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Historic Rehabilitation Project Report

To the City of Keokuk
15 May 2020

By Justin Paterson, Sara Stickney, and Ryan Whalen
University of Iowa
Department of Civil and Environmental Engineering
Project Design and Management

CEE:4850:0001
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Section I – Executive Summary

The Historic Rehabilitation Project consists of three structures on Main Street of Keokuk, Iowa with a combined area of 18,000 square feet. 619 Main St contains two stories with the second extending half the length of the first floor. 623 Main St contains three floors with the third extending two thirds of the length of the first two. 625 Main St contains three floors and is half the length of the first floors of 619 and 623. All three buildings have masonry, wood, steel, and cast-iron structural elements and share adjoining walls. All built in 1890 or before, the structures have exhibited signs of failure from water damage, fire damage, and soil settlement. JRS Engineering Inc has assessed and recommended solutions to the current structural and design issues. Though there is no desire by the client to receive a historic preservation title, the exterior will abide by Main Street Iowa guidelines. The end goal of both the City of Keokuk and JRS Engineering Inc is to restore the three structures to full use as retail space on the first floor and residential space on the second and third floors.

The first objective of the design is to seal the structures from further damage. This involves water drainage in the basements and roof repair to stop water leaks. The façade of 619 Main St must be reconnected to the main structure using a tie-back. All windows will be replaced to eliminate further pest and insect damage. Next, all failing structural elements will be replaced. This includes the 3rd floors of 623 and 625 Main St. The back portion of the 1st and 2nd floors of 623 Main St and any beams or girders with substantial rot or termite damage will also be replaced. The brick arch over windows in 625 Main St will be repaired from the fire damage and creep. The bearing wall on the 2nd floor of 619 Main St will be enhanced to counteract the signs of failure currently shown in the brick. The roofs will be rebuilt with a small slope to control the drainage of water from the roofs and a gutter system with a downspout will be installed to control the drainage.

The second design objective is to remove the damaged or unnecessary interior elements and to implement new floor plans. Most partition walls, especially those on the first floor of each building and in the residential space of 619 Main St, will be demolished. The exterior residential entrance will be removed for safety and interior stairways will be implemented at rear of buildings 623 and 625. Garage and shed additions to all three structures will be removed to enhance the exterior appearance. An open floor plan with restrooms and separate residential entries has been created for the retail spaces on the first floor of each of the structures. Two units of two bedrooms and two bathrooms each have been designed for the second floor of 619. The second floors of 623 and 625 have been designed for three and two units, respectively, of two bedrooms and one full bathroom. The third floor of both 623 and 625 each have been redesigned for three studio spaces each. All units include full kitchens with a refrigerator, oven, and dishwasher as well as washer and dryer units. Architectural, Structural, Mechanical, Electrical and Plumbing plans and documents were drafted using AutoCAD and Revit Software. Finally, electricity, plumbing, and mechanical systems will be renovated on the first floor and reinstalled in the second and third floors. The total cost estimate for this project is $1,064,000.

Section II – Organization Qualification

JRS Engineering Inc.
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JRS Engineering Inc, is an engineering firm consisting of students in the Civil and Environmental Engineering program at the University of Iowa in the capstone design class. The team members involved in the Historic Rehabilitation Project are Justin Paterson, Ryan Whalen, and Sara Stickney. All members are in their fourth year of study as civil engineering students.

Justin Paterson has a structural engineering focus area and will be serving as the technology support expert in the context of this project. Justin will be leading the design tasks to do with creating the final computer model. He will also be doing structural analysis and conducting design calculations. Structural calculations include roofing, flooring, and beams on the front of the buildings. Justin is currently working part time for Raker Rhodes Engineering, a structural engineering firm, in Iowa City. Related coursework completed includes Design of Wood Structures, Foundations of Structures, and Design of Steel Structures.

Sara Stickney has an art and pre-architecture focus area and is serving as the report editor for JRS Engineering Inc. Sara will be heading the architectural design for this project. Her previous experience relevant to this project includes work with two architecture internships with design firms: 10 Design Ltd in Hong Kong, HK and Shive-Hattery in Moline, IL. Coursework she has completed related to the project includes Structural Systems, Color Studies for Interior Design, History of Western Architecture, and Computer 3D Modeling.

Ryan Whalen is also focusing on structural engineering and is the project manager of JRS Engineering Inc. Ryan will be leading tasks relating to structural analysis, communications, and project management for the Historic Rehabilitation Project. His previous experience similar to the Historic Rehabilitation Project includes an internship with a design firm WHKS in bridge maintenance and repair. He also has civil engineering experience from an internship with Lake County, a municipal engineering division for public works in Illinois. Related coursework he has completed includes foundations of structures, design of concrete structures, and design of steel structures.

Section III – Design Services

The design project provides a cost-effective way to make the three buildings in question occupiable. The lower levels are designed to allow commercial occupants and the upper floors are designed for residential tenants. Market research has been done to design the living space on the upper floors to meet the needs of the community, and the lower levels were left as open as possible to give businesses flexibility on how they want to use the space.

The priority was bringing the front of the two-story building back into place and stabilizing it to ensure that it is structurally sound. The exterior of the buildings was then rehabilitated to keep any water from entering the building by replacing and adding a pitch to the roof of 625 Main Street. Work was also done in each basement to keep moisture from entering from below the buildings. The roofs have been redesigned due to signs of leaking inside the building. The floor framing was redesigned due to rot, sagging of the floor joists, and in some places fire damage. The substructure of the ground floors have been updated to declutter and simplify the basements. The façade beams have been redesigned to ensure that there is adequate strength to support the fronts of the buildings.

The apartment space on the upper floors was designed to match market norms to make them desirable to possible tenants. Entrances to the upper floors are as convenient as possible as to not disturb business on the bottom floors on the buildings. Computer drafts were prepared in tandem with the design to give a visual of what the final product will be. All the work was documented to ensure that all steps taken during design were in accordance with the required codes.

The buildings were designed using ASCE 7-16 load calculations, with the Allowable Strength Design criteria. The National Design Specification (NDS) for Wood Construction was used for all the wood calculations in the building. Steel members were designed using the AISC manual for steel construction. International Building Code 2015 and International Existing Building Code 2015 were used for the interior layout. The exterior of the building was restored using Conserving Buildings Manual Second Edition and in accordance to the Main Street Iowa program in order to preserve the historic aspects of the buildings.

Table 1: Work Plan

Task	Team Member	Start	End
Research			
Stabalize Façade	Ryan Whalen	2/6/20	2/17/20
Exterior Masonry	Sara Stickney	2/6/20	4/17/20
Roof Replacement	Ryan Whalen	2/6/20	2/17/20
Interior Demolition	Sara Stickney	2/6/20	2/17/20
Flooring Replacement	Justin Paterson	2/6/20	2/17/20
Basement Seal	Justin Paterson	2/6/20	2/17/20
Structural Design			
Floor Design	Justin Paterson	2/17/20	4/17/20
Roof Design	Ryan Whalen	2/17/20	4/17/20
Column Design	Justin Paterson	3/13/20	4/17/20
Final Design Calculations	All	3/23/20	4/17/20
Interior Design			
Retail Layout	Sara Stickney	2/10/20	3/9/20
Residential Entry and Egress	Sara Stickney	2/10/20	3/9/20
Apartment Layout	Sara Stickney	2/10/20	2/27/20
Appliance and Casework	Sara Stickney	3/23/20	4/7/20
Drafting			
Floor Plan	Sara Stickney	2/27/20	3/3/20
Foundation	Justin Paterson	2/27/20	4/17/20
Exterior and Bearing Walls	Justin Paterson	2/27/20	4/17/20
Floors	Justin Paterson	2/27/20	4/17/20
Roof	Ryan Whalen	3/9/20	4/17/20
Interion Column	Justin Paterson	3/13/20	4/17/20
Connection Details	Ryan Whalen	3/13/20	4/17/20
Revit Model	Sara Stickney	2/28/20	4/17/20
Mechanical	Ryan Whalen	4/6/20	4/17/20
Plumbing	Ryan Whalen	4/6/20	4/17/20
Electrical	Ryan Whalen	4/6/20	4/17/20
Final Documents			
Proposal Presentation	All	2/6/20	2/7/20
Proposal Report	All	2/6/20	2/7/20

Section IV – Constraints, Challenges, and Impacts

Constraints

A monetary constraint was in place due to the client's limited funding. There are no confirmed tenants for either the retail or residential spaces. However, no strict cost limit was provided by the City of Keokuk at any time throughout the design process. The project space for was limited to three structurally connected buildings. The space was bordered by a public alley on the North, an occupied building on the East, a public sidewalk on the South, and a lot owned by another party on the West.

