Prepared for:

NAU Challenge Course
Campus Recreation
PO Box 5773
Flagstaff, AZ 86011
Attn: Amber Heft

Design Report for Challenge Course Climbing Wall

NORTHERN ARIZONA UNIVERSITY

Submitted by:

NAU Civil Engineering
Capstone Team
Kelsey Deckert
Austin Hopper
Stephanie Sarty
Northern Arizona
University
2013

NAU Civil Engineering Capstone Team
Kelsey Deckert
Austin Hopper
Stephanie Sarty
Northern Arizona University
Building 69
Flagstaff, AZ 86001

Amber Heft
NAU Campus Recreations
PO Box 5773
Flagstaff, AZ 86011

Dear Ms. Heft,

Attached is the design report for the climbing wall at the NAU Challenge Course. At the end of the report, Appendix I includes the final plan set.

The Civil Engineering Capstone team would like to thank you for the opportunity to work with you to gain this hands-on, real world experience. We would also like to thank the Capstone professors, Wilbert Odem and Joshua Hewes, for their support and direction throughout the school year. A special thanks goes to Thomas Nelson and John Tingerthal for their help and guidance through the technical details of the design.

Sincerely,

NAU Civil Engineering Capstone Team
Please contact:
Austin Hopper
(928) 707-0090
ah439@nau.edu

Contents

1. Introduction

This report presents the final design completed by the Capstone team for the Northern Arizona Challenge Course climbing wall. The documents included in this report should contain all necessary information for:

1) Collection of funds
2) Procurement of materials
3) Earthwork
4) Climbing wall construction

The report summarizes the Capstone team's understanding of project requirements and the supplied background information for the Challenge Course. The final design plans are included, as well as how each conclusion was reached using hand calculations and program outputs versus required code regulations. Each task that was accomplished to achieve the design is listed to clarify the work that went into the project. Impacts caused by the implementation of the wall are discussed to show the Capstone team's understanding of their effect in a greater sense. The team's hope is that the report clearly displays why and how the final design was completed as it was.

2. Project Understanding

2.1 Problem Statement

The goal of the project was to design a climbing wall for the Northern Arizona University (NAU) Challenge Course. The purpose of this wall is to improve the challenge course by adding another team building activity to the course. The project was proposed by NAU, was be designed by a Civil Engineering Capstone team, and will be constructed by the Construction Management Program. The design and construction will be completed by students for no charge to NAU. NAU has asked that the structure be designed to the standards of The Association for Challenge Course Technology (ACCT), but indicated that engineering codes supersede ACCT standards.

The key stakeholder in this project is NAU Campus Recreations. NAU will be providing the funds to pay for the building materials, professional engineer's approval, and any subcontracting that is required. Other stakeholders include NAU faculty and students and other businesses or groups utilizing the climbing wall.

2.2 Background

The NAU Challenge Course is located south of the Engineering Building on the NAU campus, off of South Huffer Lane. The location of the Challenge Course is shown below in Figure 1 in the red circle (the image was taken before the Challenge Course was built). A ropes course, along with several other activities, is already in place in a fenced in area. This leaves a small designated area available for placement of the proposed wall. This specified area is shown with the yellow circle in Figure 1.

Figure 1: Location of the NAU Challenge Course (Google Maps, 2012)

Previous geotechnical studies indicate solid rock just below the ground surface. The rock will be excavated for placement of the two structural poles at a depth and width complying with ACCT code. Once the poles are placed, the remaining space within the holes will be filled with polyurethane expansion foam which will work as the foundation for the wall. The rock presents a solid foundation for the poles; however, strength of the rock was be determined to ensure it has the strength required support the wall and applied loads.

Designing the wall itself required an in-depth look at the structural demands the wall will receive. Wind and live loads will be the largest forces acting on the structure, and therefore the team's biggest concern. Load magnitudes were estimated using the ASCE 7-05 (*Minimum Design Loads for Buildings and Other Structures)* as a guide, and using LRFD (Load and Resistance Factor Design) load combinations to ensure conservative loading cases. These estimates were then checked to ensure compliance with the City of Flagstaff standards. Calculations must be completed to insure that the wall is capable of withstanding wind and live loads as well as self-weight and snow loads, with a built in factor of safety from the LRFD calculations. Safety is one of the Capstone team's biggest concerns and is vital to the project, so all calculations are conservative.

A rough wall sketch was created in order to display the Capstone team's basic plan for the design using simple calculations. This sketch was displayed the basic idea the Capstone team had for the wall design. The sketch was shown to the technical advisors and capstone professors for approval before the project moved forward. The wall sketch is shown below in Figure 2.

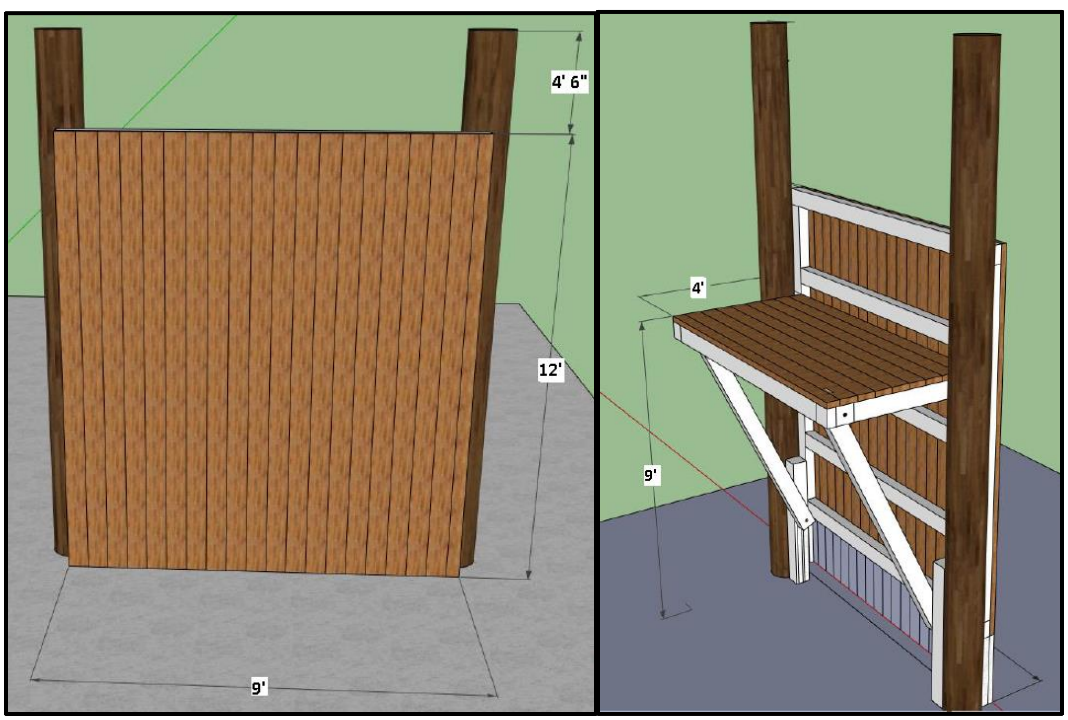


Figure 2: Rough Wall Sketches

The rough design in Figure 2 uses two wooden poles as supports for the structure with the base of the poles placed into the bedrock. All dimensions were determined according to NAU's design criteria (see Figure 3). The face of the wall is composed of a frame with Trex deck running vertically (to keep the wall face from being used like a ladder). Horizontal supports run across the back of the frame (according to the International Building Code, IBC) and a diagonal support will be added to resist swaying. The back deck is run between the two poles and will be attached to the poles with both horizontal and angled supports in order to create a small truss. A railing was added to the deck according to IBC code. A removable ladder will be purchased by NAU for entry and exit from the deck.

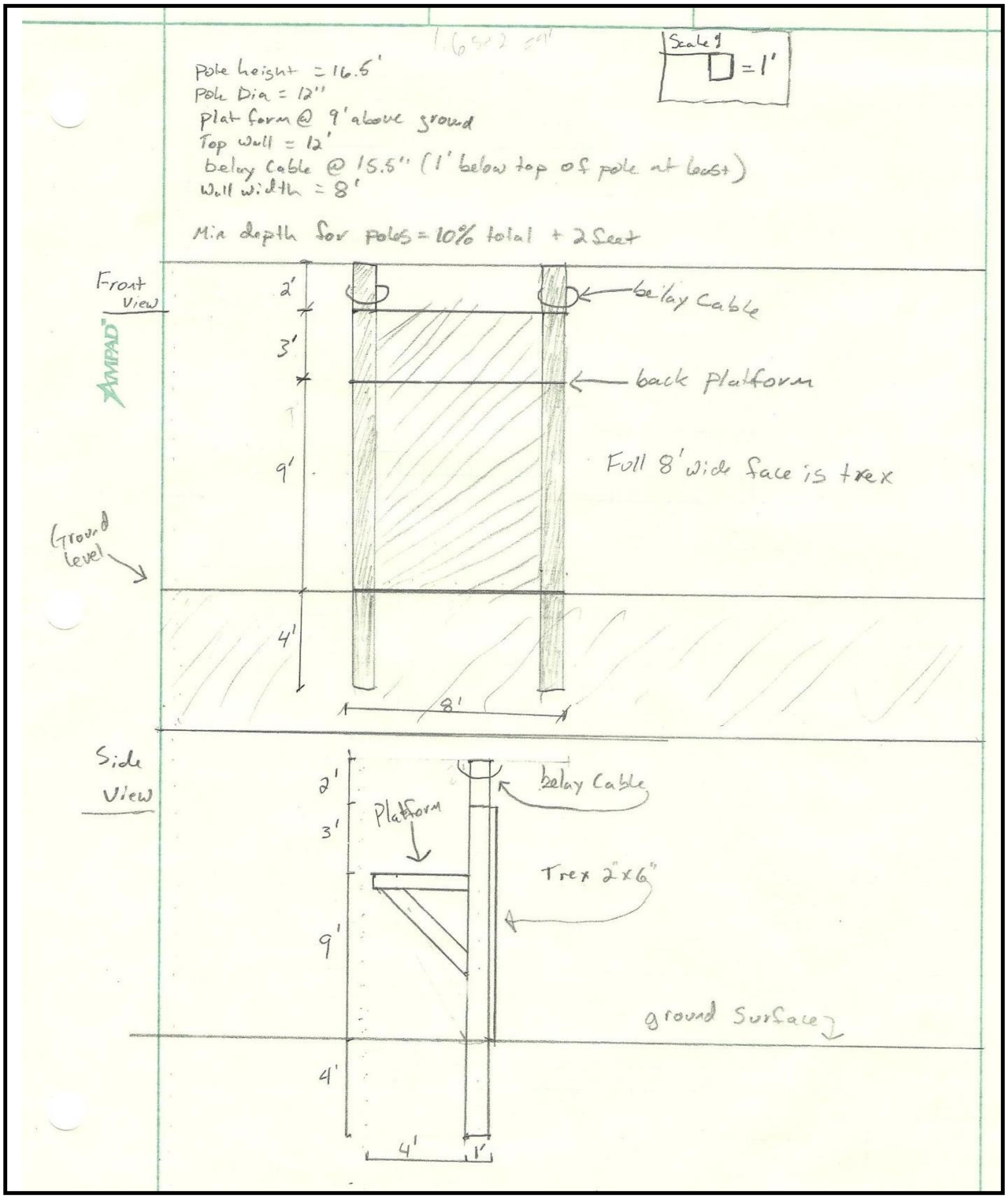


Figure 3: Design Criteria from NAU

NAU has requested that the Capstone team use the ACCT wherever applicable, but recognize that it will be superseded by engineering codes in most cases. One exception to this is the design of the belay cables. The cables will be attached to the poles according to the list of acceptable methods from ACCT (Appendix A, p. 19). Furthermore, the ACCT has regulations for the necessary sag in the belay cables (Appendix A, p. 23).

The materials to be used will include Trex Deck Lumber and 12 inch diameter Western Red cedar poles (class 3), as specified by NAU. All other materials were determined by the design team according to available resources and safety of design. Figure 4 shows part of the existing challenge course. The poles, decking, bolts, and harness tie-ins shown in Figure 4 are the same materials that will be used for the wall.

Figure 4: Existing Challenge Course and Display of Materials (Heft, 2012)

2.3 Potential Issues

This project was handed down from NAU clearly defined and obviously achievable, but the Capstone team was worried about a few challenges for the design. The original fears of the team were designing poles and a foundation that could withstand Flagstaff's powerful winds and sway and deformations of the poles making users uncomfortable. Due to these concerns, the team completed these calculations first to ensure that the team should move on with the materials originally agreed to.

3. Scope of Work

In order to clarify the work necessary for completion of this project, for both the client and the engineering team, each chronological task was addressed. The project was originally broken down into the following 11 tasks:

- Task 1: Project Management
- Task 2: Obtain Existing Documents and Required Codes
- Task 3: Analyze Available Materials
- Task 4: Develop Architectural Design
- Task 5: Structural Design
- Task 6: Construction Drawings
- Task 7: Submission to a Professional Engineer
- Task 8: Construction Support
- Task 9: Project Report
- Task 10: Poster Preparation
- Task 11: Presentation Preparation

As the project advanced, some changes to the original tasks were required. This occurred due to both new class specifications and issues arising in the design process. The completed list of tasks is shown below.

3.1 Project Management

Throughout the design process regular "checks" occurred to ensure all involved parties were in agreement, design was completed correctly, and the project was advancing in a timely manner. These "checks" included regular contact and meetings between the Capstone team, the involved advisers, and NAU.

Deliverable: Meeting agendas and/or minutes

3.2 Capstone Course Check-ins

Weekly meetings with a technical advisor were required by the Capstone course. These meetings were conducted with either John Tingerthal or Thomas Nelson while the team was in the design process phase. Furthermore, Dr. Odem requested biweekly presentations to show team advancements and arising issues. These presentations were given to Dr. Odem and two other Capstone teams to encourage questions and practice public speaking.

Deliverable: Meeting agendas and/or minutes, short PowerPoint presentations

3.3 Obtain Existing Documents and Required Codes

In order to analyze the project needs, the Capstone team will obtained and researched the documents available for the project site. These documents included the geotechnical reports, topography of the site, and as-builts. Before design can begin the team will need to be aware of all codes, regulations, and specifications that the project will have to meet. This included federal, state, and city codes, challenge course codes, NAU specifications, and any other requirements. Once this information was collected, the team determined if any additional information is necessary for the project. Requests for access to documents and/or the site were submitted to NAU.

Deliverable: Request for access

3.4 Analyze Available Materials

NAU requested that the Capstone team design the wall utilizing materials already possessed by NAU. The team required a list of available materials, quantities, and sizes in order to begin the design process. Once the list was obtained, the team identifed each materials' use and capability, and then determine any other materials the team will require.

Deliverable: Material list

3.5 Develop Architectural Design

Once all necessary information was collected, an initial design was created. The design is a sketch of the wall to ensure that the team and NAU agree on the general dimensions, functionality, and aesthetics of the structure. The sketch is similar to the sketch given in Figure 2, but redesigned for after deeper evaluation. This design was submitted to NAU for approval before technical design began.

Deliverable: CAD draft of wall

3.6 Structural Design

3.5.1 Structural Analysis

To begin the design process, the team will needed to calculate the loads that the wall will undertake. This included live load, snow load, wind load, and dead load. A factored load combination was then used for design, according to ASCE 7-05 with LRFD, which makes allowances for a conservative design. Calculations will be done by both by hand and using computer aid, using both whenever possible as a check. Calculations were completed assuming that the poles act as fixed supports in the rock and under worst-case loading.

Deliverable: Predicted loads

3.5.2 Structural Member Design

A rough sketch of the design is included above in Figure 2. This provides a general structural layout. The layout was altered and fine-tuned as information on loading was gathered and determined. Research was completed to determine the characteristics of the materials to be used. This includes strength, durability, ductility, etc. and was important in considerations for member sizing. The design used the ASD/LRFD Manual for Engineered Wood Construction (2005 Edition) to determine wood capacities.

Deliverable: Structural element designation

3.5.3 Foundation Requirement Analysis

Every determined load will be transferred to the foundation through two poles. The dimensions and material makeup of the foundation must be considered for safety and structural integrity. Calculations were completed to estimate the necessary foundation capacity, required depth of poles, and the strength of the rock base. Foundation design was completed according to ACCT standards (Appendix A, p.22).

Deliverable: Foundation specifications

3.7 Final Drawings

Every detail of the design was compiled into formal drawings in order to present the information to all involved parties. The drawings include dimensions, materials, specifications, and foundation requirements. These drawings will be handed over to both NAU and the team's involved professors for required changes, suggestions, and comments.

Deliverable: Construction Plan

3.8 Submission for Review

Once the drawings were complete, a collection of all pertinent information was given to the technical advisors for review. Feedback was given to the Capstone team to decipher if the final design was correctly completed and if it was the optimal choice.

Deliverable: Revised drawing and comments

3.10 Project Report Preparation

Once the project design was complete, the team created a final design report. This report summarizes each step in the design process and includes the final design. The report is done for the Capstone course and the client to display to the professors everything that the team completed over the course of the project.

Deliverable: Design report

3.11 Website Preparation

A website was created containing a summary of all project information for both the Capstone course and the public. The website is available through nau.edu within the College of Engineering, Forestry, and Natural Sciences program page.

Deliverable: Website

3.12 Presentation Preparation

A presentation was prepared to give to at the UGRADS Symposium for professors, students, professionals, and any other interested parties.

Deliverable: Presentation

3.13 Clarifications

All required funding will be the responsibility of NAU. Construction and subcontracting are not the responsibility of the Capstone team.

