2025

Design Report

4/11/2025

Contents

Section I - Executive Summary

A team of University of Iowa Civil & Environmental Engineering students are providing design alternatives for a former industrial building in the City of Burlington. Informally known as the Dial Building, it was constructed in the 1800s as a school furniture factory. In 1905, the Iowa Soap Company expanded into the building. Shortly afterwards, the Dial Company bought them out and began manufacturing borax and bleach in the building. It has been vacant for about 50 years.

The team explored several alternative uses and designs for the former industrial site, each of which is described in this report. With input from the city, the student team designed the restructuring to accommodate multiple uses: an event space, offices, community center, and residences. Due to a lack of available information about the building's current physical state, many parts of these plans are conjecture. The team hopes the city is able to communicate with current owners and jointly agree on a plan for the building's future that serves a wide swath of the Burlington community.

Section II Organization Qualifications and Experience

Our organization is comprised of highly skilled students from the University of Iowa. This proposed project is a part of their Senior Design Capstone Project in Civil & Environmental Engineering. Members include:

- Hayden Hoxmeier – Project Manager
- Carter Smith – Report Production
- Mason Loete – Technology Services/Structural
- Christopher Stoakes – Faculty Advisor

All the members listed bring unique skills to the project, assuring that the work will be completed to the best of our ability.

Some examples of past work members of our team have successfully undertaken that show an area of competence, include:

- Two-Story Apartment Building – Our team designed plans and developed a full two-story apartment building conducted with all wood materials. This design included calculating design loads for dead, live, wind and snow which all are requirements by the ASCE manual.
- Office Building Remodel – Managed the construction of a building that was undergoing an entire site redesign. The tasks included managing construction tasks, consulting with contractors and engineering and cost estimates. Managing these tasks in an effective and organized manner was crucial for the success of the project.
- Structural Foundations – Experience in sizing footings for certain structures. Developing foundations for all type of structural material usage. Designed retaining walls and maintaining the soil mechanics in that process.

Section III Proposed Services

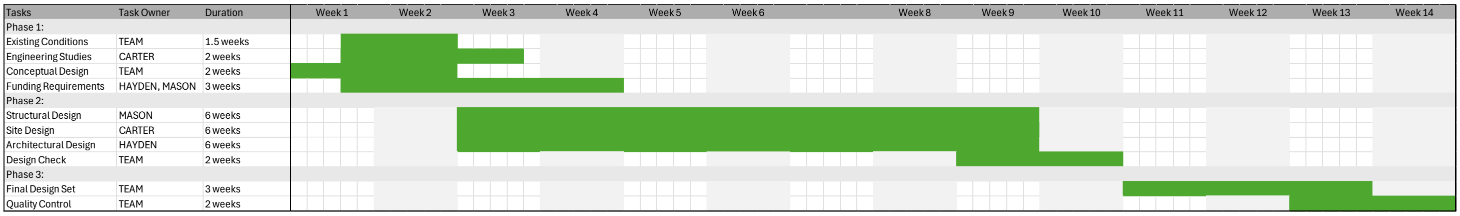
We propose the following tasks to complete the project:

- Prject Management - We will be responsible for project management activities throughout the life of the contract. The scope of activities includes but not limited to, coordinating and being responsible for scheduling meetings, managing the schedule, preparing meeting agendas and meeting minutes, tracking action items for the individuals working on the project, and preparing all submissions.
- Engineering Studies - Any studies needed before or during the design process will be covered by our team with the possibility of assistance from the City of Burlington for acquiring any previous studies on the site. Related studies will be used to establish Structural, Geomechanics, Hydraulic, Site Design, and Architecture needs.
- Design - We will cover all design elements for the project. The design plans, specifications, and cost estimates will follow city, state and AASHTO design guidelines. We will submit final documents to the City of Burlington. Our team is open to possible submittals at 60% and 90% and should be coordinated through contract.

Our team is responsible for the following tasks:

- Conceptual Design - conduct conceptual design of the site and building to clearly communicate possible alternatives to the City of Burlington. This will ensure both parties are on the same page with the direction of the project.
- Preliminary Design - prepare preliminary design. The demolition, structural, architectural, utilities and site design will be covered in this plan set.
- Final Design - present the City of Burlington with the final design plan set at the specified date. The final design plan set will include all documents from preliminary design with the new modifications and implementations acquired from the City of Burlington during the design process.

The project schedule can be seen in the following Gantt chart. The schedule is tentative and is expected to change as the project progresses. Any changes to the schedule will be noted, and any major changes will be notified to the City of Burlington. Each task is listed along with the person responsible and duration of the task. The Gantt chart covers the entirety of the projects design duration.



Section IV Constraints, Challenges, Impacts

The Industrial Building Repurposing project is subject to several key constraints, including limitations on space, project needs, scope, and schedule. These constraints must be carefully considered throughout the design process to ensure that the final proposal aligns with the project's objectives and requirements. One of the primary constraints is the timeline as the final design must be completed by May 9, 2025. Another constraint is space limitation. The design must conform to the existing dimensions of the industrial building and the site on which it’s located. No expansion of the site or building is permitted. This limitation impacts structural modifications, interior layouts, and site enhancements. Additionally, the scope and needs of the project are restricted to the objectives defined by the City of Burlington. The design must align with the city’s objectives for the site, ensuring it fits the communities’ needs and will function with surrounding elements.

This project presents many challenges due to the site's deteriorated condition and various external factors. The building has significantly exceeded its intended lifespan, and because it has been vacant for over 20 years, its current state remains unknown. This poses many concerns with the structural stability of the building as prolong neglect has led to severe deterioration of structural components, posing safety hazards when collecting existing conditions. Before any renovations can be undertaken, inspections and testing will be required to determine the integrity of load-bearing elements, foundation stability, and the extent of necessary reinforcements. Because of the poor structural condition, many reinforcement measures must be accounted for in design to ensure the building is safe to be occupied. Another challenge is the location of the site. The area experiences high crime rates and homelessness. This impacts the possible tenants of the building and attracting businesses. To create a sustainable development, the design must incorporate security measures and urban planning strategies that discourage crime while creating a welcoming environment for occupants and customers. These may include improved lighting, controlled access points, and considerations from public engagement to ensure a safe and inclusive development. Lastly, working with the current property owner presents a substantial obstacle. The owner has been unresponsive to the City of Burlington, making it difficult to facilitate progress on the redevelopment. Lack of communication may cause difficulties to acquiring site information, delaying structural assessments and limiting the scope of potential solutions. If the owner remains uncooperative, the project team may be forced to work within constraints that do not fully align with optimal redevelopment goals, potentially leading to compromises in the final design. By proactively considering these obstacles in the design phase, the project can progress toward a safe, functional, and sustainable redevelopment that benefits both the building's future occupants and the surrounding community.

The Industrial Building Repurpose project has the potential to create a lasting, positive impact on the community through enhancing the local environment. The surrounding area currently faces significant social challenges, including high crime rates and a growing homeless population. By transforming the existing space into a function and community driven development, this project can serve as a catalyst for social and economic change. One key benefit from this project is the potential to establish a community outreach center. A community center could provide valuable resources for local adolescents, offering programs to help guide them toward a brighter future. By engaging young individuals, the center can play a crucial role in reducing delinquency and foster personal development. Beyond supporting youth, the development could also serve as a stabilizer for those in need, offering essential services to help individuals experiencing homelessness regain stability. Additionally, the repurposed building will generate new employment opportunities, providing much-needed jobs for local residents. From potential roles in the community center to maintenance, this development has the potential to support economic growth and improve the overall quality of life for those struggling with unemployment. By revitalizing this space, the Industrial Building Repurpose project not only can enhance the physical landscape but also strengthen the community.

Section V Alternative Design Options

Due to the building's current unsafe condition some preliminary work will be needed, regardless of the design options proposed below. All the non-masonry additions, including the large storage facility located on the north side of the building and the addition on the west side of the building, will have to be demolished due to their non repairable condition (Figure 1). The structure will also need to be detoxified, due to lead, arsenic, mold, and wood rot fungi. The extent of detoxification will depend on the amount and location of toxins after phase one testing and inspection is completed and may require some structural components to be shored when removing rotted lumber. The facade of the structure will also need to be rehabilitated, which could include updating the entrances for ADA compliance, structural reinforcements for the exterior masonry walls and foundation, filling the large voids left in the exterior walls from the prior demolition, and new windows and exterior entrances. These facade updates could qualify for the Downtown Revitalization Fund state grant.

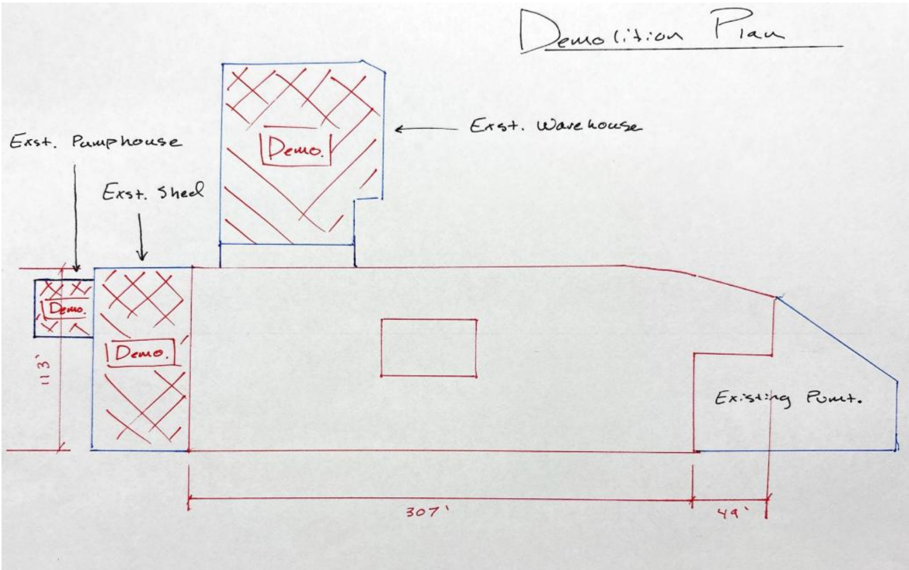


Figure 1. Demolition Plan

Design Option 1:

This option will transform the existing structure into a living space and commercial area with minimal architectural design to keep the renovations affordable. Due to the location of the building, it would be most appropriate to accommodate low-income housing on the second floor and storage facilities on the first. Unfortunately, because the status of the structure is unknown an accurate structural plan cannot be given; however, because the loads from apartment units are relatively high compared to the intended use of the original building, a brand-new steel framed structure will need to replace the existing wood structure. The existing roof will also need to be replaced with a more robust, waterproof, well insulated, and fire-resistant roof system.

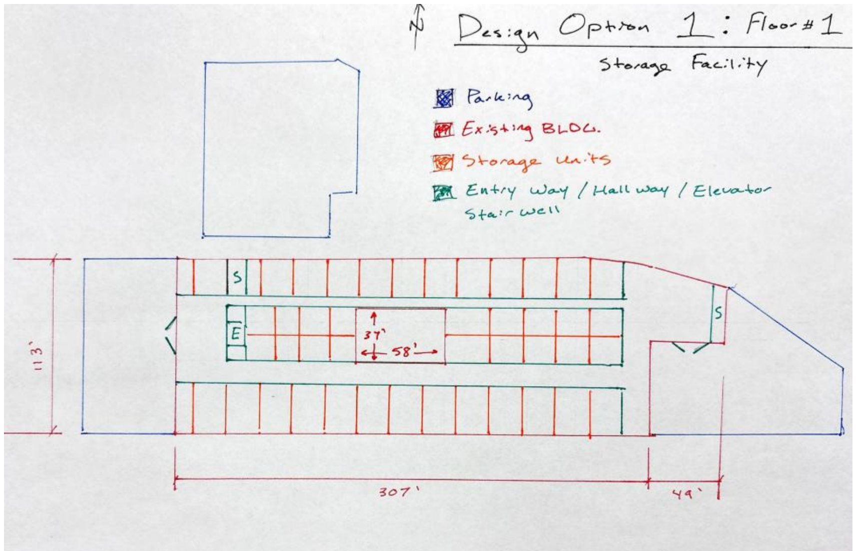


Figure 2. Design Option 1: Floor 1

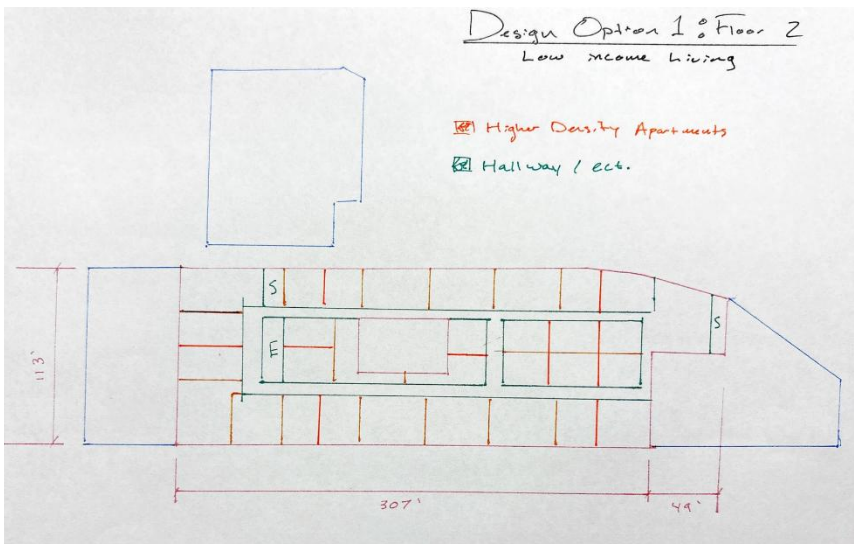


Figure 3. Design Option 1: Floor 2

Figure 4. Low Income Apartment Example

This option would probably take the least amount of time to fully develop and has the largest potential for profit. There would also be some potential state and federal grants available for developing the second-floor low-income housing. On the other hand, this design solution lacks any kind of dimension and may not adhere to the city's plan for this area.

