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Completed By	Nolan DeWitte, Eric Schaffer, Shaowen Zhu, Contessa Harold
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Volga City Opera House Renovation

Submitted to: Volga City Truck Cruise

NESC Consultants

Prepared by: Nolan DeWitte, Eric Schaffer, Shaowen Zhu, and Contessa Harold

May 15, 2020

Table of Contents

Section 1: Executive Summary

Volga City Truck Cruise, Inc (VCTC, Inc) has requested the services of NESC Design Consultants to design and renovate various aspects of the Volga City Opera House. NESC Design Consultants is a team comprised of University of Iowa civil engineering students. With backgrounds in structural engineering, architecture, urban regional planning, and civil engineering, the team has collectively worked on a diverse assortment of similar projects through their internships and courses. Eric Schaffer worked as the project manager, Contessa Harold and Nolan DeWitte focused on the production and editing of the report and presentation, and Shaowen Zhu assisted the team with technological support.

Since its official opening in 1914, the opera house has been a venue for many local events in Clayton County. However, the building recently experienced a major flood that caused significant water damage throughout the structure and rendered the building unusable. VCTC, Inc, acquired the building in 2010 with the goal of restoring it to the community hub of the area. The client hopes to provide not only an attraction for tourism from the broader River Bluffs Scenic Byway region, but also as a place to reintroduce quality arts and entertainment to a rural community that has gone long without it. The opera house is currently undergoing interior remodeling to accommodate the venue's return as the entertainment hub of the region. With this in mind, the client is interested in several additions and alterations to the existing building that will complement the current remodeling and future goals of the venue. These additions and alterations include the design of a parking lot, a solution to increase the outdoor seating capacity of the venue, a new food delivery system, and a flood protection plan to prevent flood damage to the building and its interior.

The overall project was split into four separate components. The team created design drawings for the addition of a new parking lot, a wrap-around deck, a rooftop deck with accompanying roof alterations and stairwell, a dumbwaiter system to assist with the movement of food throughout the building, and measures to protect the building and its assets against flooding.

To ensure adequate parking for the newly renovated opera house, the design team is recommending a permeable parking lot that will occupy the existing empty lot to the north of the building. The parking lot has a self-contained drainage and storage system that has been designed to handle the runoff volume generated by a 1.25 inch rainfall event with a peak runoff volume of 2 inches in 24 hours. Due to the occupancy capacity of the structure, the IBC 2015 requires 40 parking stalls. The parking lot will feature 20 parking spaces, 8 of which are ADA accessible stalls to accommodate all those who require them. On-street parking will accommodate the remaining number of required stalls. A driveway on Washington Street will be constructed to enter this parking lot. The estimated construction cost for this portion of the project is $110,000.

The client's desire to accommodate outdoor seating and show off the scenic area around the opera house led to the design of a deck on the east side of the structure. The existing ADA ramp on the north side of the building will be extended to connect to the new deck. The ADA compliant ramp extension will allow disabled visitors to access the new eastside deck and provide a more convenient way to move large equipment to the backstage. This deck will allow access to the back of the stage through an existing doorway as well as access to the new standalone stairs that lead to the rooftop deck. The estimated construction cost for the wrap-around deck component of the project is $13,300.

On the south side of the building, connecting to the east wrap-around deck, the team has recommended and completed design drawings for the addition of a standalone steel staircase that will connect to a new rooftop deck. The staircase and rooftop deck projects have been broken down into two separate projects in the cost breakdown to allow for funding flexibility for the client. However, the team recommends completing both projects at the same time to ensure operability of both projects. The contract price for the staircase alone is $16,700. The rooftop deck will provide additional seating and outdoor capacity for the opera house and serve as an attractive amenity during summer and early fall in Volga City. The team has also made recommendations and completed design drawings for roof replacement and truss modifications to support the rooftop deck. A steel roof was recently installed to provide a temporary fix after a partial roof collapse. The proposed roof replacement seeks to restore the geometry of the roof and roofing materials to that prior to the installation of the steel roof. The contract price for these roof modifications and the rooftop deck is $21,500. The combined estimated cost for the rooftop deck and staircase additions is $38,200.

The design team has also recommended the modification of the building interior and the addition of two dumbwaiters in the opera house to provide for the safe movement of food between levels. The dumbwaiter will allow for the delivery of food from the kitchen to the main floor, and from the main floor to the balcony. These dumbwaiters will save kitchen staff from utilizing dangerously steep and narrow staircases to deliver food. Modifications to the existing building to accommodate the dumbwaiters include creating holes in each floor to allow the dumbwaiters to pass through them as well as a small bump-out in the existing kitchen. One dumbwaiter will be located on the east of the building and service the kitchen and main floor. The second dumbwaiter will be located behind the bar on the main floor of the opera house and will rise to a location just east of the bar on the balcony. These locations were selected to maximize staff access while also causing the smallest visual disruption for visitors. The electrical and mechanical components of the kitchen dumbwaiter will be located on top of the track to prevent these components from being damaged from flood water. The contract price for this component of the project is $11,500.

To protect the existing structure, assets within the structure, and proposed recommendations, the team developed several flood protection measures for the opera house. These protections employ a wet floodproofing technique that will safely allow the entrance of water into the structure through 25 flood vents in controlled locations. The addition of these flood vents to the structure will reduce the destructive forces placed on the building during a flooding event by allowing the equalization of water levels on both the interior and exterior of the structure. These flood vents are insulated to ensure conditioned air is kept in and pests are kept out of the building. With water entering the building in this protection technique, the team is also recommending that the areas of the building that will be inundated with flood waters employ flood resistant materials. These materials include vinyl covering on a newly constructed east wall in the basement, and throughout the kitchen. A liquid-applied waterproofing membrane will also be applied to exposed columns in the basement in order to protect them from any aesthetic or structural damage caused by flood waters and moisture in general. Valuable assets will be protected by utility covers or moved from any flood susceptible locations during a flooding event. The existing hot water heater in the kitchen is recommended to be moved to a newly revealed full-sized recessed area that was previously the cubby space in the kitchen. During a flooding event, a utility cover around the water heater is deployed to protect sensitive components, while any non-permanent assets such as fridges and other appliances will be evacuated from the kitchen using the existing double doors on the east side of the building. The contract price of this section of the project is $16,700.

In total, the designs created by NESC Consultants will provide the Volga City Opera House with new attractive amenities in the form of newly constructed decks, new parking close to the building with an emphasis on accessible spaces, a modernized food delivery system using dumbwaiters for the safe and efficient transport of food through the building, and a flood protection plan designed to alleviate structural and asset damages caused by the next flooding event The total cost of all components of the project with mobilization, engineering fees, and contingencies included is $174,760.

NESC Consultants thanks the Volga City Truck Cruise for the opportunity to work on such an exciting project. VCTC, Inc’s dedication to the renovation of the opera house will lead to the revitalization of the venue and the reinvention of the region’s community hub, and further cement Volga City as a prime tourist destination for those near and far.

Section 2: Organization, Qualifications and Experience

1. Name of Organization

   NESC Consultants

2. Organization Location and Contact Information

   Eric Schaffer | Project Manager
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3. Organization and Design Team Description

NESC Consultants is a team composed of University of Iowa civil engineering students in the senior capstone design class. Each team member has had educational courses and job experiences that enables them to bring a unique perspective to the design team. The team members are: Eric Schaffer, Contessa Harold, Nolan DeWitte and Shaowen Zhu. Eric acted as the project manager and the primary client contact. He has experience working as part of the structural engineering department of a full-service engineering firm. At this firm, he was placed on a variety of new construction and renovation projects. This combined with Eric's course background in structures, mechanics, and materials helped him to head the structural design of the project. Contessa's elective focus area is in pre-architecture. She gained extensive experience with hands-on projects while working for a small construction company where she assisted with the construction of a covered wrap-around porch. Contessa acted as one of the report editors, assisted Eric with structural designs, and worked to meet the client's vision for the building's architecture while adhering to industry building standards. Nolan's educational focus is in urban and regional planning. He has had past experience in building remodels, large project organization, and report generation through his prior work at the Iowa Department of Transportation and Collins Aerospace. Nolan assisted throughout all elements of the project as the load demanded, particularly focusing on report generation with Contessa and flood protection design. Shaowen was responsible for technical support and maintaining the storage of documents throughout the execution of the project. He has experience as a temporary worker for the China

Construction Third Engineering Bureau Co., LTD, where he supported professional engineers in metro projects. With his background in general civil engineering, Shaowen focused on the transportation design needs of the project.

Section 3: Design Services

1. Project Scope

VCTC, Inc, acquired the building in 2010 with the goal of restoring it to the community hub of the area. The client hopes to renovate the space to reintroduce the opera house as the premier arts and entertainment venue of the region. VCTC, Inc is interested in several additions and alterations to the existing building that will complement the current remodeling and future goals of the venue. The main objective of the project was to design additions to the opera house that would supplement the current and ongoing renovations and update the opera house to complement VCTC's future goals for the space. These additions and alterations include the design of a parking lot, a solution to increase the outdoor seating capacity of the venue, a new food delivery system, and a flood protection plan to prevent flood damage to the building and its interior.

Figure 1 shows a plan view of the opera house with the designed additions. It was revealed that the adjacent lot to the north will be acquired by the opera house. This future lot was designed as a permeable parking lot with stormwater storage located beneath it. The design of two separate decks was completed in order to address the lack of outdoor seating. The lower deck on the east of the building will serve as access to the backstage door and is large enough to accommodate seating for events. This deck wraps around the building and is connected to the ground level through an extension of the building's existing ADA compliant ramp on the north side of the building. The second deck is to be constructed on the roof of the existing structure on the easternmost portion of the roof. The position of the rooftop deck allows visitors to have an unimpeded view of the green space to the east of the building and of the scenic region around Volga City. The rooftop deck can be accessed through a stand-alone staircase that is located on the south side of the building. In recent history, a partial roof collapse caused the owners of the opera house to install a temporary steel roof with a new double-pitched geometry. As such, the geometry of the roof has been redesigned to not only accommodate the rooftop deck, but to restore the roof to its original geometry prior to the installation of the temporary steel roof. Although design work on the interior of the structure was minimal, both a food delivery system and flood protection measures were recommended. The opera house is looking to become the only dine-in theater in the region. As such, a dumbwaiter manufacturer and two dumbwaiter system locations were selected to facilitate easier movement of food and beverages throughout the building. The dumbwaiter delivery system will also mitigate the potential of staff injuring themselves while carrying food up the steep balcony and stage stairways. One dumbwaiter will serve the kitchen and main floor and the other will serve the main floor and balcony. Due to the proximity of the Volga River, the region is prone to flooding. Various flood protection methods are suggested to the client. A wet floodproofing technique is employed to prevent lasting damage to the structure and its assets while also being cost effective. It’s important to note that the scope of the project changed throughout the life cycle of design. Many of the smaller goals for the project at its inception were sidelined in order to dedicate more time to the larger systemic improvements to the opera house.

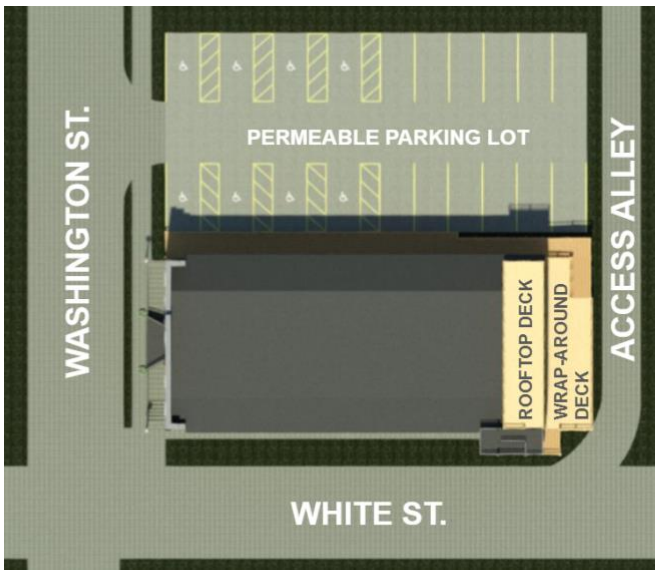

Figure 1. Plan view of exterior additions to the existing structure.

2. Work Plan

The team’s work plan to complete what is described by the project scope is illustrated in Figure 2. The project was broken down into four phases: Data Collection and Model Generation, Design Alternatives and Plan Set Production, Final Design Report and Presentation, and Editing of Final Deliverables. The individual tasks within each phase were assigned to those who have the most knowledge of the subject.

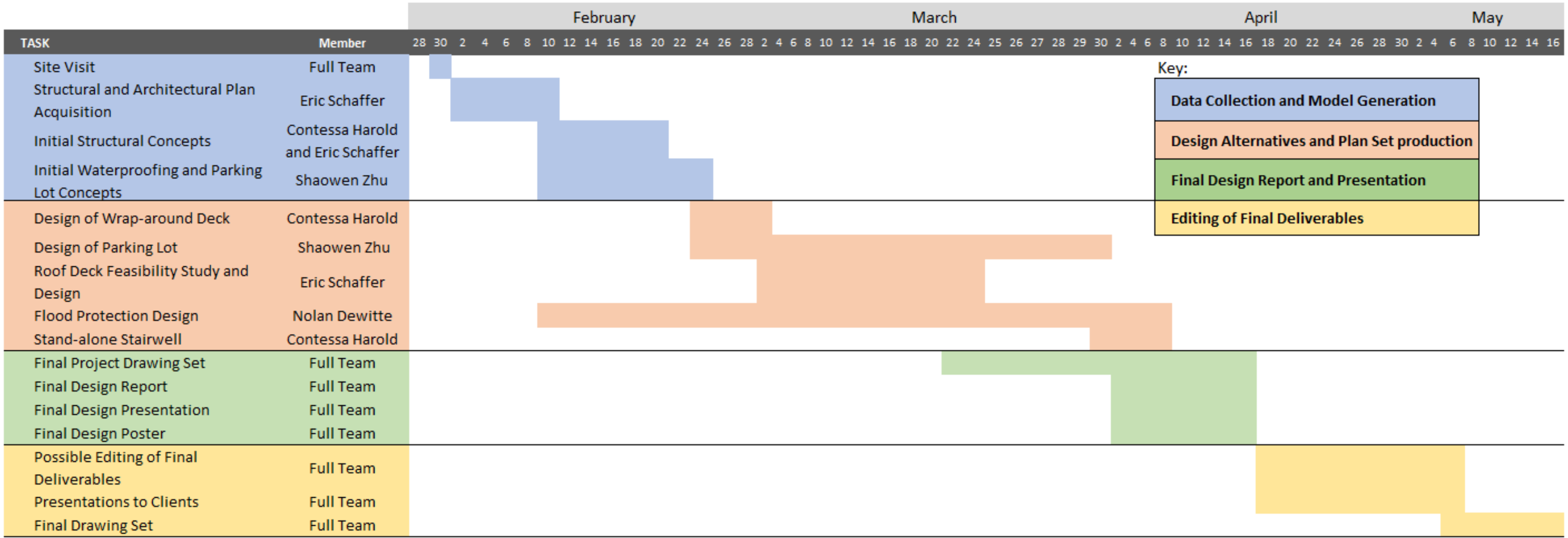

Figure 2. Gantt chart showing major project tasks and completion dates.