4. Final Design

4.1 Introduction

The design of the NAU Challenge Course climbing wall included considerations of material availability and strength, loading, design durability, deflections, safety, and more. To provide an understanding of how design conclusions were reached, the project analysis has been broken down into 5 categories. The categories overlap and can be dependent on each other, as the climbing wall works as one solid structure.

4.2 Loading

To determine the loading estimates to be used for design, ASCE 7-05 was used. For Flagstaff, however, wind and snow loads had to be increased to local standards. The wind stress was determined using ASCE 7-05 along with the Flagstaff standard of 90 mph winds. The given loads were in pounds per square foot, and were therefore distributed over the areas of the affected surfaces. The loading used for live, dead, snow, and wind loads are given in Appendix D (pg. 34).

4.3 Computer Analysis

The Capstone team decided to use computer analysis to determine the reactions and internal forces of the climbing wall. This was done to ensure consistency, include all pertinent information and specs, and for changes to be applied quickly and easily. The team used RISA 2D for analysis because it could include material strengths and specs as well as all loading types to be specified separately (e.g. live, wind, etc.). Furthermore, the program includes the capability to apply a long list of LRFD load combinations (Appendix E, p. 43) to be applied in order to ensure the largest possible load combination is the one used for analysis for the purposes of safety.

Three models were created in RISA for the purposes of this project (see Appendix E). These models consider the base of the wall to be fixed due to the bedrock and strength of foundation, but add an extra 0.5 feet to the pole height to account for any flexibility at the base. A side view was used to find the deflections and foundation requirements (p. 44). A truss model was created to find the internal member forces to ensure the wood and bolts would be capable of withstanding all required loads (p. 47). A front view was created to determine the forces applied by the belay cables and the associated deflections (p. 50).

4.4 Foundation

Originally, NAU had asked the Capstone team not to use polyurethane expansion foam for the foundation due to issues that had occurred during construction of the Challenge Course. In order to determine what material would work best for the foundation, a decision matrix was created, shown below in Table 1.

	Compacted AB	Polyurethane Foam	Concrete
Safety	4	5	2
Cost	4	5	3
Durability	5	4	2
Ease of Construction	3	2	4
Strength	4	5	5
Effect on Wood	3	5	2
TOTAL	**23**	**26**	**18**

Table 1: Foundation Decision Matrix (1-lowest, 5-highest)

The three possible materials in Table 1 include compacted AB (soil), polyurethane expansion foam, and concrete. The materials were scored on a scale of 1-5 (1 being the lowest) on safety, price, durability, ease of construction, strength, and effect on wood over time. The criteria were based on the Capstone team's interpretation of NAU's concerns along with engineering concerns. The scores were based on the team's engineering knowledge and research.

After reviewing the results of the decision matrix, the Capstone determined that polyurethane expansion foam should be used, but would be sure to inform the construction team to allow for the proper training and information can be obtained prior to construction.

The team used the original geotechnical plans for the Challenge Course to determine that the ground was purely limestone. The loading determined from RISA results was applied against the strength of limestone and foam to ensure that the ground would support the structure and loading (see Appendix D, p. 37). The required depth of embedment was determined using ACCT standards, shown in Appendix A (p. 22). The excavation diameter is required to be a minimum of 6 inches larger than the pole diameter, as per the Rainbow Technology Manual (see Appendix B, p. 25).

4.5 Wood Strength (Poles, Face, and Deck)

The climbing wall was designed using wood or Trex decking, as required by NAU. Multiple varieties of wood were used within the design as well as multiple connection types. Each wood strength, loading, and connection had to be analyzed in order to ensure a safe and sufficient design.

4.5.1 Poles

NAU required that two cedar poles be used as the supports for the wall. The diameter of the poles slightly decreased along their length, however this was negligible as the poles would be shortened for the design and the decrease is less than an inch. The forces determined in RISA were used to compare the applied shear and moment forces to those that the wood could withstand (Appendix F, p. 41). To determine the strength of the poles, the ASD/LRFD, Manual for Engineered Wood Construction (2005 Edition) was used to calculate wood adjustment factors in order to determine the ultimate pole strength (Appendix F, p. 54).

Using the RISA computations with the added belay cable loading, the deflection at the top of the poles was too large for user comfort at about 12 inches. In order to mitigate this issue, a wood strut was added at the top of the poles as a compression member. The RISA model shows the reduced deflections (Appendix E, p. 52). To connect the support beam to the poles, a Simpson CJT3 was used (Appendix C, p. 26), as it is primarily a compression connection.

4.5.2 Face

The face of the wall is technically not wood, but Trex Deck. Trex Deck is made from PVC composite and given a natural, realistic wooden texture. The Trex requires very little maintenance and does not rot, splinter, or require painting. The Trex Deck will be placed in the vertical position as to prevent climbers from using the edges of the wood to aid in getting over the wall.

The frame is composed of Douglas-Fir Larch. The spacing between joists was set according to IBC 2006 standards, and moved closer than required for safety. The connections of the frame to the poles were designed using the 2005 Edition of ASD/LRFD, Manual for Engineered Wood Construction to ensure that shearing would not be a problem, and that connections and the wood would have sufficient strength. The connections of the deck frame to the joists used Simpson Strong-Tie specifications, which were significantly higher than the wood design strength values.

4.5.3 Deck Support Truss

The Capstone team was originally wanted to support the deck with a truss, but second-guessed this plan and considered supporting the deck with two wood columns that rested on the ground. To determine which design would go into place, a decision matrix was created and shown below in Table 2.

	Truss Supported Deck	**Post Supported Deck**
Safety	3	5
Cost	4	3
Durability	4	3
Ease of Construction	5	2
Aesthetics	5	3
TOTAL	**21**	**16**

Table 2: Deck Support System Decision Matrix (1=lowest, 5=highest)

The criteria in Table 2 were determined according to client suggestions as well as the engineering design. The criteria were ranked on a scale of 1-5 (1 being the lowest) by the Capstone team according to their experience, research, and interpretation of the client's needs. A truss supported deck was chosen because it won in every criterion with the exception of safety, which would be checked by the engineers with a factor of safety included.

Sawn lumber was used for the deck support truss. The species of the sawn lumber used was Douglas Fir-Larch, as it is easily obtainable and strong enough for the purposes of this project. When designing with wood, adjustment factors must be applied, which were determined from the 2005 Edition of ASD/LRFD, Manual for Engineered Wood Construction. The adjustment factors were applied to find the allowable forces for Douglas Fir-Larch (Appendix F, p.55), which were then compared to RISA outputs, found in Appendix F (p. 49).

4.6 Belay Cables

Belay cables were a requirement handed down from NAU. The height of the cables on the poles was determined according to ACCT standards (Appendix A, p. 22), as well as the required sag (Appendices A, p 22). The calculations for sag are shown in Appendix D (p. 38), using a load increased from the ACCT suggestion for added safety. The cable was checked for strength capabilities with a factor of safety of 5, as required by ACCT codes for life-safety devices (Appendix A, p. 22).

Once the cable loading was determined, the connection for the cable was analyzed (Appendix D, p. 40). The strength capacities of the eye bolt were determined using Hughes Brothers Inc. connections information. It was determined that the bolt could potentially pullout of the wood. To fix this problem a large washer was added behind the bolt to distribute the load over more of the wood (Appendix D, p. 39).

5. Cost Estimate

Although the labor of this project will be completed free of charge to NAU, a cost estimate was created for the purposes of the Capstone course. The budget includes the cost of labor of the engineers as well as physical labor, materials, and subcontracting for a comprehensive cost estimate. The cost estimate is inclusive of all items that are incorporated into the design and construction of the wall, and it is the responsibility of NAU to determine what is already in its possession and what will need to be purchased for the construction of the wall.

5.1 Design Costs

The mass of the project costs are for the design of the wall. The Capstone team is representing an engineering company, and "paying" their employees accordingly. The Capstone team is comprised of three engineers (for the purposes of this project). The use of their time is shown below in Table 3. The budget is based on a CPFP (Cost Plus Fixed Percentage) fee.

Tasks	Austin Hopper	Kelsey Deckert	Stephanie Sarty	Total Man-Hours Per Task	Labor Cost Per Task
Project Understanding					
Meeting with Owner (and Prep)	4	4	4	12	$600.00
Meeting with Advisor (and Prep)	4	4	4	12	$600.00
Research Codes and Materials			16	16	$800.00
Obtain Existing Documents	10		10	20	$1,000.00
Architectural Design					
Rough Calculations	6	10	6	22	$1,100.00
Preliminary Drawings	15			15	$750.00
Meeting with Owner (and Prep)	4	4	4	12	$600.00
Meeting with Advisor (and Prep)	4	4	4	12	$600.00
Structural Design					
Analyze Available Materials	5	15	5	25	$1,250.00
Structural Analysis	15	35	15	65	$3,250.00
Structural Member Design	5	15	40	60	$3,000.00
Foundations Requirements	6	6	2	14	$700.00
Construction Drawings	25	10	30	65	$3,250.00
Specifications	10	20	16	46	$2,300.00
Meeting with Advisor (and Prep)	16	16	16	48	$2,400.00
Submission for Review					
Submission	2			2	$100.00
Required Alterations to Design	15	15	10	40	$2,000.00
Meeting with Advisor (and Prep)	4	4	4	12	$600.00
Design Report					
Rough Draft of Design Report	3	10	5	18	
Final Draft of Design Report	4	5	5	14	
Total Man-Hours	157	177	196	530	
Total Engineer Time Cost: $26,500.00					
10% Profit: $2,650.00					
Total Engineer Design Cost: $29,150.00					

Table 2: Design Costs

The budget in Table 3 includes the time of the three engineers comprising the Capstone team. Each task within the schedule in Figure 4 will take the time of one or more of these three engineers, and estimates of time for completion were given in the table. At the end of each task, the total time was summed and multiplied by the wage (as it is the same for each engineer in this case) displayed in Appendix G (p. 56). The costs for completion of each task were then summed to find the "break even" cost of the project. This cost was then multiplied by 10% to find the profit the project will obtain. The total cost of the project, which the client would usually be billed for, is then the break even cost plus the profit.

The wage determination for engineers is given in Appendix G, and includes hourly payment plus overhead. The result of the budgeting is a total cost of $29,150 for 530 hours of engineer's labor and overhead, as well as a 10% profit. This does not include the cost of the review and stamp from a Professional Engineer. This cost will have to be determined by NAU through taking bids and/or negotiation.

5.2 Construction Costs

The construction costs include the cost of materials, physical labor, and the subcontractor used for excavation, which is all summarized below in Table 3. The material cost includes all materials required for the wall and does not exclude those materials that NAU already has in its possession. The labor costs will be done free of charge by a Construction Management team, but are included for the purposes of the Capstone course (Appendix G, p. 56). The subcontractor may be willing to do the work free of charge, however this has not been verified, so the costs are included (Appendix G, p. 56). The total cost of construction is summarized in Table 4.

Material Cost	$3,061.41
Labor Cost	$1,877.76
Subcontractor Cost	$1,500.00
Total Climbing Wall Cost	**$6,439.17**

Table 4: Total Construction Cost

5.3 Total Cost of Project

With the total design cost in addition to the total construction costs, the final cost estimation of the climbing wall design and implementation is summarized below in Table 5, with a grand total of $35,589.17. Much of this cost will not be charged to the client in reality, and was determined solely for the purposes of the Capstone course.

Total Design Cost	$29,150.00
Total Construction Cost	$6,439.17
Total Project Cost	**$35,589.17**

Table 5: Total Project Cost

The costs for the project are about 80% due to the design costs. The Capstone team realizes that this is unrealistic, but wanted to include the hours spent on the design for purposes of the Capstone course. If the project were given to an engineering firm the time would be greatly reduced and the cost would be significantly lowered. The additional amount of time required by the students was due to inexperience in the area, unfamiliarity with the codes and regulations, extra analysis suggested by advisors for the learning experience, and additional meeting time required for technical aid throughout the project.

6. Impact of Design

The NAU Challenge Course Climbing Wall has minimal impacts involving environmental, political, and economical aspects. Disturbing ground has the potential to present environmental impacts; however, the Challenge Course is already in place and has not caused any problems thus far. No trees will be removed and there are no endangered species known to the area. The Challenge Course as a whole improves the image of the University to future students and families, which provides a positive political impact. The NAU Challenge Course aims to make the course affordable to all social groups.

This project does not contain global or regulatory impacts. The Challenge Course only impacts Flagstaff and the surrounding vicinity that are able to access and use it. The new upgraded Challenge Course uses contemporary design methods. The environmental, political, and economic impacts do not play a major role in the design or the construction of the NAU Challenge Course Climbing Wall.

7. Conclusion

NAU had requested that the wall be designed and constructed by the first weekend in April. The Capstone team designed a schedule accordingly, requiring that the design be completed and submitted to a professional engineer by the beginning of March. Although the Capstone team completed and submitted the design by the planned date, there were misunderstandings between the engineering firm and NAU. The two are still caught up in debates on payment and bids from other firms. Due to this confusion, the climbing wall was unable to be built on time and the actual implementation date is still to be determined.

The final plan set prepared by the NAU Capstone team is included in Appendix I (p. 60) with the design and specifications of the climbing wall. The plan set, along with all of the calculations and program outputs were reviewed by John Tingerthal. Unfortunately, due to the delay caused by the issues between NAU and the professional engineer, Tingerthal did not receive the Capstone team's design for review until over a month behind the Capstone team's planned review period. This resulted in rushed review by Tingerthal as well as rushed corrections by the Capstone team.

After receiving the review from Tingerthal, the Capstone team addressed the issues. Hand calculations were redone according to comments on both fluidity and technical problems. The results lead to no changes in the design of the wall, but rather clarification throughout the appendices and in the plan set.

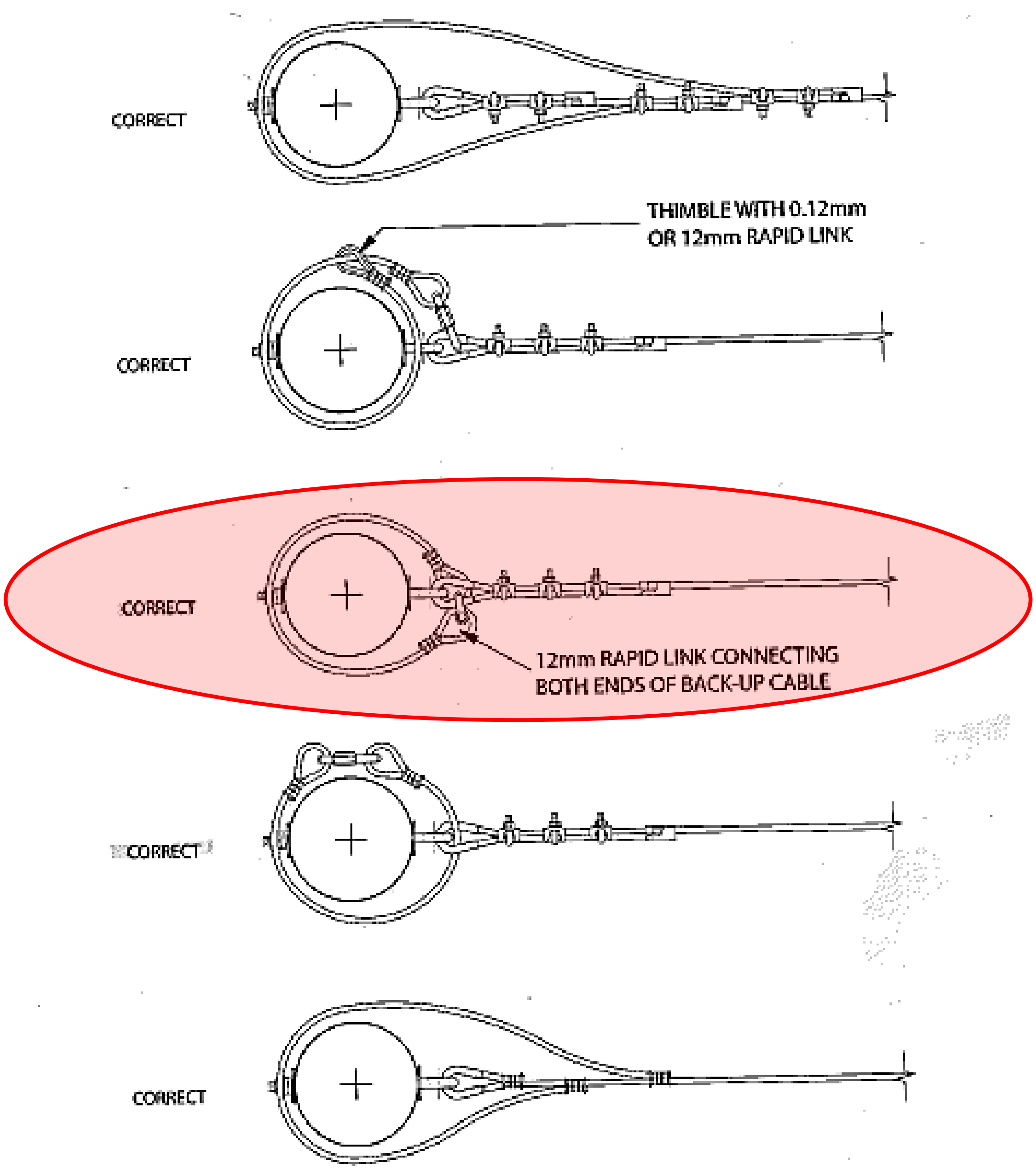
Appendix A

Information taken from ACCT

Belay Cable Attachments

DIAGRAMS FOR BACKUPS FOR BELAY CABLES AND CRITICAL GUYS

Examples of correct backups for belay cables and critical guys.