Design Option 2:

This option will transform the structure into a vibrant community center with the maximum architectural design that will turn the building from an eye sore into something pleasant. The architectural design may include a locally commissioned full wall mural on the east side of the building, corrugated steel siding to cover and trim around the wall voids left from the demolition phase, a green roof system, and landscaping.

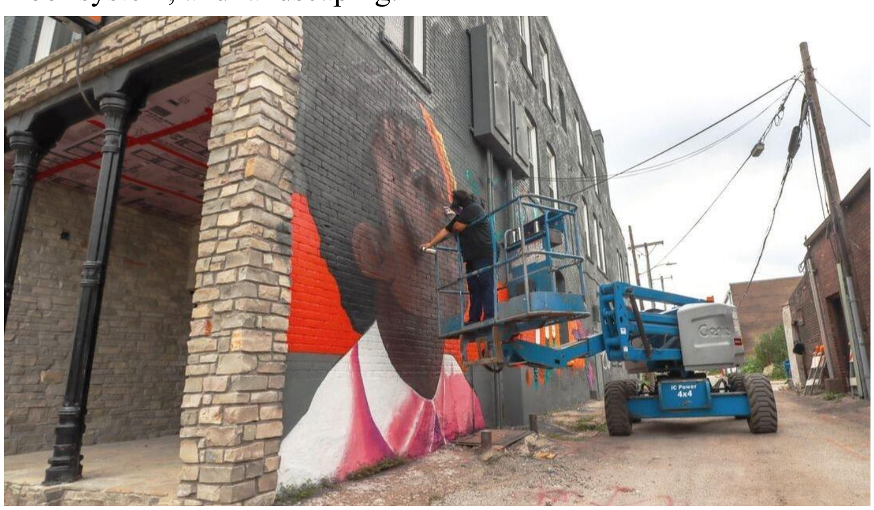


Figure 5. Wall Mural Example

Figure 6. Landscape Example

This building will be extremely versatile and serve various city needs. The first floor will be designed to accommodate cultural events and/or markets. The second floor will be designed to accommodate a donation and volunteer-based library for the benefit of the local youth with potential for youth programs and workshops. It is possible that the loading for the second-floor layout could be supported by repairing the existing wood structure; however, the roof system will need to be replaced with a steel roof to support the roof loads from a green roof.

Figure 7. First Floor Example (Flea Market)

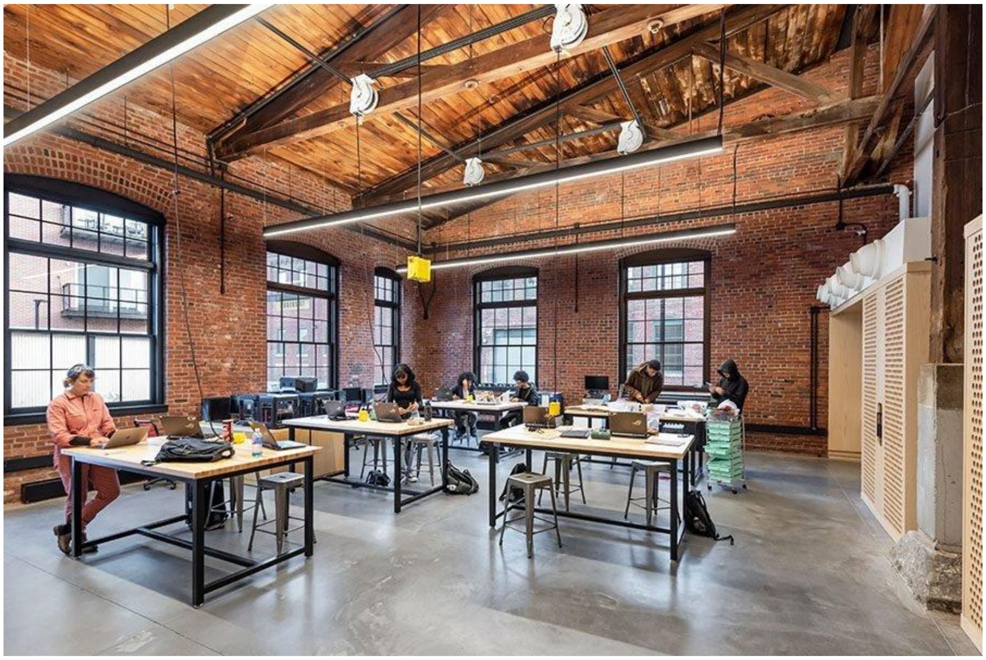


Figure 8. Second Floor Example (Study Area)

This design option will solely benefit the local community. There are also many grants available for projects like this. Unlike the first design option, this one will take the most time to develop and will be the least profitable. It will also require substantial effort from the city to build and maintain.

Design Option 3:

This design option will be a combination of aspects from the previous two options, with the first floor being utilized for a community center and the second for more desirable, spacious housing, including lofts and standard two-bedroom apartments. There will be some architectural work, such as corrugated steel siding to cover and trim around the wall voids left from the demolition phase, landscaping, and a rooftop patio for the residents. The existing wood structure will likely need to be replaced with a steel structure, and the existing roof will need to be replaced with a more robust, waterproof, well insulated, and fire-resistant roof system, including extra reinforcement under the rooftop patio.