Section 4: Constraints, Challenges, and Impacts

1. Constraints

To allow for flexibility in funding, the client specified that the additions and renovations to the existing structure needed to be designed in discrete parts. This allowed the client to complete each addition separately without a dependency on other parts of the project. As such, the design team ensured one aspect of the project did not rely on another. The only exception to this was that the rooftop deck installation must be prefaced by reroofing. The Volga Opera House is a historic landmark in the town and region, so all designs were required to maintain the historic character of the building. This was completed by ensuring the materials used fit within the already established historic design of the building. The client's initial intent to have the building listed on the National Register of Historic Places (NRHP) quickly became untenable as the prime desires of the project, the addition of a wrap-around and rooftop deck, automatically disqualified the building from being placed on the NRHP. The design team along with the client decided that the future vision of the project was the prime focus of our work. The extent of flooding of the building was unknown at the start of the project. Further exploration of potential flood levels influenced the placement of sensitive utilities and assets in the building. The placement of these assets, namely the existing hot water heater and potential dumbwaiter locations, were constrained by the flood level. Additionally, the size of the back deck was constrained by the public alley to the east of the building.

2. Challenges

The age of the building provided considerable challenges for the design team. There was little to no documentation on the construction of the building. Since the opera house will primarily be used for a tourism generating space and community event center and the building is a historic landmark in Volga City, the future functionality of the building was incorporated into its aesthetics. This provided challenges in incorporating many of the additions the client requested. The design team worked to ensure that the designed additions and alterations complemented the existing interior and exterior of the opera house. The client voiced their preference for the incorporation of reused materials. Due to this, the team sought to incorporate commonly found materials into the design. The design team was also challenged with IBC 2015 fire egress requirements and ADA accessibility for both the wrap-around and rooftop decks. While developing plans and recommendations for the opera house, previously planned renovations were occurring. Close contact with the client ensured that designs reflected and complemented these ongoing renovations.

3. Impacts within the Community

The client's vision for the Volga Opera House extends far beyond this renovation project. VCTC, Inc is dedicated to rural community revival through restoration projects using Volga as a case study. The restoration of the opera house into a community and tourism generating space that can support a wide range of events is the first step in this project. The client hopes to provide not only an attraction for tourism from the broader Clayton County area, but also as a place to reintroduce quality arts and entertainment to a rural community that has long gone without it. In this capacity, VCTC, Inc hopes to promote population growth in Volga City, especially among the 18-25 age range. In recent decades, this age group has been moving away from rural communities in search of opportunities and centers of culture in larger cities. By bringing these opportunities back to places like Volga, VCTC, Inc hopes to revitalize rural economies by incentivizing these young, and often educated, individuals to bring their skills back to smaller communities. The revitalization of this historic opera house also provides residents of the city and the region with a vision of what is possible when time and care is put into these historic buildings. The design team used this project as an opportunity to present the client with a product that will reinvent the opera house and reestablish it as the region's culture and entertainment hub.

Section 5: Alternative Solutions

The overall project has four separate components. The design of each project component was influenced by the client's future goals, project constraints, and engineering judgement and design principles. The team created design drawings for the addition of a new parking lot, a wrap-around deck, a rooftop deck with accompanying roof alterations and stairwell, a dumbwaiter system to assist with the movement of food throughout the building, and a flood protection plan to alleviate damages to the building and its assets during a flooding event. With these various project components in mind, the team presented the client with several alternative solutions for each component.

Parking Lot

The parking lot design included two parts: the parking area and underground drainage system. The number of parking stalls was a requirement dictated by the IBC 2015 and the ADA. Angled parking stall design was explored but this restricted the number and space of the stalls. In ideal conditions, a 24' two-way drive through would provide access to the lot. However, the property lines did not allow for the parking lot to be extended to the north.

The various alternatives for the parking lot pavement included porous asphalt, pervious concrete, and permeable pavers. Porous asphalt paving is able to be done quickly and efficiently. However, in the long term it would be very expensive to maintain and repair due to the price of special mixing the asphalt to protect against the extreme weather conditions in Iowa. Pervious concrete pavement is known for being very durable. The key limitations of previous concrete were the cost required for mixing and the equipment needed for maintenance. These added costs made pervious concrete undesirable to the client. Additionally, both the concrete and asphalt pavement were not in line with the existing aesthetics of the building. All three alternatives have a design life of 10 to 20 years.

Porous asphalt and pervious concrete would both require a similar filter layer and storage bed drainage systems to handle additional water runoff from the pavement. The only difference would be the depth of these systems. These pavement types require up to 8" thickness because the porous structure lowers the strength of the materials. The mix and installation must be done correctly, or they will not function properly and can lead to surface wear and appearance deterioration which decreases the durability of the product. They both required a minimum batch size of 500 sq ft, which is easily met given the size of the lot. For construction, pervious concrete requires a seven-day cure and porous asphalt requires a 24-hour cure making them labor intensive options.

Permeable pavers, on the other hand, can be manufactured off-site in a factory and quickly laid down on site after the application of a simple tack coat. This makes the installation quick and easy, which will reduce costs. Furthermore, the spacing of the pavers allows for water to easily and efficiently drain into the underlying stormwater storage system.

After comparing the various alternatives, permeable pavers were decided to be the best design option. The bricks are highly customizable with different materials and colors allowing the client to match the parking lot to the aesthetic of the building or opt for a cheaper uncolored brick option for budget flexibility. For the final design, the team decided to use locally sourced ready-mix concrete bricks. Due to their superior stormwater drainage capabilities and adequate level of bearing strength, the permeable pavers were the alternative selected for final design.

Wrap-Around Deck

The wrap-around deck's main objectives are to provide outdoor seating and access to the backstage door. The client wanted the deck to tie into the existing ADA ramp to assist handicapped visitors with accessing the back of the building as well as providing an effective way of transporting large equipment to the back of the stage. All deck alternatives were designed to be large enough to cover the existing concrete slab. While larger and more intricate designs were discussed, it was decided that given the space and readiness of materials, the deck should be relatively simple. The road on the east side of the building constrained post placement, thus limiting the width of the deck. The client and team discussed moving the road to make room for a larger deck but concluded that it may not be worth the extra expense to the client and the city. Figure 3 shows a proposed design for the more expensive deck option, which included more surface area and the construction of the deck over the road. However, the clearance height of the deck over the road would lead to a restriction of emergency personnel and their vehicles.

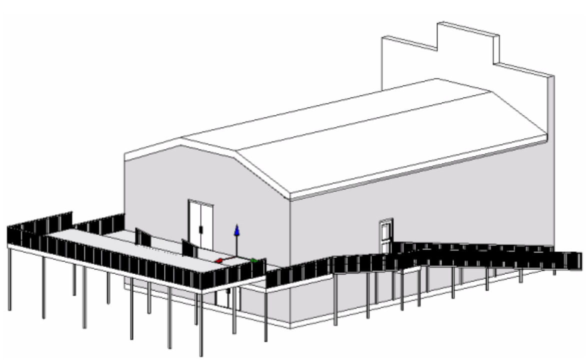

Figure 3. Concept model for wrap-around deck over road.

Given the limitations of the post locations and the preference for a spacious deck, it was decided that the design should feature a cantilevered edge. This design was also constrained due to little headspace available between the kitchen doors and backstage doors.

The final design as seen in Figure 4, was created by addressing space constraints, accommodating an ADA compliant ramp extension, and allowing access to the kitchen through the spacing of the deck posts, while also working to create the simplest and most efficient design for the client.

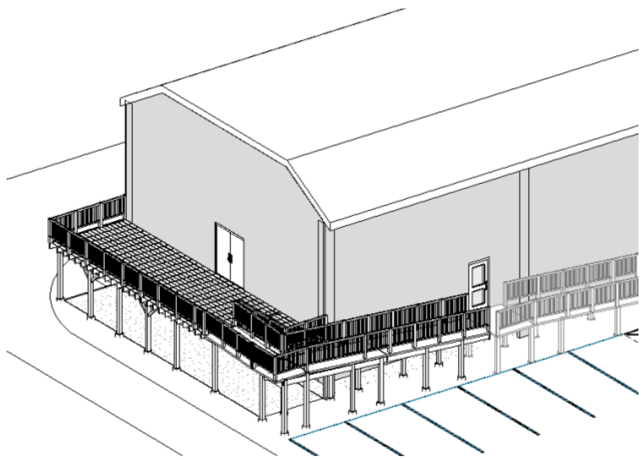

Figure 4. Final concept model for wrap-around deck.

Rooftop deck

Several deck locations and configurations were proposed to the client. The conceptual design of the rooftop deck was restricted by the lack of structural and architectural plans for the existing building. The public park to the south of the opera house and eastward green space will be used to host concerts and other events. With this in mind, the main objective of the rooftop was to allow for visitors to view the park from the deck and to provide an additional outdoor seating and standing area. The client also expressed a wish for the deck to be accessible from the balcony and have the ability to support 50 people. After research into the IBC 2015 occupation loads and associated number of required egresses, it was determined that having an occupant load of 50 would result in the need for two egresses. The cost and the space required to have two egresses made this undesirable. As such, attempts were made to maximize the occupant load without requiring two egresses. After consulting with the client, it was determined that there was an interest to restore the roof to the geometry and material type of that prior to the installation of the current steel roof. All rooftop deck alternatives were designed with this in mind. Figure 5 depicts the current roofing material and geometry.

Figure 5. Current steel roof.

Figure 6 depicts the first deck configuration discussed. The configuration allows the park to be seen from the deck while also allowing for the installation of stairs that would lead from the balcony to the new deck.

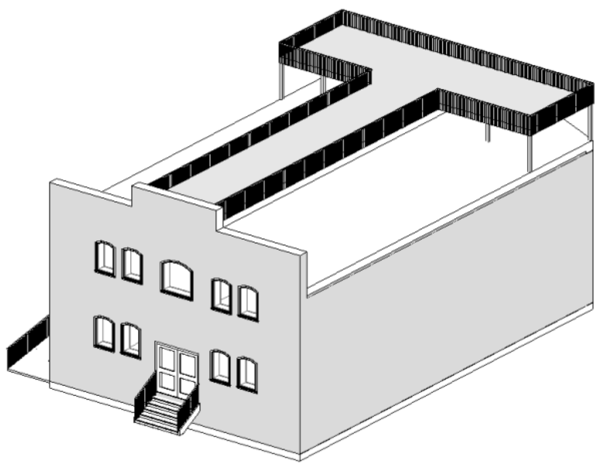

Figure 6. Concept model for the first rooftop deck alternative.

This configuration met both criteria from the client. However, the walkway from the balcony access stairs to the main deck would drastically increase the load on the supporting roof members. With limited knowledge of the existing roof structure, this configuration was not recommended.

There was an initial interest by the design team in completely redesigning the roof. The second alternative was to redesign the roof as entirely flat and have an area of the roof specifically designated to hold people as part of a built-in deck. This idea would be the most expensive option and did not seem feasible to the client, although it would give the client the option to select a completely new roof geometry.

The final alternative that was discussed with the client was to locate the rooftop deck only on the eastern most portion of the roof shown in Figure 7. This would allow for a view of the park and east green place and, due to an existing wooden truss and masonry wall, give a method to support the deck.

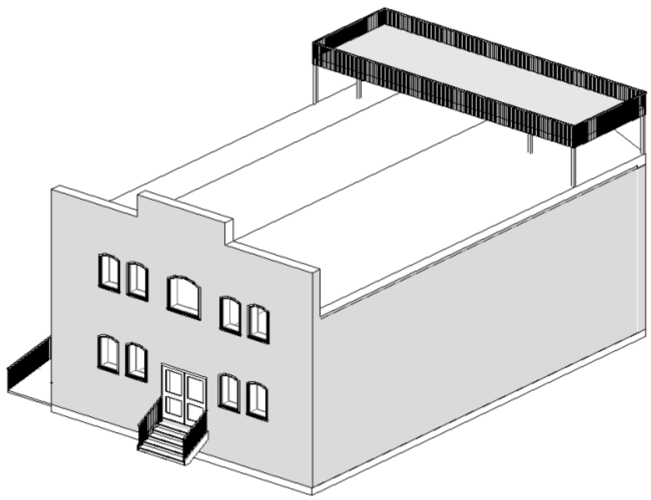

Figure 7. Concept model for rooftop deck alternative two.

This last alternative became the client's preferred option because it was more economically feasible then redesigning the whole roof to accommodate the new rooftop deck. This was also the preferred configuration structurally because the determination of the existing wooden truss's member sizes would lead to an accurate structural analysis.

Due to the location of this deck alternative, two possible egress stair locations were identified. These different locations can be seen in Figure 8. A freestanding, exterior staircase could be constructed on either the southern wall or the eastern wall. Locating the staircase adjacent to the southern wall would add a new structure to an otherwise visually unimpeded masonry wall. On the other hand, locating the staircase on the east wall would decrease the floor area and therefore the occupancy load of the wrap-around deck. To preserve the area of the wrap-around deck, the staircase location #1 was determined to be the most viable location for the rooftop deck's fire egress.

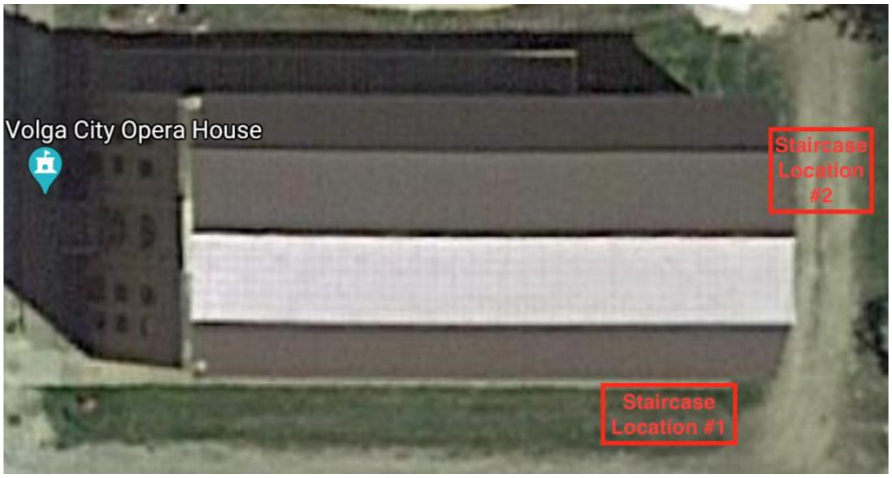

Figure 8. Concept locations for the rooftop egress stairs.

Food Delivery System

A main facet of the opera house renovation is the introduction of a food delivery system. The objective of this system is to provide an efficient way for the kitchen to deliver food to visitors on the main floor and balcony. Due to the limited space, the best option was to recommend a pair of dumbwaiters that would work to deliver the food vertically between the floors, however, the location of these dumbwaiters was variable. The first alternative was to renovate the kitchen floor to include a small protrusion for the dumbwaiter to be hidden away in. This is denoted by “Lower Dumbwaiter #1” in Figure 9. The location of the dumbwaiter keeps it out of the way of kitchen staff while also giving them easy access to it. Staff on the main floor will also find that the dumbwaiter location is very accessible to them. Another option was to place a dumbwaiter leading from the kitchen to the stage. This is denoted by “Lower Dumbwaiter #2” in Figure 9. Staff will be able to take food from the dumbwaiter and take the small stairs down from the stage to the main floor. With plans to also use the kitchen as the stage performer’s dressing room, this placement of the dumbwaiter could infringe on the area available to the stage performers when on stage or moving to the dressing room. This option seemed to be the least expensive of the two because it did not require any new floors and walls to be constructed.