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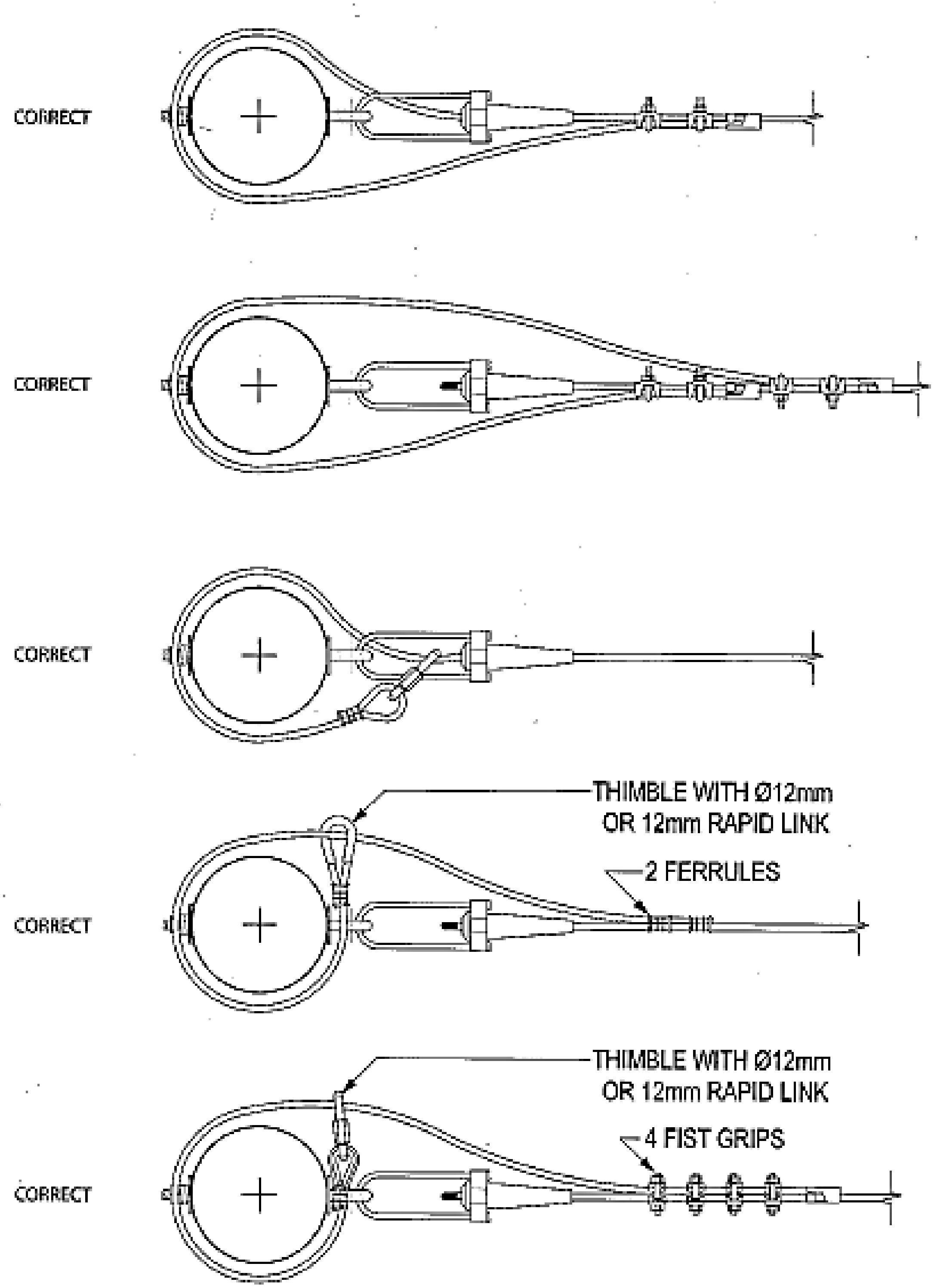
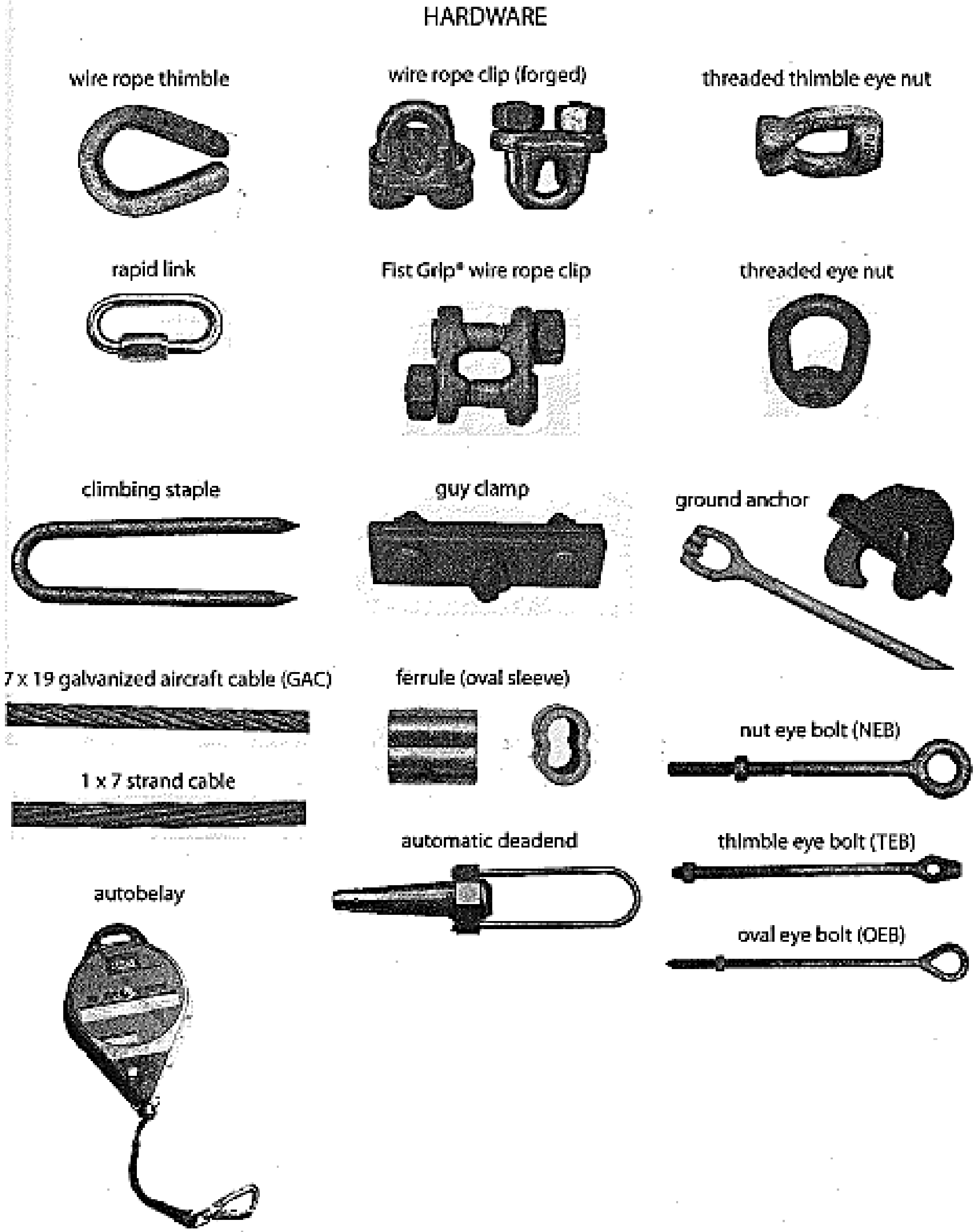

CORRECT
CORRECT
CORRECT
THIMBLE WITH Ø12mm
OR 12mm RAPID LINK
2 FERRULES
CORRECT
THIMBLE WITH Ø12mm
OR 12mm RAPID LINK
4 FIST GRIPS
CORRECT

Hardware



HARDWARE
wire rope thimble
wire rope clip (forged)
threaded thimble eye nut
rapid link
Fist Grip® wire rope clip
threaded eye nut
climbing staple
guy clamp
ground anchor
7 x 19 galvanized aircraft cable (GAC)
ferrule (oval sleeve)
1 x 7 strand cable
nut eye bolt (NEB)
automatic deadend
thimble eye bolt (TEB)
autobelay
oval eye bolt (OEB)

Factor of Safety

SECTION C: PERSONAL PROTECTION SYSTEMS AND ANCHORS

C1 BELAY CABLES

C1.1 Strength

The BELAY CABLE system, including terminations, anchors, and backups, SHALL be designed so that the minimum BREAKING STRENGTH of the cable system is five times the EXPECTED LOAD (the system DESIGN FACTOR is 5:1). The EXPECTED LOAD SHALL be determined by a QUALIFIED PERSON. Refer to Appendix A for a Discussion of Conventional Challenge Course Design and Standard E2 (Wire Rope) for more information on wire rope.

Belay Design

B2.3 Fastener Placement on Permanent Wood Poles

FASTENERS for BELAY CABLES, guy cables, PERSONAL PROTECTION ANCHORS, or other critical cables and FASTENERS on wood poles SHALL be

installed at least 12 inches (30.5 cm) from the top of a wood pole where there is no supplementary protection from the deterioration that occurs in this part of the pole (for example, rot and checks).

Foundation

Pole Setting

Under normal circumstances, wood poles are installed in "normal" ground to a minimum depth of 4 feet (122 cm) or 10% of their length plus 2 feet (61 cm), whichever is greater. Unusual media, such as sand, rock, and areas with high ground water may require different installation techniques that may require consultation with a professional engineer or other Qualified Person.

Sag

Belay Cable Sag

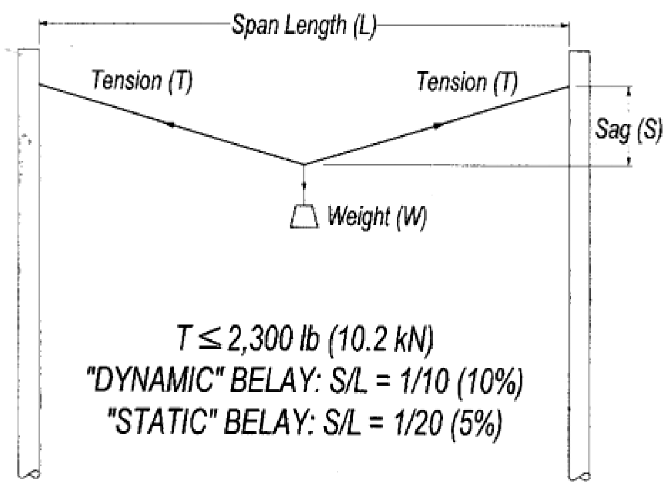
Installation and Equipment Standard C1.1 states the following: "The belay cable system, including terminations, anchors, and backups, shall be designed so that the minimum breaking strength of the cable system is five times the expected load (the system design factor is 5:1). The expected load shall be determined by a Qualified Person." On a conventionally designed horizontal belay cable using 3/8-inch 7 x 19 GAC and wire rope clips, the minimum breaking strength of the system is 11,500 lbf (51.2 kN); therefore, the working load limit is 2,300 lbf (10.2 kN). In order to assure that this load will be at or below 2,300 lbf (10.2 kN), the cable has a certain amount of sag when loaded (see Diagram AA1 below). The sag under load is different for static/self-belay elements and dynamic/top rope belay elements because the vertical load transmitted to the belay cable is approximately doubled with a dynamic/top rope belay.

If this conventional element is to be used with a dynamic/top rope belay, it is possible under normal circumstances for the participant(s) to generate vertical loads of up to 1,000 lbf (4.4 kN). This load is transmitted through the belay cable. In order to remain within the working load limit of 2,300 lbf (10.2 kN) on a loaded 3/8-inch (9.5 mm) 7 x 19 GAC cable system, a minimum sag/span ratio of 10% is required. For example, a loaded cable with 3 feet (91 cm) of sag in a 30-foot (9.1 m) span has a sag/span ratio of 10%. In other words, a loaded horizontal cable with a sag/span ratio of 10% shall not support more than 1,000 lbf (4.4 kN) of vertical load.

If the element is to be used *only* with a static/self belay (never with a dynamic/top rope belay), it is possible under normal circumstances for participant(s) to generate vertical loads of up to 500 lbf (2.2 kN). This load is also transmitted through the belay cable. In order to remain within the working load limit of 2,300 lbf (10.2 kN) on a loaded 3/8-inch (9.5 cm) 7 x 19 GAC cable system, a minimum sag/span ratio of 5% is required. For example, a loaded cable with 1.5 feet (46 cm) of sag in a 30-foot (9.1 m) span has a sag/span ratio of 5%. In other words, a loaded horizontal cable with a sag/span ratio of 5% shall not support more than 500 lbf (2.2 kN) of vertical load. The zip line element falls into this category, although due to the length of most zip lines, weight of the cable is an additional factor to consider.

It is somewhat impractical to create the 1,000 lbf (4.4 kN) load needed for an exact measurement of sag under load. A reasonable estimate may be made by suspending a weight of at least 200 lbf (0.9 kN) using a dynamic belay, and the sag measurement made. Another way of measuring the actual load in any cable is by using a tension meter (for example, a shunt-type strand dynamometer). In this case, the maximum tension can be determined by applying a known load (as referenced above) and then extrapolating by using the maximum expected static or dynamic load.

Diagram AA1



Appendix B

Information from Rainbow Technology

Rainbow's Pole Setting Foam

Technical Highlights

MATERIAL PROPERTIES AT (77ºF/25ºC)		
Property	**Value**	**Test Method**
Color		Visual
Part A	Light Brown	
Part B	Dark Brown	
Mixed	Yellow	
Working Life		
Rise Time	1.75 Minutes	ASTM D2237
Gel Time	2.5 Minutes - 3 Minutes	ASTM D2471
Tack Free Time	5.0 Minutes	
Full Cure Time	12 Hours	
Drasitic Temperature Change	Bonded - Little Chance of Cracking	
Performance (cured)		
Density	5.5 - 6.0 lbs/ft^3	ASTM D1622
Compressive Strength (psi)	75 Minimum	ASTM D1621
Porosity	>90% Closed-Cells	ASTM D2856
Water Absorption	0.02%	ASTM D2842
Shear Strength (psi)	42 Minimum	ASTM D732
Tensile Strength (psi)	64 Minimum	ASTM D1623
Cohesive Shear (dry)	22.9 psi	ASTM D3080
Cohesive Shear (wet)	20.9 psi	ASTM D3080
Chemical Resistance		ASTM D543
Water	Excellent	
Salt Water	Excellent	
Sulfuric Acid 20%	Excellent	
Gasoline	Excellent	
Diesel Fuel	Excellent	
Hydrochloric Acid 20%	Excellent	
Ammonium Hydroxide 10%	Good	
Sodium Hydroxide, Concentrate	Good	
Fungus	Excellent	

Rainbow's **Pole Setting Foam**

Volume Index Chart for Kit Requirements

1. Follow the chart to the correct hole diameter.
2. Follow the chart to the correct pole butt diameter (inches) and hole depth (feet).
3. The number will indicate the correct amount of foam needed in cubic feet.*

Example: 7 cubic feet of foam

Pole Diameter (Inches)	Hole Depth (Feet) 6	
18" Hole Diameter		
11.0	7	

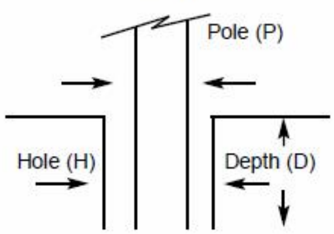
*These numbers have been rounded to the nearest cubic foot (+/-) to determine the needed amount of foam per application.

Example: 18" Hole Diameter
11" Pole Diameter
6' Depth
7 Cubic Feet of Foam

You can use the formula below to calculate the cubic feet of foam needed. In the formula, all dimensions are in inches.

Formula:

$$\frac{(H^2-P^2)D}{2200}$$



Catalog Number 79701 = 1 cubic foot kit
Catalog Number 79702 = 2 cubic feet kit
Catalog Number 79703 = 3 cubic feet kit
Catalog Number 79705 = 5 cubic feet kit
Catalog Number 79706 = 6 cubic feet kit
Catalog Number 79707 = 7 cubic feet kit

Pole Diameter (Inches)	Hole Depth (Feet) 4	5	6	7	8	9	10
8" Hole Diameter							
5.0	1	1					
6.2	1	1					
18" Hole Diameter							
7.0	6	8	9	11	12	13	15
8.0	6	7	9	10	12	12	14
9.0	6	7	8	9	11	12	13
10.0	5	6	8	9	9	11	12
11.0	5	6	7	8	9	10	11
12.0	4	5	6	7	8	9	10
13.0	4	4	5	6	7	7	9
14.0	3	4	4	5	6	6	7
15.0	2	3	4	4	5	5	6
16.0	2	2	2	3	3	3	4
24" Hole Diameter							
12.0	10	12	14	17	19	20	24
13.0	9	11	14	16	18	19	22
14.0	9	11	13	15	17	18	21
15.0	8	10	12	14	16	17	19
16.0	7	9	11	12	14	15	18
17.0	7	8	10	11	13	14	16
18.0	6	7	9	10	11	12	14
19.0	5	6	7	9	10	10	12
20.0	4	5	6	7	8	8	10
22.0	2	3	3	4	3	5	5
36" Hole Diameter							
18.0			32	37	43	45	53
20.0			30	34	39	42	49
22.0			27	31	36	38	44
24.0			24	28	32	34	39
26.0			21	24	27	29	33
28.0			17	20	23	24	27
30.0			13	15	18	19	21
32.0			9	11	12	13	15
34.0			5	6	6	7	7
	Hole Depth (Feet)						
48" Hole Diameter	7	8	9	10	11	12	14
36.0	39	44	47	55	61	66	77
38.0	33	38	40	47	52	56	66
40.0	27	31	33	39	42	46	54
42.0	21	24	25	30	33	36	41
44.0	14	16	17	20	22	24	28
46.0	8	8	9	10	12	12	15

Appendix C

Information for Connections

Architectural Products Group

ARCHITECTURAL PRODUCTS GROUP

SIMPSON Strong-Tie

CONCEALED JOIST TIES

The CJT is a concealed connector. It can be installed three ways: with no routing of header/post or beam; a routed header/post, or a routed beam.

