible Cooling
Sensible Cooling
AHU Heating
Total Cooling
Zone Heating
Chiller Load
Mech Vent + Nat Vent + Infiltration
Sun, 7 Apr 2002- Start DST
Mon, 28 Oct 2002- End DST
2002
Jan 2002
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day