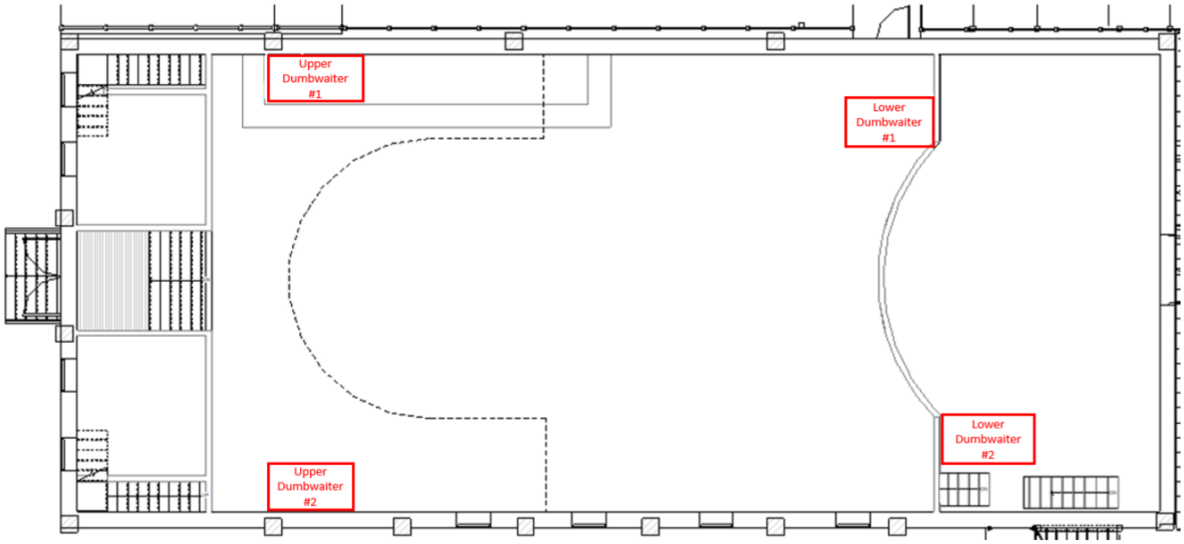

Figure 9. Alternative food delivery system locations.

The northwest and southwest corners of the main floor were the only two viable locations for the dumbwaiter that would service the main floor and the balcony. These locations can be seen in Figure 9 and are denoted by “Upper Dumbwaiter #1” and “Upper Dumbwaiter #2”. Although locating the dumbwaiter in the northwest corner of the building would allow the dumbwaiter to be easily accessible to bar staff on the balcony level, it would reduce the amount of space available to staff behind the main floor bar. The other plausible location in the southeast corner of the main floor would give the staff ample space but would cause it to be located far away from the main floor bar, the balcony bar and the most viable location for the lower level dumbwaiter.

It was determined that the lower dumbwaiter would be located on a newly constructed floor on the east side of the main floor (Lower Dumbwaiter #1). This was selected because it preserves the current usable surface area of the kitchen while also giving the main floor staff easy access to the food delivery system. The upper dumbwaiter was determined to be located in the northwest corner of the main floor (Upper Dumbwaiter #1). Although it may reduce the space behind the existing bar, it allowed for the possibility for the dumbwaiter to carry food directly from the main floor bar to the bar on the balcony level.

Flood Protection

Dry Floodproofing:

Dry floodproofing was explored as a flood protection solution early on in the project. This was the most attractive option to us as a design team initially because it meant completely protecting the space from any potential flood damage. The opera house lies in a zone A flood classification, meaning it lies within a 100-year flood plain, but data on the base flood elevation (BFE) is not available. Because of this, it was difficult to get an accurate measure of the base flood elevation of the building. Additionally, it quickly became apparent that dry floodproofing was a costly option, as the amount of entrances to the basement area meant a large number of flood protection barriers would be required. The high unit cost of these barriers quickly put this option outside the budget of the client. The team was also concerned about the hydrostatic forces that would accompany the dry floodproofing option. Protecting the historic nature of the structure was a top priority in the project, so any reinforcement of the walls to protect the structure from these hydrostatic forces would have to fit into the overall design of the building. These extra design elements would also further inflate the budget of the flood protection systems and introduce more construction elements to the project.

Wet Floodproofing:

Wet Floodproofing was also explored as an option to protect the project from flooding. Wet floodproofing is based on allowing water to enter the building in a controlled way in order to minimize damages. This option is less costly, but generally unsustainable long term. Wet floodproofing was also attractive to the team because it had the added benefit of protecting the building structure from damaging hydrostatic forces that are prevalent during a flooding event. These forces could be mitigated using vents designed to let water into the structure and would also keep pests out and conditioned air in. For the consideration of this option, the team explored various materials that would resist damage from water to flooring and wall siding. The exterior of the opera house consists of brick and concrete, two water-damage resistant materials. The kitchen area, which is inundated by about two feet of water during a flooding event as per Volga City residents' first-hand accounts, is constructed using compressed plywood, another water-damage resistant material. The existing materials within the opera house basement and kitchen area meant there would be minimal changes to these areas in a wet floodproofing scenario, further reducing the cost associated with floodproofing the opera house. The client's desire to implement more visible renovations to the opera house meant that money saved on the flood proofing element of the project made available more funds for the decks and parking lot. Additionally, because the spaces that would be inundated by water in a flooding event were spaces without many permanent elements and did not include significant assets, protecting these spaces from any water was less of a priority.

Combination of Wet and Dry Floodproofing:

Upon becoming apparent that a dry floodproofing option would be too costly to implement throughout the entire building, the team began exploration of a mixture of dry and wet floodproofing. This option was based around the fact that the kitchen area would be undergoing some significant renovations, so it would be economical to dry floodproof this area of the building. Wet floodproofing actions would then be taken in the basement area. The interior wall that separates the basement and the kitchen became our main concern in this scenario. Additional discussions with the client indicated that a two-pronged approach may be too complex at this stage, stating a preference for only one method to be implemented. Beyond this, ongoing renovations to the kitchen space were making use of vinyl material, meaning the additions the client was making to the space were conducive to a wet floodproofing option.

Section 6: Final Design Details

Permeable Parking Lot

The design size for the parking lot was 110'x 59' and is to be built in the lot north of the opera house. To maximize the number of parking lots for the given area, the final design used 90-degree angled parking stalls as shown in drawing C-1.There were 12 standard 9'x18' parking spaces and 8 accessible parking spaces with 5' wide access aisle to provide for the older population of Volga City. ADA requirements were consulted to design the 8 accessible parking stalls. To meet the minimum of 40 parking spots as required by the IBC 2015 for the max occupancy of the building, there will be several parking stalls provided on the street adjacent to the opera house. Based on a soil investigation, Volga City was found to have mostly silty loam and sandy loam soil. From the AASHTO guide for design of pavement structure, the twenty-year design thickness recommendation was 100 and the average daily truck traffic (ADTT) was equal to 1. The concrete compressive strength was calculated to be 4000 psi and flexural strength was calculated to be 580 psi. This calculation can be seen in Appendix D. The pavement thickness was determined to be 4 inches. The paved slope was assigned to be 2% and the drive through slope to be 6% from Iowa SUDAS Design Manual Chapter 5F.

The design of the drainage system was based on the Iowa DNR stormwater management manual. The system was designed to allow stormwater to drain through voids within the pavement into an underlying storage aggregate and underlying soil layer. This drainage system reduces stormwater runoff without the need for additional land acquisition. The drainage system consists of 2” of No. 8 bedding aggregate, 4” of No. 57 filter aggregates and 8” of No. 8 storage aggregate. A calculation based on the regional rainfall rate was conducted to determine these thicknesses and aggregate size, seen in Appendix D. The peak flow and minimum storage depth indicated the recommended depth of 8” was capable of handling the peak runoff volume for a storm event with rainfall larger than 2 inches in 24 hours.

The entrance and exit to the parking lot was designed with an inner turning radius of 11’. The curb ramp will be 4’ wide with a running slope of 6.25% and cross slope of 1.5%. The grade break will be 2’ wide, making it easier for disabled people to use the sidewalk.

Final cost estimations for the parking lot were composed of material price and excavations and backfill volumes. Material prices were determined based on the amount of bricks and aggregates needed for each layer, while excavation and backfill volumes were calculated based on loose and bank volume of the soil and efficiency of the equipment.

Wrap-Around Deck

The design of the wrap-around deck was constrained by the road east to the opera house and the preference for maintaining the ADA required maximum ramp slope of 1:12. The ramp was designed to comply with ADA 2010 standards, thus having 42” railings on both sides, and a minimum width of 3 feet. Designed at the maximum allowable slope, the ramp was not able to reach the stage elevation by the end of the width of the deck. Therefore, the team continued to keep the design relatively simple and make a 90° turn into the deck. A landing was created to make the change in direction easier and ADA compliant. This was deemed the best option because the ramp would be able to make use of the posts planned for the deck. The final ramp design was 5’ 0” wide, therefore the landing was required to be 5’x5’, which is also ADA compliant.

Design loads for the structure were determined using ASCE 7-10. Dead loads were based on specific weight and standard material weights. The live load value was 100 psf, the design snow load was 30 psf, and the lateral wind force and uplift force was 51 psf and 28 psf, respectively. Due to local availability and structural properties, all wood members are southern pine No. 2. Additionally, all wood members are to be pressure treated for ease of care and maintenance. The pressure treated wood helps to prevent future deterioration from rot or other forms of weathering. Using the NDS 2015 as a design guide, deck planks were determined to be 1x8 boards, joists are 2x10 at 16” O.C., beams are (2) 2x12 and the posts are 4x4. The west side of the deck is connected to the masonry wall with ½” bolts along with deck tension ties for lateral stability. For additional lateral stability transverse to the building, two interior posts were knee-braced with 4x4 members. The ramp addition is supported by 4x4 posts to mimic the design of the existing ramp. Supporting calculations for the ramp and deck can be found in Appendix E. Framing and dimensions can be seen on Design sheet A-2.

Rooftop Deck

The design of the rooftop deck was constrained by the lack of structural knowledge of the building and the IBC 2015 Chapter 10 egress requirements for assembly areas. Loading on the structure was determined using the ASCE 7-10 design loads for dead, live, snow, and wind loads. The various design load calculations can be seen in Appendix E and Appendix F. Similar to the design loads of the wrap-around deck, dead loads were determined using material weights and specific gravities, the design live load was 100 psf for assembly spaces and 20 psf for non-assembly spaces, the design snow load was 30 psf, and the design wind load was 54 psf in the lateral direction with 41 psf of uplift. Due to its abundance and weather resistant properties, all wood members will be pressure treated southern pine #2. Using the NDS 2015 as a design guide, deck planks were determined to be 1x8 boards, joists are 2x10 at 16” O.C., beams are (2) 2x12 and the posts are 6x6. It should be noted that the design of the posts was governed by the local bearing strength of the masonry wall. For lateral stability, 4x4 knee braces were added to the corner posts. Interior deck posts will bear on the existing truss above the stage. Assumptions were made about the members sizes of the truss and a structural analysis using *Ftool* was conducted to determine if the existing truss would be able to support the load from the deck. The analysis of the truss had shown that the top chord would be over stressed. An additional 2x10 will be added to the existing (3) 2x10 chord to allow the truss to support the deck. All other truss members were shown to be under capacity and thus they will not be replaced or altered. Supporting calculations for the rooftop deck design and truss analysis can be seen in Appendix F. The deck framing and dimensions can be seen on Design Sheet A-4 and the truss elevation can be seen on Design Sheet S-1.

This deck configuration also accommodates the opera house’s former roof geometry. As such, a new roof geometry and roofing materials are suggested to the client. The new roof configuration is meant to restore the roof to its original condition prior to the installation of the steel roof, and to provide a flat surface to build the future rooftop deck on top of. Aluminum shingles will be installed on the pitched portions of the roof and a protective, water resistant EDPM rubber membrane will be installed on the flat section. See Design Sheet A-4 for the roof cross-section detail. Roof resurfacing quantities are based on the square footage of the current roof.

Exterior Steel Staircase

The steel staircase was designed to service the rooftop deck and provide an IBC 2015 and IFC 2015 compliant fire egress. The main challenge when designing the egress stairs was the vertical distance the stairs would have to travel. Because of the unbraced column height, it was determined that the stairs would be constructed as a stand-alone steel structure. Design loads for live and wind loads were determined using ASCE 7-10, and AISC 360-10 was followed as the design guide. The design live load was determined to be 100 psf and the average wind pressure was 28 psf. Dead loads were determined using the weight of each steel member provided by AISC. The stairs and platforms are to be made of Niles International ½" 18 gage grated carbon steel panels. Due to the IBC 2015 size requirements for stair treads and risers, the stair stringers were constrained to be C15x40. To create an easier connection, the same shape was repeated at the top of each stairs. To save on the cost of several unnecessary columns, the turning platforms will be cantilever off the primary columns. A HSS4x2x1/8 was found to be the most appropriate size of the cantilevered members due to the torsion and moment experienced by the design loads. A moment frame lateral system is used to resist lateral forces. The lateral forces experienced by the tall structure governed the design of the columns. HSS5x5x5/16 was found to be the appropriate size for the columns. To increase the corrosion and rust resisting properties of the staircase, all steel will be galvanized. The gravity and lateral design of the staircase as well as the frame deflection check can be seen in Appendix G. A stair section and stair details can be seen on Design Sheet S-2 while stair framing and dimensions can be seen on Design Sheets A-1 through A-4.

Food Delivery System

Locating the dumbwaiters on the northeast and northwest corners of the main floor allows the staff to keep the management of food and beverages all on one side of the building. This allows the staff to easily move food around while also not impeding the viewing and movement of visitors. It was decided that the dumbwaiter would be designed by a proprietary dumbwaiter company. Powerlift Dumbwaiter Corporation provides multiple dumbwaiter variations that would satisfy the client's needs. It is recommended that the powerlift 100 is used for both food delivery dumbwaiters. Due to the potential of flooding in the region, the dumbwaiters will have the motors mounted on top of the car. This keeps the electronic components safe from potential flood waters. To accommodate the new dumbwaiters, small interior alterations must be conducted on the kitchen, main floor, and balcony levels. These alterations include creating openings in both the balcony floors and main floor to allow the dumbwaiters to pass through them and new flooring in the kitchen to support the lower dumbwaiter. These alterations will have a negligible impact on the structural performance of the floor. The dumbwaiter locations in plan view can be seen on Design Sheet A-1 through A-3 and the dumbwaiter architectural detail can be seen on Design Sheet A-1.

Flood Protection

With the client's considerations in mind, wet floodproofing was chosen as the final design alternative. Because this method relies on water entering the structure in a controlled way, design decisions were limited to material selection that allowed for the entry and exit of water into and out of the building as well as water resilient floor and wall materials.

The team first explored flood-damage resistant materials for the walls and floor of each room. Table 7-1 in FEMA P-132 was consulted for this element of the flood proofing plan. Specifically, the team explored different options for structural and finish wall materials. The team recommended construction of a new wall on the east side of the basement in front of the existing kitchen structure to provide a more cohesive space. This wall will be constructed entirely of flood-damage resistant materials derived from Table 7-1. The new wall will consist of structural 2x4s at 16" O.C., insulated with a water-resistant foam board, with a ⅝" gypsum board underneath vinyl wall tile sheets. During design, the kitchen underwent previously planned renovations including the addition of vinyl flooring. This material is consistent with the design team's recommendations and will complement the vinyl finish to be installed onto the compressed plywood walls in the kitchen which are also water-damage resistant materials. Details and locations of this new wall can be found on Design sheet A-1 and A-6.

Next was the consideration of allowing water to cleanly flow in and out of the building during a flooding event. FEMA P-132 and FEMA 551 were used to identify flood openings that could service spaces below grade. There are many commercially available flood openings on the market. The flood openings used in design were selected based on the criteria of being insulated, minimalistically designed as to not draw attention from the aesthetic of the structure and would provide adequate flood coverage for the basement and kitchen areas. The design team identified three equivalent products: the Smart Vent 1540-520, the FFV-1608-W, and the ICC breakaway flood vent. Calculations to determine the number of flood vents can be seen in Appendix C. The team determined that a minimum of 25 flood vents would be required. At least two different walls for each room must have a flood vent as a contingency. Flood vents were designed to be placed on the north, south, and west walls for the basement and the north, south, and east walls for the kitchen. An additional flood vent will be required in each room, one in the newly constructed east basement wall, and one in the existing west wall of the kitchen. These additional flood vents will ensure equal water levels between the two rooms to eliminate hydrostatic pressures on the interior walls. Exact locations for the flood vents can be seen on Design Sheet A-1.