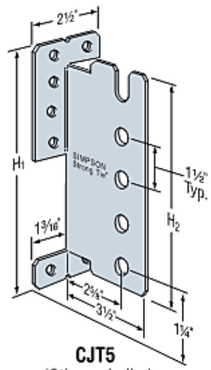
MATERIAL: 12 gauge **FINISH:** Galvanized

INSTALLATION: • Use all specified fasteners. See General Notes.

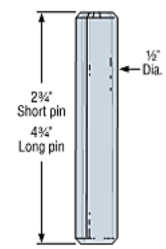
- The CJT Pack is supplied with all pins and screws required. Screws require a hex head driver.
- Router end of beam for screw heads for flush installation.
- The carried member may be sloped to 45° with full table loads.
- To provide maximum beam width for use with short pins, center in beam.
- To order: specify short (e.g. CJT3S) or long pins (e.g. CJT3L) *(see footnote #1 below)*.

OPTIONS: See technical bulletin T-CJT *(see page 230 for details)*.

CODES: See page 13 for Code Reference Key Chart.



CJT5
(Others similar)

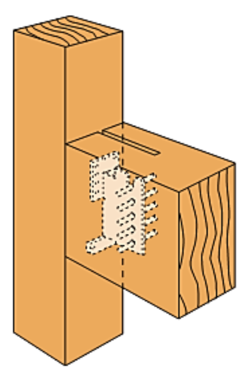


Chamfered Steel Pin
(Galvanized)

WARNING:
This connector requires special attention to ensure correct installation. The beam must be installed perpendicular to the support member. The connection's components may be damaged if the beam is rotated from its opposite end during or after installation. Damaged components may not be noticeable and may reduce the connector's load carrying capacity.

Model No.	Min. Joist Size	Dimensions		Fasteners		Allowable Loads				Code Ref.
		H_1	H_2	SDS	Pins (2¾" or 4¾")[2]	Uplift (160)	Floor (100)	Snow (115)	Roof (125)	
DOUGLAS FIR										
CJT3	4x6	5 9/16	4 7/16	6	3	985	1050	1050	1050	I18, F17
	4x8	5 9/16	4 7/16	6	3	1655	1050	1050	1050	
CJT4	4x10	7	5 15/16	8	4	2460	2440	2805	2815	
CJT5	4x12	8 9/16	7 7/16	10	5	3255	3005	3455	3755	
CJT6	4x12	10	8 15/16	12	6	4005	3535	3990	3990	
GLULAM BEAM										
CJT3	3⅛x7½	5 9/16	4 7/16	6	3	1655	1240	1240	1240	I18, F17
CJT4	3⅛x9	7	5 15/16	8	4	2460	2440	2805	2900	
CJT5	3⅛x10½	8 9/16	7 7/16	10	5	3255	3005	3455	3755	
CJT6	3⅛x12	10	8 15/16	12	6	4005	3535	4065	4420	
PSL										
CJT3	3½x9½	5 9/16	4 7/16	6	3	1655	1840	2115	2160	I18, F17
CJT4	3½x9½	7	5 15/16	8	4	2460	2145	2145	2145	
CJT5	3½x9½	8 9/16	7 7/16	10	5	3255	3005	3455	3755	
CJT6	3½x11⅞	10	8 15/16	12	6	4005	3535	4065	4420	

1. Center pin in beam. Short pin (2¾") for use with 3⅛ GLB, 4x sawn lumber or 3½" wide PSL. Long pin (4¾") for use with 5⅛ GLB, 6x sawn lumber or greater widths.
2. See technical bulletin T-CJT for additional load information with long pins *(see page 230 for details)*.



Typical CJT Installation
(Note that pins should be centered within beam)

SDS ¼"x3"
U.S. Patent 6,109,850 5,897,280

SIMPSON Strong-Tie

LTP4/LTP5/A34/A35 *Framing Angles & Plates*

The larger LTP5 spans subfloor at the top of the blocking or rim joist. The embossments enhance performance.

The LTP4 Lateral Tie Plate transfers shear forces for top plate-to-rim joist or blocking connections. Nail holes are spaced to prevent wood splitting for single and double top plate applications. May be installed over plywood sheathing.

The A35 anchor's exclusive bending slot allows instant, accurate field bends for all two- and three-way ties. Balanced, completely reversible design permits the A35 to secure a great variety of connections.

MATERIAL: LTP4/LTP5–20 gauge; all others–18 gauge

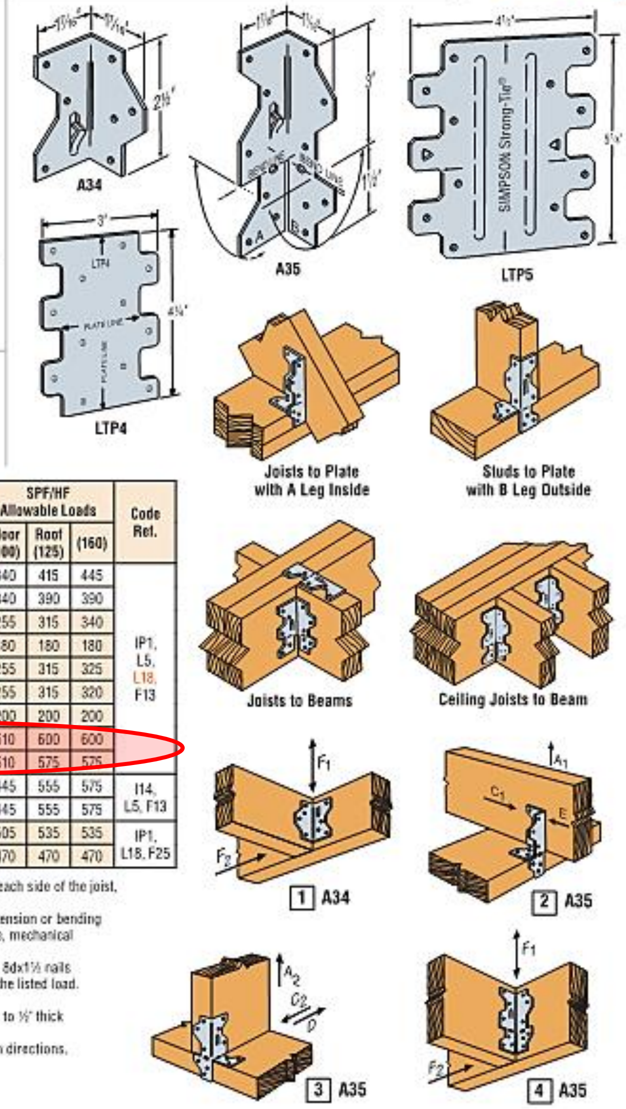
FINISH: Galvanized. Some products available in stainless steel or ZMAX® coating; see Corrosion Information, page 14-15.

INSTALLATION: • Use all specified fasteners. See General Notes.
• A35–Bend one time only.

CODES: See page 13 for Code Reference Key Chart.

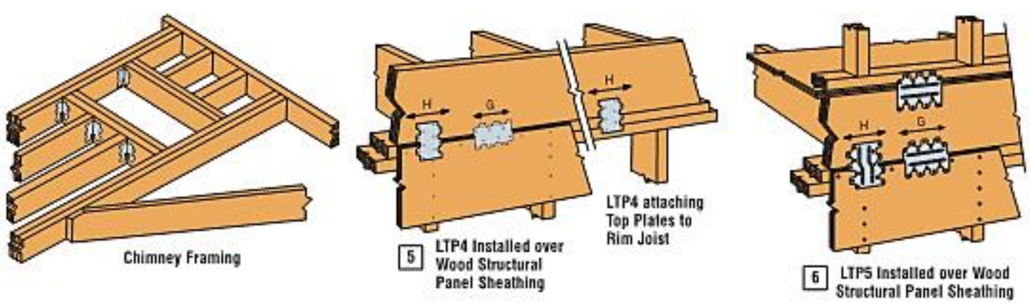
These products are available with additional corrosion protection. Additional products on this page may also be available with this option, check with Simpson Strong-Tie for details.

These products are approved for installation with the Strong-Drive SD Structural-Connector screw. See page 27 for more information.



Model No.	Type of Connection	Fasteners	Direction of Load	DF/SP Allowable Loads Floor (100)	DF/SP Allowable Loads Roof (125)	DF/SP Allowable Loads (160)	SPF/HF Allowable Loads Floor (100)	SPF/HF Allowable Loads Roof (125)	SPF/HF Allowable Loads (160)	Code Ref.
A34	1	8-8dx1½	F_1	395	485	515	340	415	445	IP1, L5, L18, F13
			F_2[5]	395	455	455	340	390	390	
A35	2	9-8dx1½	A_1, E	295	365	395	255	315	340	
			C_1	210	210	210	180	180	180	
	3	12-8dx1½	A_2	295	365	380	255	315	325	
			C_2	295	365	370	255	315	320	
			D	230	230	230	200	200	200	
	4	12-8dx1½	F_1	595	695	695	510	600	600	
			F_2[5]	595	670	670	510	575	575	
LTP4	5	12-8dx1½	G	515	645	670	445	555	575	I14, L5, F13
			H	515	645	670	445	555	575	
LTP5	6	12-8dx1½	G	585	620	620	505	535	535	IP1, L18, F25
			H	545	545	545	470	470	470	

1. Allowable loads are for one anchor. When anchors are installed on each side of the joist, the minimum joist thickness is 3".
2. Some illustrations show connections that could cause cross-grain tension or bending of the wood during loading if not reinforced sufficiently. In this case, mechanical reinforcement should be considered.
3. LTP4 can be installed over ⅜" wood structural panel sheathing with 8dx1½ nails and achieve 0.72 of the listed load, or over ½" and achieve 0.64 of the listed load. 8d commons will achieve 100% load.
4. The LTP5 may be installed over wood structural panel sheathing up to ½" thick using 8dx1½ nails with no reduction in load.
5. Connectors are required on both sides to achieve F_2 loads in both directions.
6. **NAILS:** 8dx1½ = 0.131" dia. x 1½" long.
See page 22-23 for other nail sizes and information.



T and L *Strap Ties*

T and L Strap Ties are versatile utility straps. See Architectural Products Group for aesthetically pleasing options with black powder-coated paint.

FINISH: Galvanized. See Corrosion Information, page 14-15.

CODES: See page 13 for Code Listing Key Chart.

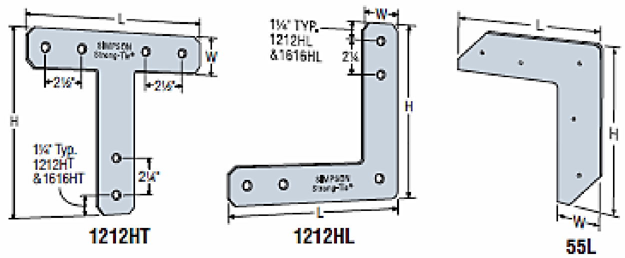
Model No.	Ga	Dimensions			Fasteners			Code Ref.
		L	H	W	Nails	Bolts Qty	Bolts Dia	
55L	16	4¾	4¾	1¼	5-10d	—	—	180
66L	14	6	6	1½	10-16d	3	⅜	
88L	14	8	8	2	12-16d	3	½	
1212L	14	12	12	2	14-16d	3	½	
66T	14	6	5	1½	8-16d	3	⅜	
128T	14	12	8	2	12-16d	3	½	
1212T	14	12	12	2	12-16d	3	½	

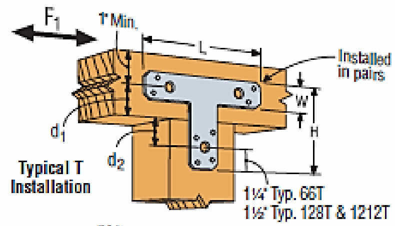
1. These connectors are not load-rated.
2. **NAILS:** 16d = 0.162" dia. x 3½" long, 10d = 0.148" dia. x 3" long. See page 22-23 for other nail sizes and information.

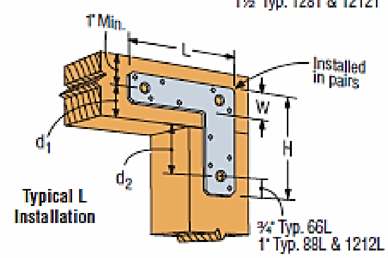
These products are available with additional corrosion protection. Additional products on this page may also be available with this option, check with Simpson Strong-Tie for details.

Model No.	Ga	Dimensions			Minimum Bolt End & Edge Distances		Bolts		Allowable Loads[1,2] Tension/Uplift (100/160)	Allowable Loads[1,2] F_1 (100/160)	Code Ref.
		W	H	L	d_1	d_2	Qty	Dia			
1212HL	7	2½	12	12	2½	4⅜	5	⅝	1535	565	170
1616HL	7	2½	16	16	2½	4⅜	5	⅝	1535	565	
1212HT	7	2½	12	12	2½	4⅜	6	⅝	2585	815	
1616HT	7	2½	16	16	2½	4⅜	6	⅝	2585	815	

1. 1212HL, 1616HL, 1212HT and 1616HT are to be installed in pairs with machine bolts in double shear. A single part with machine bolts in single shear is not load-rated.
2. Allowable loads are based on a minimum member thickness of 3½".
3. 1212HT, 1616HT loads assume a continuous beam.







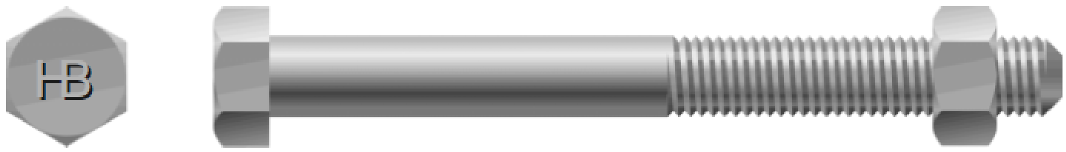
Straps & Ties

17

Home

Fasteners - Bolts

Hex Head Bolts



1/2" Hex Head Bolts

Stock No.	Item Description	Std. Pkg.	Weight 100 Pcs.
HB51-1/2-1-1/4	1/2" x 1-1/2"	250	20 lbs.
HB52-1-1/4	1/2" x 2"	250	23 lbs.
HB52-1/2-1-1/4	1/2" x 2-1/2"	250	25 lbs.
HB53-1-1/4	1/2" x 3"	250	28 lbs.
HB53-1/2-1-1/4	1/2" x 3-1/2"	200	31 lbs.
HB54-1-1/4	1/2" x 4"	100	33 lbs.
HB54-1/2-1-1/4	1/2" x 4-1/2"	100	36 lbs.
HB55-1-3/4	1/2" x 5"	100	39 lbs.
HB55-1/2-1-1/4	1/2" x 5-1/2"	100	41 lbs.
HB56-3	1/2" x 6"	100	44 lbs.
HB57-3	1/2" x 7"	100	49 lbs.
HB58-4	1/2" x 8"	100	55 lbs.
HB59-4	1/2" x 9"	50	60 lbs.
HB510-4	1/2" x 10"	50	65 lbs.
HB512-6	1/2" x 12"	50	76 lbs.
HB514-6	1/2" x 14"	50	87 lbs.

5/8" Hex Head Bolts

Stock No.	Item Description	Std. Pkg.	Weight 100 Pcs.
HB61-1/2-1-1/4	5/8" x 1-1/2"	100	31 lbs.
HB61-3/4-1-1/4	5/8" x 1-3/4"	100	33 lbs.
HB62-1-1/2	5/8" x 2"	100	35 lbs.
HB63-1-1/2	5/8" x 3"	100	44 lbs.
HB64-1-1/2	5/8" x 4"	100	52 lbs.
HB65-1-1/2	5/8" x 5"	100	60 lbs.
HB66-1-1/2	5/8" x 6"	50	68 lbs.
HB67-3	5/8" x 7"	50	77 lbs.
HB68-4	5/8" x 8"	50	85 lbs.
HB610-4	5/8" x 10"	50	101 lbs.
HB612-6	5/8" x 12"	40	118 lbs.
HB614-6	5/8" x 14"	40	134 lbs.
HB616-6	5/8" x 16"	40	151 lbs.
HB618-6	5/8" x 18"	30	167 lbs.
HB620-6	5/8" x 20"	30	184 lbs.