Demolition of some existing portions of the building pose an environmental danger due to the led paint, asbestos tile, and termite and mold. All demolished material will be treated as hazardous. The Great River Regional Waste Authority in Fort Madison, IA is the nearest location for disposal of hazardous waste. The fee is $34.00 per ton for construction and demolition waste.

The client has expressed that during the rehabilitation project process they would like for the buildings to possess a similar aesthetical look as the rest of the town to keep a historic look for the exterior of the buildings while providing a fresh and progressive look on the interior.

Challenges

Some of the challenges presented in the process of the project included dealing with buildings that were over a century old and that had been abandoned for some time with no maintenance. The structures were left vulnerable to many forms of deterioration, including water leaks, mold, pest infestations, and vandalism.

Another major problem presented in the project was infiltration and seepage underneath the buildings due to its proximity to the Mississippi River and the removal of an adjacent building. The solution needed to be inexpensive, so major foundation work was avoided.

The apartment spacing provided had to be both affordable and attractive to compete with other housing options in the area and to bring new residents to the buildings and downtown Keokuk area. The client wanted for the retail space to be laid out extremely flexible so that any future tenant/tenants could use each space individually or as a combined store front.

Additional challenges included the structural integrity of the structure as a whole. The floors and ceilings of the units needed to be demolished and structural integrity calculations were required. A structural failure of the front face of 619 Main St also needed to be corrected. The front masonry wall was being pulled forward due to an added metal façade. Many of the old apartments required demolition in 619 due to age and condition. All residential areas had to be completely redesigned for modern habitation and code requirements.

Societal Impact

The greatest societal impact on the City of Keokuk is the economic stimulation that will result from the occupancy of previously abandoned buildings. The project will revive old, unused housing space to create new and affordable apartments that will make living downtown more attractive. The project will also clean up empty buildings owned by the city while bringing them back on the tax pay role. Creating purpose for the buildings will also eliminate any aspects of urban decay that may be detrimental to the overall look and ambience of the city.

Section V – Proffer of Alternative Solutions

An alternative design was considered for the front façade. The client suggested leaving the metal covering out of concern for abiding by Main Street Iowa requirements. This alternative was beneficial in that it covered any unseemly masonry blemishes on the front of 619 as well as concealed any tie back system anchored to the front of the masonry wall. However, the weight of the metal covering was too great and posed further structural damage to the façade. In addition, the metal covering was added to the building after construction and its removal would not impact Main Street Iowa viability. Thus, it was decided that the metal covering should be removed in the final design.

Another alternative design considered was installing solar panels on the roof of either 623 or 625. Because the roofing system would be reconstructed to add a pitch, additional installation would not be too difficult for a construction crew. However, the cost of the solar panels themselves as well as maintaining them was too high for how few were able to be installed in the available space. More specific calculations can be found in Appendix B. Solar panels were not included in the final design.

When designing installation of appliances and casework in the residential units, alternative designs of either shared washer and dryer units per building or not including laundry appliances were both considered. Both designs reduced the price and filled space per unit. However, the first alternative of shared appliances required additional rooms in each building as well as an increased maintenance cost to collect change in the machines. It also increased the use of the machines therefore decreased their life expectancy. The second design was viable because there are multiple laundromats in a 10-block radius of the site, but new residential spaces in the area were including laundry facilities and the client wanted to be competitive with other local housing additions. The final design includes a smaller sized washer and dryer combination unit in every apartment.

Section VI – Final Design Details

Roof Joists and Floor Joists

Loads were calculated using Allowable Stress Design, with a dead load of 15psf and a live load of 40psf. Wood members were sized using the National Design Specification (NDS) for Wood Construction. The chosen roof joist is 2x13 Douglas fir larch No. 2 spaced 14 inches on center. The new roof joists will be installed in the same locations as the removed joists. The floor joists will utilize the same dimension lumber and will also be placed in the old locations as well. Building 619's ground floor will have a beam and column system at midspan. A built-up beam consisting of three 3x12 dimension lumber pieces will act as a point of support to maintain a typical floor joist span of 20ft. The columns supporting the beam will be 3x5 dimension lumber 10'-6" spacing. Typical sheathing will be 24/0 OSB sheathing 7/16" thick.

Column System

Building 619 will have a system of columns to support the second floor at its midspan. A W18x60 wide flange beam will support the brick wall and half of the floor load on the second floor and transfer the load to 3" pipe standard steel columns that will carry the load to the ground.

Façade Support

On the front of building 619 a continuous steel beam, size W18x60, will be supported by the exterior walls and two columns along its span to support the brick wall on the second floor of the building. Buildings 623 and 625 will use the same W18x60 to support the wall from floors two and three on the front of the building.

Façade Restoration

All awnings, overhangs, and exterior masonry coverings will be removed from the façade. The damaged brick on the exterior of building 625 will be removed and replaced with visually identical bricks, tie backs, and Type III Mortar with a ratio of 1:4 Masonry Cement: Sand for to withstand high environmental exposure.

Egress

The final design of the commercial space was required by IBC 2015 Section 1006.2 to have two exits in each building with a capacity of less than 400 occupants. All doorways abide by the necessary size requirements. The front door and back door should remain unlocked during all business hours to comply with code. Interior residential entries to buildings 623 and 625 was added as a safety precaution. A door divides the alley entry from the commercial space to prevent apartment occupants to access the commercial area outside of business hours.

The residential spaces comply with single entry codes in Section 1006.3.2(1) of IBC 2015 as the second and third floor above grade plane contain less than 4 dwelling units (apartments) per story, have a path of egress of less than 125 feet, and contain an automatic sprinkler system in accordance with IBC 2015 Section 903.3.1.1. The second floor of building 619 and the second and third floors of building 623 have windows of large enough openings to be considered emergency escapes to the roof of building 619, though they are not required by code.

ADA Compliance

All retail spaces abide by the American Disabilities Act requirements. The entry and emergency exit to each commercial space is flush with the exterior ground level, so no ramp is required. The opening between the first floors of buildings 619 and 623 has a raised step, but a ramp is not required as the main entrances of both spaces can be used. The restrooms in all retail spaces contain necessary openings and handrails.

The residential spaces are not required to be compliant in accordance with Section 1104.4 of IEBC 2015. An elevator was not economically viable in the design and is not required in existing buildings with only residential spaces on the upper floors.

Residential Floor Plan

The second floor of building 619 contains two units of two bedrooms and two full baths each (Figure 1). The units are 1,200 square feet. The existing masonry wall will be kept as it is a bearing wall to support the roof. The second floor of 623 contains three units of two bedrooms and one full bathroom each. The second floor of building 625 contains two of the similar units. Each unit is 700 square feet (Figure 2). The third floor of buildings 623 and 625 both contain three studio units each. Each unit is 480 square feet (Figure 3). A full kitchen with a refrigerator, oven, and dishwasher as well as a stacked washer/dryer combination are included in every unit.

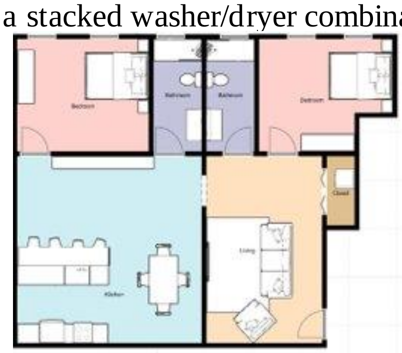


Figure 1: Two Bedroom and Two Bathroom Unit in Building 619

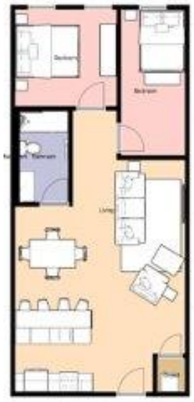


Figure 2: Two Bedroom and One Bathroom Unit in Buildings 623 and 625

Figure 3: Studio Unit in Buildings 623 and 625

Typical Kitchen

In addition to the refrigerator, oven, and dishwasher, each kitchen will also contain a double sink and both base and wall storage cabinets. Baltic wood countertop will be used for sustainability. An upper counter above the dishwasher and sink area will be added for additional dining and storage space.