Other concerns for the team were the five interior columns in the basement. Because flooding events may last multiple days, the design team has recommended three equivalent roll or spray on water resistant membranes to keep the interior columns as protected as possible. Either the MAPEI Mapelastic Aquadefense, Laticrete Hydro Ban, or Radonseal products recommended will be applied to manufacturer specifications. Additionally, the hot water heater will be relocated to a newly revealed recessed area in the kitchen where an existing cubby space is to be demolished. The hot water heater will be protected using a utility cover. The team recommends a Cobia Hot Water Heater Cover to keep floodwaters from damaging the unit. Exact locations and application instructions can be found on Design Sheet A-1 and A-6.

Section 7: Engineer’s Cost Estimate

Each component of the project has an individual cost estimate to provide options for implementation to the client. The various component cost estimations can be seen in Appendix B. Table 1 gives an overall cost if the client was to pursue all projects contained within this report.

Table 1. Total Proposed Cost Estimation

Project		Project Cost
Roof Replacement, Roof Top Deck, and Truss Alterations	$	15,900.00
Permeable Parking Lot	$	81,500.00
Food Delivery System and Associated Costs	$	8,500.00
ADA Ramp and Wrap-Around Deck	$	9,850.00
Flood Protection and Waterproofing	$	13,700.00
Exterior Steel Staircase	$	13,700.00
Total Cost	$	129,450.00
Engineering and Administration (20%)	$	25,890.00
Contigencies (10%)	$	12,945.00
Mobilization (5%)	$	6,475.00
Contract Price	$	174,760.00

Appendix A: References and Standards

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Appendix B: Component Cost Estimations

Table B1. Cost estimation for the permeable parking lot.

ITEM	Quantity	Unit	Unit Price	TOTAL
Concrete brick(6"x12"x4")	5720	SF	$ 3.00	$ 17,200.00
No.8 Aggregate(1/2in top size)	177	CY	$ 37.00	$ 6,600.00
No.57 Aggregate(1-1/2in top size)	71	CY	$ 37.00	$ 2,600.00
Excavation 16"deep/2-1/2 CY excavtor	8580	BCY	$ 3.55	$ 30,500.00
Dozer general fill	10725	LCY	$ 2.29	$ 24,600.00
Total Cost				$ 81,500.00
Engineering and Administration (%)			20	$ 16,300.00
Contigencies (%)			10	$ 8,150.00
Mobilization (%)			5	$ 4,100.00
Contract Price				$ 110,000.00

Table B2. Cost estimation for roof replacement, rooftop deck and alterations to existing truss.

ITEM	Quantity	Unit	Unit Price	TOTAL
Rubber Membrane (EPDM 45 mil)	2583	SF	$ 2.31	$ 6,000.00
Aluminum Shingles, mill finish, 0.20" thick	1476	SF	$ 2.60	$ 3,850.00
Deck Planks (1X8)*	4386	LF	$ 0.94	$ 4,125.00
Deck Joists (2X10)*	88	LF	$ 3.90	$ 345.00
Deck Beams ([2] 2X12)*	212	LF	$ 5.36	$ 1,150.00
Posts (6X6)*	50	LF	$ 6.82	$ 345.00
Knee Braces (4X4)*	26	LF	$ 3.26	$ 85.00
Total Cost				$ 15,900.00
Engineering and Administration (%)			20	$ 4,200.00
Contigencies (%)			10	$ 1,600.00
Mobilization (%)			5	$ 795.00
Contract Price				$ 21,500.00

*Prices are based on pressure treated wood.

Table B3. Cost estimation for food delivery systems and associated alterations.

ITEM	Quantity	Unit	Unit Price	TOTAL
Dumbwaiter	2	Unit	$ 3,895.00	$ 7,800.00
Kitchen Wall Alterations	72.26	SF	$ 7.54	$ 545.00
Flooring Alterations	19.25	SF	$ 4.09	$ 79.00
Total Cost				$ 8,500.00
Engineering and Administration (%)			20	$ 1,700.00
Contigencies (%)			10	$ 850.00
Mobilization (%)			5	$ 425.00
Contract Price				$ 11,500.00

Table B4. Cost estimation for exterior steel staircase.

ITEM	Quantity	Unit	Unit Price	TOTAL
HSS Tubes	128	LF	$ 43.65	$ 5,600.00
Stringers	108	LF	$ 26.93	$ 2,900.00
Stair Beam	132	LF	$ 23.20	$ 3,000.00
Steel Platform	202.5	SF	$ 10.60	$ 2,100.00
Foundations	1.4	CY	$ 52.10	$ 73.00
Excavation	1.4	BCY	$ 3.55	$ 4.97
Dozer general fill	1.75	LCY	$ 2.29	$ 4.01
Total Cost				$ 13,700.00
Engineering and Administration (%)			20	$ 1,700.00
Contigencies (%)			10	$ 850.00
Mobilization (%)			5	$ 425.00
Contract Price				$ 16,700.00

Table B5. Cost estimation for flood protection and waterproofing.

ITEM	Quantity	Unit	Unit Price	TOTAL
Flood Vent	25		$ 200.00	$ 5,000.00
Vinyl Siding	847.25	SF	$ 0.46	$ 390.00
WaterProofing Membrane	2	Gal	$ 54.48	$ 110.00
Utility Cover	1		$ 150.00	$ 150.00
Wood Studs (2x4)	373.33	LF	$ 2.75	$ 1,025.00
Insulation (Foam Board)	450	SF	$ 0.91	$ 400.00
Drywall (5/8"Gypsum Board)	450	SF	$ 0.34	$ 155.00
Total Cost				$ 13,700.00
Engineering and Administration (%)			20	$ 1,700.00
Contigencies (%)			10	$ 850.00
Mobilization (%)			5	$ 425.00
Contract Price				$ 16,700.00

Table B6. Cost estimation for ADA ramp addition and wrap-around deck.

ITEM	Quantity	Unit	Unit Price	TOTAL
Deck Planks (1X8)*	1250	LF	$ 0.94	$ 1,180.00
Deck Joists (2X10)*	497	LF	$ 3.90	$ 1,940.00
Deck Beams ([2] 2X12)*	100	LF	$ 5.36	$ 540.00
Posts (4X4)*	126	LF	$ 3.26	$ 410.00
Knee Braces (4X4)*	12	LF	$ 3.26	$ 40.00
1' Diameter Foundations	3.59	CY	$ 52.10	$ 188.00
Excavation	3.59	BCY	$ 3.55	$ 12.75
Dozer general fill	4.49	LCY	$ 2.29	$ 10.25
Total Cost				$ 9,850.00
Engineering and Administration (%)			20	$ 1,950.00
Contigencies (%)			10	$ 1,000.00
Mobilization (%)			5	$ 495.00
Contract Price				$ 13,300.00

*Prices are based on pressure treated wood.

Appendix C: Flood Protection and Waterproofing

Appendix D: Permeable Parking Lot Design

Appendix E: Wrap-Around Deck and Associated Calculations

Appendix F: Rooftop Deck and Existing Truss Analysis

Appendix G: Staircase Analysis and Design

Appendix C

Flood Protection and Waterproofing

Resultant Lateral Force due to Hydrostatic Pressure from Freestanding water and Saturated Water:

$$\gamma_w := 62.4\ \mathbf{pcf}$$

$$F_h := \frac{1}{2}\left(\gamma_w\right)\cdot\left(4\ \mathbf{ft}\right)^2 = 499.2\ \mathbf{plf}$$

$$F_{sat} := \frac{1}{2}\cdot\left(0.13\ \mathbf{pcf}\right)\cdot\left(8\ \mathbf{ft}\right)^2 + F_h = 503.36\ \mathbf{plf}$$

Determine Number of Flood Vents

Area of Basement: $A_{basement} := 3440\ \mathbf{ft}^2$

Area of Kitchen: $A_{kitchen} := 860\ \mathbf{ft}^2$

Area served by flood vent: $A_{vent} := 200\ \mathbf{ft}^2$

$$nVentsBasement := \frac{A_{basement}}{A_{vent}} = 17.2$$

About 18 Flood Vents

$$nVentsKitchen := \frac{A_{kitchen}}{A_{vent}} = 4.3$$

About 5 Food Vents

Appendix D

Permeable Parking Lot Design

Assumptions

The rainfall rate is the same as the Iowa Average.

The parking lots are use for regular size passenger car.

The concrete provide by the company have enough strength.

The people in the building are 300-400.

Soil test form lab will be conducted and have the same result as USDA.

$Area := 110\ \boldsymbol{ft} \cdot 59\ \boldsymbol{ft} = \left(6.49 \cdot 10^{3}\right)\ \boldsymbol{ft}^{2}$

Single parking area

$9\ \boldsymbol{ft} \cdot 18\ \boldsymbol{ft} = 162\ \boldsymbol{ft}^{2}$

ADA parking area

$\left(5\ \boldsymbol{ft} + 9\ \boldsymbol{ft}\right) \cdot 18\ \boldsymbol{ft} = 252\ \boldsymbol{ft}^{2}$

Total parking area

$12 \cdot 162\ \boldsymbol{ft}^{2} + 8 \cdot 252\ \boldsymbol{ft}^{2} = \left(3.96 \cdot 10^{3}\right)\ \boldsymbol{ft}^{2}$

Drainage part

$I := 100\%$

$Rv := 0.05 + 0.009 \cdot 100 = 0.95$

$WQv := 1.25 \cdot Rv = 1.188$

P=1.25in/24 hours

$$CN := \frac{1000}{\left(\left(10 + 5 \cdot 1.25 + 10 \cdot WQv\right) - \left(10 \cdot WQv^{2} + 1.25 \cdot WQv \cdot 1.25\right)\right)} = 82.183$$

Tc=1.5hrs

qu=500csm/in

$Ia := 0.041$

$PeakQ := 500 \cdot 6.49 \cdot 10^{3} \cdot 3.587 \cdot 10^{-8} \cdot 1.188 = 0.138$

$minPArea := PeakQ \cdot 3600 \cdot \frac{12}{10} = 597.374$

$minStorage := 1.188 \cdot \frac{1}{12} \cdot 6490 \cdot \frac{1}{minPArea} \cdot 0.35 = 0.376$

$dp := 4\ in$
$db := 2\ in$
$df := 4\ in$
$ds := 8\ in$

Total depth

$d := dp + db + df + ds = 1.5\ ft$

Volume of soil: $V := d \cdot Area = \left(9.735 \cdot 10^{3}\right)\ ft^{3}$

Compressive strength: $f'c := 4000$ psi

Flexural strength: $MR := 2.3\ f'c^{\frac{2}{3}} = 579.564$ psi

Appendix E

Wrap-Around Deck and Associated Calculations

Design Standards and Codes:
- ASCE 7-10
- NDS 2015

ASCE Ch 4: Live Loads

Design Live Loads:

Assembly: $q_{la} := 100\ psf$

Roof Live Load: $q_{lr} := 20\ psf$

ASCE Ch 7: Snow Load

Design Snow Loads:

Balanced Snow Load:

Importance Factor: $I_s := 1.0$

Ground Snow Load: $p_g := 30\ psf$

Exposure Factor (C, Fully Exposed): $C_e := 0.9$

Thermal Factor: $C_t := 1.0$

Flat Roof Snow Load: $p_f := 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot p_g = 18.9\ psf$

$p_f := \max\left(I_s \cdot p_g, p_f\right) = 30\ psf$

ASCE Ch 26: Wind Loads

Design Wind Loads:

The proposed structure is an enclosed simple diaphragm building. Therefore the simplified method can be used.

Risk Category(II):	$I_w := 1.0$
Wind Speed:	$V := 115\ \mathbf{mph}$
Exposure Category:	C
Enclosure Class:	Open
Mean Roof Height:	$h_{mean} := 32\ \mathbf{ft}$
Vertical projected area:	$A_f := 10\ \mathbf{in} \cdot 43\ \mathbf{ft}$
Horizontal projected area:	$A_r := 10\ \mathbf{ft} \cdot 43\ \mathbf{ft}$
Building Width:	$B := 43\ \mathbf{ft}$
Building length:	$L := 100\ \mathbf{ft}$

Coefficients:

Topographic Wind Speed-up:	$K_{zt} := 1.0$
Wind Directionality Factor:	$K_d := 0.85$
Velocity Pressure Factor:	$K_h := 0.98$

Wind Velocity Pressure: $$q_h := \frac{0.00256\ \mathbf{psf}}{(\mathbf{mph})^2} \cdot K_h \cdot K_{zt} \cdot K_d \cdot V^2 = 28.202\ \mathbf{psf}$$

Wrap-Around Deck

Wind Effect on deck

Risk Category(II):	$I_w := 1.0$
Wind Speed:	$V := 115\ \mathbf{mph}$
Exposure Category:	C
Topographic Wind Speed-up:	$K_{zt} := 1.0$
Enclosure Class:	Open

Coefficients:

Topographic Wind Speed-up: $K_{zt} := 1.0$

Wind Directionality Factor: $K_d := 0.85$

Velocity Pressure Factor: $K_z := 0.98$

Gust Effect Factor: $G := 0.85$

Force Coefficient: $C_f := 1.3$ Figure 29.5-1

Wind Velocity Pressure: $q_z := \frac{0.00256\ \mathbf{psf}}{(\mathbf{mph})^2} \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2 = 28.202\ \mathbf{psf}$

Longitudinal Wind: $A_f = 41.667\ \mathbf{ft}^2$ $B = 43\ \mathbf{ft}$ $L = 12\ \mathbf{ft}$ $h_{mean} = 8.833\ \mathbf{ft}$

$0.15\ B \cdot h_{mean} = 56.975\ \mathbf{ft}^2$

$GC_{r1} := 1.85$

$GC_{r2} := 1.0$

Lateral wind force: $q_{wlonglateral} := q_z \cdot (GC_{r1}) = 52.174\ \mathbf{psf}$

Uplift force: $q_{wlonguplift} := q_z \cdot (GC_{r2}) = 28.202\ \mathbf{psf}$

Transverse Wind:

$GC_{r1} := 1.85$

$GC_{r2} := 1.0$

Lateral wind force: $q_{wtranslateral} := q_z \cdot (GC_{r1}) = 52.174\ \mathbf{psf}$

Uplift force: $q_{wtransuplift} := q_z \cdot (GC_{r2}) = 28.202\ \mathbf{psf}$

Deck planks:

Plank span: $s := 16\ in$

Tributary Width: $w_t := 7.25\ in$

Loading:

Dead:

$w_{dplanks} := w_{planks} = 1.296\ plf$

Live:

$w_{lplanks} := q_l \cdot w_t = 60.417\ plf$

1. Load Combination: 1.0D +1.0L

$$w_{uplanks1} := 1.0 \cdot w_{dplanks} + 1.0 \cdot w_{lplanks} = 61.7\ plf$$

$$V_{uplanks1} := \frac{1}{2}\ w_{uplanks1} \cdot s = 41.1\ lbf$$

$$M_{uplanks1} := \frac{w_{uplanks1} \cdot s^2}{8} = 13.7\ lbf \cdot ft$$

Bending Check:

Bending Demand:

$$M_{uplanks1} = 13.7\ lbf \cdot ft$$

$$f_b := \frac{M_{uplanks1}}{S_{y1x8}} = 242.011\ psi$$

Bending Capacity: $F_b := 1100\ psi$

$C_D := 1.0$ $C_M := 1.0$ $C_L := 1.0$ $C_{fu} := 1.15$ $C_i := 1.0$

$C_t := 1.0$ $C_r := 1.15$ $C_F := 1.3$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1891.2\ psi$$