3/4" Hex Head Bolts

Stock No.	Item Description	Std. Pkg.	Weight 100 Pcs.
HB72-1-3/4	3/4" x 2"	100	56 lbs.
HB72-1/2-1-3/4	3/4" x 2-1/2"	100	62 lbs.
HB73-1-3/4	3/4" x 3"	100	68 lbs.
HB74-2	3/4" x 4"	50	80 lbs.
HB75-2	3/4" x 5"	50	91 lbs.
HB76-3	3/4" x 6"	50	103 lbs.
HB77-3	3/4" x 7"	40	115 lbs.
HB78-4	3/4" x 8"	40	127 lbs.
HB710-4	3/4" x 10"	30	151 lbs.
HB712-6	3/4" x 12"	30	175 lbs.
HB714-6	3/4" x 14"	30	198 lbs.
HB716-6	3/4" x 16"	25	222 lbs.
HB718-6	3/4" x 18"	20	246 lbs.
HB720-6	3/4" x 20"	20	270 lbs.
HB722-6	3/4" x 22"	20	293 lbs.
HB724-6	3/4" x 24"	15	317 lbs.
HB726-6	3/4" x 26"	15	341 lbs.
HB728-8	3/4" x 28"	15	365 lbs.
HB730-8	3/4" x 30"	10	390 lbs.
HB732-8	3/4" x 32"	10	424 lbs.

Note: Other lengths available.

Hughes Brothers, Inc.
P.O. Box 159 / 210 N. 13th / Seward, NE 68434 / Phone (402) 643-2991 / Fax (402) 643-2149

Fasteners - Washers

Home

Round Washers

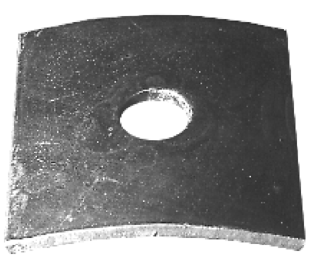
Hughes Brothers Round Washers are galvanized in accordance with ASTM A153 standards.

Stock No.	Bolt Size	Hole Size	Outside Dia.	Thickness	Std. Pkg.	Weight 100 Pcs.
RW1-30	3/8"	7/16"	1"	14 ga.	1,000	2 lbs.
RW2-30	3/8"	7/16"	2"	11 ga.	200	21 lbs.
RW1-3/8-50	1/2"	9/16"	1-3/8"	10 ga.	500	3 lbs.
RW1-1/2-50	1/2"	9/16"	1-1/2"	11 ga.	500	10 lbs.
RW2-50	1/2"	9/16"	2"	1/4"	200	21 lbs.
RW1-1/2-60	5/8"	11/16"	1-1/2"	11 ga.	500	10 lbs.
RW2-60	5/8"	11/16"	2"	1/4"	200	21 lbs.
RW3-60	5/8"	11/16"	3"	1/4"	100	50 lbs.
RW2-70	3/4"	13/16"	2"	1/4"	200	21 lbs.
RW3-70	3/4"	13/16"	3"	1/4"	100	50 lbs.
RW2-80	7/8"	15/16"	2"	1/4"	200	21 lbs.
RW3-80	7/8"	15/16"	3"	1/4"	100	45 lbs.
RW3-100	1"	1-1/16"	3"	1/4"	100	42 lbs.

Home

Fasteners - Washers

Square Curved Washers

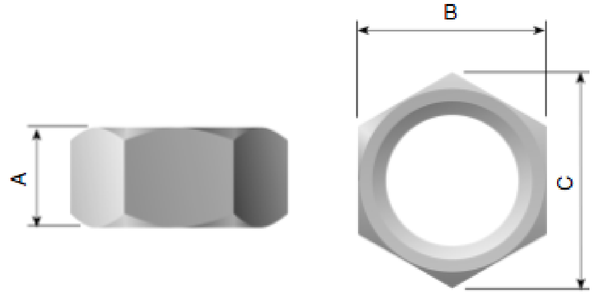


Hughes Brothers Square Curved Washers are curved edge-to-edge. Square curved washers are galvanized in accordance with ASTM A153.

Stock No.	Bolt Size	Hole Size	Outside Dimensions/ Thickness	Std. Pkg.	Weight 100 Pcs.
SCW3-60	5/8"	11/16"	3" x 3" x 1/4"	100	63 lbs.
SCW3-70	3/4"	13/16"	3" x 3" x 1/4"	100	63 lbs.
SCW4-60	5/8"	11/16"	4" x 4" x 1/4"	50	113 lbs.
SCW4-70	3/4"	13/16"	4" x 4" x 1/4"	50	113 lbs.
SCW4-80	7/8"	15/16"	4" x 4" x 1/4"	50	113 lbs.
SCW4-100	1"	1-1/16"	4" x 4" x 1/4"	50	113 lbs.

Hex Nuts

Hughes Brothers Hex Nuts are compatible with all ANSI C135.1 hardware. Hex nuts are tapped oversize in accordance with ASTM A563.



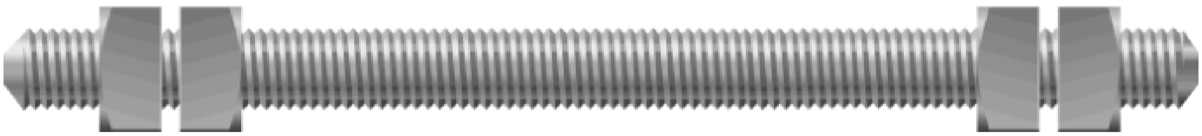
Stock No.	Item Description	A	B	C	Weight 100 Pcs.
HN30	3/8"	21/64"	9/16"	5/8"	2 lbs.
HN50	1/2"	7/16"	3/4"	7/8"	4 lbs.
HN60	5/8"	35/64"	15/16"	1"	9 lbs.
HN70	3/4"	41/64"	1-1/8"	1-1/4"	10 lbs.
HN80	7/8"	3/4"	1-5/16"	1-1/2"	20 lbs.
HN100	1"	55/64"	1-1/2"	1-5/8"	27 lbs.
HN120	1-1/4"	1-1/16"	1-7/8"	2-1/8"	55 lbs.

Hughes Brothers, Inc.
P.O. Box 159 / 210 N. 13th / Seward, NE 68434 / Phone (402) 643-2991 / Fax (402) 643-2149

Home

Fasteners - Threaded Rods

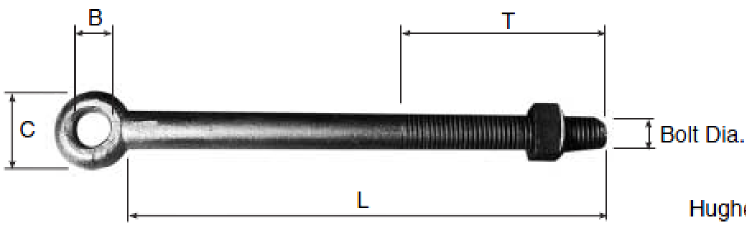
Full Threaded Rods



Stock No.	Item Description	Std. Pkg.	Weight 100 Pcs.
1/2" Full Threaded Rods			
TR512-F	1/2" x 12"	50	75 lbs.
TR514-F	1/2" x 14"	50	84 lbs.
TR516-F	1/2" x 16"	50	94 lbs.
TR520-F	1/2" x 20"	50	112 lbs.
TR522-F	1/2" x 22"	50	121 lbs.
TR524-F	1/2" x 24"	50	130 lbs.
5/8" Full Threaded Rods			
TR612-F	5/8" x 12"	25	125 lbs.
TR614-F	5/8" x 14"	25	139 lbs.
TR616-F	5/8" x 16"	25	154 lbs.
TR620-F	5/8" x 20"	25	182 lbs.
TR622-F	5/8" x 22"	25	196 lbs.
TR624-F	5/8" x 24"	25	211 lbs.
3/4" Full Threaded Rods			
TR712-F	3/4" x 12"	30	180 lbs.
TR714-F	3/4" x 14"	30	205 lbs.
TR716-F	3/4" x 16"	25	221 lbs.
TR718-F	3/4" x 18"	25	242 lbs.
TR720-F	3/4" x 20"	20	262 lbs.
TR722-F	3/4" x 22"	20	283 lbs.
TR724-F	3/4" x 24"	15	304 lbs.
TR726-F	3/4" x 26"	15	325 lbs.
TR728-F	3/4" x 28"	15	346 lbs.
TR730-F	3/4" x 30"	15	366 lbs.
TR732-F	3/4" x 32"	10	387 lbs.
TR734-F	3/4" x 34"	10	408 lbs.
TR736-F	3/4" x 36"	10	429 lbs.
TR738-F	3/4" x 38"	10	449 lbs.
TR740-F	3/4" x 40"	10	470 lbs.
TR742-F	3/4" x 42"	10	491 lbs.

Stock No.	Item Description	Std. Pkg.	Weight 100 Pcs.
7/8" Full Threaded Rods			
TR812-F	7/8" x 12"	20	262 lbs.
TR814-F	7/8" x 14"	20	291 lbs.
TR816-F	7/8" x 16"	15	320 lbs.
TR818-F	7/8" x 18"	15	349 lbs.
TR820-F	7/8" x 20"	15	378 lbs.
TR822-F	7/8" x 22"	15	406 lbs.
TR824-F	7/8" x 24"	10	435 lbs.
TR826-F	7/8" x 26"	10	464 lbs.
TR828-F	7/8" x 28"	10	493 lbs.
TR830-F	7/8" x 30"	10	522 lbs.
TR832-F	7/8" x 32"	10	551 lbs.
TR834-F	7/8" x 34"	10	580 lbs.
TR836-F	7/8" x 36"	10	609 lbs.
TR838-F	7/8" x 38"	10	638 lbs.
TR840-F	7/8" x 40"	5	667 lbs.
TR842-F	7/8" x 42"	5	696 lbs.

2724 Forged Eyebolt



Hughes Brothers 2724 Forged Eyebolts are manufactured from SAE C1018 cold drawn or ASTM A36 steel. Hughes Brothers eyebolts are hot dip galvanized in accordance with ASTM A153. Each 2724 shoulder eyebolt is furnished with one nut.

Also available in 1" and 1-1/4" diameter rod by special order.

Tensile Strengths

Bolt Diameter	Minimum Tensile Strength
1/2"	7,800 lbs.
5/8"	12,400 lbs.
3/4"	18,350 lbs.
7/8"	25,400 lbs.

Stock No.	Bolt Dia.	L	T	B	C	Weight 100 Pcs.
1/2" Forged Eyebolts						
2724.56-4	1/2"	6"	4"	11/16"	1-1/4"	39 lbs.
2724.58-4	1/2"	8"	4"	11/16"	1-1/4"	51 lbs.
2724.510-4	1/2"	10"	4"	11/16"	1-1/4"	62 lbs.
2724.512-4	1/2"	12"	4"	11/16"	1-1/4"	73 lbs.
2724.514-4	1/2"	14"	4"	11/16"	1-1/4"	84 lbs.
2724.516-4	1/2"	16"	4"	11/16"	1-1/4"	95 lbs.
2724.518-4	1/2"	18"	4"	11/16"	1-1/4"	107 lbs.
2724.520-4	1/2"	20"	4"	11/16"	1-1/4"	117 lbs.
5/8" Forged Eyebolts						
2724.64-2	5/8"	4"	2"	13/16"	1-5/8"	48 lbs.
2724.64-3	5/8"	4"	3"	13/16"	1-5/8"	48 lbs.
2724.65-3	5/8"	5"	3"	13/16"	1-5/8"	60 lbs.
2724.66-3	5/8"	6"	3"	13/16"	1-5/8"	68 lbs.
2724.68-4	5/8"	8"	4"	13/16"	1-5/8"	85 lbs.
2724.610-4	5/8"	10"	4"	13/16"	1-5/8"	101 lbs.
2724.612-4	5/8"	12"	4"	13/16"	1-5/8"	124 lbs.
2724.614-6	5/8"	14"	6"	13/16"	1-5/8"	132 lbs.
2724.616-6	5/8"	16"	6"	13/16"	1-5/8"	150 lbs.
2724.618-6	5/8"	18"	6"	13/16"	1-5/8"	167 lbs.
2724.620-6	5/8"	20"	6"	13/16"	1-5/8"	187 lbs.
2724.622-6	5/8"	22"	6"	13/16"	1-5/8"	200 lbs.
2724.624-6	5/8"	24"	6"	13/16"	1-5/8"	220 lbs.
2724.626-8	5/8"	26"	8"	13/16"	1-5/8"	236 lbs.
2724.628-8	5/8"	28"	8"	13/16"	1-5/8"	252 lbs.
2724.630-8	5/8"	30"	8"	13/16"	1-5/8"	268 lbs.
2724.632-8	5/8"	32"	8"	13/16"	1-5/8"	289 lbs.
2724.634-8	5/8"	34"	8"	13/16"	1-5/8"	307 lbs.

Stock No.	Bolt Dia.	L	T	B	C	Weight 100 Pcs.
3/4" Forged Eyebolts						
2724.74-2	3/4"	4"	2"	13/16"	1-7/8"	80 lbs.
2724.75-3	3/4"	5"	3"	13/16"	1-7/8"	88 lbs.
2724.76-3	3/4"	6"	3"	13/16"	1-7/8"	105 lbs.
2724.77-3	3/4"	7"	3"	13/16"	1-7/8"	116 lbs.
2724.78-4	3/4"	8"	4"	13/16"	1-7/8"	128 lbs.
2724.710-4	3/4"	10"	4"	13/16"	1-7/8"	150 lbs.
2724.712-4	3/4"	12"	4"	13/16"	1-7/8"	175 lbs.
2724.714-6	3/4"	14"	6"	13/16"	1-7/8"	199 lbs.
2724.716-6	3/4"	16"	6"	13/16"	1-7/8"	219 lbs.
2724.718-6	3/4"	18"	6"	13/16"	1-7/8"	246 lbs.
2724.720-6	3/4"	20"	6"	13/16"	1-7/8"	271 lbs.
2724.722-6	3/4"	22"	6"	13/16"	1-7/8"	295 lbs.
2724.724-6	3/4"	24"	6"	13/16"	1-7/8"	321 lbs.
2724.726-8	3/4"	26"	8"	13/16"	1-7/8"	345 lbs.
2724.728-8	3/4"	28"	8"	13/16"	1-7/8"	369 lbs.
7/8" Forged Eyebolts						
2724.85-3	7/8"	5"	3"	15/16"	2-1/8"	108 lbs.
2724.86-3	7/8"	6"	3"	15/16"	2-1/8"	126 lbs.
2724.87-3	7/8"	7"	3"	15/16"	2-1/8"	145 lbs.
2724.88-4	7/8"	8"	4"	15/16"	2-1/8"	163 lbs.
2724.810-4	7/8"	10"	4"	15/16"	2-1/8"	201 lbs.
2724.812-4	7/8"	12"	4"	15/16"	2-1/8"	237 lbs.
2724.814-6	7/8"	14"	6"	15/16"	2-1/8"	276 lbs.
2724.816-6	7/8"	16"	6"	15/16"	2-1/8"	308 lbs.
2724.818-6	7/8"	18"	6"	15/16"	2-1/8"	344 lbs.
2724.820-6	7/8"	20"	6"	15/16"	2-1/8"	379 lbs.
2724.822-6	7/8"	22"	6"	15/16"	2-1/8"	407 lbs.
2724.824-6	7/8"	24"	6"	15/16"	2-1/8"	452 lbs.
2724.826-8	7/8"	26"	8"	15/16"	2-1/8"	467 lbs.

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Appendix D

Hand Calculations

Loading

* Loads

- From ASCE 7-05:
  + Deck Dead = 7 psf
  + Deck Snow = 48 psf
  + Deck Live = 100 psf
  + Wind = 24.4 psf
    * 90 mph

Note: Deck Dead is applied only to the back horizontal deck.