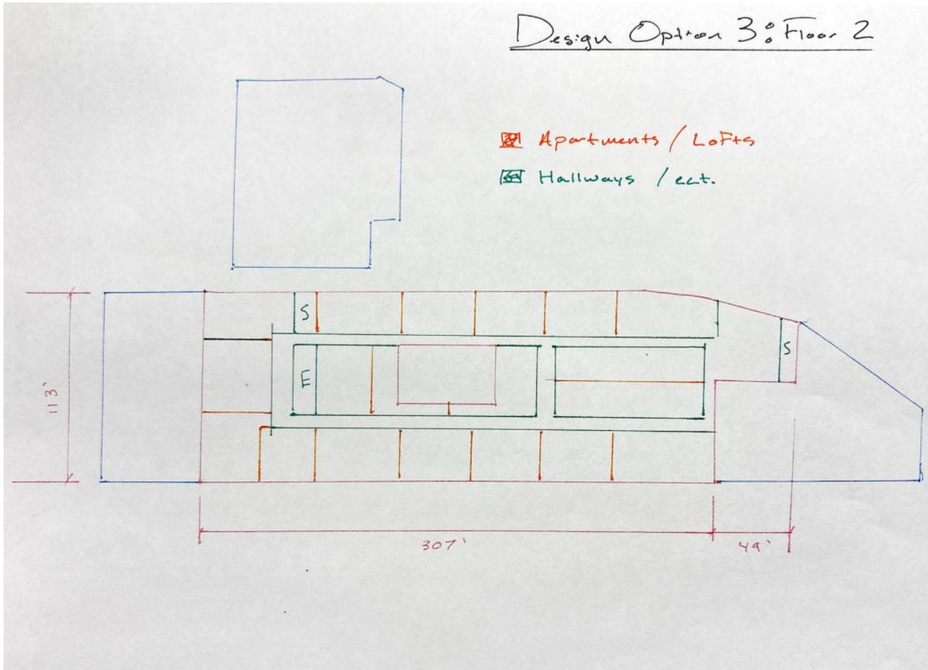


Figure 9. Design Option 3: Floor 2

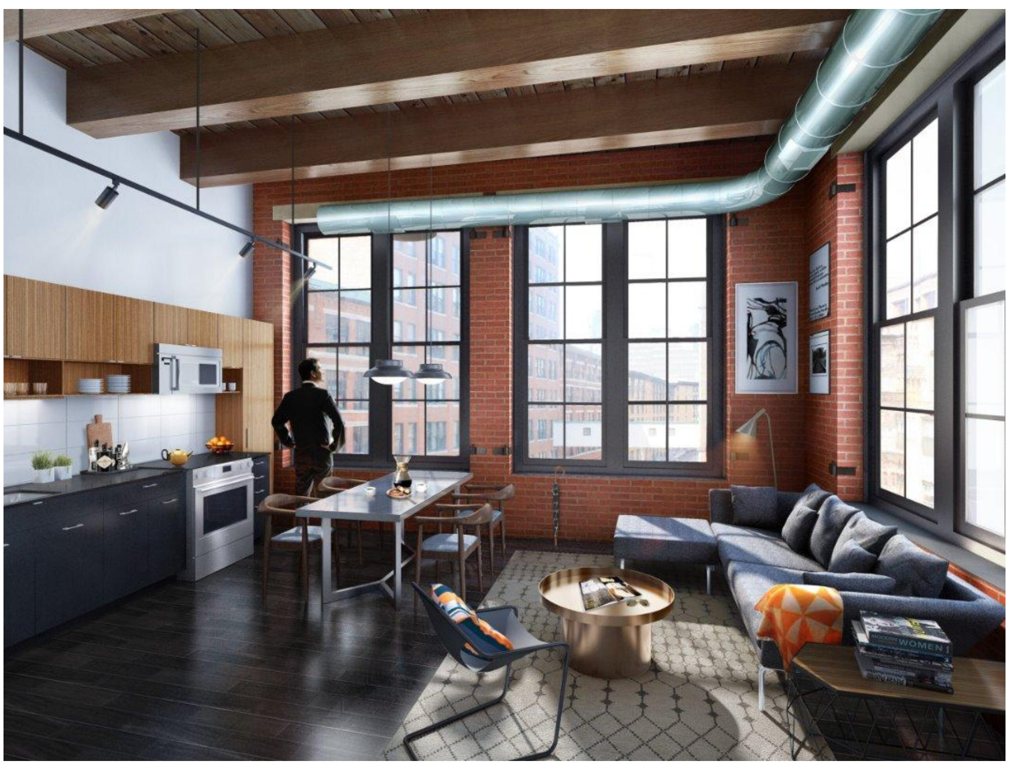


Figure 10. Floor 2 Room Layout Example

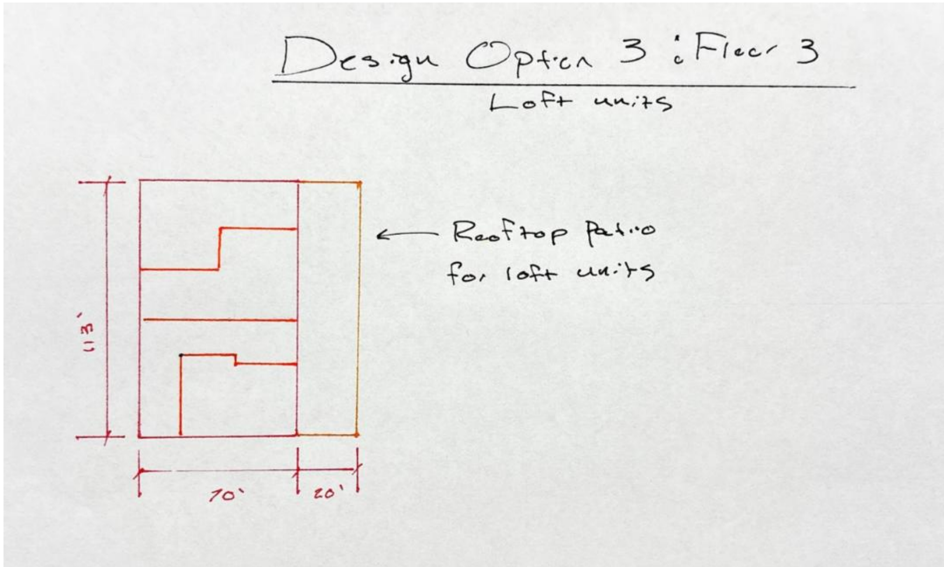


Figure 11. Design Option 3: Floor 3

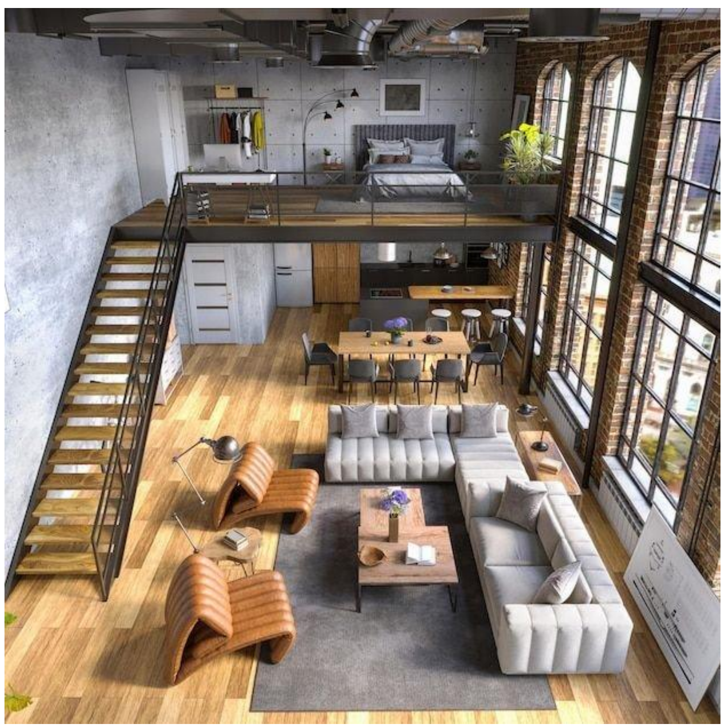
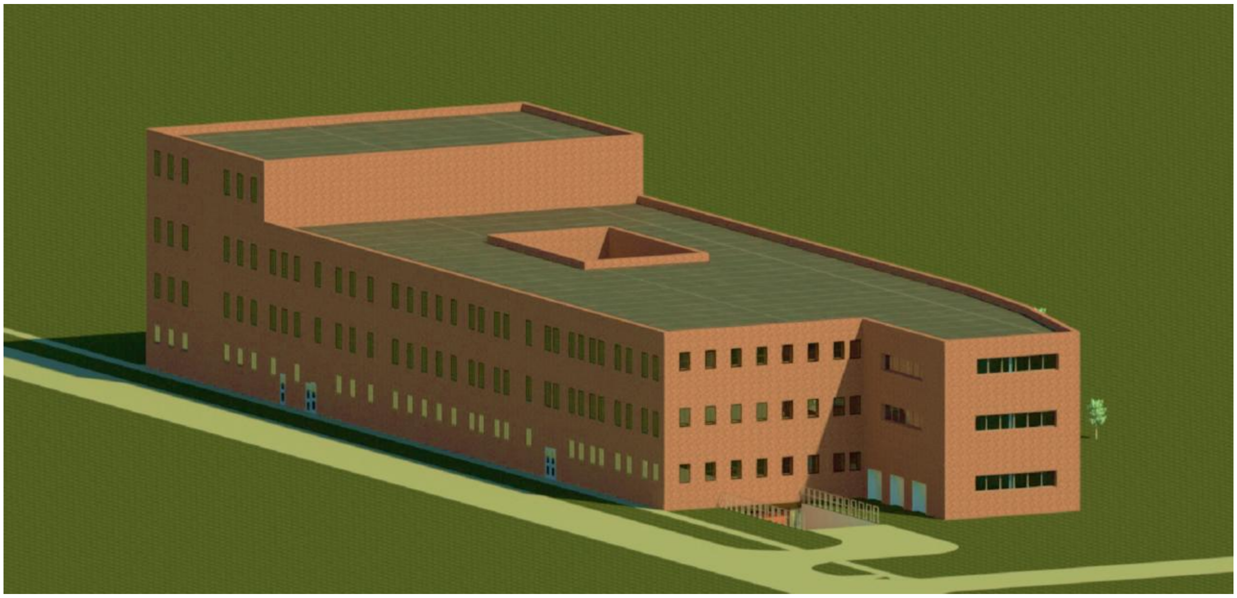


Figure 12. Floor 3 Loft Example

Like the first design option, this one will open the project to developers and will speed up the construction time; similarly, like the second design option, the first floor of the building will be a versatile asset of the city and a means to give back to the local community. Additionally, there will be a range of state and federal grants available for this design option.

Section VI Final Design Details



Demolition

After reviewing the integrity of each section of the building as well as each addition, demolition will be required for all three additions to the north as well as the two additions to the west. These pieces of property were deemed unsalvageable and would be unsafe to work on. By demoing these additions, there will be more space for site work opportunities and will allow to incorporate more natural features to the property.

In addition to the structural demolition, the current sidewalk, all street access driveways, and the concrete pad located in the southeast corner of the property will need to be torn out. Due to the regrading of the land and deteriorating conditions, all concrete currently on the property will be removed.

Lastly, all current trees must be taken out to ensure access for heavy equipment entering and exiting the site for demolition and construction. They will be replaced at different locations around the site.

These details can be found on sheet D.01.

Site Design

The reenergized site introduces a fresh redesign while improving the surrounding area. This 1.28-acre location offers new opportunities and the potential to restore natural features lost as the site deteriorated.

The existing site grading poses several challenges, including limited first-floor access on the east side and inadequate water runoff management. To address these issues, the grading will be reconfigured around the east wing to provide compliant access to the first floor and prevent water accumulation at the foundation. This will be achieved by implementing a steeper slope just north of the sidewalk to meet the first-floor elevation. Additionally, a shallow swale will be installed east of the entry to capture and redirect surface runoff, channeling it to the north side of the site to mitigate potential seepage. Minimal grading will also be imposed around the site to configure to the new site features. These details can be found on sheet L.01.

A new access drive located at the southeast corner of the site is the primary structural addition. This feature will allow residents and visitors to access from Valley Street to the underground parking located beneath the building. This access drive was designed using SUDAS standards and is an 8" PCC pavement. In addition, a dumpster access drive will be located at the northeast corner of the site, providing entry for refuse trucks. This drive also follows SUDAS standards and will be an 8" PCC pavement. These details can be found on sheet C.01.

A new sidewalk will replace the existing one and will align with the updated site grading. A dedicated access walk on the east elevation will provide private entry for residents. An additional access walk on the north elevation will connect the residential wing and community center, serving as a secondary entry point and facilitating access to the dumpster enclosure at the northeast corner. All pedestrian pathways are designed in compliance with SUDAS specifications and ADA accessibility standards to ensure full functionality for all users. These details can be found on sheet C.01.

New bluegrass seeding will be spread on the north and west lawns covering the demolished areas and extending to the property lines to ensure all previous dirt patches are restored to a new grass field. In addition, Kentucky Coffee trees will be planted along the north lawn property line to add privacy from the rail line that runs along the northeast part of the property line. Green Velvet Boxwood will run along the outside of the proposed north access walkway and northwest corner of the building to ensure more privacy while also introducing more natural features and attracting wildlife. These details can be found on sheet L.02.

Architectural

The building is designed to clearly separate residential spaces from recreational and office areas. On the west side, floors 1 through 4 are intended for residential units, offering a quieter, more private area for long-term living.

Below the main structure, the basement and underground floor are used entirely for parking, serving both the residential and public sides of the building. Parking access is provided internally, allowing residents and guests to easily reach their destinations without leaving the building. Each wing of the building includes two stairwells and an elevator, providing full vertical access and meeting life safety and ADA accessibility requirements. This circulation setup keeps traffic flow efficient while maintaining separate access paths for each use. This design has a total of 75 spaces with 3 spaces fulfilling our ADA requirements. These spaces can be shown in sheets AD.01 and AD.02.

The east side of the building is designed with community, flexibility, and accessibility in mind. Floors 1 and 2 serve as large, open recreational areas that support a wide range of uses, from public events and community gatherings to workshops, wellness activities, and collaborative programs. These flexible spaces are intentionally positioned at the heart of the community-facing side of the building, encouraging interaction and making it easy for visitors to engage with the space. On the third floor, the east wing transitions into a professional setting, providing office spaces for administrative staff and on-site support. This mix of public and private programming allows the building to remain active throughout the day while serving a diverse set of users.

In contrast to the activity-focused east wing, the residential portion of the project prioritizes comfort, peace, and practicality. The development includes 20 thoughtfully designed living units, each carefully arranged to maximize space efficiency while welcoming in natural light. With five distinct floor plans, the units support a variety of living arrangements—whether for individuals, couples, or small families—while maintaining a consistent standard of comfort, functionality, and everyday convenience. A rendering of one of the bedrooms in our unit is shown in figure 13 below.

Figure 13: Bedroom Rendering **Figure 14: Kitchen Rendering**

A key design goal throughout the project was to honor and preserve the architectural beauty of the existing brick structure. Rather than replace or overshadow it, the new construction embraces the original building's character by highlighting the craftsmanship and materiality of the brick façade. Exposed brick surfaces are incorporated into both interior and exterior design elements, creating a visual and tactile connection between old and new. This approach not only grounds the building in its historical context but also adds warmth, texture, and authenticity to the modern spaces being introduced.

The west wing of the building includes a large, two-story open space that's designed for flexible commercial and community use. This area is meant to host a variety of events such as indoor farmers markets, community gatherings, vendor pop-ups, weddings, and other public or private activities. The layout is open across both floors with very few permanent walls, allowing the space to be easily rearranged depending on the type of event. Fgure 14 provides an example of a kitchen in the community space.

Figure 15: Community Space Rendering

The open floor plan makes it easy for people to walk through and gives event organizers ample space to set up booths, tables, or seating. (See Figure 15.) The high ceilings and large windows provide plenty of natural light during the day.

Restrooms are located within the building and can be easily accessed from the commercial space. These facilities are designed to meet building code and ADA accessibility requirements and support events of varying size and duration. Storage areas are also included nearby to support event setup and equipment needs.

Located on the third floor of the east wing, the building includes two office units, each approximately 9,000 square feet. These spaces are designed to provide a quiet, focused environment away from the busier recreational areas on the lower floors. Placing the offices above public event spaces keeps building functions organized and separated by use. Each unit includes 56 open desk stations arranged for flexible team layouts, along with 5 private offices and 2 meeting rooms to support individual work and group collaboration. A shared kitchen is also provided in each unit, offering space for staff to store food, prepare meals, and take breaks without leaving the office floor. Restrooms are located on the third floor for easy access. Large exterior windows provide natural daylight for the workspace, creating a more comfortable working environment throughout the day. Office staff and visitors can reach the third floor from the ground level or directly from the underground parking garage using the east wing elevator. The stairwells in each wing also provide additional vertical access. (See Figure 16.)

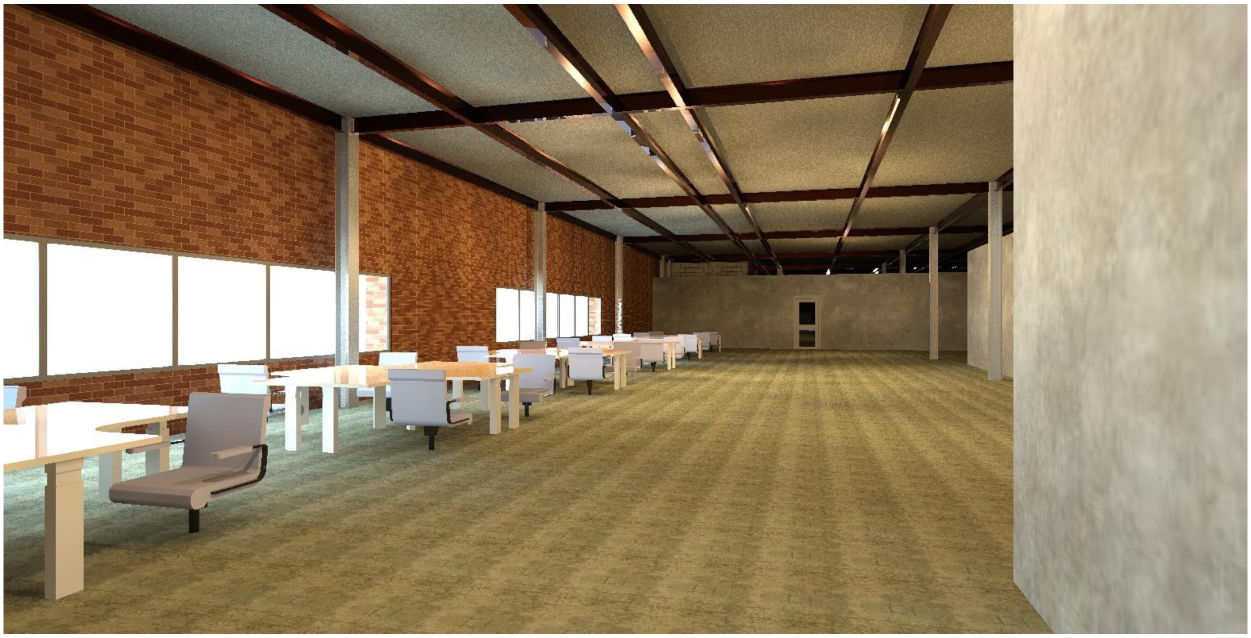


Figure 16: Office Space Rendering

Offices may serve as administrative support for the building or be leased to outside tenants. Floor plans can be found in Architectural sheets AD.06 & AD.07.