Utility:

$$u := \frac{f_b}{F_b'} = 0.128$$

Shear Check:

Shear Demand:

$$V_{uplanks1} = 41.1 \ \mathbf{lbf}$$

$$f_v := \frac{3 \cdot V_{uplanks1}}{2 \cdot A_{1x8}} = 11.348 \ \mathbf{psi}$$

Shear Capacity: $F_v := 175 \ \mathbf{psi}$

$$C_D := 1.0 \qquad C_M := 1.0 \qquad C_t := 1.0 \qquad C_i := 1.0$$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175 \ \mathbf{psi}$$

Utility:

$$u := \frac{f_v}{F_v'} = 0.065$$

Deck Joists:

Joist span: $l_{joists} := 10 \ \mathbf{ft}$

Joist spacing: $s := 16 \ \mathbf{in}$

Loading:

Dead:

$$w_{self} := w_{joists} = 3.308 \ \mathbf{plf}$$

$$w_{djoists} := w_{self} + s \cdot q_{planks} = 7.078 \ \mathbf{plf}$$

Live:

$$w_{ljoists} := q_l \cdot s = 133.333 \ \mathbf{plf}$$

1. Load Combination: 1.0D +1.0L

$$w_{ujoists1} := 1.0 \cdot w_{djoists} + 1.0 \cdot w_{ljoists} = 140.4 \ \mathbf{plf}$$

Cantilever Joists

Joist span: $l_{joists2} := 12 \ \mathbf{ft} - 3 \ \mathbf{in} - 5.5 \ \mathbf{in} - 10 \ \mathbf{ft} = 15.5 \ \mathbf{in}$

Joist spacing: $s := 16 \ \mathbf{in}$

Loading:

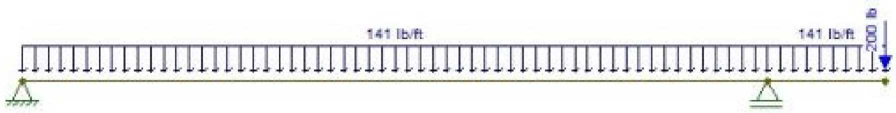
Dead:

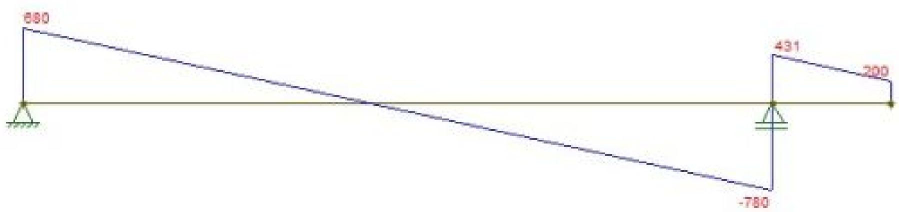
$w_{self} := w_{joists} = 3.308$ $\boldsymbol{plf}$

$w_{djoists} := w_{self} + s \cdot q_{planks} = 7.078$ $\boldsymbol{plf}$

Live:

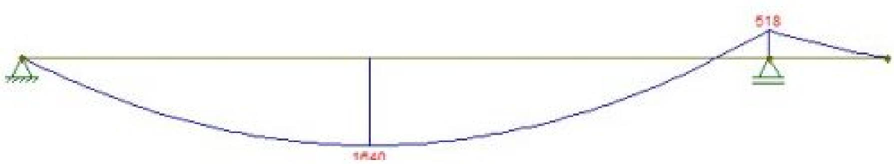
$w_{ljoists} := q_l \cdot s = 133.333$ $\boldsymbol{plf}$





lbf

$V_{ujoists1} := 780$ $\boldsymbol{lbf}$



$lbf \cdot ft$

$M_{ujoists1} := 1640$ $\boldsymbol{ft \cdot lbf}$

Joist Properties:

Deck Joist: 2x10

$A_{2x10} = 13.88$ $\boldsymbol{in}^2$ $\quad S_{x2x10} := 21.39$ $\boldsymbol{in}^3$ $\quad I_{x2x10} := 98.93$ $\boldsymbol{in}^4$

1. Load Combination: 1.0D + 1.0Lr

<u>Bending Check:</u>

Bending Demand:

$M_{ujoists1} = \left(1.6 \cdot 10^3\right)$ $\boldsymbol{lbf \cdot ft}$

$$f_b := \frac{M_{ujoists1}}{S_{x2x10}} = 920.056 \text{ } \boldsymbol{psi}$$

Bending Capacity: $F_b := 800\ psi$

$C_D := 1.0 \quad C_M := 1.0 \quad C_L := 1.0 \quad C_{fu} := 1.0 \quad C_i := 1.0$

$C_t := 1.0 \quad C_r := 1.15 \quad C_F := 1.1$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1012\ psi$$

Utility:

$$u := \frac{f_b}{F_b'} = 0.909$$

Shear Check:

Shear Demand:

$$V_{ujoists1} = 780\ lbf$$

$$f_v := \frac{3 \cdot V_{ujoists1}}{2 \cdot A_{2x10}} = 84.294\ psi$$

Shear Capacity: $F_v := 175\ psi$

$C_D := 1.0 \quad C_M := 1.0 \quad C_t := 1.0 \quad C_i := 1.0$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ psi$$

Utility:

$$u := \frac{f_v}{F_v'} = 0.482$$

Uplift Check:

3. Load Combination: 0.6D + 0.6W

$$q_{wlonguplift} = 28.202\ psf$$

$$s := 16\ in$$

$$w_w := s \cdot q_{wlonguplift} = 37.603\ plf$$

$$w_d := w_{djoists} = 7.078\ plf$$

$$w_{uuplift} := 0.6 \cdot w_d - 0.6 \cdot w_w = -18.315\ plf$$

Deflection Check:

Determine E': $E := 1.4 \cdot 10^6$ ***psi*** $I_{x2x10} = 98.93$ ***in***^{4}

$C_M := 1.0$ $C_t := 1.0$ $C_i := 1.0$ $C_T := 1.0$

$$E' := E \cdot C_M \cdot C_t \cdot C_i \cdot C_T = \left(1.4 \cdot 10^6\right) \textbf{ psi}$$

Short term deflection:

$$w_{ST} := 0.5 \cdot w_{ljoists} = 66.667 \textbf{ plf}$$

$$\delta_{ST} := \frac{5 \cdot w_{ST} \cdot l_{joists}^{\ 4}}{384 \cdot E' \cdot I_{x2x10}} = 0.108 \textbf{ in}$$ $l_{joists} = 10$ ***ft***

$$\Delta_{ST} := \frac{l_{joists}}{} = 0.333 \textbf{ in}$$

$$\delta_{ST} \le \Delta_{ST} = 1$$

Long term deflection:

$$w_{LT} := 0.5 \cdot w_{ljoists} + w_{djoists} = 73.745 \textbf{ plf}$$

$$\delta_{LT} := \frac{5 \cdot w_{LT} \cdot l_{joists}^{\ 4}}{384 \cdot E' \cdot I_{x2x10}} = 0.12 \textbf{ in}$$

$$\delta_{Total} := 1.5 \cdot \delta_{LT} + \delta_{ST} = 0.288 \textbf{ in}$$

$$\delta_{Total} \le \Delta_{Total} = 1$$

Deck Beams:

Beam span: $l_{beams} := 9$ ***ft***

Beam spacing: $s := 7$ ***ft*** tributary width

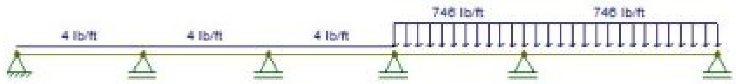
Live:

$$w_{lbeams} := q_l \cdot s = 700 \textbf{ plf}$$

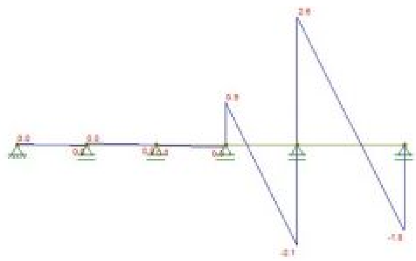
1. Load Combination: 1.0D +1.0L

Full Live and Dead:

$$w_{ubeams1} := 1.0 \cdot w_{dbeams} + 1.0 \cdot w_{lbeams} = 745.2 \textbf{ plf}$$

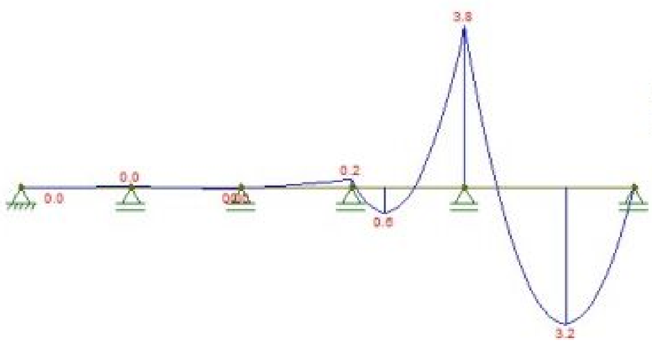


worst case scenario



$V_{neg} := 2.1\ \mathbf{kip}$

$V_{pos} := 2.6\ \mathbf{kip}$



$M_{pos} := 3.8\ \mathbf{kip \cdot ft}$
$M_{neg} := 3.2\ \mathbf{kip \cdot ft}$

$V_{ubeams1} := \max\left(V_{pos}, V_{neg}\right) = 2.6\ \mathbf{kip}$
$M_{ubeams1} := \max\left(M_{pos}, M_{neg}\right) = 3.8\ \mathbf{kip \cdot ft}$

Load Combination 2: 0.6D + 0.6W

$w_{dbeams2} := 0.6 \cdot w_{dbeams} = 27.123\ \mathbf{plf}$

$w_{trib} := 7\ \mathbf{ft}$

$w_{wbeams2} := w_{trib} \cdot q_{wlonguplift} = 197.414\ \mathbf{plf}$

$w_{ubeams2} := 0.6 \cdot w_{dbeams2} - 0.6 \cdot w_{wbeams2} = -102.175\ \mathbf{plf}$

Beam Properties:

Deck Beam: (2) 2x12

$A_{2x12} = 16.875\ \mathbf{in}^2 \quad S_{x2x12} := 31.64\ \mathbf{in}^3 \quad I_{x2x12} := 178.0\ \mathbf{in}^4$

1. Load Combination: 1.0D + 1.0Lr

Bending Check:

Bending Demand:

$$M_{ubeams1} = 3.8\ \boldsymbol{kip \cdot ft}$$

$$f_b := \frac{M_{ubeams1}}{2 \cdot S_{x2x12}} = 720.607\ \boldsymbol{psi}$$

Bending Capacity: $F_b := 750\ \boldsymbol{psi}$

$C_D := 1.0$ $C_M := 1.0$ $C_L := 1.0$ $C_{fu} := 1.0$

$C_t := 1.0$ $C_r := 1.0$ $C_F := 1.0$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 750\ \boldsymbol{psi}$$

Utility:

$$u := \frac{f_b}{F_b'} = 0.961$$

Shear Check:

Shear Demand:

$$V_{ubeams1} = \left(2.6 \cdot 10^3\right)\ \boldsymbol{lbf}$$

$$f_v := \frac{3 \cdot V_{ubeams1}}{2 \cdot \left(2 \cdot A_{2x12}\right)} = 115.556\ \boldsymbol{psi}$$

Shear Capacity: $F_v := 175\ \boldsymbol{psi}$

$C_D := 1.0$ $C_M := 1.0$ $C_t := 1.0$ $C_i := 1.0$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ \boldsymbol{psi}$$

Utility:

$$u := \frac{f_v}{F_v'} = 0.66$$

Bearing Check:

Bearing Demand:

$$V_{ubeams1} = \left(2.6 \cdot 10^3\right)\ \boldsymbol{lbf}$$

Bearing area:

$$f_b := \frac{V_{ubeams1}}{A_{4x4}} = 212.245 \ \boldsymbol{psi}$$

Bearing Capacity: $F_{cp} := 625 \ \boldsymbol{psi}$

$C_M := 1.0 \qquad C_t := 1.0 \qquad C_i := 1.0$

Utility:

$$u := \frac{f_b}{F_{cp}'} = 0.34$$

<u>Deflection Check:</u>

Determine E': $E := 1.4 \cdot 10^6 \ \boldsymbol{psi}$

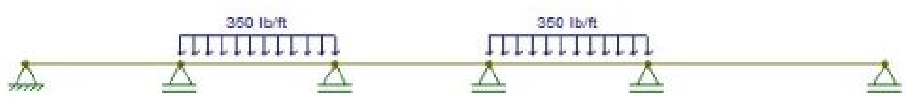
$C_M := 1.0 \qquad C_t := 1.0 \qquad C_i := 1.0 \qquad C_T := 1.0$

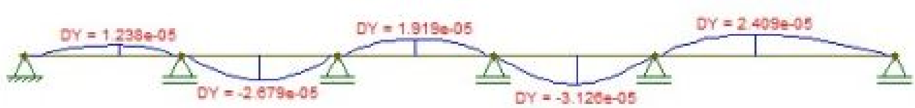
$$E' := E \cdot C_M \cdot C_t \cdot C_i \cdot C_T = \left(1.4 \cdot 10^6\right) \ \boldsymbol{psi}$$

Fully Loaded Beam:

Short term deflection:

$$w_{ST} := 0.5 \cdot w_{lbeams} = 350 \ \boldsymbol{plf}$$





$$\delta_{LT} := 0.000124 \ \boldsymbol{in}$$

$$\delta_{Total} := 1.5 \cdot \delta_{LT} + \delta_{ST} = \left(2.79 \cdot 10^{-4}\right) \ \boldsymbol{in}$$

$$\Delta_{Total} := \frac{l_{beams}}{240} = 0.45 \ \boldsymbol{in}$$

$$\delta_{Total} \le \Delta_{Total} = 1$$

Deck Beam Supporting Ramp:

Beam Loading:

$w_{djoists} := w_{djoists} \cdot w_t = 3.156$ ***plf***

$w_{ljoists} := w_{ljoists} \cdot w_t = 59.443$ ***plf***

$w_u := 1.0 \cdot w_{djoists} + 1.0 \cdot w_{ljoists} = 62.599$ ***plf***

Load from Deck Beam:

$L := 10.5$ ***ft*** $\quad w_t := 3$ ***ft*** $+ 4$ ***in***

$w_{self} := w_{beam} = 4.023$ ***plf***

$w_{dbeams} := 4 \cdot w_{self} + w_t \cdot q_{planks} + w_t \cdot q_{joists} = 30.842$ ***plf***

$w_{lbeam} := w_t \cdot q_l = 333.333$ ***plf***

$w_{u1} := 1.0 \cdot w_{dbeams} + 1.0 \cdot w_{lbeam} = 364.175$ ***plf***

$P_u := 0.5 \cdot w_{u1} \cdot L = 1.912$ ***kip***

Load from Ramp Joists:

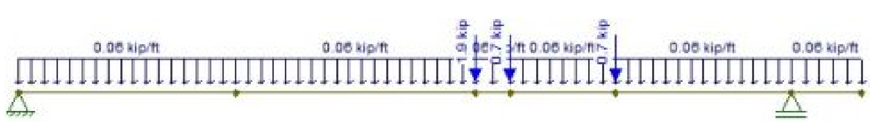
$w_{djoists} := 7.078$ ***plf***

$w_{ljoists} := 133.33$ ***plf***

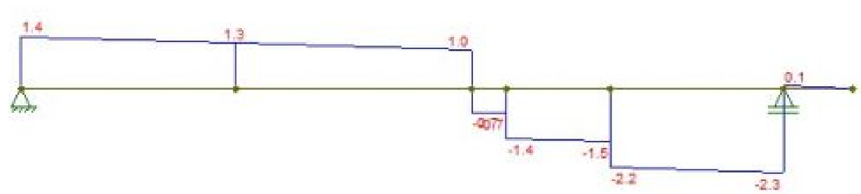
$w_u := 1.0 \cdot w_{djoists} + 1.0 \cdot w_{ljoists} = 140.408$ ***plf***

$P_u := 0.5 \cdot w_u \cdot L = 0.737$ ***kip***

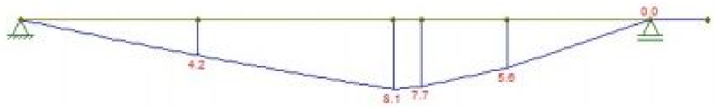
Beam Model:



Shear Diagram:



Moment Diagram:



$M_{ubeams} := 8.1\ \mathbf{kip \cdot ft}$ $\quad V_{ubeams} := 2.3\ \mathbf{kip}$

Beam Properties:

Deck Beam: (4) 2x12

$A_{2x12} = 16.88\ \mathbf{in}^2$ $\quad S_{x2x12} := 31.64\ \mathbf{in}^3$ $\quad I_{x2x12} := 178\ \mathbf{in}^4$

1. Load Combination: 1.0D + 1.0Lr

Bending Check:

Bending Demand:

$M_{ubeams} = 8.1\ \mathbf{kip \cdot ft}$

$$f_b := \frac{M_{ubeams}}{4 \cdot S_{x2x12}} = 768.015\ \mathbf{psi}$$

Bending Capacity: $F_b := 750\ \mathbf{psi}$

$C_D := 1.0$ $\quad C_M := 1.0$ $\quad C_L := 1.0$ $\quad C_{fu} := 1.0$ $\quad C_i := 1.0$

$C_t := 1.0$ $\quad C_r := 1.0$ $\quad C_F := 1.0$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 750\ \mathbf{psi}$$

Utility: $u := \dfrac{f_b}{F_b'} = 1.024$ OK.