- Live Load: $(100\ lb/ft^2)(4\ ft)(8\ ft) \Rightarrow LL = 3200\ lb$
- Dead Load: $(7\ lb/ft^2)(4\ ft)(8\ ft) \Rightarrow DL = 224\ lb$.
- Snow Load: $(48\ lb/ft^2)(4\ ft)(8\ ft) \Rightarrow SL = 1536\ lb$
  + SL will be ignored b/c SL & LL will not be applied at same time & LL governs.
- Wind Load: $(24.4\ lb/ft^2)(12\ ft)(9\ ft) = 2635.2\ lb$

Front Face Loads for Simpson A35

Climbing Wall-FrontDeck loads for Simpson A35

Wind load = 24.4 PSF

Load Area = 92" W X 135" L = 12,420 in^2 ÷ 144" = 86.25 ft^2

Total Wind load on face of Deck = 86.25 ft^2 • 24.4 PSF = 2104.5 lbs

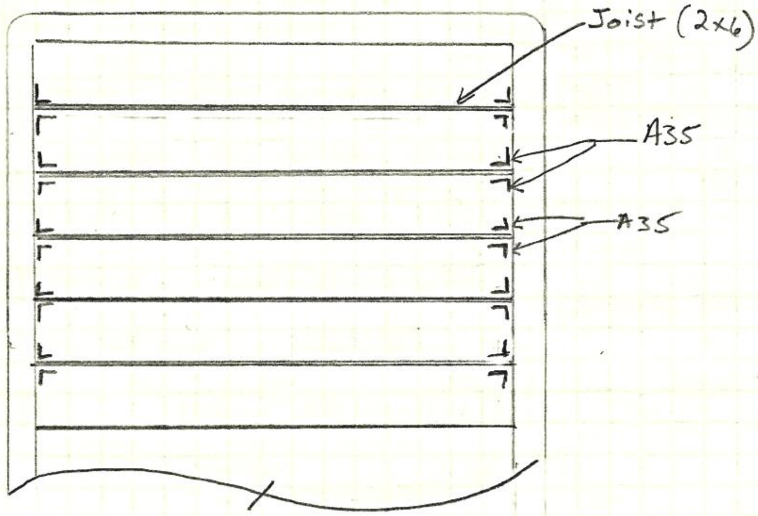
# of Joists = 11ea

# of A35 = 44ea

load per Joist = $\frac{2104.5 \text{ lbs}}{11 \text{ Joists}}$ = 191.32 lbs

A35 Sipson tie Allowable load (Each) = 510lb – From Simpson tie

Allowable load Per Joist = 510lb • 4 = 2040lb



Rear Deck Joist Hangers - A35

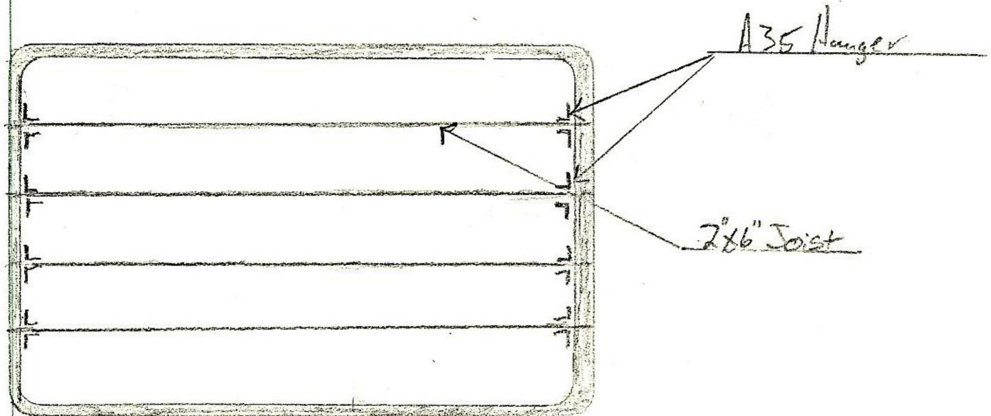
load Area = 55 5/8" x 84" = $\frac{4672.5 \text{ in}^2}{144 \text{ in}}$ = 32.45 ft²

Live load = 100 psf

Deck live load = 100 psf · 32.45 ft² = 3245 lb

# of Joists = 4

# of A35 = 16



* Actual load per Joist $= \frac{3245 \text{ lb}}{4} =$ 811.25 lb

A35 Simpson tie Allowable load (Each) = 510 lb — (from Simpson tie)

* Allowable per Joist = 510 · 4 = 2040 lb

Foundation

• Vertically:

- Vertical Foundation Pressure of Rock: 4,000psF

+ $A_{c\text{-}s} = \left(\frac{\pi}{4}\right)(1)^2 = 0.785\ Ft^2$

+ $P_{allow} = 4{,}000\frac{lb}{Ft^2}\left(0.785Ft^2\right) = 3.14K$

- $P_{applied} = 2.138K$ (RISA, Appendix C)

$P_{applied} < P_{allowed}$ ✓

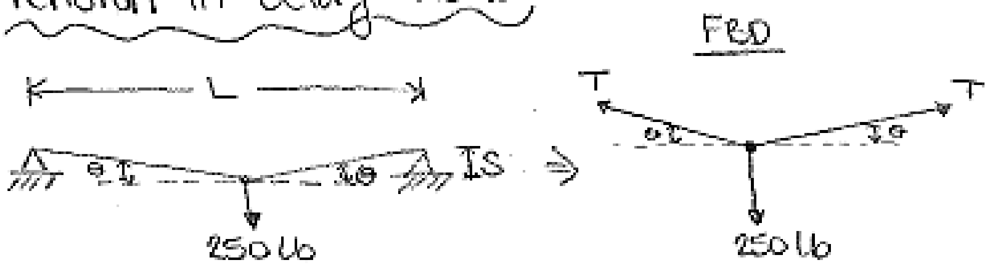
$$\frac{P_{allowed}}{P_{applied}} = \frac{3.14}{2.138} = 1.47 = FS$$

• Depth of Embedment:

= minimum of 4 Feet

Belay Cables

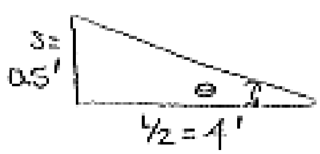
* Tension in Belay Cable



- CCCZLT Standards (pg 69): $S/L = 1/20$ for Static Belay

$L = 8' \Rightarrow S_{min} = 1/20(8) = 2/5 = 0.4$ feet $= S_{min}$

+ Will use $S = 0.5$ feet

- 

$\tan\theta = \frac{0.5}{4} \Rightarrow \theta = \tan^{-1}\left(\frac{0.5}{4}\right) \Rightarrow$

$\theta = 7.125°$

- $+\uparrow \sum F_y = 0 = 2T(\sin\theta) - 250\text{ lb} \Rightarrow T = \frac{250\text{ lb}}{2\sin(7.125°)} \Rightarrow$

$T = 1{,}007.78\text{ lb} * 5 = 5038.91\text{ lb}$ (CCCZLT Standards pg. 10 Section C1.1)

Tension in cables: 5039 lb

* Multiline II Rope:

diameter = 1/2" → Tensile Strength = 5,800 lb

- **Minimum Rope diameter = 1/2"**

* GAC Wire Rope:

diameter = 3/8" → minimum breaking strength / lbs = 14,400
7 x 19 construction

* Belay Cable Attachment

Wood Bearing:

$F_{3"} = 560\ \text{lb/in}^2$

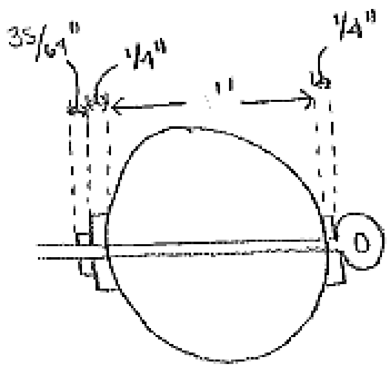
$F_{c\perp} \geq \frac{1.875}{\phi}(F_{c\perp}) = \frac{1.875}{0.9}(255\ \text{lb/in}^2) = 531.25\ \frac{\text{lb}}{\text{in}^2}$

$F_{3"} > F_{c\perp}$ ∴ Must use bigger washer

$F_{4"} = 315\ \text{lb/in}^2$, $F_{4"} < F_{c\perp}$ ✓

∴ 4x4x1/4 Curved Washer (does not come in 1/2" ø bolt size)

Use 5/8" ø Forged Eye Bolt (2724.616-6) with 4"x4" Curved Washer (CW60) and 5/8" ø Hex Nut (HN60) from Hughes Brothers, Inc.



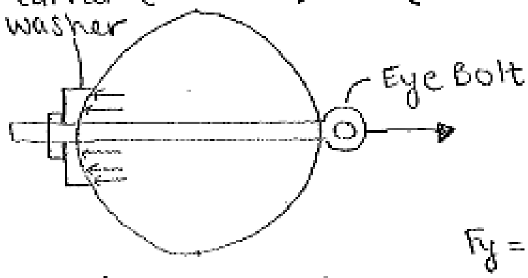
Minimum bolt length:

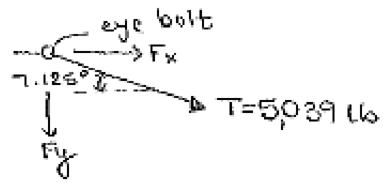
12" + 1/4" + 35/64" + 1/4" = 13.05"

use 16"

Eye Bolts

curved (3x3x 1/4") or (4x4x1/4)





$F_x = \cos(7.125°)(5039\text{ lb}) \Rightarrow$

$F_x = 5{,}000\text{ lb}$

$F_y = \sin(7.125°)(5039\text{ lb}) \Rightarrow F_y = 625\text{ lb}$

- $(P/A)_3 = 5039\text{ lb}/(3'' \times 3'') = 560\text{ lb/in}^2 = F_3$

OR

$(P/A)_4 = 5039\text{ lb}/(4 \times 4) = 315\text{ lb/in}^2 = F_4$

- $F_y = 36\text{ ksi}$

$P_{allow_3} = (3'')(1/4'')(36\text{ ksi}) = 27\text{ K}$

$P_{allow_4} = (4'')(1/4'')(36\text{ ksi}) = 36\text{ K}$

∴ 3"x3"x1/4" Square Curved Washer → Minimum

because $T < F_y$ $(5.04\text{K} < 27\text{ K})$

- Bolt Diameter = 1/2" ⇒ Minimum Tensile Strength = 7,800 lbs

$T < T_{min}$ ∴ 1/2" Forged Eye bolt → Minimum

Pole Strength

Cedar Pole for Bending Stress

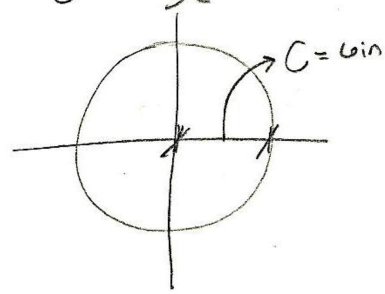
- RISA Values: $M_{applied} = 16.9k\text{-}ft$
  $V_{applied} = 2.112k$ * See Appendix E

- Excel Factored Values:
  $F_b' = 2245.32\ psi$ * See Appendix F

- Bending Stress Applied

$$F_b = \frac{M_{applied}}{S} \qquad S = \frac{I}{c} = \frac{\pi d^4}{64} \cdot \frac{2}{d} = \frac{\pi d^3}{32}$$

$$M_{applied} = 16900\ lb\text{-}ft \left(\frac{12\ in}{1\ ft}\right)$$



$$M_{applied} = 202800\ lb\text{-}in$$

$$F_b = \left[\frac{202800\ lb\text{-}in}{\left(\frac{\pi (12in)^3}{32}\right)}\right] \qquad F_b = 1195.43\ \frac{lb}{in^2}$$

- Comparing Bending Stress Applied to Allowed

$F_b = 1195.43\ psi$ = applied

$F_b' = 2245.32\ psi$ = allowed

$F_b < F_b'$ ✓

Cedar Pole | For Shear Stress

- RISA Values: $M_{applied} = 16.9$ k-ft

  $V_{applied} = 2.112$ k * See Appendix E

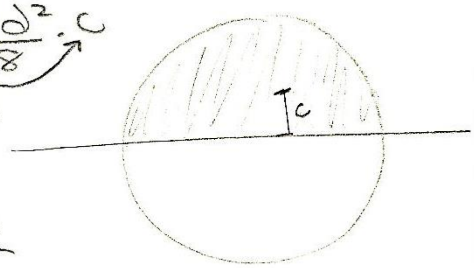
- Excel Factored Values:

  $F_v' = 205.20$ psi * See Appendix F

- Shear stress Applied:

$$F_v = \frac{VQ}{I \cdot b} \qquad Q = \frac{\pi d^2}{8} \cdot c$$

$V_{applied} = 2.112$K $c = 0.4244d$



$$I_{\text{half circle}} = \frac{\pi d^4}{128}$$

$$b = d/2$$

$$F_v = \frac{V\,\pi d^2(.4244d)(128)(2)}{(8)(\pi d^4)(d)} = \frac{V(108.6464)}{8d^2} = \tau$$

$$\frac{2112\text{lb}\,(108.6464)}{8(12\text{in}^2)} = 199.185\,\frac{\text{lb}}{\text{in}^2}$$

$$F_v = 199.185\text{psi}$$

- Comparing shear stress Applied to Allowed

$F_v = 199.185$ psi = applied

$F_v' = 205.20$ psi = allowed

$F_v < F_v'$ ✓

Appendix E

RISA Outputs

Wood Property Inputs

Custom Wood Properties

	Label	Fb [ksi]	Ft [ksi]	Fv [ksi]	Fc [ksi]	E [ksi]	SCL
1	LVL_PRL_1.5E_2	2.25	1.5	.22	1.95	1500	☑
2	LVL_PRL_2.0E_2	2.9	1.9	.285	2.75	2000	☑
3	LVL_Microllam_1.	2.6	1.555	.285	2.51	1900	☑
4	PSL_Parallam_2.	2.9	2.025	.29	2.9	2000	☑
5	PSL_Parallam_1.	2.4	1.755	.18	2.5	1800	☑
6	LSL_TimberStran	2.325	1.07	.31	2.05	1550	☑
7	LSL_TimberStran	1.7	1.075	.4	1.4	1300	☑
8	Cedar	1.35	1	.095	.75	940	☐
9	Douglas	.9	.575	.18	1.35	1600	☐

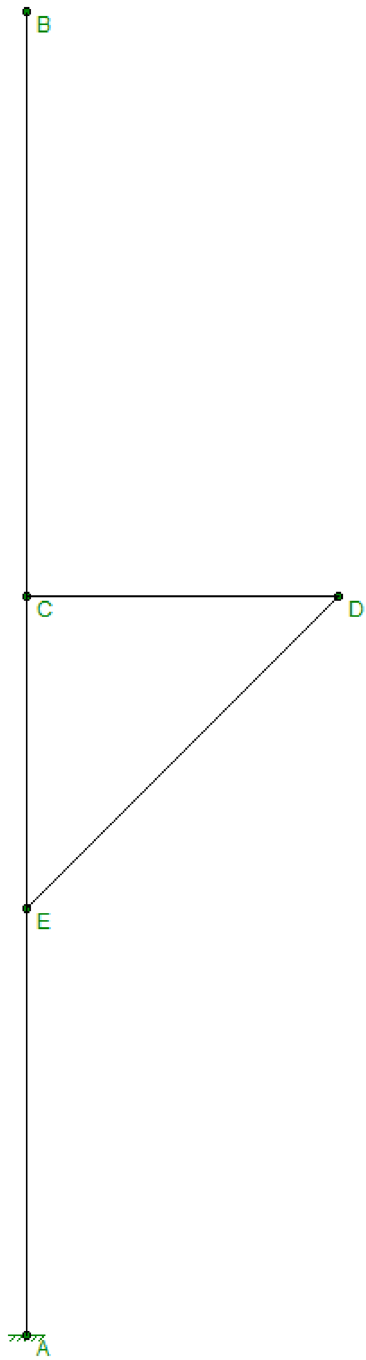
Load Combinations

Load Combinations

Combinations | Design

	Description	Sol...	PD...	SR...	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor	BLC	Factor
1	ASCE 1	☑			DL	1.4												
2	ASCE 2 (a)	☑			DL	1.2	LL	1.6	LLS	1.6	RLL	.5						
3	ASCE 2 (b)	☑			DL	1.2	LL	1.6	LLS	1.6	SL	.5						
4	ASCE 2 (c)	☑			DL	1.2	LL	1.6	LLS	1.6	RL	.5						
5	ASCE 3 (a)	☑			DL	1.2	RLL	1.6	LL	1	LLS	1						
6	ASCE 3 (b)	☑			DL	1.2	RLL	1.6	WL	.8								
7	ASCE 3 (c)	☑			DL	1.2	SL	1.6	LL	1	LLS	1						
8	ASCE 3 (d)	☑			DL	1.2	SL	1.6	WL	.8								
9	ASCE 3 (e)	☑			DL	1.2	RL	1.6	LL	1	LLS	1						
10	ASCE 3 (f)	☑			DL	1.2	RL	1.6	WL	.8								
11	ASCE 4 (a)	☑			DL	1.2	WL	1.6	LL	1	LLS	1	RLL	.5				
12	ASCE 4 (b)	☑			DL	1.2	WL	1.6	LL	1	LLS	1	SL	.5				
13	ASCE 4 (c)	☑			DL	1.2	WL	1.6	LL	1	LLS	1	RL	.5				
14	ASCE 5	☑			DL	1.2	EL	1	LL	1	LLS	1	SL	.2				
15	ASCE 6	☑			DL	.9	WL	1.6										
16	ASCE 7	☑			DL	.9	EL	1										

Side View Model



Side View Inputs

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Temp [F]
1	A	0	0	70
2	B	0	17	70
3	C	0	9.5	70
4	D	4	9.5	70
5	E	0	5.5	70

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Rotation[k-...
1	A	Reaction	Reaction	Reaction
2	C			
3	D			
4	E			

Member Primary Data

Primary | Advanced | Hot Rolled | Cold Formed | Wood | Concrete Beam | Concrete Column | Aluminum

	Label	I Joint	J Joint	Rotate...	Section/Sh...	Type	Design List	Material	Design ...
1	AB	A	B		12RND	Beam	Rectangular	Cedar	Typical
2	Cd	C	D		4X6	Beam	Rectangular	Douglas	Typical
3	DE	D	E		4X6	Beam	Rectangular	Douglas	Typical

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Joint	Point	Distrib...
1	Live	LL				1	
2	Wind	WL					1
3	Dead	DL					1
4		None					

Member Distributed Loads

Member | Wall Panel

BLC 2:Wind | Next BLC | Prev BLC

	Member Label	Directi...	Start Magn...	End Magni...	Start Locat...	End Locati...
1	AB	X	.11	.11	0	12

Member Point Loads

Member | Wall Panel

BLC 1:Live | Next BLC | Prev BL

	Member Label	Directi...	Magnitude...	Location[ft,...
1	Cd	y	-1.6	2

Member Distributed Loads

Member | Wall Panel

BLC 3:Dead | Next BLC | Prev BLC

	Member Label	Directi...	Start Magn...	End Magni...	Start Locat...	End Locati...
1	Cd	Y	-.112	-.112	0	4

Side View Results

Joint Deflections (By Combination)

	L...	Joint Label	X [in]	Y [in]	Rotatio...
1	13	A	0	0	0
2	13	B	1.956	-.002	-1.191e-2
3	13	C	.884	-.002	-1.185e-2
4	13	D	.885	-.534	-1.009e-2
5	13	E	.356	-.001	-9.506e-3