Typical Bathroom

All residential bathrooms contain a bath and shower combination, a toilet and a vanity with a sink. The vanity will have under sink storage of 48" cabinets. Some bathrooms in building 619 contain windows which will be treated with opaque window film as to maintain occupants' privacy.

Wall Details

Any existing wallpaper on the brick walls will be removed, exposing all brick walls. All masonry surfaces will be scrubbed by brush with waterless Enviroshield poultice to remove debris such as dirt, dust, and soot, in the case of building 625.

All curtain walls will be 2x4 studs at 24" O.C. with drywall and 2x4 top plates with a pressure treated base plates. Mineral wool insulation will be used in all partition walls for cost effectiveness and sound absorption. All partition walls will be painted white and white wood trim will be installed along the baseboards and doorways.

Floor Details
All commercial flooring will be demolished and replaced with hardwood flooring (Figure 1.1). In any residential location where joists and beams are removed, flooring will also be removed. An estimated 12,000 square feet of flooring with be replaced. All replaced residential flooring will match the existing wood floors. Any floor coverings in the residential spaces will be removed. All hardwood floors will be finished-in-place with polyurethane for durability and easier maintenance (Figure 4).

Figure 4: Flooring Finish Example

Ceiling Details
All lead paint will be removed from the ceiling tiles of the commercial spaces and the tiles will be repainted with flat white tin paint and primer. An estimated 215 square feet will be repainted. All residential areas will have a gypsum board conventional ceiling mounted to the beams above and a smooth, white plaster finish.

Basement Details
The basement will be sealed using a vapor barrier for all buildings. Small gravel will be layered on the bare soil to allow water under the barrier to drain. Then the plastic vapor barrier will be placed over the rock to seal out any moisture trying to make its way into the building. In building 619 some concrete work will be required to install columns that support the floors above, which will take place before the vapor barrier is installed.

Section VII – Engineer's Cost Estimate

The total cost estimate for this project is $1,063,365. The design cost estimate is based on 300 billable hours at an hourly salary ranging from $28 to $40 per hour and an overhead multiplier of 3. The estimated administration cost is calculated as 3% of the project cost and the contingency is 10% of the project cost.

Table 2: Total Cost Estimate by Category

Category	Price ($)
Electrical	62,991
Plumbing	24,282
Mechanical	184,005
Casework	61,428
Finishes	97,983
Structural	158,018
Construction	184,900
Demolition	138,000
Design	29,425
Administration	28,231
Contigency	94,103
Total Cost	1,063,365

Section VIII – References

International Code Council. (2015). *International Building Code*. Falls Church, Virginia: International Code Council.

International Code Council. (2015). *International Existing Building Code*. Falls Church, Virginia: International Code Council.

United States. (2010). *2010 ADA standards for accessible design*. Washington, D.C.: Dept. of Justice.

Weaver, M. E. (1997). *Conserving Buildings: A Manual of Techniques and Materials*. New York: Chichester Wiley.

Section IV – Proposal Attachments

Appendix A – Design Calculations

Dead Load Calculations

A dead load of 15 psf will be used throughout the ground floor. $D := 15\ psf$

Floor Dead Load Components			
Floor Finish	hardwood flooring, 3/4 in	3	
Concrete Topping	NA	0	1.50
Floor Underlayment	wood panel underlayment, 1/4 in	0.75	
Subfloor	plywood/OSB, 5/8 in	2.1	
Floor Framing	2x12 @ 16" o.c.	3.5	
Ceiling Insulation	NA	0	2.50
Ceiling	NA	0	
Lighting	no	0	
Mechanical	yes	4	
Plumbing	yes	1	

SUMMARY

Component	Load (psf)
Upper Roof Dead Load Components	0.00
Lower Roof Dead Load Components	0
Floor Dead Load Components	14.35
Total	14.35

Live Load

The chosen live load is 50 psf. (ASCE 7-10, Table 4-1) $L_L := 40\ psf$

623 and 625

Joist Loading

$w_{dj} := D \cdot \left(\frac{14}{12}\ ft\right) = 17.5\ plf$ Loading Due to Dead Load

$w_{Lj} := L_L \cdot \left(\frac{14}{12}\ ft\right) = 46.667\ plf$ Loading Due to Live Load

Design Calculations for Joists

$L := 20\ ft$ $D := 15\ psf$ $L_L := 40\ psf$

$w_{dj} := D \cdot \left(\frac{14}{12}\ ft\right) = 17.5\ plf$ Loading Due to Dead Load

$w_{Lj} := L_L \cdot \left(\frac{14}{12}\ ft\right) = 46.667\ plf$ Loading Due to Live Load

Due to dead load:

$R_d := \frac{w_{dj} \cdot L}{2} = 0.175\ kip$ $V_{maxd} := R_d = 0.175\ kip$

$$M_{maxd} := R_d \cdot \frac{L}{2} - \frac{w_{dj} \cdot \left(\frac{L}{2}\right)^2}{2} = 0.875\ kip \cdot ft$$

Due to live load:

$R_L := \frac{w_{Lj} \cdot L}{2} = 0.467\ kip$ $V_{maxL} := R_L = 0.467\ kip$

$$M_{maxL} := R_L \cdot \frac{L}{2} - \frac{w_{Lj} \cdot \left(\frac{L}{2}\right)^2}{2} = 2.333\ kip \cdot ft$$

$w := w_{dj} + w_{Lj} = 64.167\ plf$

$R := \frac{w \cdot L}{2} = 0.642\ kip$ $V_{maxj} := R = 0.642\ kip$

$M_{maxj} := R \cdot \frac{L}{2} - \frac{w \cdot \left(\frac{L}{2}\right)^2}{2} = 3.208\ kip \cdot ft$

$S := 31.64\ in^3$ (2x12)

$f_b := \frac{M_{maxj}}{S} = 1217\ psi$

$F_b := 900\ psi$ $C_D := 1$ $C_M := 1$ $C_t := 1$ $C_L := 1$ $C_F := 1$

$C_{fu} := 1$ $C_i := 1$ $C_r := 1.15$

$F_b' := F_b \cdot \left(C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r\right) = 1035\ psi$

$S := 52.73\ in^3$

$f_b := \frac{M_{maxj}}{S} = 730.135\ psi$ 3x12

Shear Calculations

$F_{cp} := 625\ psi$ $C_b := 1$

$F_{cp}' := F_{cp} \cdot \left(C_M \cdot C_t \cdot C_i \cdot C_b\right) = 625\ psi$

Deflection

$E := 1600000\ psi$ $I := 296.6\ in^4$

$E' := E \cdot \left(C_M \cdot C_t \cdot C_i\right) = 1600000\ psi$

$w := 0.5 \cdot w_{Lj} = 23.333\ plf$

$\delta_{STj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.177\ in$

$w := w_{dj} + 0.5 \cdot w_{Lj} = 40.833\ plf$

$\delta_{LTj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.31\ in$

$\delta_{TOTj} := 1.5 \cdot \delta_{LTj} + \delta_{STj} = 0.642\ in$

$\Delta_{STj} := \frac{L}{480} = 0.5\ in$

$\Delta_{TOTj} := \frac{L}{360} = 0.667\ in$

Floor Shall be 3x12 @ 14 in O.C.