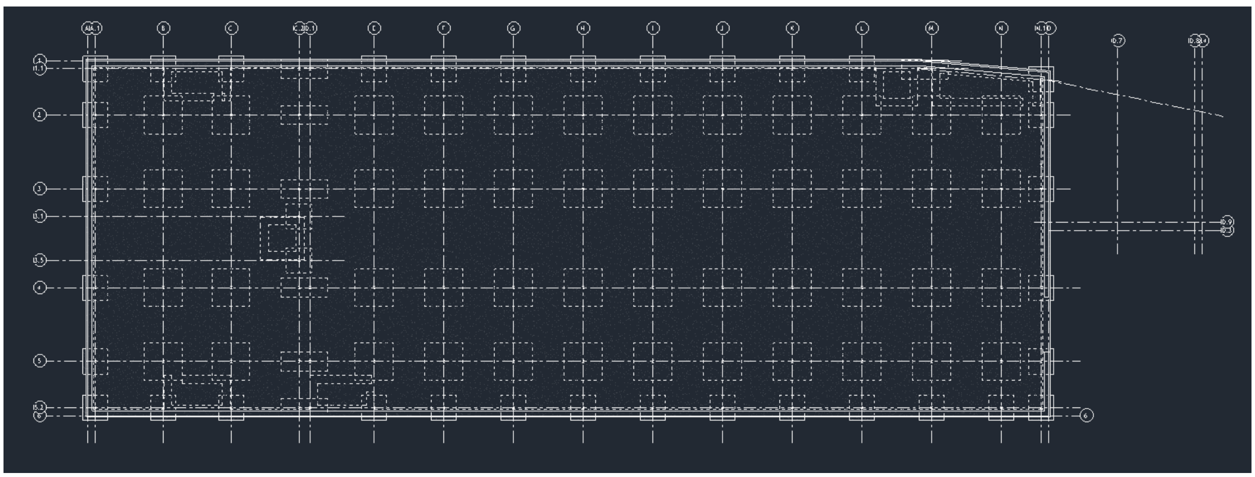
Structural

The structural design of the proposed complex was carried out using a steel framing system to meet the project's spatial, architectural, and performance requirements. The design process involved comprehensive structural analysis and member selection based on established industry standards and tools. The AISC Steel Construction Manual served as the primary reference for designing all steel members, with column sizes selected using the provided load tables and design aids to ensure efficiency and compliance with strength and serviceability limits.

Loading conditions were developed in accordance with ASCE 7, which outlines the minimum design loads for buildings and other structures. Various load combinations were applied to reflect realistic scenarios the structure could be subjected to over its lifespan, including dead load, live load, wind, and snow. Snow loads, in particular, were calculated using the AISC Hazard Tool to obtain accurate, site-specific environmental data. This information was then incorporated into the structural analysis models to ensure the building's performance remained reliable under both typical and extreme conditions. The full structural system, including beams, girders, and columns, was analyzed to meet code requirements and to optimize material usage while maintaining structural integrity and safety.

Due to the intended nature of the proposed complex, steel was chosen as the primary material for the structural frame in order to accommodate large girder span lengths and to meet the architectural detailing requirements. Steel's versatility and strength made it ideal for handling the design constraints while still allowing for open interior spaces. The structural frame was divided into three major sections, each with its own unique set of design challenges and constraints: the basement or parking garage, the west residential side of the building, and the east side, which houses office and community space.

The column grid was carefully laid out to ensure efficient vertical load transfer from the roof level all the way down to the foundation, while also maintaining practical spacing. Specifically, columns were spaced far enough apart to accommodate two driving lanes and four rows of parking within the basement level, satisfying both structural and functional requirements. This allowed for optimal use of the underground space without compromising structural integrity.



On the east side of the building, a courtyard is located near the center of the structure. The position of this courtyard introduced a significant design challenge, particularly at the basement level. Its location made it physically impossible to place a continuous vertical column line that runs from the foundation to the roof while still providing adequate driving clearance in the parking garage. To resolve this, the columns located directly underneath the courtyard terminate at the first floor. To maintain structural continuity and load transfer, a secondary row of columns was introduced behind the courtyard. These columns not only served a structural purpose but also became a design feature, helping to define and open up the adjacent community space.

However, the discontinuity introduced by terminating columns at the first floor and relocating them behind the courtyard created a critical structural issue—namely, large deflections and bending stresses in the beams that support the upper floors. To manage these forces and maintain structural performance, transfer girders were designed and placed beneath the relocated columns. These girders were specifically sized and reinforced to handle the concentrated loads and increased moment demands, ensuring the system could accommodate the vertical loads without excessive deformation or failure

Section VII Engineer’s Cost Estimate

The total cost for the construction, which includes materials and labor, is $15,000,000. These costs were calculated using the Iowa Department of Transportation Bid Tabs, Iowa Public Works Bureau. A detailed breakdown of these costs can be found in Appendix B

The total estimated cost to complete this project is $21,000,000. This amount includes all engineering services, materials, labor, and construction. It also accounts for construction administration at 20% and a contingency allowance of 20% to cover unforeseen conditions or adjustments during implementation.

Section VIII Attachments

Appendix A

Design Specifications and Standards:

Americans with Disabilities Act of 1990, 42 U.S.C. § 12101 et seq. (1990).

American Institute of Steel Construction. (2017). *Steel construction manual* (16th ed.). American Institute of Steel Construction.

City of Burlington. (n.d.). *Code of ordinances of the City of Burlington, Iowa.*

City of Burlington. (n.d.). *Tree planting listing permit / Approval required to plant a tree in city right-of-way – Contact forestry dept.*

International Code Council. (2021). *2021 International building code.* International Code Council.

Iowa Legislature. (n.d.). *Iowa Code § 216C – Persons with disabilities: Access to public places.*

Iowa Statewide Urban Design and Specifications (SUDAS). (n.d.). *Design manual: Chapter 5 – Roadway design, section 5C – Geometric design criteria.*

Iowa Statewide Urban Design and Specifications (SUDAS). (n.d.). *Design manual: Chapter 8 – Parking lots, section 8B – Layout and design.*

Iowa Statewide Urban Design and Specifications (SUDAS). (n.d.). *Design manual: Chapter 12 – Pedestrian and bicycle facilities, section 12A-2 – Pedestrian facilities.*

Appendix B

UNIVERSITY OF IOWA
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
Project Design & Management

(CEE: 4850:0001)

Final Report # 02-Spring2025

Industrial Building Repurposing

Discipline	Cost (USD)
Demolition	$1,000,000.00
Site	$1,000,000.00
Structural	$4,000,000.00
Shoring	$1,500,000.00
MEP	$5,500,000.00
Architectural	$2,000,000.00
Materials and Labor	$15,000,000.00
Construction and Administration (20%)	$3,000,000.00
Contingency (20%)	$3,000,000.00
Total Construction	$21,000,000.00

Appendix C

Site Work:

City of Burlington - Tree Planting Listing

Permit / Approval Required to Plant a Tree in City Right-of-Way - Contact Forestry Dept.

9-12 Feet: Curb to Property Line/Sidewalk

Common Name	Scientific Name	Cultivars/ Selections	Pros	Cons	Flowers
American Elm ***	*Ulmus Americana*	Jefferson, Prairie Expedition (Lewis and Clark), Princeton	Upright Fast Growing	Aggressive Pruning Required Early	
Bald Cypress	*Taxodium distichum*		Unique Bark		
Black Tupelo	*Nyssa slyvatica*		Fall Color	Double Leaders Need Pruned	
Ginkgo (male only)	*Ginkgo biloba (Male Only)*	Autumn Gold, Golden Colonnade, Halka, Magyar, Presidential Gold, Princeton Sentry	Fall Color		
Kentucky Coffee tree	*Gymnocladus dioicus*	Espresso (seedless)			
Larch	*Larix decidua*				
Sweet gum	*Liquidambar styracillua*	Fruitless Variety's Recommended	Fall Color, Maple Replacement	Seeds are Persistent	
Thorn-less Honey locust	*Gleditisia triacanthos*	Northern Acclaim, Skyline, Shademaster	Fast Growth		
Hardy Rubber Tree	*Eucommia ulmoides*				
Macho Cork Tree	*Phellodendron spp.*				
Ornamental Pear	*Pyrus spp.*	"Westwood" Korean Sun, Capitol, Aristocrat, Redspire	Some have good fall color	Poor Branch Angles, Prone to Storm Damage	Spring
Turkish Filbert	*Corylus colurna*				
European Hornbeam	*Carpinus betulus*	Emerald Avenue	Unique Form	Pruning	
Japanese Zelkova	*Zelkova serrata*	Wireless, City Sprite, Green Village, Green Vase	Vase Shape	Poor Branch Angles	
Norway Maple	*Acer platanoides*		Foliage	Frost Cracks	

Table 5C-1.01: Preferred Roadway Elements

Elements Related to Functional Classification

Design Element	Local		Collector		Arterial	
	R	***C/I***	***R***	***C/I***	***R***	***C/I***
General						
Design level of service[1]	D	D	C/D	C/D	C/D	C/D
Lane width (single lane) (ft)[2]	10.5	12	12	12	12	12
Two-way left-turn lanes (TWLTL) (ft)	N/A	N/A	14	14	14	14
Width of new bridges (ft)[3]	See Footnote 3					
Width of bridges to remain in place (ft)[4]	----------	----------	----------	----------	----------	----------
Vertical clearance (ft)[5]	14.5	14.5	14.5	14.5	16.5	16.5
Object setback (ft)[6]	3	3	3	3	3	3
Clear zone (ft)	Refer to Table 5C-1.03, Table 5C-1.04, and 5C-1, C, 1					
Urban						
Curb offset (ft)[7]	2	2	2	3	3	3
Parking lane width (ft)	8	8	8	10	N/A	N/A
Roadway width with parking on one side[8]	26/27/31[9]	34	34	37	N/A	N/A
Roadway width without parking[10]	26	31	31	31	31	31
Raised median with left-turn lane (ft)[11]	N/A	N/A	19.5	20.5	20.5	20.5
Cul-de-sac radius (ft)	45/48[12]	45/48[12]	N/A	N/A	N/A	N/A
Rural Sections in Urban Areas						
Shoulder width (ft)						
ADT: under 400	4	4	6	6	10	10
ADT: 400 to 1,500	6	6	6	6	10	10
ADT: 1,500 to 2000	8	8	8	8	10	10
ADT: above 2,000	8	8	8	8	10	10
Foreslope (H:V)	4:1	4:1	4:1	4:1	6:1	6:1
Backslope (H:V)	4:1	4:1	4:1	4:1	4:1	4:1

R = Residential, C/I = Commercial/Industrial

Table 8B-1.02: Minimum Parking Dimensions

Parking Lot Dimension				Parking Angle (θ)				
				Two-way Aisle			One-way Aisle	
				90°	60°	45°	60°	45°
Stall Projection			SP	18'-0"	15'-7"	12'-9"	15'-7"	12'-9"
Aisle Width			A	24'-0"	25'-10"	29'-8"	20'-4"	21'-6"
Base Module			M_1	60'-0"	57'-0"	55'-2"	51'-6"	47'-0"
Single Loaded Module			M_2	42'-0"	39'-0"	37'-7"	32'-6"	29'-5"
Wall to Interlock			M_3	60'-0"	55'-10"	52'-2"	49'-4"	44'-0"
Interlock to Interlock			M_4	60'-0"	53'-8"	49'-2"	47'-2"	41'-0"
Overhang			o	2'-6"	2'-2"	1'-9"	2'-2"	1'-9"
Stall Width	*8'-6"*	Width Projection	WP	8'-6"	9'-10"	12'-0"	9'-10"	12'-0"
		Interlock	i	0'-0"	2'-2"	3'-0"	2'-2"	3'-0"
	9'-0"	Width Projection	WP	9'-0"	10'-5"	12'-9"	10'-5"	12'-9"
		Interlock	i	0'-0"	2'-3"	3'-2"	2'-3"	3'-2"

Appendix D

Structural:

Performed by: Mason Loete

Structural Design Calculations

Table of Contents

Balanced and Unbalanced Snow Load Calculation Summary

Balanced Snow Load

$win := 109\ mph$

- Risk category + importance factor

$RiskCat := 2$ $\quad I_s := 1.0$

- Ground Snow Load

$$P_g := 36\ \frac{lbf}{ft^2}$$

- Roof Snow Load Factor

$C_e := 1.0$ *Assume partially Exposed*

$C_t := 1.1$

$C_s := 1.0$

- Balanced Snow Load

$$P_s := 0.7 \cdot C_s \cdot C_e \cdot C_t \cdot I_s \cdot P_g = 27.72\ psf$$

- Unbalanced Snow load

$l_u := 15.44$ $\quad W_2 := 0.55$ $\quad p_g := 3$

$$\gamma := \left(0.13 \cdot P_g \cdot \frac{ft^2}{lbf} + 14\right) \frac{lb}{ft^3} = 18.68\ \frac{lb}{ft^3}$$ snow unit weight

$$h_D := 1.5 \cdot \sqrt{\frac{\left(P_g \cdot \frac{ft^2}{lbf}\right)^{0.74} \cdot l_u^{\,0.7} \cdot W_2^{\,1.7}}{\gamma \cdot \frac{ft^3}{lb}}} = 2.049 \qquad S := \frac{12}{4} = 3$$

$$d_w := \frac{8}{3} \cdot h_D \cdot \sqrt{S} = 9.465 \qquad h_w := \frac{\left(h_D \cdot \gamma \cdot \frac{ft^3}{lb}\right)}{\sqrt{S}} = 22.1$$

$P_s = 27.72\ psf$ $\quad 0.3 \cdot P_s = 8.316\ psf$

Wind Pressures

5. MWFRS Design Wind Pressure Calculations

$B_N := 356\ ft$

$L_N := 113\ ft$

Building Classification

$RiskCat = 2$

Wind load Parameters

$V := 109\ mph$ basic wind speed (hazard tool)

$K_{zt} := 1.0$ topography factor (26.8)

$K_d := 0.85$ Directional Factor (26.6-1)

$exposure := \text{"B"}$ Assumed suburban are (26.7.2)