Shear Check:

Shear Demand:

$V_{ubeams} = 2.3\ \mathbf{kip}$

$$f_v := \frac{3 \cdot V_{ubeams}}{2 \cdot (4 \cdot A_{2x12})} = 51.096\ \mathbf{psi}$$

Shear Capacity: $F_v := 175\ \mathbf{psi}$

$C_D := 1.0$ $\quad C_M := 1.0$ $\quad C_t := 1.0$ $\quad C_i := 1.0$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ \mathbf{psi}$$

Utility:

$$u := \frac{f_v}{F_v{'}} = 0.292$$

<u>Bearing Check:</u>

Bearing Demand:

$$V_{ubeams} = 2.3\ \boldsymbol{kip}$$

Bearing area: $A_{4x4} = 12.25\ \boldsymbol{in}^2$

$$f_b := \frac{V_{ubeams}}{A_{4x4}} = 187.755\ \boldsymbol{psi}$$

Bearing Capacity: $F_{cp} := 625\ \boldsymbol{psi}$

$C_M := 1.0$ $C_t := 1.0$ $C_i := 1.0$

$$F_{cp}{'} := F_{cp} \cdot C_M \cdot C_t \cdot C_i = 625\ \boldsymbol{psi}$$

Utility:

$$u := \frac{f_b}{F_{cp}{'}} = 0.3$$

<u>Deflection Check:</u>

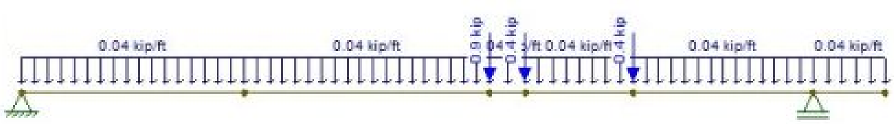
Determine E': $E := 1.4 \cdot 10^6\ \boldsymbol{psi}$ $I_{x2x12} = 178\ \boldsymbol{in}^4$

$C_M := 1.0$ $C_t := 1.0$ $C_i := 1.0$ $C_T := 1.0$

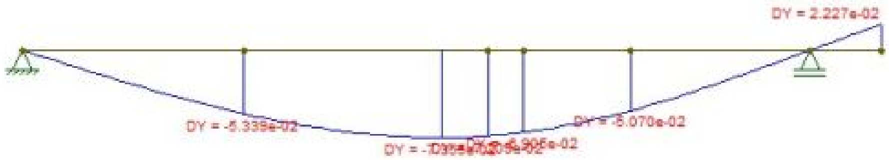
$$E' := E \cdot C_M \cdot C_t \cdot C_i \cdot C_T = 1400\ \boldsymbol{ksi}$$

Short term deflection: 0.5L

Beam Model:



Deflection Diagram:



$\delta_{ST} := 0.07 \ \boldsymbol{in}$

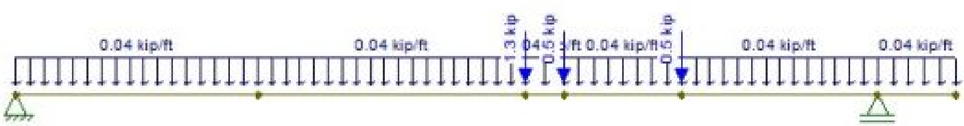
$l_{beams} := 12 \ \boldsymbol{ft}$

$\Delta_{ST} := \dfrac{l_{beams}}{360} = 0.4 \ \boldsymbol{in}$

$\delta_{ST} \le \Delta_{ST} = 1$

Long term deflection: 1.0D +0.5L

Beam Model:



Deflection Diagram:

$\delta_{LT} := 0.09 \ \boldsymbol{in}$

$\delta_{Total} := 1.5 \cdot \delta_{LT} + \delta_{ST} = 0.205 \ \boldsymbol{in}$

$l_{beams} := 12 \ \boldsymbol{ft}$

$\Delta_{Total} := \dfrac{l_{beams}}{240} = 0.6 \ \boldsymbol{in}$

$\delta_{Total} \le \Delta_{Total} = 1$

Deck Posts:

Post tributary area:

Exterior Post: $A_{tribe} := (2\ ft + 10.5\ in) \cdot (7\ ft) = 20.125\ ft^2$

Edge Post (overhang): $A_{tribo} := (5\ ft + 9\ in) \cdot 7\ ft = 40.25\ ft^2$

Edge Post (interior): $A_{tribi} := 9.5\ ft \cdot 7\ ft = 66.5\ ft^2$

Loading:

Dead: $h_{post} := 6\ ft + 8\ in$

$P_{self} := w_{post} \cdot h_{post} = 19.464\ lbf$

Exterior Post: $P_{dpostse} := A_{tribe} \cdot (q_{planks} + q_{joists}) + P_{self} = 126.304\ lbf$

Edge Post (overhang): $P_{dpostso} := A_{tribo} \cdot (q_{planks} + q_{joists}) + P_{self} = 233.143\ lbf$

Edge Post (interior): $P_{dpostsi} := A_{tribi} \cdot (q_{planks} + q_{joists}) + P_{self} = 372.5\ lbf$

Live:

Exterior Post: $P_{lpostse} := A_{tribe} \cdot q_l = (2.013 \cdot 10^3)\ lbf$

Edge Post (overhang): $P_{lpostso} := A_{tribo} \cdot q_l = (4.025 \cdot 10^3)\ lbf$

Edge Post (interior): $P_{lpostsi} := A_{tribi} \cdot q_l = (6.65 \cdot 10^3)\ lbf$

Wind:

Exterior Post: $P_{wpostse} := A_{tribe} \cdot q_{wlonguplift} = 567.566\ lbf$

Edge Post (overhang): $P_{wpostso} := A_{tribo} \cdot q_{wlonguplift} = (1.135 \cdot 10^3)\ lbf$

Edge Post (interior): $P_{wpostsi} := A_{tribi} \cdot q_{wlonguplift} = (1.875 \cdot 10^3)\ lbf$

Load Combinations:

1. Load Combination: 1.0D +1.0L

Exterior Post: $P_{upostse1} := 1.0 \cdot P_{lpostse} + 1.0 \cdot P_{dpostse} = \left(2.139 \cdot 10^{3}\right)$ ***lbf***

Edge Post (overhang): $P_{upostso1} := 1.0 \cdot P_{lpostso} + 1.0 \cdot P_{dpostso} = \left(4.258 \cdot 10^{3}\right)$ ***lbf***

Edge Post (interior): $P_{upostsi1} := 1.0 \cdot P_{lpostsi} + 1.0 \cdot P_{dpostsi} = \left(7.022 \cdot 10^{3}\right)$ ***lbf***

2. Load Combination: 0.6D - 0.6W

Exterior Post: $P_{upostse2} := 0.6 \cdot P_{dpostse} - 0.6 \cdot P_{wpostse} = -264.758$ ***lbf***

Edge Post (overhang): $P_{upostso2} := 0.6 \cdot P_{dpostso} - 0.6 \cdot P_{wpostso} = -541.193$ ***lbf***
Edge Post (interior): $P_{upostsi2} := 0.6 \cdot P_{dpostsi} - 0.6 \cdot P_{wpostsi} = -901.762$ ***lbf***

<u>Gravity Design</u>

Post Properties:

Deck Post: 4x4

$A_{4x4} = 12.25$ ***in***^{2} $\quad d := 3.5$ ***in*** $\quad b := 3.5$ ***in***

1. Load Combination: 1.0D + 1.0Lr

<u>Compression Check:</u>

Compression Demand:

Worst Case Compression Force:

$P_{upostso1} = 4258.1$ ***lbf***

$$f_c := \frac{P_{upostso1}}{A_{4x4}} = 347.604 \text{ psi}$$

Compression Capacity: $F_c := 525$ ***psi***

Minimum Elastic Modulus: $E_{min} := 440000$ ***psi***

$C_M := 1.0 \qquad C_t := 1.0 \qquad C_i := 1.0$

$E_{min}' := E_{min} \cdot C_M \cdot C_t \cdot C_i = \left(4.4 \cdot 10^{5}\right)$ ***psi***

$C_D := 1.0 \qquad C_M := 1.0 \qquad C_F := 1.15 \qquad C_i := 1.0 \qquad C_t := 1.0$

Calculation of Cp:

$K_e := 1.0 \qquad l_u := h_{post} = 6.667\ \textbf{ft}$

$l_e := K_e \cdot l_u = 6.667\ \textbf{ft}$

$c := 0.8$

$$\alpha := \frac{1 + \frac{F_{ce}}{F_{cstar}}}{2 \cdot c} = 1.342 \qquad \beta := \frac{\frac{F_{ce}}{F_{cstar}}}{c} = 1.433$$

$C_p := \alpha - \sqrt{\alpha^2 - \beta} = 0.736$

$F_c' := C_p \cdot F_{cstar} = 444.402\ \textbf{psi}$

Utility:

$$u := \frac{f_c}{F_c'} = 0.782$$

<u>Uplift Check:</u>

Tension Demand:

Tension Force on Post:

Exterior Posts: $P_{upostse2} = -264.758\ \textbf{lbf}$

Edge Posts (overhang): $P_{upostso2} = -541.193\ \textbf{lbf}$

Edge Posts (interior): $P_{upostsi2} = -901.762\ \textbf{lbf}$

Tension Stress on Posts:

Exterior Posts: $$f_{te} := \frac{-P_{upostse2}}{A_{4x4}} = 21.613\ \textbf{psi}$$

Edge Posts (overhang): $$f_{to} := \frac{-P_{upostso2}}{A_{4x4}} = 44.179\ \textbf{psi}$$

Edge Posts (interior): $$f_{ti} := \frac{-P_{upostsi2}}{A_{4x4}} = 73.613\ \textbf{psi}$$

Tension Capacity: $F_t := 675\ \textbf{psi}$

$C_D := 1.6 \qquad C_M := 1.0 \qquad C_t := 1.0 \qquad C_F := 1.5 \qquad C_i := 1.0$

$F_t' := F_t \cdot C_D \cdot C_M \cdot C_t \cdot C_i \cdot C_F = \left(1.62 \cdot 10^3\right)$ ***psi***

Utility:

Exterior Posts: $\frac{f_{te}}{F_t'} = 0.013$

Edge Posts (overhang): $\frac{f_{to}}{F_t'} = 0.027$

Edge Posts (interior): $\frac{f_{ti}}{F_t'} = 0.045$

Lateral Analysis:

Longitudinal Lateral System:

All the lateral load is transfers to the lateral system through the deck plank and joist diaphragm. Therefore the beams will not be designed as part of the lateral system.

3. Load Combination: D + 0.6W

Dead:

$s := 8$ ***in***

$w_d := w_{joists} + s \cdot q_{planks} = 5.193$ ***plf***

Wind:

Longitudinal Wind:

$q_{wlonglateral} = 52.174$ ***psf***

Depth of deck: $w_t := 9.25$ ***in*** $+ 1$ ***in***

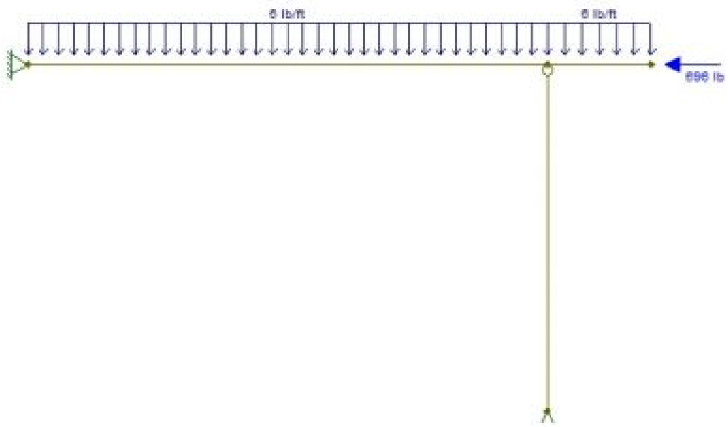
Width of deck: $B := 52$ ***ft***

Long of deck: $L := 12$ ***ft***

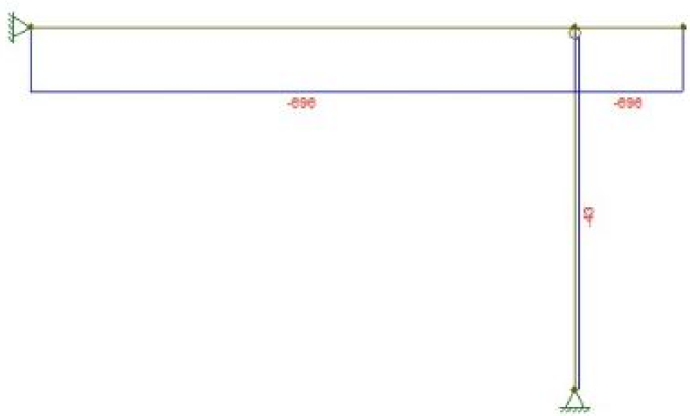
$w_{wlonglateral} := 0.6 \cdot w_t \cdot q_{wlonglateral} = 26.739$ ***plf***

$$P_{wlonglateral} := \frac{w_{wlonglateral} \cdot B}{2} = 0.695\ \boldsymbol{kip}$$

Model:



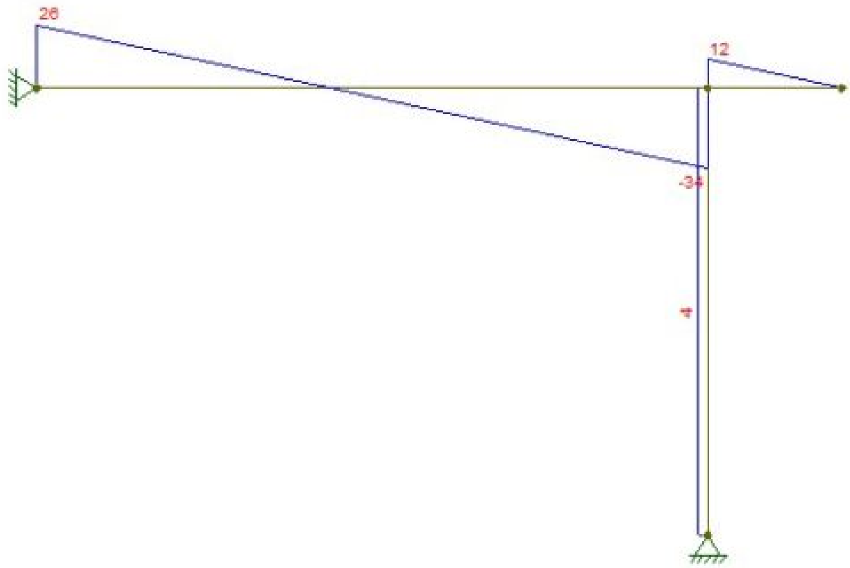
Axial Force Diagram (lbf):



Max post axial force: $A_{postl} := 43\ \boldsymbol{lbf}$

Max knee brace axial force: $A_{bracel} := 0\ \boldsymbol{lbf}$

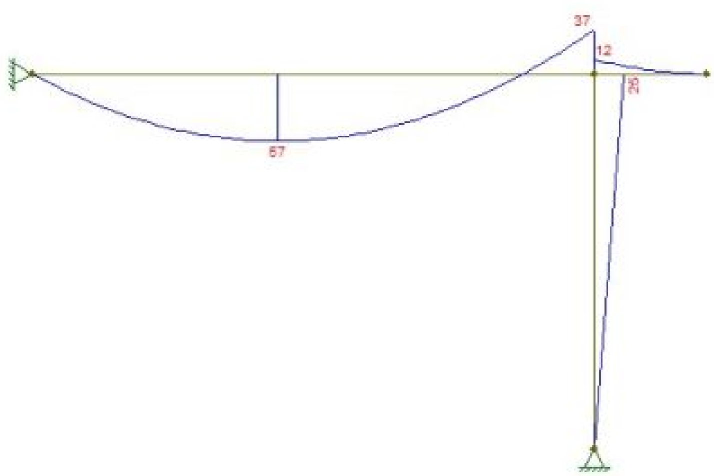
Shear Force Diagram (lbf):



Max post shear force: $V_{postl} := 4\ \mathbf{lbf}$

Max knee brace shear force: $V_{bracel} := 0\ \mathbf{lbf}$

Bending Moment Diagram (lbf-ft):



Max post bending moment: $M_{postl} := 25\ \mathbf{lbf} \cdot \mathbf{ft}$

Max knee brace bending moment: $M_{bracel} := 0\ \mathbf{lbf} \cdot \mathbf{ft}$

Deflection:

$\delta := 0.0000112\ \mathbf{in}$

Tension reaction at wall: $r := 704\ \boldsymbol{lbf}$

Transverse Lateral System:

3. Load Combination: D + 0.6W

Dead:

$w_t := 7\ \boldsymbol{ft}$

$w_{post} = 45.205\ \boldsymbol{plf}$

$P_{self} := w_{post} \cdot h_{post} = 19.464\ \boldsymbol{lbf}$

$A_{trib} := (3\ \boldsymbol{ft} + 9\ \boldsymbol{in}) \cdot (5\ \boldsymbol{ft}) = 18.75\ \boldsymbol{ft}^2$

$P_{dpostlat} := P_{self} + A_{trib} \cdot q_{planks} + A_{trib} \cdot q_{joists} = 119.004\ \boldsymbol{lbf}$

Transverse Wind:

Wind:

$q_{wtranslateral} = 52.174\ \boldsymbol{psf}$

Depth of deck: $w_t := 11.25\ \boldsymbol{in} + 0.75\ \boldsymbol{in}$

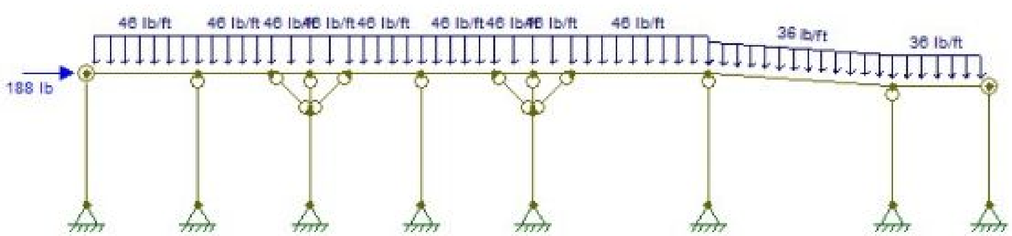
Width of deck: $B := 43\ \boldsymbol{ft}$

Long of deck: $L := 12\ \boldsymbol{ft}$

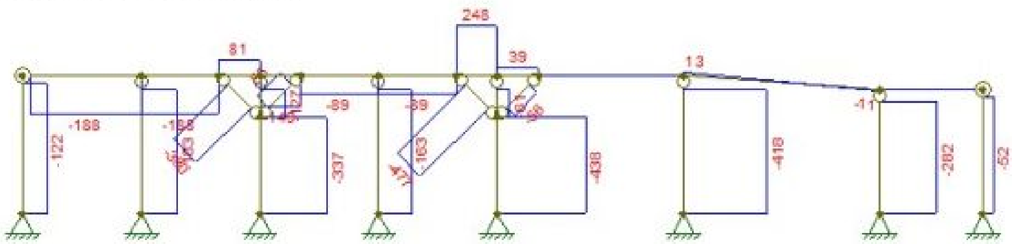
$w_{wtranslateral} := 0.6 \cdot w_t \cdot q_{wtranslateral} = 31.304\ \boldsymbol{plf}$

$$P_{wtranslateral} := \frac{w_{wtranslateral} \cdot L}{2} = 0.188\ \boldsymbol{kip}$$

Model:



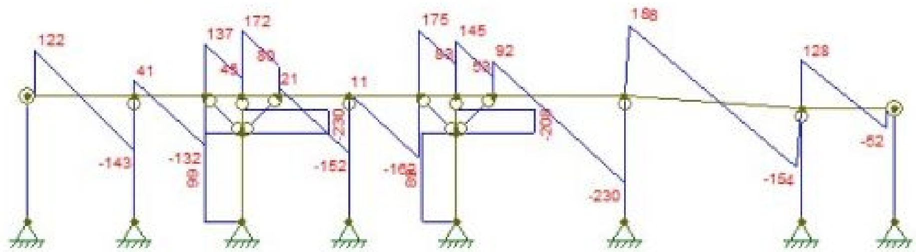
Axial Force Diagram (lbf):



Max post axial force: $A_{postt} := 438$ ***lbf***

Max knee brace axial force: $A_{bracet} := 477$ ***lbf***

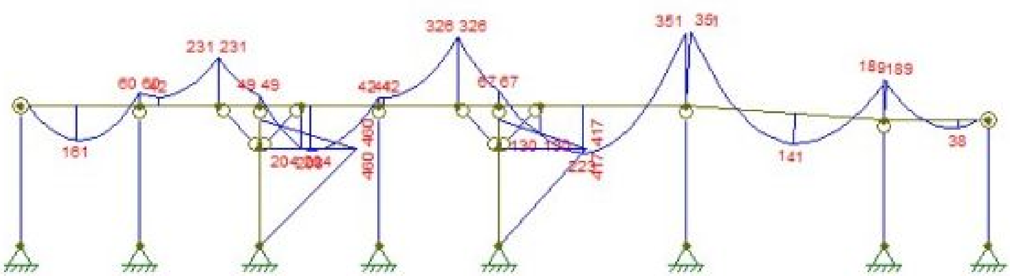
Shear Force Diagram (lbf):



Max post shear force: $V_{postt} := 230$ ***lbf***

Max knee brace shear force: $V_{bracet} := 0$ ***lbf***

Bending Moment Diagram (lbf-ft):



Max post bending moment: $M_{postt} := 460$ ***lbf · ft***

Max knee brace bending moment: $M_{bracet} := 0$ ***lbf · ft***

Design Values:

Post: $A_{post} := \max\left(A_{postl}, A_{postt}\right) = 438$ ***lbf***

$V_{post} := \max\left(V_{postl}, V_{postt}\right) = 230\ \mathbf{lbf}$

$M_{post} := \max\left(M_{postl}, M_{postt}\right) = 460\ \mathbf{lbf \cdot ft}$

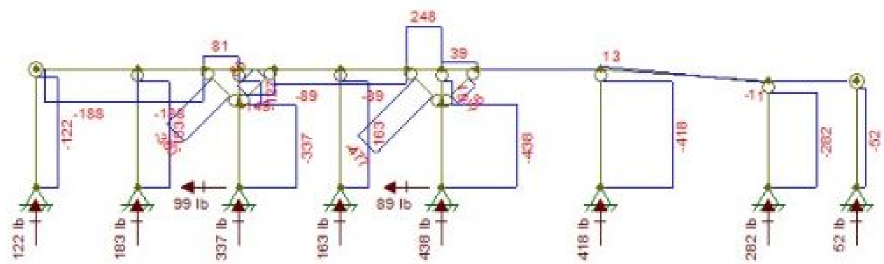
Knee Brace:

$A_{brace} := \max\left(A_{bracel}, A_{bracet}\right) = 477\ \mathbf{lbf}$

$V_{brace} := \max\left(V_{bracel}, V_{bracet}\right) = 0\ \mathbf{lbf}$

$M_{brace} := \max\left(M_{bracel}, M_{bracet}\right) = 0\ \mathbf{lbf \cdot ft}$

Reaction Forces:



$Ry := 438\ \mathbf{lbf}$ $\qquad Rx := 99\ \mathbf{lbf}$

<u>Posts:</u> $\quad A_{4x4} = 12.25\ \mathbf{in}^2 \qquad S_{x4x4} := 27.73\ \mathbf{in}^3$

$A_{post} = 438\ \mathbf{lbf}$

$V_{post} = 230\ \mathbf{lbf}$

$M_{post} = 460\ \mathbf{lbf \cdot ft}$

Compression and Bending Check:

Compression and Bending Demand:

$$f_c := \frac{A_{post}}{A_{4x4}} = 35.755\ \mathbf{psi}$$

$$f_b := \frac{M_{post}}{S_{x4x4}} = 199.062\ \mathbf{psi}$$

Compression and Bending Capacity:

$E_{min} := 1200\ \mathbf{ksi} \qquad d := 5.5\ \mathbf{in}$

$C_M := 1.0 \qquad C_t := 1.0 \qquad C_i := 1.0$

$$E_{min}' := E_{min} \cdot C_M \cdot C_t \cdot C_i = \left(1.2 \cdot 10^6\right) \; psi$$

Compression Check: $F_c := 1450 \; psi$

$C_D := 1.6$ $C_M := 1.0$ $C_F := 1.0$ $C_t := 1.0$ $C_i := 1.0$

$l_u := h_{post} = 6.667 \; ft$ $K_e = 1$

$l_e := K_e \cdot l_u = 6.667 \; ft$

Calculated Cp:

$$F_{ce} := \frac{0.822 \cdot E_{min}'}{\left(\frac{l_e}{d}\right)^2} = 4.662 \; ksi$$

$$F_{cstar} := F_c \cdot C_D \cdot C_M \cdot C_t \cdot C_i \cdot C_F = \left(2.32 \cdot 10^3\right) \; psi$$

$c := 0.8$

$$\alpha := \frac{1 + \frac{F_{ce}}{F_{cstar}}}{2 \cdot c} = 1.881 \qquad \beta := \frac{\frac{F_{ce}}{F_{cstar}}}{c} = 2.512$$

$$C_p := \alpha - \sqrt{\alpha^2 - \beta} = 0.868$$

$$F_c' := C_p \cdot F_{cstar} = \left(2.014 \cdot 10^3\right) \; psi$$

Bending Check: $F_b := 1100 \; psi$

$C_D := 1.6$ $C_M := 1.0$ $C_L := 1.0$ $C_{fu} := 1.0$ $C_i := 1.0$

$C_t := 1.0$ $C_r := 1.0$ $C_F := 1.0$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1760 \; psi$$

Moment amplification Factor:

$$B_1 := \left(1 - \frac{f_c}{F_{ce}}\right)^{-1} = 1.008$$

$f_b = 199.062 \; psi$

Utility: $\frac{f_c}{F_c'} = 0.018$ $\frac{f_b}{F_b'} = 0.113$ $\left(\frac{f_c}{F_c'}\right)^2 + B_1 \cdot \left(\frac{f_b}{F_b'}\right) = 0.114$

Knee Braces: $A_{4x4} = 12.25\ in^2$

$A_{brace} = 477\ lbf$

Tension Check:

Tension Demand:

$$f_t := \frac{A_{brace}}{A_{4x4}} = 38.939\ psi$$

Tension Capacity: $F_t := 675\ psi$

$C_D := 1.6 \qquad C_M := 1.0 \qquad C_t := 1.0 \qquad C_F := 1.5 \qquad C_i := 1.0$

$$F_t' := F_t \cdot C_D \cdot C_M \cdot C_t \cdot C_F \cdot C_i = 1620\ psi$$

Utility: $\dfrac{f_t}{F_t'} = 0.024$

Compression Check: $F_c := 1450\ psi$

$C_D := 1.6 \qquad C_M := 1.0 \qquad C_F := 1.15 \qquad C_t := 1.0 \qquad C_i := 1.0$

$$l_u := \sqrt{(2\ ft)^2 + (2\ ft)^2} = 2.828\ ft \qquad K_e = 1$$

$$l_e := K_e \cdot l_u = 2.828\ ft \qquad d := 1.5\ in$$

Calculated Cp:

$$F_{ce} := \frac{0.822 \cdot E_{min}'}{\left(\frac{l_e}{d}\right)^2} = 1.927\ ksi$$

$$F_{cstar} := F_c \cdot C_D \cdot C_M \cdot C_t \cdot C_i \cdot C_F = \left(2.668 \cdot 10^3\right)\ psi$$

$c := 0.8$

$$\alpha := \frac{1 + \frac{F_{ce}}{F_{cstar}}}{2 \cdot c} = 1.076 \qquad \beta := \frac{\frac{F_{ce}}{F_{cstar}}}{c} = 0.903$$

$C_p := \alpha - \sqrt{\alpha^2 - \beta} = 0.571$

$F_c' := C_p \cdot F_{cstar} = \left(1.522 \cdot 10^3\right)\ \mathbf{psi}$

Utility: $\dfrac{f_c}{F_c'} = 0.023$

Ramp Analysis:

Gravity Analysis:

Ramp Planks:

Plank span: $s_{ramp} := 1.5\ \mathbf{ft}$

Tributary Width: $w_{tramp} := 7.5\ \mathbf{in}$

Loading:

Dead:

$w_{dplanksR} := w_{planks} = 1.296\ \mathbf{plf}$

Live:

$w_{lplanksR} := q_l \cdot w_{tramp} = 62.5\ \mathbf{plf}$

1. Load Combination: 1.0D +1.0L

$w_{uplanks1R} := 1.0 \cdot w_{dplanksR} + 1.0 \cdot w_{lplanksR} = 63.8\ \mathbf{plf}$

$V_{uplanks1R} := \dfrac{1}{2}\ w_{uplanks1R} \cdot s_{ramp} = 47.8\ \mathbf{lbf}$

$M_{uplanks1R} := \dfrac{w_{uplanks1R} \cdot s_{ramp}^{\ 2}}{8} = 17.9\ \mathbf{lbf} \cdot \mathbf{ft}$

Ramp Joists/Beams:

Joist span: $l_{joistsR} := 11\ \mathbf{ft}$

Joist spacing: $s_{rampj} := 18\ \mathbf{in}$

Loading: $q_{joists} := \dfrac{w_{joists}}{21\ \mathbf{in}} = 1.89\ \mathbf{psf}$

Dead:

$w_{selfR} := w_{joists} = 3.308 \; \boldsymbol{plf}$

$w_{djoistsR} := w_{selfR} + s_{rampj} \cdot q_{planks} = 7.55 \; \boldsymbol{plf}$

Live:

$w_{ljoistsR} := q_l \cdot s_{rampj} = 150 \; \boldsymbol{plf}$

$M_{ujoists1R} := 2379 \; \boldsymbol{lbf \cdot ft}$

$V_{ujoists1R} := 1400 \; \boldsymbol{lbf}$

Gravity Design

Deck Planks:

Plank Properties:

Deck Planks: 1x8

$A_{1x8} = 0.038 \; \boldsymbol{ft}^2$ $S_{y1x8} := 0.680 \; \boldsymbol{in}^3$

1. Load Combination: 1.0D + 1.0Lr

Bending Check:

Bending Demand:

$M_{uplanks1R} = 17.9 \; \boldsymbol{lbf \cdot ft}$

$f_b := \dfrac{M_{uplanks1R}}{S_{y1x8}} = 316.635 \; \boldsymbol{psi}$

Bending Capacity: $F_b := 925 \; \boldsymbol{psi}$

$C_D := 1.0$ $C_M := 1.0$ $C_L := 1.0$ $C_{fu} := 1.15$ $C_i := 1.0$

$C_t := 1.0$ $C_r := 1.15$ $C_F := 1.3$

$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1590.3 \; \boldsymbol{psi}$

Utility:

$$u := \frac{f_b}{F_b'} = 0.199$$

Shear Check:

Shear Demand:

$$V_{uplanks1R} = 47.8\ \boldsymbol{lbf}$$

$$f_v := \frac{3 \cdot V_{uplanks1R}}{2 \cdot A_{1x8}} = 13.198\ \boldsymbol{psi}$$

Shear Capacity: $F_v := 175\ \boldsymbol{psi}$

$C_D := 1.0 \qquad C_M := 1.0 \qquad C_t := 1.0 \qquad C_i := 1.0$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ \boldsymbol{psi}$$

Utility:

$$u := \frac{f_v}{F_v'} = 0.075$$

Ramp Joists/Beams:

Joist Properties:

Deck Joist: 2x10

$A_{2x10} = 13.88\ \boldsymbol{in}^2 \qquad S_{x2x10} := 21.39\ \boldsymbol{in}^3 \qquad I_{x2x10} := 98.93\ \boldsymbol{in}^4$

1. Load Combination: 1.0D + 1.0Lr

Bending Check:

Bending Demand:

$$M_{ujoists1R} = \left(2.4 \cdot 10^3\right)\ \boldsymbol{lbf \cdot ft}$$

$$f_b := \frac{M_{ujoists1R}}{S_{x2x10}} = \left(1.335 \cdot 10^3\right)\ \boldsymbol{psi}$$

Bending Capacity: $F_b := 800\ psi$

$C_D := 1.0$ $C_M := 1.0$ $C_L := 1.0$ $C_{fu} := 1.0$ $C_i := 1.0$

$C_t := 1.0$ $C_r := 1.15$ $C_F := 1.1$

$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1012\ psi$

Utility:

$$u := \frac{f_b}{F_b'} = 0.961$$

Shear Check:

Shear Demand:

$$V_{ujoists1R} = \left(1.4 \cdot 10^3\right)\ lbf$$

$$f_v := \frac{3 \cdot V_{ujoists1R}}{2 \cdot A_{2x10}} = 151.297\ psi$$

Shear Capacity: $F_v := 175\ psi$

$C_D := 1.0$ $C_M := 1.0$ $C_t := 1.0$ $C_i := 1.0$

$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ psi$

Utility:

$$u := \frac{J_v}{F_v'} = 0.865$$

Deck Guard Rail

ASCE Point Load: $P_{railing} := 200\ lbf$

Railing Height: $h_{railing} := 42\ in$

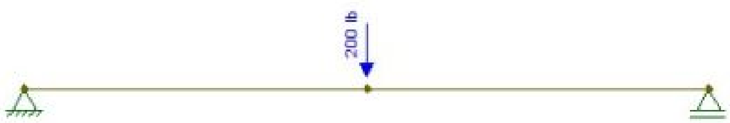
Railing Post Spacing: $s := 5.375\ ft$

Case 1: Point load applied to mid-span of top railing

$$V_{urailing} := \frac{P_{railing}}{2} = 100\ \boldsymbol{lbf}$$

$$M_{urailing} := \frac{P_{railing} \cdot s}{4} = 268.75\ \boldsymbol{lbf \cdot ft}$$

Model:

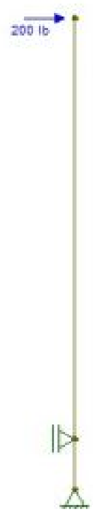


Case 2: Point load applied directly to top of railing post $a := 42\ \boldsymbol{in}$ $l := 5\ \boldsymbol{in}$

$$V_{urailingpost} := P_{railing} = 200\ \boldsymbol{lbf} \qquad R_{bottom} := \frac{P_{railing} \cdot a}{l} = 1.68\ \boldsymbol{kip}$$

$$M_{urailingpost} := P_{railing} \cdot a = 700\ \boldsymbol{lbf \cdot ft} \qquad R_{top} := \frac{P_{railing} \cdot (l + a)}{l} = 1.88\ \boldsymbol{kip}$$

Model:



Rail Post Properties:

$A_{4x4} = 12.25\ \boldsymbol{in}^2$ $S_{x4x4} := 7.15\ \boldsymbol{in}^3$

Top and Bottom Rail Properties:

$A_{2x4} = 5.25\ \boldsymbol{in}^2$ $S_{x2x4} := 3.06\ \boldsymbol{in}^3$

Case 1: Point Load applied to mid-span of top railing

Bending Check:

Bending Demand:

$$M_{urailing} = 268.8\ \boldsymbol{lbf \cdot ft}$$

$$f_b := \frac{M_{urailing}}{S_{x2x4}} = \left(1.054 \cdot 10^3\right)\ \boldsymbol{psi}$$

Bending Capacity: $F_b := 1100\ \boldsymbol{psi}$

$C_D := 1.0$ $C_M := 1.0$ $C_L := 1.0$ $C_{fu} := 1.0$ $C_i := 1.0$

$C_t := 1.0$ $C_r := 1.0$ $C_F := 1.5$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1650\ \boldsymbol{psi}$$

Utility:

$$u := \frac{f_b}{F_b'} = 0.639$$

Shear Check:

Shear Demand:

$$V_{urailing} = 100\ \boldsymbol{lbf}$$

$$f_v := \frac{3 \cdot V_{urailing}}{2 \cdot A_{2x4}} = 28.571\ \boldsymbol{psi}$$

Shear Capacity: $F_v := 175\ \boldsymbol{psi}$

$C_D := 1.0$ $C_M := 1.0$ $C_t := 1.0$ $C_i := 1.0$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ \boldsymbol{psi}$$

Utility:

$$u := \frac{f_v}{F_v'} = 0.163$$

Case 2: Point load applied directly to top of railing post

<u>Bending Check:</u>

Bending Demand:

$$M_{urailingpost} = 700\ \mathbf{lbf \cdot ft}$$

$$f_b := \frac{M_{urailingpost}}{S_{x4x4}} = \left(1.175 \cdot 10^3\right)\ \mathbf{psi}$$

Bending Capacity: $F_b := 1100\ \mathbf{psi}$

$C_D := 1.0$ $C_M := 1.0$ $C_L := 1.0$ $C_{fu} := 1.0$ $C_i := 1.0$

$C_t := 1.0$ $C_r := 1.0$ $C_F := 1.5$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1650\ \mathbf{psi}$$

Utility:

$$u := \frac{f_b}{F_b'} = 0.712$$

<u>Shear Check:</u>

Shear Demand:

$$V_{urailingpost} = 200\ \mathbf{lbf}$$

$$f_v := \frac{3 \cdot V_{urailingpost}}{2 \cdot A_{2x4}} = 57.143\ \mathbf{psi}$$

Bending Capacity: $F_v := 175\ \mathbf{psi}$

$C_D := 1.0$ $C_M := 1.0$ $C_t := 1.0$ $C_i := 1.0$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ \mathbf{psi}$$

Utility:

$$u := \frac{f_v}{F_v'} = 0.327$$

Appendix F

Rooftop Deck and Existing Truss Analysis

Design Standards and Codes:
- ASCE 7-10
- NDS 2015

ASCE Ch 29: Wind Loads on Buildings appurtenances and other structures

Wind Effects on Rooftop Deck:

Longitudinal Wind:

Rooftop Structure Coefficients: $GC_{r1} := 1.9$

$GC_{r2} := 1.46$

Lateral wind force: $q_{wlonglateral} := q_h \cdot \left(GC_{r1}\right) = 53.584 \; \mathbf{psf}$

Uplift force: $q_{wlonguplift} := q_h \cdot \left(GC_{r2}\right) = 41.175 \; \mathbf{psf}$

Transverse Wind:

Rooftop Structure Coefficients: $GC_{r1} := 1.9$

$GC_{r2} := 1.46$

Lateral wind force: $q_{wtranslateral} := q_h \cdot \left(GC_{r1}\right) = 53.584 \; \mathbf{psf}$

Uplift force: $q_{wtransuplift} := q_h \cdot \left(GC_{r2}\right) = 41.175 \; \mathbf{psf}$

Rooftop Deck Gravity Analysis and Design

Longitudinal Wind:

Rooftop Structure Coefficients: $GC_{r1} := 1.9$

$GC_{r2} := 1.46$

Lateral wind force: $q_{wlonglateral} := q_h \cdot (GC_{r1}) = 53.584\ psf$

Uplift force: $q_{wlonguplift} := q_h \cdot (GC_{r2}) = 41.175\ psf$

Transverse Wind:

Rooftop Structure Coefficients: $GC_{r1} := 1.9$

$GC_{r2} := 1.46$

Lateral wind force: $q_{wtranslateral} := q_h \cdot (GC_{r1}) = 53.584\ psf$

Uplift force: $q_{wtransuplift} := q_h \cdot (GC_{r2}) = 41.175\ psf$

Deck Planks:

See Appendix D for deck plank calculations.

Deck Joists:

Joist span: $l_{joists} := 10\ ft$

Joist spacing: $s := 16\ in$

Loading:

Dead:

$w_{self} := w_{joists} = 3.308\ plf$

$w_{djoists} := w_{self} + s \cdot q_{planks} = 5.9\ plf$

Live:

$$w_{ljoists} := q_l \cdot s = 133.333\ \boldsymbol{plf}$$

1. Load Combination: 1.0D +1.0L

$$w_{ujoists1} := 1.0 \cdot w_{djoists} + 1.0 \cdot w_{ljoists} = 139.2\ \boldsymbol{plf}$$

$$V_{ujoists1} := \frac{w_{ujoists1} \cdot l_{joists}}{2} = 696.168\ \boldsymbol{lbf}$$

$$M_{ujoists1} := \frac{w_{ujoists1} \cdot l_{joists}^{2}}{8} = \left(1.74 \cdot 10^{3}\right)\ \boldsymbol{lbf \cdot ft}$$

Joist Properties:

Deck Joist: 2x10

$A_{2x10} = 13.88\ \boldsymbol{in}^2$ $S_{x2x10} := 21.39\ \boldsymbol{in}^3$ $I_{x2x10} := 98.93\ \boldsymbol{in}^4$

1. Load Combination: 1.0D + 1.0Lr

Bending Check:

Bending Demand:

$$M_{ujoists1} = \left(1.7 \cdot 10^{3}\right)\ \boldsymbol{lbf \cdot ft}$$

$$f_b := \frac{M_{ujoists1}}{S_{x2x10}} = 976.392\ \boldsymbol{psi}$$

Bending Capacity: $F_b := 800\ \boldsymbol{psi}$

$C_D := 1.0$ $C_M := 1.0$ $C_L := 1.0$ $C_{fu} := 1.0$ $C_i := 1.0$

$C_t := 1.0$ $C_r := 1.15$ $C_F := 1.1$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1012\ \boldsymbol{psi}$$

Utility:

$$u := \frac{f_b}{F_b'} = 0.965$$

Shear Check:

Shear Demand:

$$V_{ujoists1} = 696.2\ \boldsymbol{lbf}$$

$$f_v := \frac{3 \cdot V_{ujoists1}}{2 \cdot A_{2x10}} = 75.234\ \boldsymbol{psi}$$

Shear Capacity: $F_v := 175\ psi$

$C_D := 1.0 \quad C_M := 1.0 \quad C_t := 1.0 \quad C_i := 1.0$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ psi$$

Utility:

$$u := \frac{f_v}{F_v'} = 0.43$$

Deflection Check:

Determine E': $E := 1.4 \cdot 10^6\ psi$ $I_{x2x10} = 98.93\ in^4$

$C_M := 1.0 \quad C_t := 1.0 \quad C_i := 1.0 \quad C_T := 1.0$

$$E' := E \cdot C_M \cdot C_t \cdot C_i \cdot C_T = \left(1.4 \cdot 10^6\right)\ psi$$

Short term deflection:

$$w_{ST} := 0.5 \cdot w_{ljoists} = 66.667\ plf$$

$$\delta_{ST} := \frac{5 \cdot w_{ST} \cdot l_{joists}^{\ 4}}{384 \cdot E' \cdot I_{x2x10}} = 0.108\ in$$

$$\Delta_{ST} := \frac{l_{joists}}{360} = 0.333\ in$$

$$\delta_{ST} \le \Delta_{ST} = 1$$

Long term deflection:

$$w_{LT} := 0.5 \cdot w_{ljoists} + w_{djoists} = 72.567\ plf$$

$$\delta_{LT} := \frac{5 \cdot w_{LT} \cdot l_{joists}^{\ 4}}{384 \cdot E' \cdot I_{x2x10}} = 0.118\ in$$

$$\delta_{Total} := 1.5 \cdot \delta_{LT} + \delta_{ST} = 0.285\ in$$

$$\Delta_{Total} := \frac{l_{joists}}{240} = 0.5\ in$$

$$\delta_{Total} \le \Delta_{Total} = 1$$

Deck Beams:

Beam span: $l_{beams1} := 7.5\ ft$ $l_{beams2} := 7\ ft$

Beam spacing: $w_{trib} := 5\ ft$

Loading:

Dead:

$w_{self} := w_{beam} = 4.023\ plf$

$w_{dbeams} := 2 \cdot w_{self} + w_{trib} \cdot q_{planks} + w_{trib} \cdot q_{joists} = 30.172\ plf$

Live:

$w_{lbeams} := q_l \cdot w_{trib} = 500\ plf$

1. Load Combination: 1.0D +1.0L

Deck Posts:

Rooftop Deck Lateral Analysis and Design

Analysis of Existing Roof Truss

Assumptions:

- Existing truss has (3) 2x6 webs and (3) 2x10 chords
- Masonry walls are made of hollow clay units the require no special inspection

Using reactions from deck posts:

Appendix G

Staircase Analysis and Design

Design Standards and Codes:

ASCE 7-10
NDS 2015
AISC 360-10

Assumptions:

- Stair stringers, beams, and columns create a moment frame.
- Deflection criteria is set at h/500.
- Guard railing has a 10 plf allowance

Wind Effects on Staircase (strength):

Wind Effects on Staircase (Serviceability):

Gravity Analysis and Design

Lateral Analysis and Design

- Soil is silty loam.
- Equation 18-1 from IBC 2015 is applicable

Stairwell Foundation Sizing:

Assumptions:

- Soil is silty loam.
- Equation 18-1 from IBC 2015 is applicable