Roof Calculations

$D := 20\ psf$
$L_L := 20\ psf$

$p_g := 20\ psf$ Ground Snow Load
$C_e := 1$ Exposer factor
$C_t := 1$ Thermal factor
$I_s := 1$ Importance factor
$p_f := 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot p_g = 14\ psf$ Flat roof snow load

Load combination D + Lr governs

$L := 20\ ft$

$w_{dj} := D \cdot \left(\frac{14}{12}\ ft\right) = 23.333\ plf$ Loading Due to Dead Load

$w_{Lj} := L_L \cdot \left(\frac{14}{12}\ ft\right) = 23.333\ plf$ Loading Due to Live Load

Due to dead load:

$R_d := \frac{w_{dj} \cdot L}{2} = 0.233\ kip$ $V_{maxd} := R_d = 0.233\ kip$

$M_{maxd} := R_d \cdot \frac{L}{2} - \frac{w_{dj} \cdot \left(\frac{L}{2}\right)^2}{2} = 1.167\ kip \cdot ft$

Due to live load:

$R_L := \frac{w_{Lj} \cdot L}{2} = 0.233\ kip$ $V_{maxL} := R_L = 0.233\ kip$

$M_{maxL} := R_L \cdot \frac{L}{2} - \frac{w_{Lj} \cdot \left(\frac{L}{2}\right)^2}{2} = 1.167\ kip \cdot ft$

$w := w_{dj} + w_{Lj} = 46.667\ plf$

$R := \frac{w \cdot L}{2} = 0.467\ kip$ $V_{maxj} := R = 0.467\ kip$

$M_{maxj} := R \cdot \frac{L}{2} - \frac{w \cdot \left(\frac{L}{2}\right)^2}{2} = 2.333\ kip \cdot ft$

$S := 31.64\ in^3$ (2x12)

$f_b := \frac{M_{maxj}}{S} = 885\ psi$

$F_b := 900\ psi$ $C_D := 1$ $C_M := 1$ $C_t := 1$ $C_L := 1$

$C_{fu} := 1$ $C_i := 1$ $C_r := 1.15$

$F_b' := F_b \cdot \left(C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r\right) = 1035\ psi$

$S := 52.73\ in^3$

$f_b := \frac{M_{maxj}}{S} = 531.007\ psi$ 3x12

Shear Calculations

$F_{cp} := 625\ psi$ $C_b := 1$

$F_{cp}' := F_{cp} \cdot (C_M \cdot C_t \cdot C_i \cdot C_b) = 625\ psi$

Deflection

$E := 1600000\ psi$ $I := 296.6\ in^4$

$E' := E \cdot (C_M \cdot C_t \cdot C_i) = 1600000\ psi$

$w := 0.5 \cdot w_{Lj} = 11.667\ plf$

$\delta_{STj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.089\ in$

$w := w_{dj} + 0.5 \cdot w_{Lj} = 35\ plf$

$\delta_{LTj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.266\ in$

$\delta_{TOTj} := 1.5 \cdot \delta_{LTj} + \delta_{STj} = 0.487\ in$

$\Delta_{STj} := \frac{L}{480} = 0.5\ in$

$\Delta_{TOTj} := \frac{L}{360} = 0.667\ in$

Floor Shall be 3x12 @ 14 in O.C.

Sheathing Choice:

$Loading := D + L_L = 40\ psf$
Unblocked
Supports 14 in O.C.
Select 24/0 OSB Sheathing
Thickness: 7/16

Steel Beam on front of 623

$\gamma_{brick} := 135\ pcf$ $h := 26\ ft$ $t := 22\ in$

$w_w := \gamma_{brick} \cdot h \cdot t = 6435\ plf$

$w := w_w = (6.435 \cdot 10^3)\ plf$

$R := \frac{w \cdot L}{2} = 64.35\ kip$ $V_u := R = 64.35\ kip$

$$M_u := R \cdot \frac{L}{2} - \frac{w \cdot \left(\frac{L}{2}\right)^2}{2} = 321.75\ kip \cdot ft$$

W18x60 $E := 29000\ ksi$ $F_y := 50\ ksi$

$A := 17.6\ in^2$ $d := 18.2\ in$ $b_f := 7.56\ in$ $t_f := 0.695\ in$ $t_w := 0.415\ in$

$k := 1.1\ in$

$h := d - 2 \cdot k = 16\ in$ $J := 6.03\ in^4$ $C_w := 9940\ in^6$

$I_x := 984\ in^4$ $Z_x := 123\ in^3$ $S_x := 108\ in^3$ $r_x := 7.47\ in$

$I_y := 50.1\ in^4$ $Z_y := 20.6\ in^3$ $S_y := 13.3\ in^3$ $r_y := 1.68\ in$

$$\lambda_w := \frac{h}{t_w} = 38.554 \quad \le \quad 3.76 \cdot \sqrt{\frac{E}{F_y}} = 90.553$$

Flexure

FLB

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 5.439$$

$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{F_y}} = 9.152$ $\lambda_{rf} := 1 \cdot \sqrt{\frac{E}{F_y}} = 24.083$

$$\phi M_n := 0.9 \cdot F_y \cdot Z_x = 461\ kip \cdot ft$$

LTB

$$L_p := 1.76 \cdot r_y \cdot \sqrt{\frac{E}{F_y}} = 71.209\ in$$

$r_{ts} := \sqrt{\frac{\sqrt{I_y \cdot C_w}}{S_x}} = 2.556\ in$ $h_0 := d - t_f = 17.505\ in$ $c := 1$

$$L_r := 1.95 \cdot r_{ts} \cdot \frac{E}{0.7 \cdot F_y} \cdot \sqrt{\frac{J \cdot c}{S_x \cdot h_0} + \sqrt{\left(\frac{J \cdot c}{S_x \cdot h_0}\right)^2 + 6.76 \cdot \left(\frac{0.7 \cdot F_y}{E}\right)^2}} = 361.563\ in$$

$$\phi M_n := 0.9 \cdot F_y \cdot Z_x = 461\ kip \cdot ft$$

$$DCR := \frac{M_u}{\phi M_n} = 0.698$$

Shear

$$\frac{h}{t_w} = 38.554 \quad \leq \quad 2.24 \cdot \sqrt{\frac{E}{F_y}} = 53.946$$

$$\phi_v := 1$$

$$\phi V_n := 0.6 \cdot F_y \cdot d \cdot t_w = 227\ kip$$

$$DCR := \frac{V_u}{\phi V_n} = 0.284$$

619

Joist Loading

$w_{dj} := D \cdot \left(\frac{14}{12} ft\right) = 23.333\ plf$ Loading Due to Dead Load

$w_{Lj} := L_L \cdot \left(\frac{14}{12} ft\right) = 23.333\ plf$ Loading Due to Live Load

Design Calculations for Joists

Ground Floor

$L := 20\ ft$ $D := 15\ psf$ $L_L := 40\ psf$

$w_{dj} := D \cdot \left(\frac{14}{12} ft\right) = 17.5\ plf$ Loading Due to Dead Load

$w_{Lj} := L_L \cdot \left(\frac{14}{12} ft\right) = 46.667\ plf$ Loading Due to Live Load

Due to dead load:

$R_d := \frac{w_{dj} \cdot L}{2} = 0.175\ kip$ $V_{maxd} := R_d = 0.175\ kip$

$$M_{maxd} := R_d \cdot \frac{L}{2} - \frac{w_{dj} \cdot \left(\frac{L}{2}\right)^2}{2} = 0.875\ kip \cdot ft$$

Due to live load:

$R_L := \frac{w_{Lj} \cdot L}{2} = 0.467\ kip$ $V_{maxL} := R_L = 0.467\ kip$

$$M_{maxL} := R_L \cdot \frac{L}{2} - \frac{w_{Lj} \cdot \left(\frac{L}{2}\right)^2}{2} = 2.333\ kip \cdot ft$$

$w := w_{dj} + w_{Lj} = 64.167\ plf$

$R := \frac{w \cdot L}{2} = 0.642\ kip$ $V_{maxj} := R = 0.642\ kip$

$$M_{maxj} := R \cdot \frac{L}{2} - \frac{w \cdot \left(\frac{L}{2}\right)^2}{2} = 3.208\ kip \cdot ft$$

$S := 31.64\ in^3$ (2x12)

$$f_b := \frac{M_{maxj}}{S} = 1217\ psi$$

$F_b := 900\ psi$ $C_D := 1$ $C_M := 1$ $C_t := 1$ $C_L := 1$ $C_F := 1$

$C_{fu} := 1$ $C_i := 1$ $C_r := 1.15$

$$F_b' := F_b \cdot \left(C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r\right) = 1035\ psi$$

$S := 52.73\ in^3$

$$f_b := \frac{M_{maxj}}{S} = 730.135\ psi$$ 3x12

Shear Calculations

$F_{cp} := 625\ psi$ $C_b := 1$

$$F_{cp}' := F_{cp} \cdot \left(C_M \cdot C_t \cdot C_i \cdot C_b\right) = 625\ psi$$

Deflection

$E := 1600000\ psi$ $I := 296.6\ in^4$

$$E' := E \cdot \left(C_M \cdot C_t \cdot C_i\right) = 1600000\ psi$$

$$w := 0.5 \cdot w_{Lj} = 23.333\ plf$$

$$\delta_{STj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.177\ in$$

$$w := w_{dj} + 0.5 \cdot w_{Lj} = 40.833\ plf$$

$$\delta_{LTj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.31\ in$$

$$\delta_{TOTj} := 1.5 \cdot \delta_{LTj} + \delta_{STj} = 0.642\ in$$

$$\Delta_{STj} := \frac{L}{480} = 0.5\ in$$

$$\Delta_{TOTj} := \frac{L}{360} = 0.667\ in$$

Floor Shall be 3x12 @ 14 in O.C.