$surfaceRoughness := \text{"B"}$

Ke

$z_{ground} := 735.47\ ft$ $K_e := \exp\left(-0.0000362 \cdot \frac{z_{ground}}{ft}\right) = 0.974$

G gust effect

$G := 0.85$ Building is low rise (26.9)

Internal Pressure Coefficient

$GC_{pi} := 0.18$ (table 26.11-1)

Effective area + mean roof height

$MRH := \frac{(15\ ft + 10\ in) + 11\ ft}{2} = 13.417\ ft$

Kz

$K_z := 0.57$ for MWFRS (table 26.10-1)

Velocity Pressures

$$q_z := \frac{0.00256\ psf}{mph^2} \cdot K_z \cdot K_{zt} \cdot K_d \cdot K_e \cdot V^2 = 14.349\ psf$$

$$q_p := \frac{0.00256\ psf}{mph^2} \cdot K_z \cdot K_{zt} \cdot K_d \cdot K_e \cdot V^2 = 14.349\ psf$$ for MWFRS

$K_d = 0.85$ $GC_{pi} = 0.18$

Wind Direction North

North Wind Variables

$B_N = 356\ ft$ $L_N = 113\ ft$

$h := MRH = 13.417\ ft$ $\theta := 18.43$

$\frac{L_N}{B_N} = 0.317$ $\frac{h}{L_N} = 0.119$

$\frac{h}{2} = 6.708\ ft$ $h = 13.417\ ft$ $2 \cdot h = 26.833\ ft$

North External Pressure Coefficient

Cp Wall surf. 1-6

$$C_{PNW} := \begin{bmatrix} 0.8 \\ -0.7 \\ -0.5 \\ -0.7 \\ -0.5 \\ -0.7 \end{bmatrix}$$

Cp Roof parallel to wind direction surf. 8 and 9

$$C_{PNP} := \begin{bmatrix} -0.9 \\ -0.9 \\ -0.5 \\ -0.3 \end{bmatrix}$$

$$L_{roof} := \begin{bmatrix} \frac{h}{2} \\ h \\ 2\ h \\ L_N \end{bmatrix} ft = \begin{bmatrix} 6.708 \\ 13.417 \\ 26.833 \\ 113 \end{bmatrix} ft^2$$

Cp Roof surf. 7 and 10

$C_{PNR} := \begin{bmatrix} -0.3 \\ 0 \end{bmatrix}$ *for surface 7 rounding theta to 20

North Wind Pressures

surface 1-6: $p_1 := q_z \cdot K_d \cdot G \cdot C_{PNW}(0) - q_z \cdot K_d \cdot GC_{pi} = 6.098\ psf$

$p_2 := q_z \cdot K_d \cdot G \cdot C_{PNW}(1) - q_z \cdot K_d \cdot GC_{pi} = -9.452\ psf$

$p_3 := q_z \cdot K_d \cdot G \cdot C_{PNW}(2) - q_z \cdot K_d \cdot GC_{pi} = -7.379\ psf$

$p_4 := q_z \cdot K_d \cdot G \cdot C_{PNW}(3) - q_z \cdot K_d \cdot GC_{pi} = -9.452\ psf$

$p_5 := q_z \cdot K_d \cdot G \cdot C_{PNW}(4) - q_z \cdot K_d \cdot GC_{pi} = -7.379\ psf$

$p_6 := q_z \cdot K_d \cdot G \cdot C_{PNW}(5) - q_z \cdot K_d \cdot GC_{pi} = -9.452\ psf$

surface 7: $p_7 := q_z \cdot K_d \cdot G \cdot C_{PNR}(0) - q_z \cdot K_d \cdot GC_{pi} = -5.306\ psf$

surface 10: $p_{10} := q_z \cdot K_d \cdot G \cdot C_{PNR}(1) - q_z \cdot K_d \cdot GC_{pi} = -2.195\ psf$

surface 8: $p_{8a} := q_z \cdot K_d \cdot G \cdot C_{PNP}(0) - q_z \cdot K_d \cdot GC_{pi} = -11.526\ psf$

$p_{8b} := q_z \cdot K_d \cdot G \cdot C_{PNP}(1) - q_z \cdot K_d \cdot GC_{pi} = -11.526\ psf$

$p_{8c} := q_z \cdot K_d \cdot G \cdot C_{PNP}(2) - q_z \cdot K_d \cdot GC_{pi} = -7.379\ psf$

$p_{8d} := q_z \cdot K_d \cdot G \cdot C_{PNP}(3) - q_z \cdot K_d \cdot GC_{pi} = -5.306\ psf$

surface 9: $p_{9a} := q_z \cdot K_d \cdot G \cdot C_{PNP}(0) - q_z \cdot K_d \cdot GC_{pi} = -11.526\ psf$

$p_{9b} := q_z \cdot K_d \cdot G \cdot C_{PNP}(1) - q_z \cdot K_d \cdot GC_{pi} = -11.526\ psf$

$p_{9c} := q_z \cdot K_d \cdot G \cdot C_{PNP}(2) - q_z \cdot K_d \cdot GC_{pi} = -7.379\ psf$

$p_{9d} := q_z \cdot K_d \cdot G \cdot C_{PNP}(3) - q_z \cdot K_d \cdot GC_{pi} = -5.306\ psf$

Live Load

$l_{roof} := 20\ psf$ $\quad l_{office} := 50\ psf$ $\quad l_{gym} := 100\ psf$

$l_{garage} := 40\ psf$ $\quad l_{room} := 40\ psf$

- Community Space: chose live load for gymnasium because it is the most conservative for a multi use space

Dead Load

$P_s = 27.72\ psf$ $\quad d_{roof} := 10\ psf$ $\quad d_{floor} := 93\ psf$ $\quad d_{cs} := 85\ psf$ $\quad d_p := 72\ psf$

- Roof includes: decking, vapor layer, insulation, waterproof membrane
- Floor includes: decking, 6 in. conc, partition walls

LFRD Factored Loading

Roof

$w_{roof1} := 1.2 \cdot d_{roof} + 0.5 \cdot P_s = 25.86\ psf$

$w_{roof2} := 1.2 \cdot d_{roof} + 1.6 \cdot l_{roof} = 44\ psf$

$w_{roof} := 1.2 \cdot d_{roof} + 1.6 \cdot P_s = 56.352\ psf$

Community space

$w_{cs} := 1.2 \cdot d_{cs} + 1.6 \cdot l_{gym} = 262\ psf$

Residential Floor

$w_{floor} := 1.6 \cdot l_{room} + 1.2 \cdot d_{floor} = 175.6\ psf$

Office Space

$w_{office} := 1.2 \cdot d_{floor} + 1.6 \cdot l_{office} = 191.6\ psf$

Parking Garage

$w_p := 1.6 \cdot l_{garage} + 1.2 \cdot d_p = 150.4\ psf$

Roof Joist Design

- **Demand**

$l_j := 21\ ft + 8\ in = 21.667\ ft$ $\qquad$ $trib := 8\ ft$

$w_j := w_{roof} \cdot trib = 0.451\ \dfrac{kip}{ft}$ $\qquad$ $R_{jr} := \dfrac{w_j \cdot l_j}{2} = 4.884\ kip$

$M_{jr} := \dfrac{w_j \cdot {l_j}^2}{8} = 26.454\ kip \cdot ft$ $\qquad$ $V_{jr} := R_{jr} = 4.884\ kip$

- **Capacity** **w12*19 A992 section**

$F_y := 50\ ksi$ $\qquad$ $E := 29000\ ksi$ $\qquad$ $Z_x := 24.7\ in^3$ $\qquad$ $I := 130\ in^4$

1. Plastic Moment

$.9M_{px} := \left(F_y \cdot Z_x\right) \cdot 0.9 = 92.625\ kip \cdot ft$ $\qquad$ $DCR := \dfrac{M_{jr}}{.9M_{px}} = 0.286$

2. Shear

$\phi V_n := 79.2\ kip$ $\qquad$ $DCR_v := \dfrac{V_{jr}}{\phi V_n} = 0.062$

3. Total Deflection

$\Delta_{Tj} := \dfrac{5 \cdot w_j \cdot {l_j}^4}{384 \cdot E \cdot I} = 0.593\ in$ $\qquad$ $\delta_{Tj} := \dfrac{l_j}{360} = 0.722\ in$ $\qquad$ $\Delta_{Tj} \le \delta_{Tj} = 1$

- These joist are overdesigned for proper connection to beam

Roof Beam Design

- **Demand**

$R_b := \frac{R_{jr}}{kip} \cdot 3 = 14.652$ $\quad P_1 := \frac{R_{jr}}{kip} = 4.884$ $\quad P_2 := 2 \cdot \frac{R_{jr}}{kip} = 9.768$ $\quad s := \frac{39}{5}$

$$M_1(x) := -R_b \cdot x + M_1 \xrightarrow{solve, M_1, float, 4} 14.65 \cdot x$$

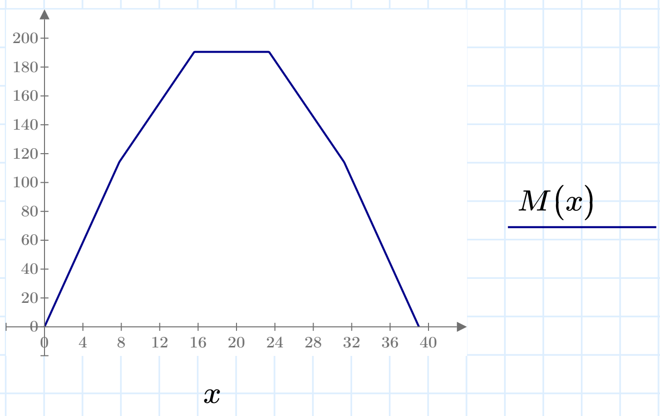
$$M_2(x) := -R_b \cdot x + M_2 + P_1 \cdot (x - s) \xrightarrow{solve, M_2, float, 4} 9.768 \cdot x + 38.09$$

$$M_3(x) := -R_b \cdot x + M_3 + P_1 \cdot (x - s) + P_2 \cdot (x - 2 \cdot s) \xrightarrow{solve, M_3, float, 4} 0.1 \cdot 10^{-15} \cdot x + 190.5$$

$$M_4(x) := -R_b \cdot x + M_4 + P_1 \cdot (x - s) + P_2 \cdot (x - 2 \cdot s) + P_2 \cdot (x - 3 \cdot s) \xrightarrow{solve, M_4, float, 4} -9.768 \cdot x + 419.0$$

$$M_5(x) := -R_b \cdot x + M_5 + P_1 \cdot (x - s) + P_2 \cdot (x - 2 \cdot s) + P_2 \cdot (x - 3 \cdot s) + P_1 \cdot (x - 4 \cdot s) \xrightarrow{solve, M_5, float, 4} -14.65 \cdot x + 571.4$$

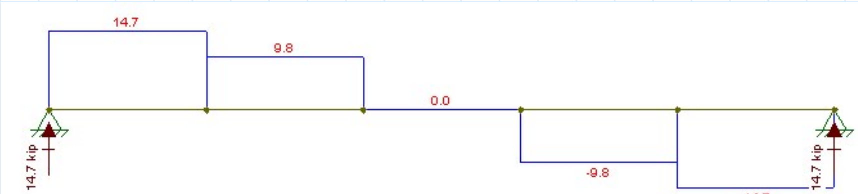
$$M(x) := \begin{cases} M_1(x) & \text{if } x < s \\ M_2(x) & \text{else if } s \le x < 2 \cdot s \\ M_3(x) & \text{else if } 2 \cdot s \le x < 3 \cdot s \\ M_4(x) & \text{else if } 3 \cdot s \le x < 4 \cdot s \\ M_5(x) & \text{else} \end{cases}$$



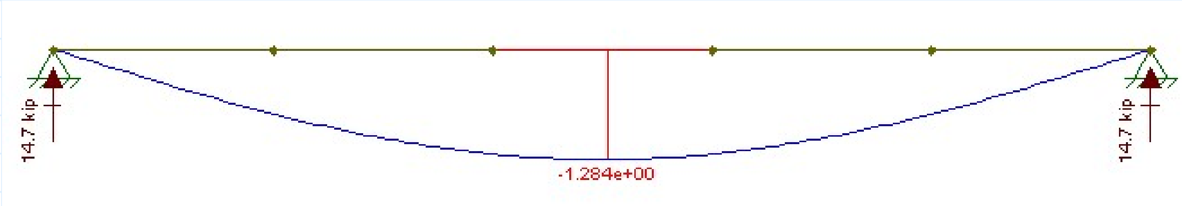
$x := 0, 0.1 .. 26$ $\quad g := 2$ $\quad x_{max} := \text{maximize}(M, g) = 17$

$M_b := M(x_{max}) \cdot kip \cdot ft = 190.5\ kip \cdot ft$ $\quad R_{roof} := R_b \cdot kip = 14.652\ kip$

Shear Diagram



Deflection Diagram



$V_{br} := R_{roof} = 14.652\ kip$ $\quad \Delta_{Tb} := 1.284\ in$ $\quad l_{br} := 39\ ft$

- **Capacity** **w18*76 A992 section** clear $(Z_x, .9M_{px}, DCR, \phi V_n, DCR_v)$

$Z_x := 163\ in^3$

1. Plastic Moment

$.9M_{px} := (F_y \cdot Z_x) \cdot 0.9 = 611.25\ kip \cdot ft$ $\quad DCR := \frac{M_b}{.9M_{px}} = 0.312$

2. Shear

$\phi V_n := 232\ kip$ $\quad DCR_v := \frac{V_{br}}{\phi V_n} = 0.063$

3. Total Deflection

$\Delta_{Tb} = 1.284\ in$ $\quad \delta_{Tb} := \frac{l_{br}}{360} = 1.3\ in$ $\quad \Delta_{Tb} \le \delta_{Tb} = 1$

- A W24*68 will be used because it it more structurally efficient, with a higher section modulus and inertia it will also be stronger.