Member Section Forces (By Combination)

	L...	Member Label	S...	Axial[k]	Shear[k]	Mome...
1	13	AB	1	2.138	2.112	16.947
2			2	2.138	1.364	9.561
3			3	1.115	1.286	2.582
4			4	0	0	0
5			5	0	0	0
6	13	Cd	1	-.67	1.115	.834
7			2	-.67	.98	-.213
8			3	-.67	-.754	-1.126
9			4	-.67	-.888	-.305
10			5	-.67	-1.023	.651
11	13	DE	1	1.197	.25	.651
12			2	1.197	.25	.297
13			3	1.197	.25	-.056
14			4	1.197	.25	-.409
15			5	1.197	.25	-.762

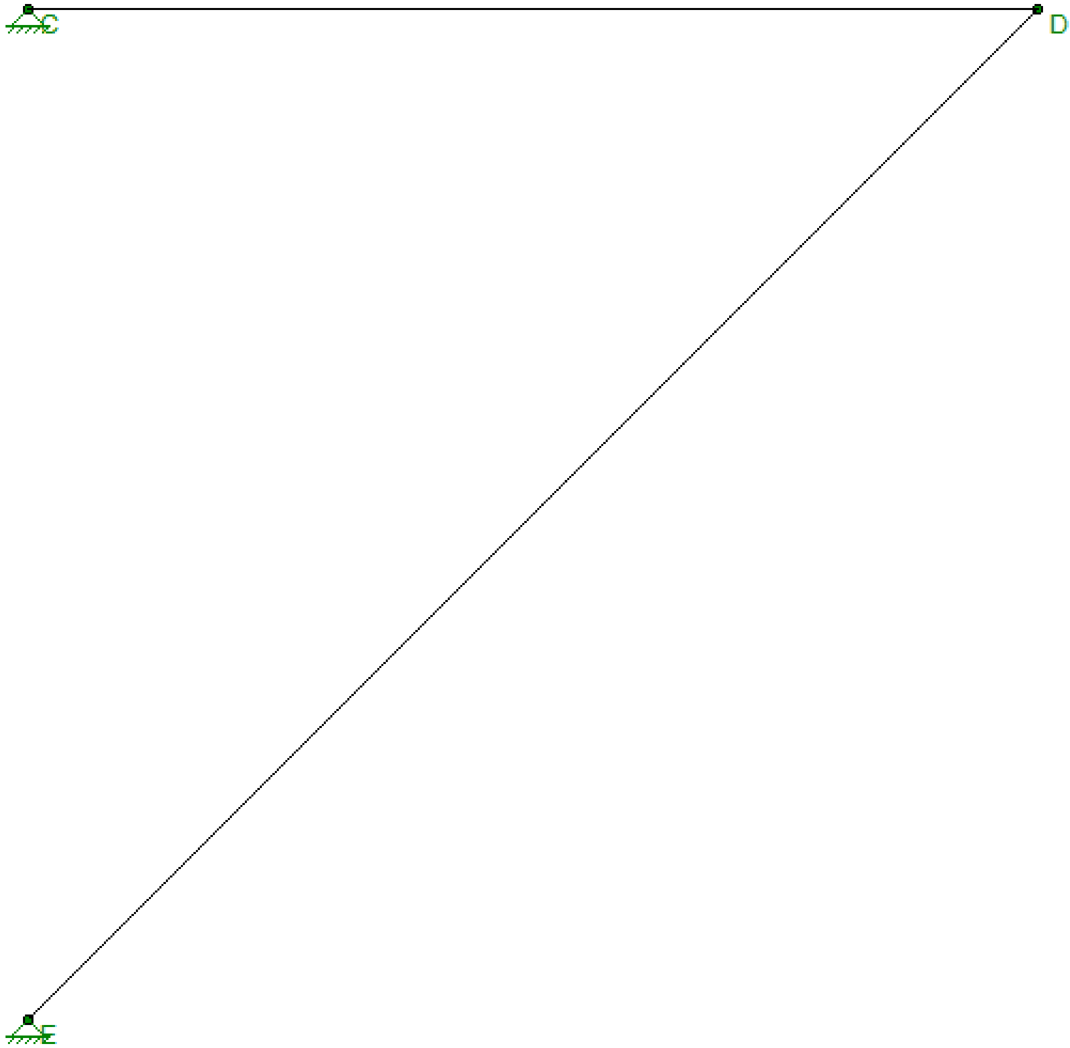
Joint Reactions (By Combination)

	L...	Joint Label	X [k]	Y [k]	MZ [k-ft]
1	13	A	-2.112	2.138	16.947
2	13	Totals:	-2.112	2.138	
3	13	COG (ft):	X: 2	Y: 9.5	

Member Section Deflections (By Combination)

	L...	Member Label	S...	x [in]	y [in]	(n) L/y ...
1	13	AB	1	0	0	NC
2			2	-.001	-.224	911.209
3			3	-.002	-.743	274.733
4			4	-.002	-1.348	151.349
5			5	-.002	-1.956	104.32
6	13	Cd	1	.884	-.002	NC
7			2	.884	-.149	3322.968
8			3	.884	-.292	1967.515
9			4	.884	-.416	3103.439
10			5	.885	-.534	NC
11	13	DE	1	-.248	1.003	90.418
12			2	-.249	.82	119.678
13			3	-.249	.623	183.263
14			4	-.25	.429	385.48
15			5	-.251	.252	NC

Truss Model



Truss Model Inputs

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Joint	Point	Distrib...
1	Dead	DL					1
2	Live	LL				1	
3		None					

Wood Material Properties

Hot Rolled | Cold Formed | Wood | Concrete | Masonry | Aluminum | General

	Label	Species	Grade	Cm	Emod	Nu	Ther...	Dens[k...
13	Douglas	Douglas	na	☐	1	.3	.3	.035

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Temp [F]
1	C	0	4	70
2	D	4	4	70
3	E	0	0	70

Member Point Loads

Member | Wall Panel

BLC 2:Live | Next BLC | Prev BL(

	Member Label	Directi...	Magnitude...	Location[ft,...
1	CD	Y	-1.6	2

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Rotation[k-...	Footing
1	C	Reaction	Reaction		
2	D				
3	E	Reaction	Reaction		

Member Distributed Loads

Member | Wall Panel

BLC 1:Dead | Next BLC | Prev BLC

	Member Label	Directi...	Start Magn...	End Magni...	Start Locat...	End Locati...
1	CD	Y	-.112	-.112	0	4

Member Primary Data

Primary | Advanced | Hot Rolled | Cold Formed | Wood | Concrete Beam | Concrete Column | Aluminum

	Label	I Joint	J Joint	Rotate...	Section/Sh...	Type	Design List	Material	Design ...
1	CD	C	D		4X6	Beam	Rectangular	Douglas	Typical
2	DE	D	E		4X6	Beam	Rectangular	Douglas	Typical

Truss Model Results

Joint Deflections (By Combination)

	L...	Joint Label	X [in]	Y [in]	Rotatio...
1	12	C	0	0	-3.051e-3
2	12	D	.002	-.007	2.005e-3
3	12	E	0	0	-1.118e-3

Member Section Forces (By Combination)

	L...	Member Label	S...	Axial[k]	Shear[k]	Mome...
1	12	CD	1	-1.069	.92	0
2			2	-1.069	.786	-.853
3			3	-1.069	-.949	-1.571
4			4	-1.069	-1.083	-.555
5			5	-1.069	-1.218	.595
6	12	DE	1	1.617	.105	.595
7			2	1.617	.105	.447
8			3	1.617	.105	.298
9			4	1.617	.105	.149
10			5	1.617	.105	0

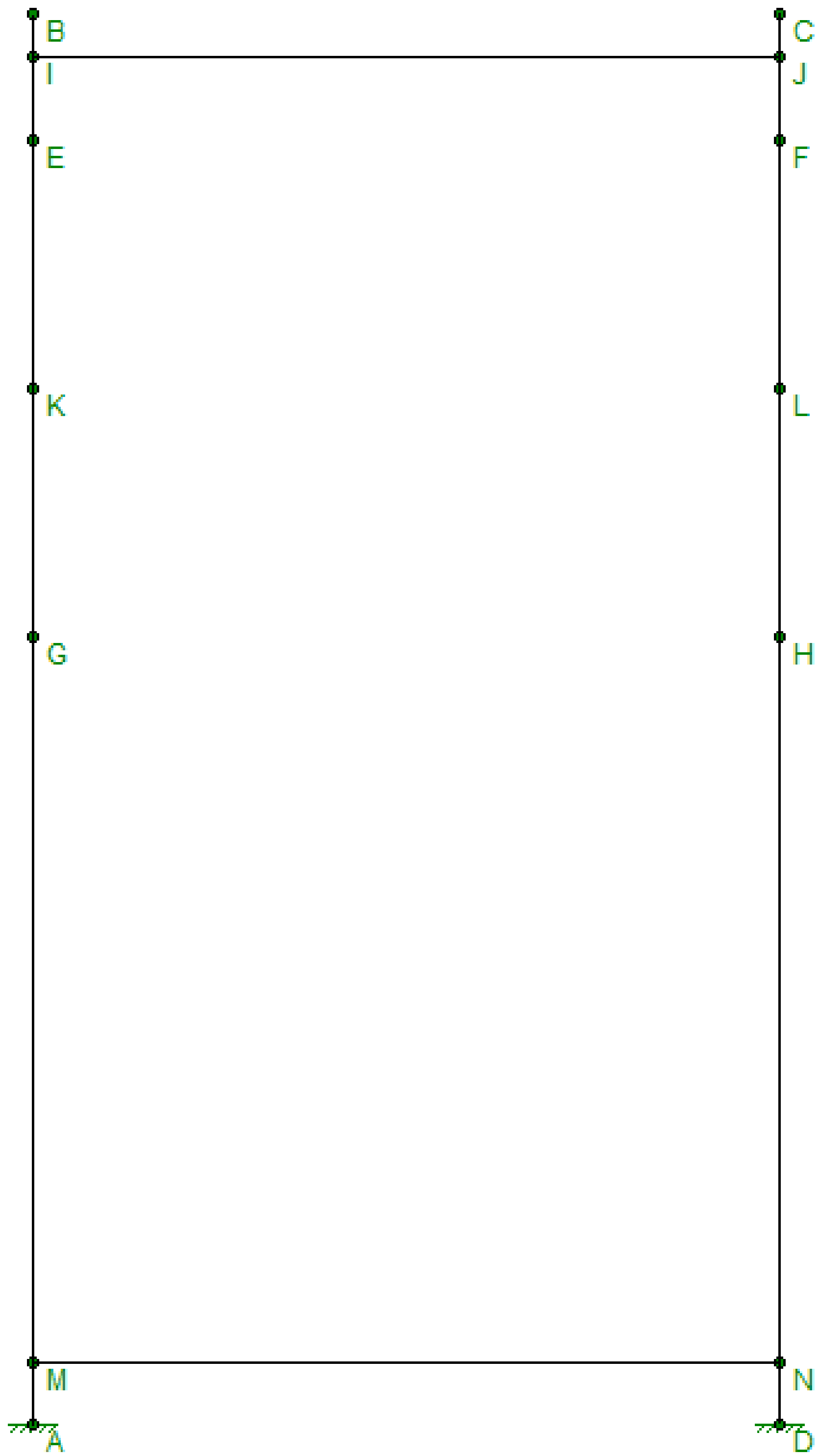
Joint Reactions (By Combination)

	L...	Joint Label	X [k]	Y [k]	MZ [k-ft]
1	12	C	-1.069	.92	0
2	12	E	1.069	1.218	0
3	12	Totals:	0	2.138	
4	12	COG (ft):	X: 2	Y: 4	

Member Section Deflections (By Combination)

	L...	Member Label	S...	x [in]	y [in]	(n) L/y ...
1	12	CD	1	0	0	NC
2			2	0	-.033	1525.519
3			3	0	-.048	1085.981
4			4	.001	-.033	1705.029
5			5	.002	-.007	NC
6	12	DE	1	.004	.006	NC
7			2	.003	.028	2927.373
8			3	.002	.029	2561.451
9			4	0	.018	4098.322
10			5	0	0	NC

Front View Model



Front View Inputs

Wood Material Properties

Hot Rolled | Cold Formed | Wood | Concrete | Masonry | Aluminum | General

	Label	Species	Grade	Cm	Emod	Nu	Ther...	Dens[k...
13	Cedar	Cedar	na	☐	1	.3	.3	.035
14	Douglas	Douglas	na	☐	1	.3	.3	.035

Member Primary Data

Primary | Advanced | Hot Rolled | Cold Formed | Wood | Concrete Beam | Concrete Column | Aluminum

	Label	I Joint	J Joint	Rotate...	Section/Sh...	Type	Design List	Material	Design ...
1	AB	A	B		12RND	Beam	Rectangular	Cedar	Typical
2	CD	C	D		12RND	Beam	Rectangular	Cedar	Typical
3	IJ	I	J		4X6	Beam	Rectangular	Douglas	Typical
4	MN	M	N		4X6	Beam	Rectangular	Douglas	Typical

Member Point Loads

Member | Wall Panel

BLC 1:Live | Next BLC | Prev BLC

	Member Label	Directi...	Magnitude...	Location[ft,...
1	AB	X	5	15.5
2	CD	X	-5	1.5

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Rotation[k-...
1	A	Reaction	Reaction	Reaction
2	D	Reaction	Reaction	Reaction
3	E			
4	F			

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Temp [F]
1	A	0	0	70
2	B	0	17	70
3	C	9	17	70
4	D	9	0	70
5	E	0	15.5	70
6	F	9	15.5	70
7	G	0	9.5	70
8	H	9	9.5	70
9	I	0	16.5	70
10	J	9	16.5	70
11	K	0	12.5	70
12	L	9	12.5	70
13	M	0	.75	70
14	N	9	.75	70

Front View Results

Joint Reactions (By Combination)

	L...	Joint Label	X [k]	Y [k]	MZ [k-ft]
1	15	A	.11	0	1.993
2	15	D	-.11	0	-1.993
3	15	Totals:	0	0	
4	15	COG (ft):	NC	NC	

Joint Deflections (By Combination)

	L...	Joint Label	X [in]	Y [in]	Rotatio...
1	15	A	0	0	0
2	15	B	-.006	0	2.379e-3
3	15	C	.006	0	-2.379e-3
4	15	D	0	0	0
5	15	E	.037	0	2.092e-3
6	15	F	-.037	0	-2.092e-3
7	15	G	.081	0	-4.812e-4
8	15	H	-.081	0	4.812e-4
9	15	I	.008	0	2.379e-3
10	15	J	-.008	0	-2.379e-3
11	15	K	.082	0	5.253e-4
12	15	L	-.082	0	-5.253e-4
13	15	M	0	0	-2.193e-4
14	15	N	0	0	2.193e-4

Member Section Forces (By Combination)

	L...	Member Label	S...	Axial[k]	Shear[k]	Mome...
1	15	AB	1	0	-.11	1.993
2			2	0	.433	.587
3			3	0	.433	-1.252
4			4	0	.433	-3.092
5			5	0	0	0
6	15	CD	1	0	0	0
7			2	0	-.433	-3.092
8			3	0	-.433	-1.252
9			4	0	-.433	.587
10			5	0	.11	1.993
11	15	IJ	1	4.567	0	.285
12			2	4.567	0	.285
13			3	4.567	0	.285
14			4	4.567	0	.285
15			5	4.567	0	.285
16	15	MN	1	.543	0	-.026
17			2	.543	0	-.026
18			3	.543	0	-.026
19			4	.543	0	-.026
20			5	.543	0	-.026

Member Section Deflections (By Combination)

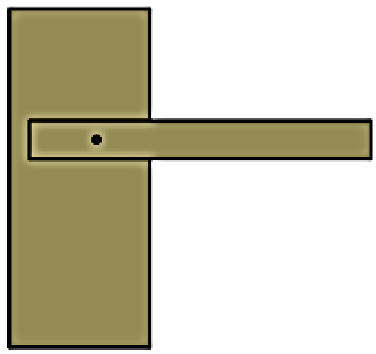
	L...	Member Label	S...	x [in]	y [in]	(n) L/y ...
1	15	AB	1	0	0	NC
2			2	0	-.028	7005.329
3			3	0	-.073	2663.636
4			4	0	-.08	2398.872
5			5	0	.006	NC
6	15	CD	1	0	.006	NC
7			2	0	-.08	2398.872
8			3	0	-.073	2663.636
9			4	0	-.028	7005.329
10			5	0	0	NC
11	15	IJ	1	.008	0	NC
12			2	.004	.048	2241.947
13			3	0	.064	1681.46
14			4	-.004	.048	2241.947
15			5	-.008	0	NC
16	15	MN	1	0	0	NC
17			2	0	-.004	NC
18			3	0	-.006	NC
19			4	0	-.004	NC
20			5	0	0	NC