Beam Loading

$P := 0.642\ kip$ $P_L := 0.467\ kip$ $L := 10.5\ ft$

$s := 14\ in$

$w := \frac{P}{s} = 550.286\ plf$ $w_L := \frac{P_L}{s} = 400\ plf$

Due to live load:

$R_L := \frac{w_L \cdot L}{2} = 2.102\ kip$ $V_{maxL} := R_L = 2.102\ kip$

$$M_{maxL} := R_L \cdot \frac{L}{2} - \frac{w_L \cdot \left(\frac{L}{2}\right)^2}{2} = 5.516\ kip \cdot ft$$

$w := w = 550.286\ plf$

$R := \frac{w \cdot L}{2} = 2.889\ kip$ $V := R = 2.889\ kip$

$$M := R \cdot \frac{L}{2} - \frac{w \cdot \left(\frac{L}{2}\right)^2}{2} = 7.584\ kip \cdot ft$$

$F_b' = 1035\ psi$

$$S_{req} := \frac{M}{F_b'} = 87.926\ in^3$$

Built up beam 3 2x12 dimension lumber

$b := 1.5\ in \cdot 3 = 4.5\ in$

$d := 11.25\ in$ $I := \frac{d^3 \cdot b}{12} = 533.936\ in^4$

$c := \frac{d}{2} = 5.625\ in$ $S := \frac{I}{c} = 94.922\ in^3$

$$f_b := \frac{M}{S} = 959\ psi$$

$$DCR := \frac{f_b}{F_b'} = 0.926$$ Ok

$F_{cp} := 625\ psi$ $C_b := 1$

$$F_{cp}' := F_{cp} \cdot (C_M \cdot C_t \cdot C_i \cdot C_b) = 625\ psi$$

$A := b \cdot d = 50.625\ in^2$ $V := 2.8\ kip$

$$f_{cp} := \frac{V}{A} = 55.309\ psi$$ Ok

Deflection

$$E := 1600000\ psi$$

$$E' := E \cdot (C_M \cdot C_t \cdot C_i) = 1600000\ psi$$

$$w_{ST} := 0.5 \cdot w_L = 200.143\ plf$$

$$\delta_{STj} := \frac{5 \cdot w_{ST} \cdot L^4}{384 \cdot E' \cdot I} = 0.064\ in$$

$$w := w = 550.286\ plf$$

$$\delta_{LTj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.176\ in$$ $w = 550.286\ plf$

$$\delta_{TOTj} := 1.5 \cdot \delta_{LTj} + \delta_{STj} = 0.328\ in$$

$$\Delta_{STj} := \frac{L}{480} = 0.263\ in$$

$$\Delta_{TOTj} := \frac{L}{360} = 0.35\ in$$

Floor Beam: Built up 3 3x12 dimension lumber

Column Loading:

$P := 3\ kip$

$F_c := 700\ psi$

$A_{min} := \frac{P}{F_c} = 4.286\ in^2$

(1) 3x5 dimension lumber

$A := 6.75\ in^2 \qquad C_D := 1 \qquad l_e := 7.333\ ft \qquad C_F := 1$

$F_{cstar} := F_c \cdot (C_D \cdot C_M \cdot C_t \cdot C_i \cdot C_F) = 700\ psi$

$E_{min} := 580000\ psi \qquad C_T := 1$

$E_{min}' := E_{min} \cdot (C_M \cdot C_t \cdot C_i \cdot C_T) = (5.8 \cdot 10^5)\ psi$

$$F_{cE} := \frac{0.822 \cdot E_{min}'}{\left(\frac{l_e}{4.5\ in}\right)^2} = (1.247 \cdot 10^3)\ psi$$

$c := 0.8$

$$C_P := \frac{1 + \left(\frac{F_{cE}}{F_{cstar}}\right)}{2 \cdot c} - \sqrt{\left(\frac{1 + \left(\frac{F_{cE}}{F_{cstar}}\right)}{2 \cdot c}\right)^2 - \frac{\frac{F_{cE}}{F_{cstar}}}{c}} = 0.847$$

$F_c' := F_{cstar} \cdot C_P = 593\ psi \qquad f_c := \frac{P}{A} = 444\ psi$ Ok

$$DCR := \frac{f_c}{F_c'} = 0.75$$

Roof Loading

$D := 20\ psf$
$L_L := 20\ psf$

$p_g := 20\ psf$ Ground Snow Load
$C_e := 1$ Exposer factor
$C_t := 1$ Thermal factor
$I_s := 1$ Importance factor
$p_f := 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot p_g = 14\ psf$ Flat roof snow load

drift height

$$h_d := \left(0.43 \cdot \sqrt[3]{40} \cdot \sqrt[4]{30}\right) - 1.5 = 1.942$$

$h_d := 2\ ft$ $h_c := 18\ ft$

$$W := \frac{4 \cdot {h_d}^2}{h_c} = 0.889\ ft$$

Governing Combination D+Lr
Same Design as 623 and 625.

3x12, 14" O.C.

Upper Floor:

$L := 20\ ft$ $D := 15\ psf$ $L_L := 40\ psf$

$$w_{dj} := D \cdot \left(\frac{14}{12}\ ft\right) = 17.5\ plf$$ Loading Due to Dead Load

$$w_{Lj} := L_L \cdot \left(\frac{14}{12}\ ft\right) = 46.667\ plf$$ Loading Due to Live Load

Due to dead load:

$$R_d := \frac{w_{dj} \cdot L}{2} = 0.175\ kip \qquad V_{maxd} := R_d = 0.175\ kip$$

$$M_{maxd} := R_d \cdot \frac{L}{2} - \frac{w_{dj} \cdot \left(\frac{L}{2}\right)^2}{2} = 0.875\ kip \cdot ft$$

Due to live load:

$$R_L := \frac{w_{Lj} \cdot L}{2} = 0.467\ kip \qquad V_{maxL} := R_L = 0.467\ kip$$

$$M_{maxL} := R_L \cdot \frac{L}{2} - \frac{w_{Lj} \cdot \left(\frac{L}{2}\right)^2}{2} = 2.333\ kip \cdot ft$$

$$w := w_{dj} + w_{Lj} = 64.167\ plf$$

$$R := \frac{w \cdot L}{2} = 0.642\ kip \qquad V_{maxj} := R = 0.642\ kip$$

$$M_{maxj} := R \cdot \frac{L}{2} - \frac{w \cdot \left(\frac{L}{2}\right)^2}{2} = 3.208\ kip \cdot ft$$

$S := 31.64\ in^3$ (2x12)

$$f_b := \frac{M_{maxj}}{S} = 1217\ psi$$

$F_b := 900\ psi$ $\quad C_D := 1$ $\quad C_M := 1$ $\quad C_t := 1$ $\quad C_L := 1$ $\quad C_F := 1$

$C_{fu} := 1$ $\quad C_i := 1$ $\quad C_r := 1.15$

$$F_b' := F_b \cdot \left(C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r\right) = 1035\ psi$$

$S := 52.73\ in^3$

$$f_b := \frac{M_{maxj}}{S} = 730.135\ psi$$ 3x12

Shear Calculations

$F_{cp} := 625\ psi$ $\quad C_b := 1$

$$F_{cp}' := F_{cp} \cdot \left(C_M \cdot C_t \cdot C_i \cdot C_b\right) = 625\ psi$$

Deflection

$E := 1600000\ psi$ $\quad I := 296.6\ in^4$

$$E' := E \cdot \left(C_M \cdot C_t \cdot C_i\right) = 1600000\ psi$$

$$w := 0.5 \cdot w_{Lj} = 23.333\ plf$$

$$\delta_{STj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.177\ in$$

$$w := w_{dj} + 0.5 \cdot w_{Lj} = 40.833\ plf$$

$$\delta_{LTj} := \frac{5 \cdot w \cdot L^4}{384 \cdot E' \cdot I} = 0.31\ in$$

$$\delta_{TOTj} := 1.5 \cdot \delta_{LTj} + \delta_{STj} = 0.642\ in$$

$$\Delta_{STj} := \frac{L}{480} = 0.5\ in$$

$$\Delta_{TOTj} := \frac{L}{360} = 0.667\ in$$

Floor Shall be 3x12 @ 14 in O.C.