USE : W24*68

Residential and Office Joist Design

- **Demand**

$l_{jo} := 22\ ft + 3\ in = 22.25\ ft$ $\quad$ $\boxed{trib} := 4\ ft + 10.5\ in = 4.875\ ft$

$w_{jo} := w_{office} \cdot trib = 0.934\ \frac{kip}{ft}$ $\quad$ $R_{jo} := \frac{w_{jo} \cdot l_{jo}}{2} = 10.391\ kip$ $\quad$ $V_{jo} := R_{jo}$

$M_{jo} := \frac{w_j \cdot {l_{jo}}^2}{8} = 27.898\ kip \cdot ft$

- **Capacity** $\quad$ **w14*26 A992 section** $\quad$ clear $\left(Z_x, .9M_{px}, DCR, \phi V_n, DCR_v\right)$

$Z_x := 40.2\ in^3$ $\quad$ $\boxed{I} := 245\ in^4$

1. Plastic Moment

$.9M_{px} := \left(F_y \cdot Z_x\right) \cdot 0.9 = 150.75\ kip \cdot ft$ $\quad$ $DCR := \frac{M_{jo}}{.9M_{px}} = 0.185$

2. Shear

$\phi V_n := 106\ kip$ $\quad$ $DCR_v := \frac{V_{jo}}{\phi V_n} = 0.098$

3. Total Deflection

$\Delta_{Tjo} := \frac{5 \cdot w_{jo} \cdot {l_{jo}}^4}{384 \cdot E \cdot I} = 0.725\ in$ $\quad$ $\delta_{Tjo} := \frac{l_{jo}}{360} = 0.742\ in$ $\quad$ $\Delta_{Tjo} \le \delta_{Tjo} = 1$

Residential and Office Beam Design

- **Demand**

$l_{bo} := 39\ ft$ $\quad w_{bo} := \frac{R_{jo} \cdot 12}{l_{bo}} = 3.197\ \frac{kip}{ft}$ $\quad R_{F3} := \frac{w_{bo} \cdot l_{bo}}{2} = 62.348\ kip$

$M_{bo} := \frac{w_{bo} \cdot l_{bo}^{2}}{8} = 607.891\ kip \cdot ft$ $\quad R_{bo} := \frac{w_{bo} \cdot l_{bo}}{2} = 62.348\ kip$ $\quad V_{bo} := R_{bo}$

- **Capacity** **w30*108 A992 section** clear $(Z_x, .9M_{px}, DCR, \phi V_n, DCR_v)$

$Z_x := 346\ in^3$ $\quad I := 4470\ in^4$

1. Plastic Moment

$.9M_{px} := (F_y \cdot Z_x) \cdot 0.9 = (1.298 \cdot 10^3)\ kip \cdot ft$ $\quad DCR := \frac{M_{bo}}{.9M_{px}} = 0.469$

2. Shear

$\phi V_n := 487\ kip$ $\quad DCR_v := \frac{V_{bo}}{\phi V_n} = 0.128$

3. Total Deflection

$\Delta_{Tbo} := \frac{5 \cdot w_{bo} \cdot l_{bo}^{4}}{384 \cdot E \cdot I} = 1.284\ in$ $\quad \delta_{Tbo} := \frac{l_{bo}}{360} = 1.3\ in$ $\quad \Delta_{Tbo} \le \delta_{Tbo} = 1$

- The office LFRD load combo is being used for both the residential and office space because it is similar in value.
- The maximum tributary area is being used to calculate the demand for the residential and office space beams and joists, leaving the residential members slightly over designed.

Community Space Joist Design

- **Demand**

$l_{jc} := 22\ ft + 3\ in = 22.25\ ft$ $\qquad$ $trib := 4.5\ ft$

$w_{jc} := w_{cs} \cdot trib = 1.179\ \frac{kip}{ft}$ $\qquad$ $R_{csj} := \frac{w_{jc} \cdot l_{jc}}{2} = 13.116\ kip$

$M_{jc} := \frac{w_{jc} \cdot {l_{jc}}^2}{8} = 72.96\ kip \cdot ft$ $\qquad$ $R_{jc} := \frac{w_{jc} \cdot l_{jc}}{2} = 13.116\ kip$ $\qquad$ $V_{jc} := R_{jo}$

- **Capacity** **w14*34 A992 section** $\qquad$ clear $\left(Z_x, .9M_{px}, DCR, \phi V_n, DCR_v\right)$

$Z_x := 54.6\ in^3$ $\qquad$ $I := 340\ in^4$

1. Plastic Moment

$.9M_{px} := \left(F_y \cdot Z_x\right) \cdot 0.9 = 204.75\ kip \cdot ft$ $\qquad$ $DCR := \frac{M_{jc}}{.9M_{px}} = 0.356$

2. Shear

$\phi V_n := 487\ kip$ $\qquad$ $DCR_v := \frac{V_{jc}}{\phi V_n} = 0.021$

3. Total Deflection

$\Delta_{Tjc} := \frac{5 \cdot w_{jc} \cdot {l_{jc}}^4}{384 \cdot E \cdot I} = 0.659\ in$ $\qquad$ $\delta_{Tjc} := \frac{l_{jc}}{360} = 0.742\ in$ $\qquad$ $\Delta_{Tjc} \le \delta_{Tjc} = 1$

Community Space Beam Design

- **Demand**

$l_{bc} := 31.5\ ft$ $\quad w_{bc} := \dfrac{R_{csj} \cdot 10}{l_{bc}} = 4.164\ \dfrac{kip}{ft}$ $\quad R_{csb} := w_{bc} \cdot l_{bc} \cdot 0.5 = 65.582\ kip$

$M_{bc} := \dfrac{w_{bc} \cdot l_{bc}^{\ 2}}{8} = 516.457\ kip \cdot ft$ $\quad R_{bc} := \dfrac{w_{bc} \cdot l_{bc}}{2} = 65.582\ kip$ $\quad V_{bc} := R_{bc}$

- **Capacity** **w24*104 A992 section** $\quad \text{clear}\left(Z_x, .9M_{px}, DCR, \phi V_n, DCR_v\right)$

$Z_x := 289\ in^3$ $\quad I := 3100\ in^4$

1. Plastic Moment

$.9M_{px} := \left(F_y \cdot Z_x\right) \cdot 0.9 = \left(1.084 \cdot 10^3\right)\ kip \cdot ft$ $\quad DCR := \dfrac{M_{bc}}{.9M_{px}} = 0.477$

2. Shear

$\phi V_n := 362\ kip$ $\quad DCR_v := \dfrac{V_{bc}}{\phi V_n} = 0.181$

3. Total Deflection

$\Delta_{Tbc} := \dfrac{5 \cdot w_{bc} \cdot l_{bc}^{\ 4}}{384 \cdot E \cdot I} = 1.026\ in$ $\quad \delta_{Tbc} := \dfrac{l_{bc}}{360} = 1.05\ in$ $\quad \Delta_{Tbc} \le \delta_{Tbc} = 1$

Community Center Design

- Transfer Girder Load
- from columns on line 2.1

$R_{roof} = 14.652\ kip$ $R_{F3} = 62.348\ kip$ $l_{tg} := 16\ ft + 7.5\ ft = 23.5\ ft$

$P_c := R_{roof} \cdot 2 + R_{F3} \cdot 2 = 153.999\ kip$ $l := 22\ ft + 3\ in = 22.25\ ft$

$w_{cs} = 262\ psf$ $t_1 := 4\ ft$ $t_2 := 2\ ft + (3.75\ ft \cdot 0.5) = 3.875\ ft$ $t_3 := 3.9\ ft$

$w_1 := w_{cs} \cdot t_1 = (1.048 \cdot 10^3)\ plf$ $P_a := w_1 \cdot l = 23.318\ kip$

$w_2 := w_{cs} \cdot t_2 = (1.015 \cdot 10^3)\ plf$ $P_b := w_2 \cdot l = 22.589\ kip$

$w_3 := w_{cs} \cdot t_3 = (1.022 \cdot 10^3)\ plf$ $P_c := w_3 \cdot l = 22.735\ kip$

Computer Input

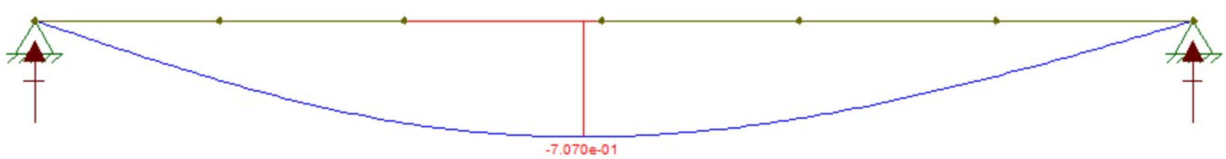
$P_1 := P_a = 23.318\ kip$ $P_4 := P_b + 154\ kip = 176.589\ kip$

$P_2 := P_a = 23.318\ kip$ $P_5 := P_c = 22.735\ kip$

$P_3 := P_a = 23.318\ kip$

Bending

Deflection



- **Demand**

$M_{tg} := 1080.52\ kip \cdot ft$ $R_{tg} := 155.47\ kip$ $V_{tg} := R_{tg} = 155.47\ kip$

- **Capacity** **w30*108 A992 section** clear $\left(Z_x, .9M_{px}, DCR, \phi V_n, DCR_v\right)$

$Z_x := 346\ in^3$ $I := 4470\ in^4$

1. Plastic Moment

$.9M_{px} := \left(F_y \cdot Z_x\right) \cdot 0.9 = \left(1.298 \cdot 10^3\right)\ kip \cdot ft$ $DCR := \dfrac{M_{tg}}{.9M_{px}} = 0.833$

2. Shear

$\phi V_n := 487\ kip$ $DCR_v := \dfrac{V_{tg}}{\phi V_n} = 0.319$

3. Total Deflection

$\Delta_{Ttg} := 0.707\ in$ $\delta_{Ttg} := \dfrac{l_{tg}}{360} = 0.783\ in$ $\Delta_{Ttg} \le \delta_{Ttg} = 1$

Wall Transfer Girder Design

- Grid line D

$\gamma_{brick} := 120 \ \frac{lbf}{ft^3}$ $\quad b_{wall} := 1.5 \ ft$ $\quad h_{wall} := 55.5 \ ft$ $\quad l_{g1} := 31.5 \ ft$ $\quad l_{g2} := 23.5 \ ft$

$w_{wall} := \gamma_{brick} \cdot b_{wall} \cdot h_{wall} = 9.99 \ \frac{kip}{ft}$

- **Demand**

$M_{tg2} := \frac{w_{wall} \cdot l_{g1}^{\ 2}}{8} = \left(1.239 \cdot 10^3\right) \ kip \cdot ft$ $\quad V_{tg2} := \frac{w_{wall} \cdot l_{g1}}{2} = 157.343 \ kip$

- **Capacity** **w36*135 A992 section** clear $\left(Z_x, .9M_{px}, DCR, \phi V_n, DCR_v\right)$

$Z_x := 509 \ in^3$ $\quad I := 7800 \ in^4$

1. Plastic Moment

$.9M_{px} := \left(F_y \cdot Z_x\right) \cdot 0.9 = \left(1.909 \cdot 10^3\right) \ kip \cdot ft$ $\quad DCR := \frac{M_{tg2}}{.9M_{px}} = 0.649$

2. Shear

$\phi V_n := 577 \ kip$ $\quad DCR_v := \frac{V_{tg2}}{\phi V_n} = 0.273$

3. Total Deflection

$\Delta_T := \frac{5 \cdot w_{wall} \cdot l_{g1}^{\ 4}}{384 \cdot E \cdot I} = 0.978 \ in$ $\quad \delta_T := \frac{l_{g1}}{360} = 1.05 \ in$ $\quad \Delta_T \le \delta_T = 1$

- **Beams**

$$R_{g2} := \frac{w_{wall} \cdot l_{g2}}{2} = 117.383 \; kip \qquad R_{g1} := \frac{w_{wall} \cdot l_{g1}}{2} = 157.343 \; kip$$

$$R_g := R_{g1} + R_{g2} + 135 \; plf \cdot \left(0.5 \cdot \left(l_{g2} + l_{g1}\right)\right) = 278.438 \; kip \qquad P := R_g = 278.438 \; kip$$

- **Demand**

$$M_{tgb} := \frac{P \cdot b_{wall}}{4} = 104.414 \; kip \cdot ft \qquad R_{tgb} := P = 278.438 \; kip \qquad V_{tgb} := P = 278.438 \; kip$$

- **Capacity** **w24*68 A992 section** $\text{clear}\left(Z_x, .9M_{px}, DCR, \phi V_n, DCR_v\right)$

$$Z_x := 177 \; in^3 \qquad I := 1830 \; in^4$$

1. Plastic Moment

$$.9M_{px} := \left(F_y \cdot Z_x\right) \cdot 0.9 = 663.75 \; kip \cdot ft \qquad DCR := \frac{M_{tgb}}{.9M_{px}} = 0.157$$