Appendix F

Excel Outputs

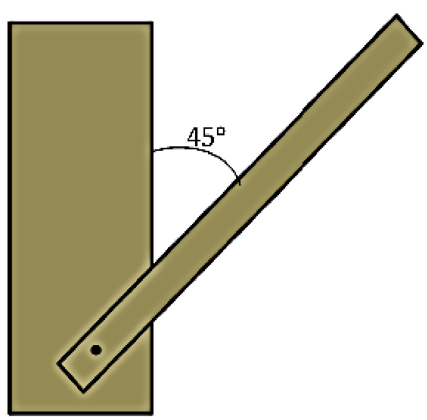
Adjustment Factors for Dowel-type Fasteners											
Z, lb											Z'
Z	C_M	C_t	C_g	C_Δ	C_{eg}	C_{di}	C_{tn}	K_F	ϕ_z	λ	
836.65	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.32	0.65	1.00	**1,807.16**

t_m	12	in
t_s	3.5	in
F_{em}	4,050	psi (11.3.2)
F_{es}	2,600	psi (11.3.2)
F_{yb}	45,000	psi
D	0.75	in
R_e	1.56	
R_t	3.43	
θ	90	deg.
kθ	1.25	
k_1	1.67	
k_2	1.29	
k_3	1.12	
I_m	7,290.00	lb
I_s	1,365.00	lb
II	2,526.50	lb
III_m	2,851.72	lb
III_s	836.65	lb
IV	969.23	lb
Failure	836.65	lb



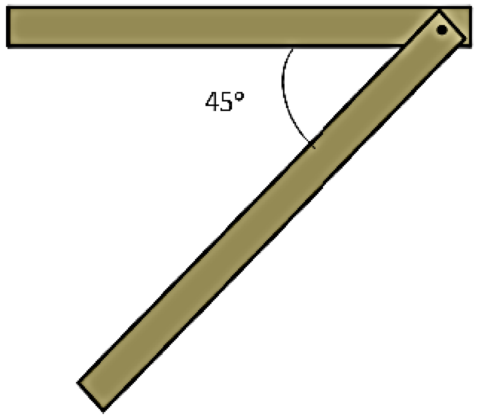
Adjustment Factors for Dowel-type Fasteners											
Z, lb											Z'
Z	C_M	C_t	C_g	C_Δ	C_{eg}	C_{di}	C_{tn}	K_F	ϕ_z	λ	
929.61	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.32	0.65	1.00	**2,007.95**

t_m	12	in
t_s	3.5	in
F_{em}	4,050	psi (11.3.2)
F_{es}	2,600	psi (11.3.2)
F_{yb}	45,000	psi
D	0.75	in
R_e	1.56	
R_t	3.43	
θ	45	deg.
kθ	1.125	
k_1	1.67	
k_2	1.29	
k_3	1.12	
I_m	8,100.00	lb
I_s	1,516.67	lb
II	2,807.22	lb
III_m	3,168.58	lb
III_s	929.61	lb
IV	1,076.92	lb
Failure	929.61	lb



Adjustment Factors for Dowel-type Fasteners											
Z, lb											Z'
Z	C_M	C_t	C_g	C_Δ	C_{eg}	C_{di}	C_{tn}	K_F	ϕ_z	λ	
970.79	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.32	0.65	1.00	2,096.91

t_m	3.5	in
t_s	3.5	in
F_{em}	5,600	psi (11.3.2)
F_{es}	2,600	psi (11.3.2)
F_{yb}	45,000	psi
D	0.75	in
R_e	2.15	
R_t	1.00	
θ	45	deg.
$k\theta$	1.125	
k_1	0.64	
k_2	1.76	
k_3	0.99	
I_m	3,266.67	lb
I_s	1,516.67	lb
II	1,076.82	lb
III_m	1,353.42	lb
III_s	970.79	lb
IV	1,140.39	lb
Failure	970.79	lb



Adjustment Factors for Round Timber Poles Western Red Cedar											
F_c, psi											Fb'
F_c	C_t	C_u		C_P	C_{cs}		C_{sp}	K_F	ϕ_c	λ	
750	1	1		0.38	1.04		0.80	2.40	0.90	1	647.19
F_b, psi											Ft'
F_b	C_t	C_u	C_F				C_{sp}	K_F	ϕ_b	λ	
1,350	1	1	1				0.77	2.54	0.85	1	2,245.32
F_v, psi											Fv'
F_v	C_t	C_u						K_F	ϕ_v	λ	
95	1	1						2.88	0.75	1	205.20
F_{cper}, psi											Fcper'
F_{cper}	C_t	C_u				C_b		K_F	ϕ_c	λ	
255	1	1				1.00		2.08	0.90	1	478.13
E, psi											E'
E	C_t										
940,000	1										940,000
E_{min}, psi											Emin'
E_{min}	C_t							K_F	ϕ_s		
500,000	1							1.76	0.85		750,000

Adjustment Factors for Sawn Lumber Douglas Fir-Larch No. 2														
F_b, psi														F_b'
F_b	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r				K_F	ϕ_b	λ	
900	0.85	1.00	1.00	1.30	1.05	0.80	1.15				2.54	0.85	1.00	**2,067.29**
F_t, psi														F_t'
F_t	C_M	C_t		C_F		C_i					K_F	ϕ_t	λ	
575	1.00	1.00		1.30		0.80					2.70	0.80	1.00	**1,291.68**
F_v, psi														F_v'
F_v	C_M	C_t				C_i					K_F	ϕ_v	λ	
180	0.97	1.00				0.80					2.88	0.75	1.00	**301.71**
F_{cper}, psi														F_{cper}'
F_{cper}	C_M	C_t				C_i	C_r			C_b	K_F	ϕ_c	λ	
625	0.67	1.00				1.00	1.15			1.10	2.08	0.90	1.00	**993.22**
F_c, psi														F_c'
F_c	C_M	C_t		C_F		C_i		C_P			K_F	ϕ_c	λ	
1,350	0.80	1.00		1.10		0.80		1.00			2.40	0.90	1.00	**2,052.86**
E, psi														E'
E	C_M	C_t				C_i								
1,600,000	0.90	1.00				0.95								**1,368,000**
E_{min}, psi														E_{min}'
E_{min}	C_M	C_t				C_i			C_T		K_F	ϕ_s		
580,000	0.90	1.00				0.95			1.03		1.76	0.85		**764,420**

Appendix G

Cost Calculations

Engineer Wage Determination

Column	Hourly Wage	Overhead Rate	Labor Multiplier	Total Cost/Hour
Austin	$20.00	1.5	2.5	$50.00
Kelsey	$20.00	1.5	2.5	$50.00
Stephanie	$20.00	1.5	2.5	$50.00

The table shown above displays the determination of engineer wages as well as an explanation of the break even cost. Each engineer is being paid a wage of $20 per hour. The "company", however, has many other expenses to take care of that are not directly billed to the client. These expenses are called overhead and refer to insurance, office supplies, utilities, employee benefits, and much more. The cost of overhead in this case was estimated to be about 1.5 times the wages of an engineer, and needed to be added to the existing engineer wage, resulting in a "labor multiplier" of 2.5

Physical Labor Costs

Estimated Structure Crew				
Description	*Quantity*	*Hours*	*Rate*	*Total*
Foreman	1	16	$40.56	$648.96
Laborer	3	16	$25.60	$1,228.80
Total Estimated Structure Crew Cost				**$1,877.76**

The labor costs included in the table above were determined using rsmeansconstructiondata.com using a heavy civil job description.

Subcontractor Costs

Estimated Drilling Subcontractor			
Description	*Quantity*	*Unit Cost*	*Total*
16" x 5' Hole	2	$750.00	$1,500.00

Material Cost Determination

Estimated Materials Cost				
Material	*Quantity*	*Type*	*Unit Cost*	*Total with Tax 9.446%*
Red Cedar Poles	41	LF	$12.50	$560.91
6" x 6" Lumber	40	LF	$3.38	$147.97
4" x 6" Lumber	34	LF	$2.50	$93.03
4" x 4" Lumber	16	LF	$1.81	$31.70
2" x 6" Lumber	150	LF	$1.29	$211.78
2" x 4" Lumber	33	LF	$0.85	$30.70
2" x 2" Lumber	80	LF	$0.61	$53.41
5/4" x 6" Trex	270	LF	$2.81	$830.37
3/4" All Thread	18	LF	$3.46	$68.16
3/4" x 8" Bolt	10	EA	$1.10	$12.04
3/4" Washers	34	EA	$0.52	$19.35
3/4" Nuts	34	EA	$2.02	$75.17
5/8" x 6" Bolt	16	EA	$0.81	$14.18
5/8" Washer	32	EA	$0.41	$14.36
5/8" Nut	16	EA	$0.75	$13.13
Simpson 1212HL	8	EA	$13.98	$122.40
Simpson CJT3	2	EA	$23.00	$50.35
Simpson A35	72	EA	$0.56	$44.13
Rounded Metal Plate	2	EA	$15.00	$32.83
Forged Eyebolt	2	EA	$35.20	$77.05
Wire Rope Clip	6	EA	$15.25	$100.14
Rainbow Technology Foam	1	EA	$250.00	$273.62
Trex Deck Screws	10	LB	$7.99	$87.45
1.5" Deck Screws	5	LB	$4.78	$26.16
3" Deck Screws	5	LB	$4.78	$26.16
Belay Cable	20	LF	$2.05	$44.87
Total Estimated Materials Cost				**$3061.41**

*The “Type” column in the table above specifies how the quantities are measured.

LF= Per Lineal Foot, EA= Each, LB= Per Pound

Appendix H

International Residential Code

R502.6 Bearing.

The ends of each joist, beam or girder shall have not less than 1.5 inches (38 mm) of bearing on wood or metal and not less than 3 inches (76 mm) on masonry or concrete except where supported on a 1-inch-by-4-inch (25.4 mm by 102 mm) ribbon strip and nailed to the adjacent stud or by the use of approved joist hangers.

R502.6.1 Floor systems.

Joists framing from opposite sides over a bearing support shall lap a minimum of 3 inches (76 mm) and shall be nailed together with a minimum three 10d face nails. A wood or metal splice with strength equal to or greater than that provided by the nailed lap is permitted.

R502.6.2 Joist framing.

Joists framing into the side of a wood girder shall be supported by approved framing anchors or on ledger strips not less than nominal 2 inches by 2 inches (51 mm by 51 mm).

R502.7 Lateral restraint at supports.

Joists shall be supported laterally at the ends by full-depth solid blocking not less than 2 inches (51 mm) nominal in thickness; or by attachment to a full-depth header, band or rim joist, or to an adjoining stud or shall be otherwise provided with lateral support to prevent rotation.

JOIST SPACING (inches)	SPECIES AND GRADE		DEAD LOAD = 10 psf				DEAD LOAD = 20 psf			
			2×6	2×8	2×10	2×12	2×6	2×8	2×10	2×12
			Maximum floor joist spans							
			(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)
12	Douglas fir-larch	SS	11- 4	15- 0	19- 1	23- 3	11- 4	15- 0	19- 1	23- 3
	Douglas fir-larch	#1	10-11	14- 5	18- 5	22- 0	10-11	14- 2	17- 4	20- 1
	Douglas fir-larch	#2	10- 9	14- 2	17- 9	20- 7	10- 6	13- 3	16- 3	18-10
	Douglas fir-larch	#3	8- 8	11- 0	13- 5	15- 7	7-11	10- 0	12- 3	14- 3
	Hem-fir	SS	10- 9	14- 2	18- 0	21-11	10- 9	14- 2	18- 0	21-11
	Hem-fir	#1	10- 6	13-10	17- 8	21- 6	10- 6	13-10	16-11	19- 7
	Hem-fir	#2	10- 0	13- 2	16-10	20- 4	10- 0	13- 1	16- 0	18- 6
	Hem-fir	#3	8- 8	11- 0	13- 5	15- 7	7-11	10- 0	12- 3	14- 3
	Southern pine	SS	11- 2	14- 8	18- 9	22-10	11- 2	14- 8	18- 9	22-10
	Southern pine	#1	10-11	14- 5	18- 5	22- 5	10-11	14- 5	18- 5	22- 5
	Southern pine	#2	10- 9	14- 2	18- 0	21- 9	10- 9	14- 2	16-11	19-10
	Southern pine	#3	9- 4	11-11	14- 0	16- 8	8- 6	10-10	12-10	15- 3
	Spruce-pine-fir	SS	10- 6	13-10	17- 8	21- 6	10- 6	13-10	17- 8	21- 6
	Spruce-pine-fir	#1	10- 3	13- 6	17- 3	20- 7	10- 3	13- 3	16- 3	18-10
	Spruce-pine-fir	#2	10- 3	13- 6	17- 3	20- 7	10- 3	13- 3	16- 3	18-10
	Spruce-pine-fir	#3	8- 8	11- 0	13- 5	15- 7	7-11	10- 0	12- 3	14- 3
16	Douglas fir-larch	SS	10- 4	13- 7	17- 4	21- 1	10- 4	13- 7	17- 4	21- 0
	Douglas fir-larch	#1	9-11	13- 1	16- 5	19- 1	9- 8	12- 4	15- 0	17- 5
	Douglas fir-larch	#2	9- 9	12- 7	15- 5	17-10	9- 1	11- 6	14- 1	16- 3
	Douglas fir-larch	#3	7- 6	9- 6	11- 8	13- 6	6-10	8- 8	10- 7	12- 4
	Hem-fir	SS	9- 9	12-10	16- 5	19-11	9- 9	12-10	16- 5	19-11
	Hem-fir	#1	9- 6	12- 7	16- 0	18- 7	9- 6	12- 0	14- 8	17- 0
	Hem-fir	#2	9- 1	12- 0	15- 2	17- 7	8-11	11- 4	13-10	16- 1
	Hem-fir	#3	7- 6	9- 6	11- 8	13- 6	6-10	8- 8	10- 7	12- 4
	Southern pine	SS	10- 2	13- 4	17- 0	20- 9	10- 2	13- 4	17- 0	20- 9
	Southern pine	#1	9-11	13- 1	16- 9	20- 4	9-11	13- 1	16- 4	19- 6
	Southern pine	#2	9- 9	12-10	16- 1	18-10	9- 6	12- 4	14- 8	17- 2
	Southern pine	#3	8- 1	10- 3	12- 2	14- 6	7- 4	9- 5	11- 1	13- 2
	Spruce-pine-fir	SS	9- 6	12- 7	16- 0	19- 6	9- 6	12- 7	16- 0	19- 6
	Spruce-pine-fir	#1	9- 4	12- 3	15- 5	17-10	9- 1	11- 6	14- 1	16- 3
	Spruce-pine-fir	#2	9- 4	12- 3	15- 5	17-10	9- 1	11- 6	14- 1	16- 3
	Spruce-pine-fir	#3	7- 6	9- 6	11- 8	13- 6	6-10	8- 8	10- 7	12- 4
19.2	Douglas fir-larch	SS	9- 8	12-10	16- 4	19-10	9- 8	12-10	16- 4	19- 2
	Douglas fir-larch	#1	9- 4	12- 4	15- 0	17- 5	8-10	11- 3	13- 8	15-11
	Douglas fir-larch	#2	9- 1	11- 6	14- 1	16- 3	8- 3	10- 6	12-10	14-10
	Douglas fir-larch	#3	6-10	8- 8	10- 7	12- 4	6- 3	7-11	9- 8	11- 3
	Hem-fir	SS	9- 2	12- 1	15- 5	18- 9	9- 2	12- 1	15- 5	18- 9
	Hem-fir	#1	9- 0	11-10	14- 8	17- 0	8- 8	10-11	13- 4	15- 6
	Hem-fir	#2	8- 7	11- 3	13-10	16- 1	8- 2	10- 4	12- 8	14- 8
	Hem-fir	#3	6-10	8- 8	10- 7	12- 4	6- 3	7-11	9- 8	11- 3
	Southern pine	SS	9- 6	12- 7	16- 0	19- 6	9- 6	12- 7	16- 0	19- 6
	Southern pine	#1	9- 4	12- 4	15- 9	19- 2	9- 4	12- 4	14-11	17- 9
	Southern pine	#2	9- 2	12- 1	14- 8	17- 2	8- 8	11- 3	13- 5	15- 8
	Southern pine	#3	7- 4	9- 5	11- 1	13- 2	6- 9	8- 7	10- 1	12- 1
	Spruce-pine-fir	SS	9- 0	11-10	15- 1	18- 4	9- 0	11-10	15- 1	17- 9
	Spruce-pine-fir	#	8- 9	11- 6	14- 1	16- 3	8- 3	10- 6	12-10	14-10
	Spruce-pine-fir	#2	8- 9	11- 6	14- 1	16- 3	8- 3	10- 6	12-10	14-10
	Spruce-pine-fir	#3	6-10	8- 8	10- 7	12- 4	6- 3	7-11	9- 8	11- 3
24	Douglas fir-larch	SS	9- 0	11-11	15- 2	18- 5	9- 0	11-11	14- 9	17- 1
	Douglas fir-larch	#1	8- 8	11- 0	13- 5	15- 7	7-11	10- 0	12- 3	14- 3
	Douglas fir-larch	#2	8- 1	10- 3	12- 7	14- 7	7- 5	9- 5	11- 6	13- 4
	Douglas fir-larch	#3	6- 2	7- 9	9- 6	11- 0	5- 7	7- 1	8- 8	10- 1
	Hem-fir	SS	8- 6	11- 3	14- 4	17- 5	8- 6	11- 3	14- 4	16-10[a]
	Hem-fir	#1	8- 4	10- 9	13- 1	15- 2	7- 9	9- 9	11-11	13-10
	Hem-fir	#2	7-11	10- 2	12- 5	14- 4	7- 4	9- 3	11- 4	13- 1
	Hem-fir	#3	6- 2	7- 9	9- 6	11- 0	5- 7	7- 1	8- 8	10- 1
	Southern pine	SS	8-10	11- 8	14-11	18- 1	8-10	11- 8	14-11	18- 1

Appendix I

Plan Set

This appendix contains the final design plan set for the NAU Challenge Course climbing wall. This is the summation of the Capstone coursework for the team.