Floor Load being transferred into wall

$$R_L := 0.467\ kip$$

$$w_f := \frac{2 \cdot R}{14\ in} = 1100\ plf \qquad w_{fL} := \frac{2 \cdot R_L}{14\ in} = 801\ plf$$

$$R_R := 0.467\ kip \qquad R_{RL} := 0.233\ kip$$

$$w_r := \frac{2 \cdot R_R}{14\ in} = 801\ plf \qquad w_{rL} := \frac{2 \cdot R_{RL}}{14\ in} = 399\ plf$$

Wall Load

$$\gamma_{brick} := 135\ pcf \qquad h := 10.5\ ft \qquad t := 22\ in$$

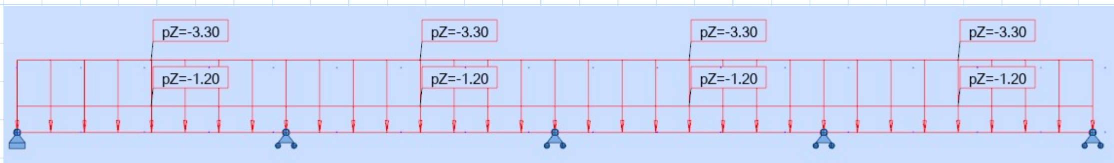
$$w_w := \gamma_{brick} \cdot h \cdot t = 2599\ plf$$

Steal Beam Supporting Upper Floor

Beam Loading

total

$$w := w_f + w_r + w_w = 4499\ plf$$



$M_u := 215\ kip \cdot ft$ $\qquad V_u := 57.86\ kip$

W18x60 $\qquad E := 29000\ ksi \qquad F_y := 50\ ksi$

$A := 17.6\ in^2 \qquad d := 18.2\ in \qquad b_f := 7.56\ in \qquad t_f := 0.695\ in \qquad t_w := 0.415\ in$

$k := 1.1\ in$

$h := d - 2 \cdot k = 16\ in \qquad J := 6.03\ in^4 \qquad C_w := 9940\ in^6$

$I_x := 984\ in^4 \qquad Z_x := 123\ in^3 \qquad S_x := 108\ in^3 \qquad r_x := 7.47\ in$

$I_y := 50.1\ in^4 \qquad Z_y := 20.6\ in^3 \qquad S_y := 13.3\ in^3 \qquad r_y := 1.68\ in$

$$\lambda_w := \frac{h}{t_w} = 38.554 \qquad \le \qquad 3.76 \cdot \sqrt{\frac{E}{F_y}} = 90.553$$

Flexure

FLB

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 5.439$$

$$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{F_y}} = 9.152 \qquad \lambda_{rf} := 1 \cdot \sqrt{\frac{E}{F_y}} = 24.083$$

$$\phi M_n := 0.9 \cdot F_y \cdot Z_x = 461\ kip \cdot ft$$

LTB

$$L_p := 1.76 \cdot r_y \cdot \sqrt{\frac{E}{F_y}} = 71.209\ in$$

$$r_{ts} := \sqrt{\frac{\sqrt{I_y \cdot C_w}}{S_x}} = 2.556\ in \qquad h_0 := d - t_f = 17.505\ in \qquad c := 1$$

$$L_r := 1.95 \cdot r_{ts} \cdot \frac{E}{0.7 \cdot F_y} \cdot \sqrt{\frac{J \cdot c}{S_x \cdot h_0} + \sqrt{\left(\frac{J \cdot c}{S_x \cdot h_0}\right)^2 + 6.76 \cdot \left(\frac{0.7 \cdot F_y}{E}\right)^2}} = 361.563\ in$$

$$\phi M_n := 0.9 \cdot F_y \cdot Z_x = 461\ kip \cdot ft$$

$$DCR := \frac{M_u}{\phi M_n} = 0.466$$

Shear

$$\frac{h}{t_w} = 38.554 \quad \le \quad 2.24 \cdot \sqrt{\frac{E}{F_y}} = 53.946$$

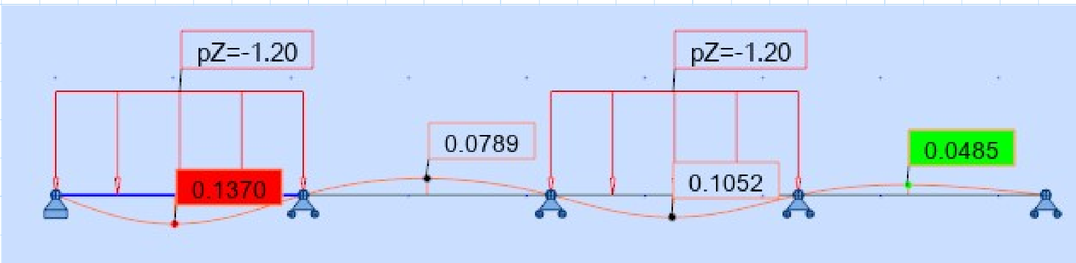
$$\phi_v := 1$$

$$\phi V_n := 0.6 \cdot F_y \cdot d \cdot t_w = 227\ kip$$

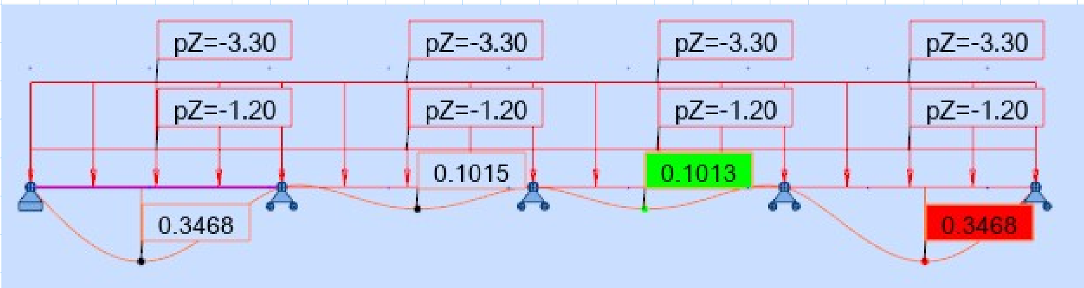
$$DCR := \frac{V_u}{\phi V_n} = 0.255$$

Deflection

Short term



Long term



$L := 21\ ft$

$\delta_{LT} := 0.3468\ in \quad \delta_{ST} := 0.137\ in \quad \delta_{TOT} := 1.5 \cdot \delta_{LT} + \delta_{ST} = 0.657\ in$

$$\Delta_{STj} := \frac{L}{480} = 0.525\ in \qquad \Delta_{TOTj} := \frac{L}{360} = 0.7\ in$$

$$DCR := \frac{\delta_{ST}}{\Delta_{STj}} = 0.261 \qquad DCR := \frac{\delta_{TOT}}{\Delta_{TOTj}} = 0.939$$