2. Shear

$$\phi V_n := 295 \; kip \qquad DCR_v := \frac{V_{tgb}}{\phi V_n} = 0.944$$

3. Total Deflection

$$\Delta_T := \frac{P \cdot b_{wall}^{\;3}}{48 \cdot E \cdot I} = \left(6.375 \cdot 10^{-4}\right) \; in \qquad \delta_T := \frac{b_{wall}}{360} = 0.05 \; in \qquad \Delta_T \le \delta_T = 1$$

Columns

- **East BSMNT Column Design**
  - Basement to first floor

$V_{tgb} = 278.438\ kip$ $\quad L_c := 14\ ft$

$P_{tg} := V_{tgb} + 2 \cdot R_{csj} = 304.67\ kip$

USE: W8*40 $\quad \phi_c P_n := 321\ kip$

- **East Discontinuous Columns**
  - two sections 20 and 19 feet

$A_{dc} := 30.75\ ft \cdot (11.25\ ft + 11.125\ ft) = 688.031\ ft^2$

$P_1 := w_{office} \cdot A_{dc} = 131.827\ kip$ $\quad P_2 := w_{roof} \cdot A_{dc} = 38.772\ kip$

$P_{dc} := P_1 + P_2 = 170.599\ kip$ $\quad L_c := 26\ ft$

USE: w8*58 $\quad \phi_c P_n := 1\ kip$

- **Under wall columns**
  - three sections: 16,20,16
  - four sections:

East

$$A_{tf1} := \left(\frac{23.5\ ft}{2} + \frac{31.5\ ft}{2}\right) \cdot \frac{20.5\ ft}{2} = 281.875\ ft^2$$

$P_{1e} := w_{cs} \cdot A_{tf1} = 73.851\ kip$

$P_{2e} := w_{office} \cdot A_{tf1} = 54.007\ kip$

$P_{3e} := w_{roof} \cdot A_{tf1} = 15.884\ kip$

$$P_{s2e} := \frac{R_g}{2} + P_{1e} + P_{2e} + P_{3e} = 282.961\ kip$$

$P_{s1} := P_{3e} + P_{2e} = 69.891\ kip$

USE: w10*68 $\quad \phi_c P_n := 1\ kip$

USE: w8*31 $\quad \phi_c P_n := 1\ kip$

West

$$A_{tf2} := \left(\frac{23.5\ ft}{2} + \frac{31.5\ ft}{2}\right) \cdot \frac{21.8\ ft}{2} = 299.75\ ft^2$$

$P_{1w} := w_{floor} \cdot A_{tf2} = 52.636\ kip$

$P_{2w} := w_{roof} \cdot A_{tf2} = 16.892\ kip$

$$P_{s2w} := \frac{R_g}{2} + 4 \cdot P_{1w} + P_{2e} + P_{3e} = 419.655\ kip$$

$P_{s1w} := 2 \cdot P_{1w} + P_{2w} = 122.164\ kip$

USE: w10*88 $\quad \phi_c P_n := 1\ kip$

USE: w8*31 $\quad \phi_c P_n := 1\ kip$

- **WEST**

$A_{res} := 21.8\ ft \cdot \left(\frac{23.5\ ft}{2} + \frac{32.5\ ft}{2}\right) = 610.4\ ft^2$

$P_{floor} := \left(w_{floor} \cdot A_{res}\right) = 107.186\ kip$

$P_{rr} := A_{res} \cdot w_{roof} = 34.397\ kip$

$P_{res} := P_{rr} + P_{floor} \cdot 4 = 463.142\ kip$

Roof to 4rd

$P_{wt} := P_{rr} + P_{floor} = 141.584\ kip$

USE: W8*31 $\boxed{\phi_c P_n} := 266\ kip$

3rd to BSMT

$P_{res} = 463.142\ kip$

USE: W8*58 $\boxed{\phi_c P_n} := 514\ kip$

- **EAST**

$A_{tr} := 22.25\ ft \cdot \left(\frac{39\ ft}{2} + \frac{38.25 \cdot ft}{2}\right) = 859.406\ ft^2$

$P_r := A_{tr} \cdot w_{roof} = 48.429\ kip$

$P_o := A_{tr} \cdot w_{office} = 164.662\ kip$

$A_{cs} := 22.25\ ft \cdot \left(\frac{31.5\ ft}{2} + \frac{23.5 \cdot ft}{2}\right) = 611.875\ ft^2$

$P_{cs} := A_{cs} \cdot w_{cs} = 160.311\ kip$

$P_{east} := P_r + P_o + P_{cs} = 373.403\ kip$

Roof to office

$\boxed{P_{wt}} := P_r + P_o = 213.091\ kip$

USE: W8*31 $\boxed{\phi_c P_n} := 266\ kip$

office to BSMT $\boxed{L_c} := 26\ ft$

$P_{east} = 373.403\ kip$

USE: W10*88 $\boxed{\phi_c P_n} := 514\ kip$

Footings

F1 Square Footing - single story column under transfer girder

$P_{f1} := P_{tg} = 304.67\ kip$

F2 Combine Footing - middle wall columns

F3 Square Footing - Standard West Footing

$P_{f3} := P_{res} = 463.142\ kip$

F4 Wall Footing - under all walls

$\gamma_{cmu} := 135\ pcf \cdot 12\ in = 135\ psf$

$\boxed{w_{wall}} := \gamma_{brick} \cdot 18\ in = 180\ psf$

Footing F1

Rebar variables

$A_4 := 0.2\ in^2$ $d_4 := 0.5\ in$

$A_5 := 0.31\ in^2$ $d_5 := 0.625\ in$

$A_6 := 0.44\ in^2$ $d_6 := 0.75\ in$

$A_7 := 0.6\ in^2$ $d_7 := 0.875\ in$

$A_8 := 0.79\ in^2$ $d_8 := 1\ in$

Bar #	Nominal dia (in)	Actual dia (in)	Area (in^2)	Perimeter (in)	Weight (lb/ft)
#2	$\frac{2}{8}$ = 0.250	0.250	0.050	0.790	0.167
#3	$\frac{3}{8}$ = 0.375	0.375	0.110	1.180	0.376
#4	$\frac{4}{8}$ = 0.500	0.500	0.200	1.570	0.668
#5	$\frac{5}{8}$ = 0.625	0.625	0.310	1.960	1.043
#6	$\frac{6}{8}$ = 0.750	0.750	0.440	2.360	1.502
#7	$\frac{7}{8}$ = 0.875	0.875	0.600	2.750	2.044
#8	$\frac{8}{8}$ = 1.000	1.000	0.790	3.140	2.670
#9	$\frac{9}{8}$ = 1.125	1.128	1.000	3.540	3.400
#10	$\frac{10}{8}$ = 1.250	1.270	1.270	3.990	4.303
#11	$\frac{11}{8}$ = 1.375	1.410	1.560	4.430	5.313
#14	$\frac{14}{8}$ = 1.750	1.693	2.250	5.320	7.650
#18	$\frac{18}{8}$ = 2.250	2.257	4.000	7.090	13.600

F1 design

$B := 8\ ft$ $w := 1\ ft$

$f_{c'} := 3500\ psi$ $f_y := 60\ ksi$ $w_c := 150\ pcf$ $P_{LR} := 8\ kip$

Assumed variables

$t_f := 18\ in$ $cc := 3\ in$ $d := t_f - cc - d_7 = 14.125\ in$

factored soil pressure

$P_u := P_{f1} = 304.67\ kip$

$$q_u := \frac{P_u}{B^2} + 40\ psf = \left(4.8 \cdot 10^3\right)\ psf$$

check shear strength

one way

$$V_u := q_u \cdot B \cdot \left(\frac{B-w}{2} - d\right) = 89.209\ kip$$

$$\phi V_N := 0.75 \left(\frac{2 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot \frac{B}{in} \cdot \frac{d}{in}}{1000}\right) \cdot kip = 120.333\ kip$$

$$DRC := \frac{V_u}{\phi V_N} = 0.741$$

Two Way shear

$\text{clear}\left(\phi V_N, V_u, DRC\right)$

$\beta := 1 \qquad \alpha_s := 40$

$b_o := 2 \cdot (w+d) + 2 \cdot (w+d) = 104.5\ in$

$V_{c1} := \left(2 + \frac{4}{\beta}\right) \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 523.95\ kip$

$V_{c2} := \left(\frac{\alpha_s \cdot d}{b_o} + 2\right) \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 646.79\ kip$

$V_{c3} := 4 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 349.3\ kip$

$\phi V_N := 0.75 \cdot V_{c3} = 261.975\ kip$

$V_u := q_u \cdot \left(B^2 - (41\ in)^2\right) = 251.191\ kip \qquad DRC := \frac{V_u}{\phi V_N} = 0.959$

design steel reinforcement

$f := \frac{B}{2} - \frac{w}{2} = 42\ in$

$M_u := \frac{q_u \cdot B \cdot f^2}{2} = 235.223\ kip \cdot ft$

Select steel reinforcement

$j := 0.9 \qquad \phi_m := 0.9$

$A_{smin} := \frac{M_u}{\phi_m \cdot f_y \cdot j \cdot d} = 4.112\ in^2$

Possible rebar configuration

$n := \frac{A_{smin}}{A_4} = 20.559 \quad n := \frac{A_{smin}}{A_5} = 13.264 \quad n1 := \frac{A_{smin}}{A_6} = 9.345 \quad n := \frac{A_{smin}}{A_7} = 6.853 \quad n := \frac{A_{smin}}{A_8} = 5.205$

$s := \frac{B}{n1} = 10.273\ in$

Moment strength

$A_s := A_7 \cdot 7 = 4.2\ in^2$ $\beta_1 := 0.85$

$d := t_f - cc - d_7 - 0.5 \cdot d_7 = 13.688\ in$

$a := \dfrac{A_s \cdot f_y}{\beta_1 \cdot f_{c'} \cdot B} = 0.882\ in$

$c := \dfrac{a}{\beta_1} = 1.038\ in$

$\varepsilon_s := 0.003 \cdot \left(\dfrac{d-c}{c}\right) = 0.037$

$M_N := A_s \cdot f_y \cdot \left(d - \dfrac{a}{2}\right) = 278.173\ kip \cdot ft$

$\phi M_N := M_N \cdot \phi_m = 250.356\ kip \cdot ft$

$DCR := \dfrac{M_u}{\phi M_N} = 0.94$

Development Length

bar clear spacing $\psi_t := 1$ $\psi_e := 1$

$s := \dfrac{B - cc - cc - d_7}{n-1} = 21.196\ in$

$s_{clr} := s - d_7 = 20.321\ in$

$s_{clr} \geq 2 \cdot d_7 = 1$

"case 2"

$cc \geq d_7 = 1$

development length

$l_d := \dfrac{f_y \cdot \psi_t \cdot \psi_e}{\left(20 \cdot \sqrt{\dfrac{f_{c'}}{psi}}\right) \cdot psi} \cdot d_7 = 44.371\ in$

$l_{ext} := f - cc = 39\ in$

$l_{ext} \geq l_d = 0$ "not good"

90 degree hooks

$$l_{dh} := \frac{0.02 \cdot \psi_e \cdot f_y}{\sqrt{\frac{f_{c'}}{psi}} \cdot psi} \cdot 1\ in = 20.284\ in$$

$$l_{ext} \geq l_{dh} = 1 \qquad \text{“ok”}$$

For foundations "F1" use 7 #7 rebars with 90 degree hooks. The foundations thickness will be 18 inches.