Columns Extending from ground to second floor

$L := 18\ ft \quad E := 29000\ ksi \quad r_x := 1.17\ in$

$L_c := 0.8 \cdot L = 14.4\ ft \quad G := 11200\ ksi \quad r_y := 1.17\ in$

$$F_{ex} := \frac{\pi^2 \cdot E}{\left(\frac{L_c}{r_x}\right)^2} = 13.12\ ksi$$

$$F_{ey} := \frac{\pi^2 \cdot E}{\left(\frac{L_c}{r_y}\right)^2} = 13.12\ ksi$$

$I_x := 2.85\ in^4 \quad I_y := 2.85\ in^4 \quad A_g := 2.07\ in^2 \quad x_0 := 0\ in \quad y_0 := 0\ in$

$$r_0 := \left(\frac{I_x + I_y}{A_g} + {x_0}^2 + {y_0}^2\right)^{0.5} = 1.659\ in \qquad C_w := 0\ in^6 \qquad J := 5.69\ in^4$$

$$F_{ez} := \left(\frac{\pi^2 \cdot E \cdot C_w}{(L_c)^2} + G \cdot J\right) \cdot \frac{1}{A_g \cdot {r_0}^2} = 11180.4\ ksi$$

clear $(F_{ex}, F_{ey}, F_{ez}, F_e, y_0, x_0, r_0)$

$F_{ex} := 63.21 \quad x_0 := 0$

$F_{ey} := 55.21 \quad y_0 := 0$

$F_{ez} := 6925.9 \quad r_0 := 2.5$

$$f := (F_e - F_{ex})(F_e - F_{ey})(F_e - F_{ez}) - {F_e}^2 (F_e - F_{ey})\left(\frac{{x_0}^2}{{r_0}^2}\right) - {F_e}^2 (F_e - F_{ex})\left(\frac{{y_0}^2}{{r_0}^2}\right) \xrightarrow{solve, F_e} \begin{bmatrix} 6925.9 \\ 63.21 \\ 55.21 \end{bmatrix}$$

$F_e := min(f) \cdot ksi = 55.21\ ksi$

$F_y := 50\ ksi$

$$\frac{F_y}{F_e} = 0.906$$

$$F_{cr} := \left(0.658^{\left(\frac{F_y}{F_e}\right)}\right) \cdot F_y = 34.225\ ksi$$

$$\phi := 0.9$$

$\phi P_n := \phi \cdot F_{cr} \cdot A_g = 63.762\ kip$ OK

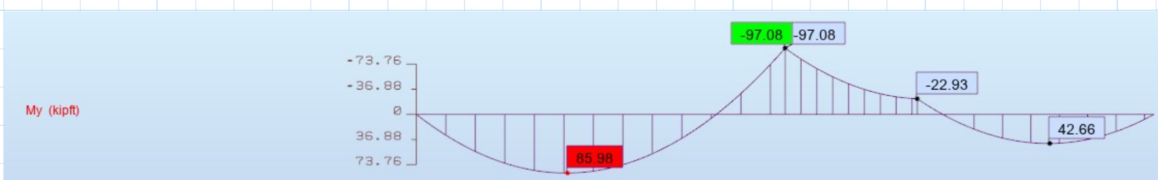
$$DCR := \frac{V_u}{\phi P_n} = 0.907$$

3" Pipe Standard Column

<u>Steel Beam on front of Building</u>

$\gamma_{brick} := 135\ pcf$ $h := 10.5\ ft$ $t := 22\ in$

$$w_w := \gamma_{brick} \cdot h \cdot t = 2599\ plf$$



$M_u := 97.08\ kip \cdot ft$ $V_u := 30.85\ kip$

W18x60 $E := 29000\ ksi$ $F_y := 50\ ksi$

$A := 17.6\ in^2$ $d := 18.2\ in$ $b_f := 7.56\ in$ $t_f := 0.695\ in$ $t_w := 0.415\ in$

$k := 1.1\ in$

$h := d - 2 \cdot k = 16\ in$ $J := 6.03\ in^4$ $C_w := 9940\ in^6$

$I_x := 984\ in^4$ $Z_x := 123\ in^3$ $S_x := 108\ in^3$ $r_x := 7.47\ in$

$I_y := 50.1\ in^4$ $Z_y := 20.6\ in^3$ $S_y := 13.3\ in^3$ $r_y := 1.68\ in$

$\lambda_w := \frac{h}{t_w} = 38.554 \quad \leq \quad 3.76 \cdot \sqrt{\frac{E}{F_y}} = 90.553$

Flexure

FLB

$\lambda_f := \frac{b_f}{2 \cdot t_f} = 5.439$

$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{F_y}} = 9.152 \qquad \lambda_{rf} := 1 \cdot \sqrt{\frac{E}{F_y}} = 24.083$

$\phi M_n := 0.9 \cdot F_y \cdot Z_x = 461\ kip \cdot ft$

LTB

$L_p := 1.76 \cdot r_y \cdot \sqrt{\frac{E}{F_y}} = 71.209\ in$

$r_{ts} := \sqrt{\frac{\sqrt{I_y \cdot C_w}}{S_x}} = 2.556\ in \qquad h_0 := d - t_f = 17.505\ in \qquad c := 1$

$$L_r := 1.95 \cdot r_{ts} \cdot \frac{E}{0.7 \cdot F_y} \cdot \sqrt{\frac{J \cdot c}{S_x \cdot h_0} + \sqrt{\left(\frac{J \cdot c}{S_x \cdot h_0}\right)^2 + 6.76 \cdot \left(\frac{0.7 \cdot F_y}{E}\right)^2}} = 361.563\ in$$

$\phi M_n := 0.9 \cdot F_y \cdot Z_x = 461\ kip \cdot ft$

$DCR := \frac{M_u}{\phi M_n} = 0.21$

Shear

$\frac{h}{t_w} = 38.554 \quad \leq \quad 2.24 \cdot \sqrt{\frac{E}{F_y}} = 53.946$

$\phi_v := 1$

$$\phi V_n := 0.6 \cdot F_y \cdot d \cdot t_w = 227\ kip$$

$$DCR := \frac{V_u}{\phi V_n} = 0.136$$

Deflection

Long term

$L := 21\ ft$

$\delta_{LT} := 0.1834\ in$ $\delta_{ST} := 0\ in$ $\delta_{TOT} := 1.5 \cdot \delta_{LT} + \delta_{ST} = 0.275\ in$

$$\Delta_{TOTj} := \frac{L}{360} = 0.7\ in \qquad DCR := \frac{\delta_{TOT}}{\Delta_{TOTj}} = 0.393$$

Class Activity #1

Define Variables

$b_1 := 20\ ft$ $h_1 := 88\ ft$ $b_2 := 20\ ft$ $h_2 := 88\ ft$ $b_3 := 43\ ft + 10\ in = 43.833\ ft$ $h_3 := 62\ ft$

Design Calculations

Total Sq ft Calc.

$A_{\#1} := b_1 \cdot h_1 = (1.76 \cdot 10^3)\ ft^2$ $A_{\#2} := b_2 \cdot h_2 = (1.76 \cdot 10^3)\ ft^2$ $A_{\#3} := b_3 \cdot h_3 = (2.718 \cdot 10^3)\ ft^2$

$A_{Total} := A_{\#1} + A_{\#2} + A_{\#3} = (6.238 \cdot 10^3)\ ft^2$ $A_{usable} := 0.75 \cdot A_{Total} = (4.678 \cdot 10^3)\ ft^2$

$System := 66\ \frac{ft^2}{kW}$ $Cost := \frac{¤ \cdot 3.39}{W}$ $Size_{system} := \frac{A_{Total}}{System} = 94.51\ kW$

$Cost_{Total} := Cost \cdot Size_{system} = 320389\ ¤$

Per Unit Calc.

$Usage_{avg} := 9000 \frac{kW \cdot hr}{yr}$ $Sunlight := 1600 \frac{kW \cdot hr}{kW \cdot yr}$ $efficiency := 0.85$

$System_{size} := \frac{Usage_{avg} \cdot efficiency}{Sunlight} = 4.781 \; kW$

$\#Units := 10$ $Energy_{Req} := \#Units \cdot System_{size} = 47.813 \; kW$

$Cost_{Total} := Cost \cdot Energy_{Req} = 162084$ ¤

Panel.

$Panel := 320 \; W$ $\#Panels := \frac{Energy_{Req}}{Panel} = 149.414$ $Area_{Req} := Energy_{Req} \cdot System = \left(3.156 \cdot 10^{3}\right) ft^{2}$

$A_{panel} := 17.6 \; ft^{2}$ $Area_{Req} := A_{panel} \cdot \#Panels = \left(2.63 \cdot 10^{3}\right) ft^{2}$

Return on Investment.

$$Retail_{Useage} := 22.5 \ \frac{kW \cdot hr}{ft^2}$$

$$A_{619} := (136 \ ft + 2 \ in) \cdot (40 \ ft + 2 \ in) = (5.469 \cdot 10^3) \ ft^2$$

$$A_{623} := (136 \ ft + 2 \ in) \cdot (18 \ ft + 2 \ in) = (2.474 \cdot 10^3) \ ft^2$$

$$A_{625} := (87 \ ft + 2 \ in) \cdot (18 \ ft + 2 \ in) = (1.584 \cdot 10^3) \ ft^2$$

$$A_{RetailTotal} := A_{619} + A_{623} + A_{625} = (9.527 \cdot 10^3) \ ft^2$$

$$Retail_{UseTotal} := Retail_{Useage} \cdot A_{RetailTotal} = 214348.125 \ kW \cdot hr$$

$$Housing_{usage} := 11000 \ kW \cdot hr$$

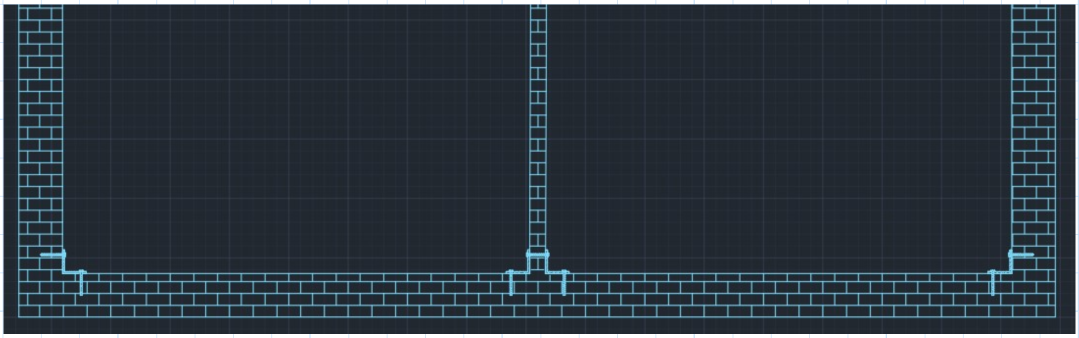
$$\#units := 5.5$$

$$Housing_{useTotal} := Housing_{usage} \cdot \#units = 60500 \ kW \cdot hr$$

$$Energy_{Req} := Retail_{UseTotal} + Housing_{useTotal} = 274848.125 \ kW \cdot hr$$

$$System_{10k} := 15000 \ kW \cdot hr$$

Class Activity #1



Define Variables

$\gamma_{brick} := 115\ pcf$ $\quad t_{wall} := 22\ in$ $\quad L_{wall} := 43\ ft + 8\ in = 43.667\ ft$ $\quad h_s := 9.5\ ft$

$t_{bear} := 8\ in$

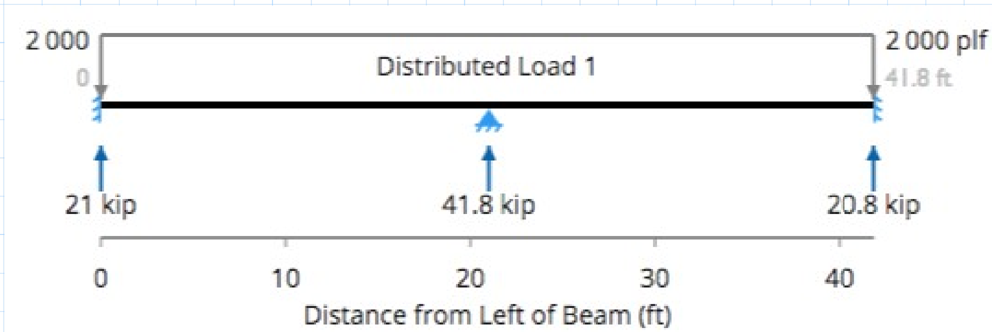
Design Calculations

$$A_{wall} := t_{wall} \cdot 1\ ft = 264\ in^2$$

$$W_{wall} := \gamma_{brick} \cdot t_{wall} \cdot L_{wall} \cdot h_s = 87.461\ kip \qquad w_{self} := \gamma_{brick} \cdot t_{wall} \cdot h_s = 2.003\ klf$$

$$L := L_{wall} - t_{wall} = 41.833\ ft \qquad a := 19\ ft + 9\ in + \frac{t_{wall}}{2} + \frac{t_{bear}}{2} = 21\ ft$$

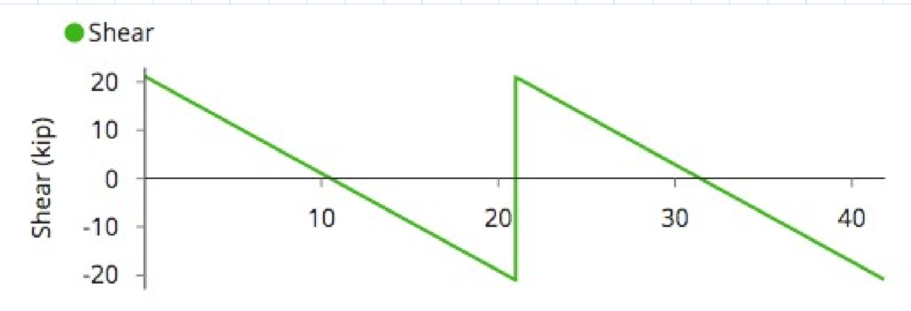
$$R_L := \frac{w_{self} \cdot \frac{L^2}{2}}{L} = 41.894\ kip \qquad R_R := w_{self} \cdot L - R_L = 41.894\ kip$$



$R_{left} := 21\ kip$ $R_{mid} := 41.8\ kip$ $R_{right} := 20.8\ kip$

$V = R_{left} - w_{self} \cdot x$ $0 \le x < a$

$V = R_{left} + R_{mid} - w_{self} \cdot x$ $a \le x < L$

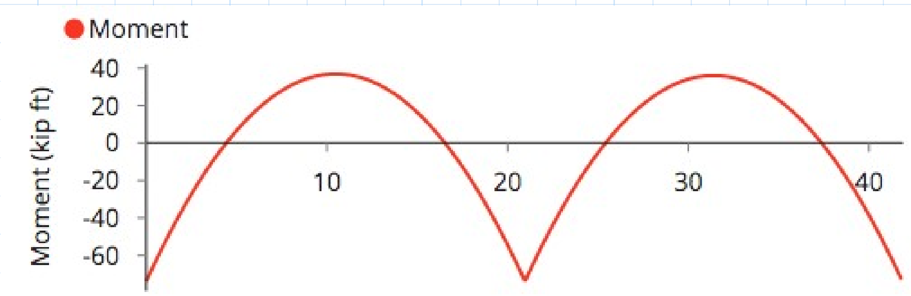


$V_u := R_{left} = 21\ kip$

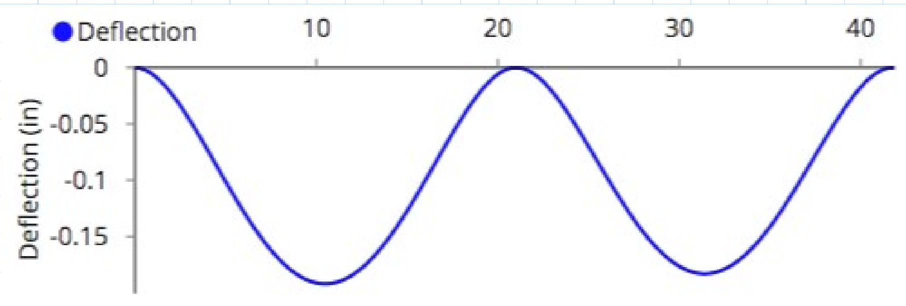
$M_{left} := -73.8\ kip \cdot ft$ $M_{mid} := 0\ kip \cdot ft$ $M_{right} := -72\ kip \cdot ft$

$M = M_{left} + R_{left} \cdot x - w_{self} \cdot \frac{x^2}{2}$ $0 \le x < a$

$M = M_{left} + R_{left} \cdot x + R_{mid} \cdot (x - a) - w_{self} \cdot \frac{x^2}{2}$ $a \le x < L$



$x := 0\ ft$ $M_u := M_{left} + R_{left} \cdot x - w_{self} \cdot \frac{x^2}{2} = -73.8\ kip \cdot ft$



$\delta_{max} := -0.192\ in$ $\le$ $0.25\ in$ Design is adequate.