F2 design: combined

- East Side

$P_{s2e} = 282.961\ kip \qquad P_{s2w} = 419.655\ kip$

$B := 5\ ft$

Assumed variables

$P_u := P_{s2e} = 282.961\ kip \qquad t_f := 24\ in \qquad cc := 3\ in \qquad d := t_f - cc - d_8 = 20\ in$

factored soil pressure

$$q_u := \frac{P_u}{B^2} + 40\ psf = 11.358\ ksf$$

check shear strength

one way

$$V_u := q_u \cdot B \cdot \left(\frac{B - w}{2} - d\right) = 18.931\ kip$$

$$\phi V_N := 0.75 \left(\frac{2 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot \frac{B}{in} \cdot \frac{d}{in}}{1000}\right) \cdot kip = 106.489\ kip$$

$$DRC := \frac{V_u}{\phi V_N} = 0.178$$

Two Way shear

$\text{clear}\left(\phi V_N, V_u, DRC\right)$

$\beta := 1 \qquad \alpha_s := 40$

$b_o := 2 \cdot (w + d) + 2 \cdot (w + d) = 128\ in$

$V_{c1} := \left(2 + \dfrac{4}{\beta}\right) \cdot \sqrt{\dfrac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 908.71\ kip$

$V_{c2} := \left(\dfrac{\alpha_s \cdot d}{b_o} + 2\right) \cdot \sqrt{\dfrac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = \left(1.249 \cdot 10^3\right)\ kip$

$V_{c3} := 4 \cdot \sqrt{\dfrac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 605.807\ kip$

$\phi V_N := 0.75 \cdot V_{c3} = 454.355\ kip$

$V_u := q_u \cdot \left(B^2 - (41\ in)^2\right) = 151.367\ kip \qquad DRC := \dfrac{V_u}{\phi V_N} = 0.333$

design steel reinforcement

$f := \dfrac{B}{2} - \dfrac{w}{2} = 24\ in$

$M_u := \dfrac{q_u \cdot B \cdot f^2}{2} = 113.585\ kip \cdot ft$

Select steel reinforcement

$j := 0.9 \qquad \phi_m := 0.9$

$A_{smin} := \dfrac{M_u}{\phi_m \cdot f_y \cdot j \cdot w} = 2.337\ in^2$

Possible rebar configuration

$n := \dfrac{A_{smin}}{A_4} = 11.686 \qquad n := \dfrac{A_{smin}}{A_5} = 7.539 \qquad n := \dfrac{A_{smin}}{A_6} = 5.312$

$n := \dfrac{A_{smin}}{A_8} = 2.958 \qquad n := \dfrac{A_{smin}}{A_7} = 3.895$

Moment strength

$A_s := A_8 \cdot 4 = 3.16\ in^2$ $\beta_1 := 0.85$ $n := 4$

$d := t_f - cc - d_8 - 0.5 \cdot d_8 = 19.5\ in$

$$a := \frac{A_s \cdot f_y}{\beta_1 \cdot f_{c'} \cdot B} = 1.062\ in$$

$$c := \frac{a}{\beta_1} = 1.25\ in$$

$$\varepsilon_s := 0.003 \cdot \left(\frac{d-c}{c}\right) = 0.044$$

$$M_N := A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right) = 299.709\ kip \cdot ft$$

$\phi M_N := M_N \cdot \phi_m = 269.738\ kip \cdot ft$

$$DCR := \frac{M_u}{\phi M_N} = 0.421$$

Development Length

bar clear spacing $\psi_t := 1$ $\psi_e := 1$

$$s := \frac{B - cc - cc - d_6}{n-1} = 17.75\ in$$

$s_{clr} := s - d_6 = 17\ in$

$s_{clr} \geq 2 \cdot d_6 = 1$

"case 2"

$cc \geq d_6 = 1$

development length

$$l_d := \frac{f_y \cdot \psi_t \cdot \psi_e}{\left(20 \cdot \sqrt{\frac{f_{c'}}{psi}}\right) \cdot psi} \cdot d_6 = 38.032\ in$$

$l_{ext} := f - cc = 21\ in$

$l_{ext} \geq l_d = 0$ "okay"

90 degree hooks

$$l_{dh} := \frac{0.02 \cdot \psi_e \cdot f_y}{\sqrt{\frac{f_{c'}}{psi}} \cdot psi} \cdot 1\ in = 20.284\ in$$

$l_{ext} \geq l_{dh} = 1$ "not needed"

- **West Side**

$P_{s2e} = 282.961\ kip$ $P_{s2w} = 419.655\ kip$

$B := 8\ ft$

Assumed variables

$P_u := P_{s2w} = 419.655\ kip$ $t_f := 24\ in$ $cc := 3\ in$ $d := t_f - cc - d_8 = 20\ in$

factored soil pressure

$$q_u := \frac{P_u}{B^2} + 40\ psf = 6.597\ ksf$$

check shear strength

one way

$$V_u := q_u \cdot B \cdot \left(\frac{B - w}{2} - d\right) = 96.758\ kip$$

$$\phi V_N := 0.75 \left(\frac{2 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot \frac{B}{in} \cdot \frac{d}{in}}{1000}\right) \cdot kip = 170.383\ kip$$

$$DRC := \frac{V_u}{\phi V_N} = 0.568$$

Two Way shear

$\text{clear}\left(\phi V_N, V_u, DRC\right)$

$\beta := 1 \qquad \alpha_s := 40$

$b_o := 2 \cdot (w+d) + 2 \cdot (w+d) = 128 \; in$

$V_{c1} := \left(2 + \dfrac{4}{\beta}\right) \cdot \sqrt{\dfrac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 908.71 \; kip$

$V_{c2} := \left(\dfrac{\alpha_s \cdot d}{b_o} + 2\right) \cdot \sqrt{\dfrac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = \left(1.249 \cdot 10^3\right) \; kip$

$V_{c3} := 4 \cdot \sqrt{\dfrac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 605.807 \; kip$

$\phi V_N := 0.75 \cdot V_{c3} = 454.355 \; kip$

$V_u := q_u \cdot \left(B^2 - (41 \; in)^2\right) = 345.203 \; kip \qquad DRC := \dfrac{V_u}{\phi V_N} = 0.76$

design steel reinforcement

$f := \dfrac{B}{2} - \dfrac{w}{2} = 42 \; in$

$M_u := \dfrac{q_u \cdot B \cdot f^2}{2} = 323.258 \; kip \cdot ft$

Select steel reinforcement

$j := 0.9 \qquad \phi_m := 0.9$

$A_{smin} := \dfrac{M_u}{\phi_m \cdot f_y \cdot j \cdot w} = 6.651 \; in^2$

Possible rebar configuration

$n := \dfrac{A_{smin}}{A_4} = 33.257 \quad n := \dfrac{A_{smin}}{A_5} = 21.456 \quad n := \dfrac{A_{smin}}{A_6} = 15.117$

$n := \dfrac{A_{smin}}{A_8} = 8.419 \quad n := \dfrac{A_{smin}}{A_7} = 11.086$

Moment strength

$A_s := A_8 \cdot 8 = 6.32\ in^2$ $\quad \beta_1 := 0.85$ $\quad n := 8$

$d := t_f - cc - d_8 - 0.5 \cdot d_8 = 19.5\ in$

$a := \dfrac{A_s \cdot f_y}{\beta_1 \cdot f_{c'} \cdot B} = 1.328\ in$

$c := \dfrac{a}{\beta_1} = 1.562\ in$

$\varepsilon_s := 0.003 \cdot \left(\dfrac{d - c}{c}\right) = 0.034$

$M_N := A_s \cdot f_y \cdot \left(d - \dfrac{a}{2}\right) = 595.222\ kip \cdot ft$

$\phi M_N := M_N \cdot \phi_m = 535.7\ kip \cdot ft$

$DCR := \dfrac{M_u}{\phi M_N} = 0.603$

Development Length

bar clear spacing $\quad \psi_t := 1$ $\quad \psi_e := 1$

$s := \dfrac{B - cc - cc - d_6}{n - 1} = 12.75\ in$

$s_{clr} := s - d_6 = 12\ in$

$s_{clr} \geq 2 \cdot d_6 = 1$

"case 2"

$cc \geq d_6 = 1$

development length

$l_d := \dfrac{f_y \cdot \psi_t \cdot \psi_e}{\left(20 \cdot \sqrt{\dfrac{f_{c'}}{psi}}\right) \cdot psi} \cdot d_6 = 38.032\ in$

$l_{ext} := f - cc = 39\ in$

$l_{ext} \geq l_d = 1$ "okay"

90 degree hooks

$$l_{dh} := \frac{0.02 \cdot \psi_e \cdot f_y}{\sqrt{\frac{f_{c'}}{psi}} \cdot psi} \cdot 1\ in = 20.284\ in$$

$l_{ext} \geq l_{dh} = 1$ “not needed”

For foundations "F2" use 8 #8 rebars. The foundations thickness will be 24 inches and 6'*15'

F3 design: combined

$B := 12\ ft$

Assumed variables

$P_u := P_{f3} = 463.142\ kip$ $t_f := 24\ in$ $cc := 3\ in$ $d := t_f - cc - d_8 = 20\ in$

factored soil pressure

$$q_u := \frac{P_u}{B^2} + 40\ psf = 3.256\ ksf$$

check shear strength

one way

$$V_u := q_u \cdot B \cdot \left(\frac{B - w}{2} - d\right) = 149.788\ kip$$

$$\phi V_N := 0.75 \left(\frac{2 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot \frac{B}{in} \cdot \frac{d}{in}}{1000}\right) \cdot kip = 255.575\ kip$$

$$DRC := \frac{V_u}{\phi V_N} = 0.586$$

Two Way shear

$\text{clear}\left(\phi V_N, V_u, DRC\right)$

$\beta := 1 \qquad \alpha_s := 40$

$b_o := 2 \cdot (w+d) + 2 \cdot (w+d) = 128 \ in$

$$V_{c1} := \left(2 + \frac{4}{\beta}\right) \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 908.71 \ kip$$

$$V_{c2} := \left(\frac{\alpha_s \cdot d}{b_o} + 2\right) \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = \left(1.249 \cdot 10^3\right) \ kip$$

$$V_{c3} := 4 \cdot \sqrt{\frac{f_{c'}}{psi}} \cdot psi \cdot b_o \cdot d = 605.807 \ kip$$

$\phi V_N := 0.75 \cdot V_{c3} = 454.355 \ kip$

$V_u := q_u \cdot \left(B^2 - (41 \ in)^2\right) = 430.89 \ kip \qquad DRC := \dfrac{V_u}{\phi V_N} = 0.948$

design steel reinforcement

$$f := \frac{B}{2} - \frac{w}{2} = 66 \ in$$

$$M_u := \frac{q_u \cdot B \cdot f^2}{2} = 591.012 \ kip \cdot ft$$

Select steel reinforcement

$j := 0.9 \qquad \phi_m := 0.9$

$$A_{smin} := \frac{M_u}{\phi_m \cdot f_y \cdot j \cdot w} = 12.161 \ in^2$$

Possible rebar configuration

$n := \dfrac{A_{smin}}{A_4} = 60.804 \quad n := \dfrac{A_{smin}}{A_5} = 39.228 \quad n := \dfrac{A_{smin}}{A_6} = 27.638 \quad n := \dfrac{A_{smin}}{A_7} = 20.268 \quad n := \dfrac{A_{smin}}{A_8} = 15.393$

Moment strength

$A_s := A_8 \cdot 10 = 7.9\ in^2$ $\qquad \beta_1 := 0.85$ $\qquad n := 10$

$d := t_f - cc - d_8 - 0.5 \cdot d_8 = 19.5\ in$

$$a := \frac{A_s \cdot f_y}{\beta_1 \cdot f_{c'} \cdot B} = 1.106\ in$$

$$c := \frac{a}{\beta_1} = 1.302\ in$$

$$\varepsilon_s := 0.003 \cdot \left(\frac{d-c}{c}\right) = 0.042$$

$$M_N := A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right) = 748.398\ kip \cdot ft$$

$$\phi M_N := M_N \cdot \phi_m = 673.558\ kip \cdot ft$$

$$DCR := \frac{M_u}{\phi M_N} = 0.877$$

Development Length

bar clear spacing $\qquad \psi_t := 1$ $\qquad \psi_e := 1$

$$s := \frac{B - cc - cc - d_6}{n-1} = 15.25\ in$$

$$s_{clr} := s - d_6 = 14.5\ in$$

$s_{clr} \geq 2 \cdot d_6 = 1$

"case 2"

$cc \geq d_6 = 1$

development length

$$l_d := \frac{f_y \cdot \psi_t \cdot \psi_e}{\left(20 \cdot \sqrt{\frac{f_{c'}}{psi}}\right) \cdot psi} \cdot d_6 = 38.032\ in$$

$$l_{ext} := f - cc = 63\ in$$

$l_{ext} \geq l_d = 1$ $\qquad$ "ok"

90 degree hooks

$$l_{dh} := \frac{0.02 \cdot \psi_e \cdot f_y}{\sqrt{\frac{f_{c'}}{psi}} \cdot psi} \cdot 1\ in = 20.284\ in$$

$l_{ext} \geq l_{dh} = 1$ “not needed”

For foundations "F3" use 10 #8 rebars. The foundations thickness will be 24'' and 12' sq

F4 Column Design

$B := 4\ ft$ $\quad w_{elev} := 2\ kip$ $\quad w_{stair} := 70\ psf$ $\quad P_u := \gamma_{brick} \cdot b_{wall} \cdot h_{wall} = 9.99\ \frac{kip}{ft}$

$c := b_{wall} = 1.5\ ft$ $\quad \phi := 0.75$ $\quad b_w := 1\ ft$

Shear

$$d_u := \frac{P_u \cdot \frac{ft}{lbf} \cdot \left(\frac{B-c}{in}\right)}{48 \cdot \phi \cdot \frac{b_w}{in} \cdot \sqrt{f_{c'} \cdot \frac{in^2}{lbf}} + 2 \cdot P_u \cdot \frac{ft}{lbf}} = 6.581 \qquad d := d_u \cdot in$$

$$V_{uc} := P_u \cdot \left(\frac{B-c-2 \cdot d}{B}\right) = 3.504\ \frac{1}{ft} \cdot kip$$

Moment

$$l := \frac{B - \frac{c}{2}}{2} = 19.5\ in$$

$$M_{uc} := \frac{P_u \cdot l^2}{2 \cdot B} = 3.297\ kip \cdot \frac{ft}{ft}$$

$$A_s := \left(\frac{f_{c'} \cdot b_w}{1.176 \cdot f_y}\right) \cdot \left(d - \sqrt{d^2 - \frac{2.353 \cdot M_{uc} \cdot ft}{\phi \cdot f_{c'} \cdot b_w}}\right) = 0.136\ in^2$$

$$\rho := \frac{A_s}{d} = 0.021\ in$$

For foundations "F4" use 10 #8 rebars. The foundations thickness will be 4 ft

joiswa