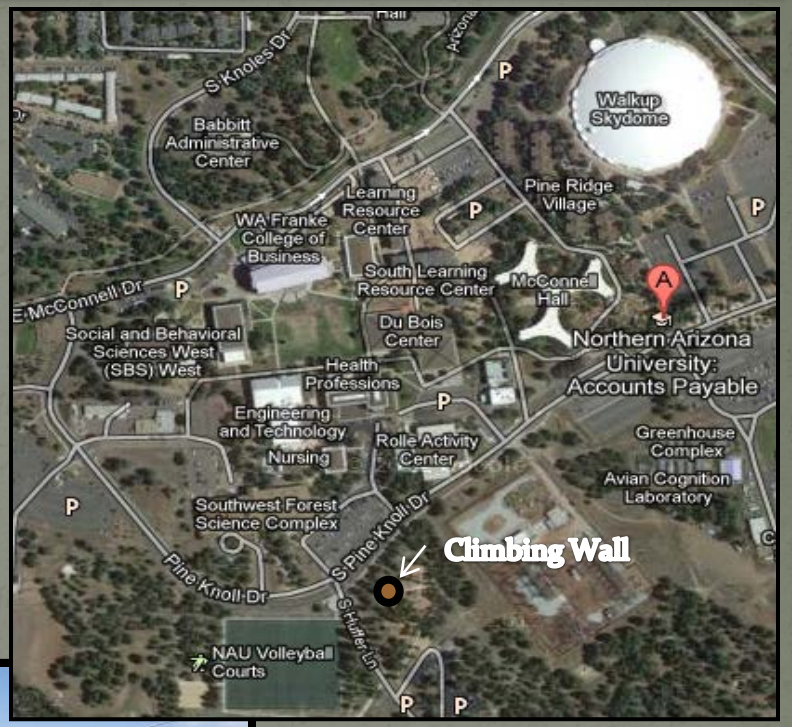
NAU Challenge Course Climbing Wall Design

Austin Hopper – Project Manager
Kelsey Deckert – Structural Engineer
Stephanie Sarty – Materials Engineer

Problem Statement

- Design Climbing Wall for NAU Challenge Course
  - Location
    - Flagstaff, Arizona
  - Owner
    - Northern Arizona University
  - Stake Holders
    - NAU Campus Recreations
    - Challenge Course Users

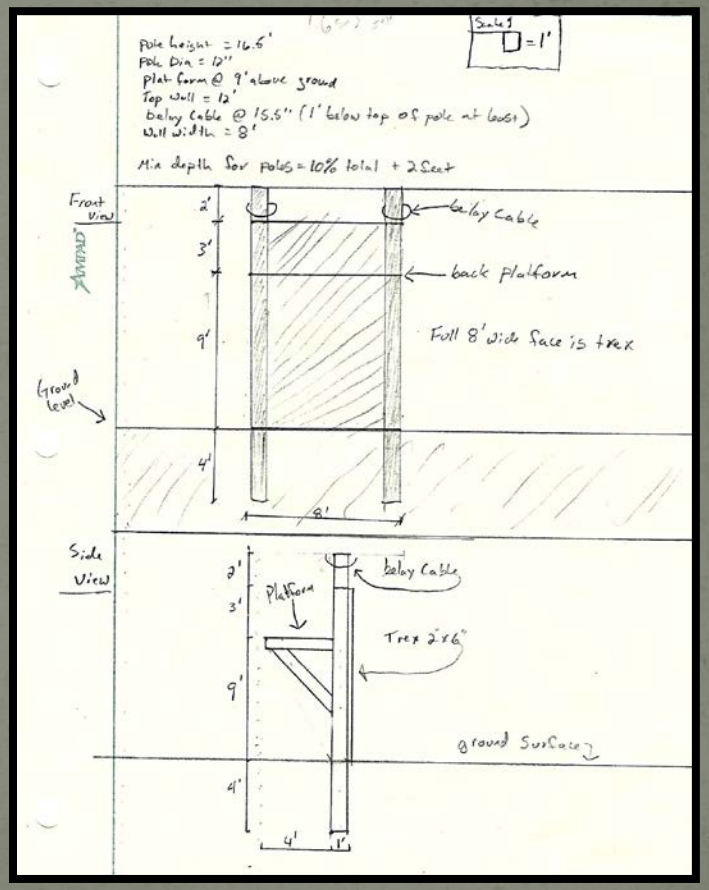


Area Map (Google.com)


Photographer: NAU Construction Management

Problem Statement

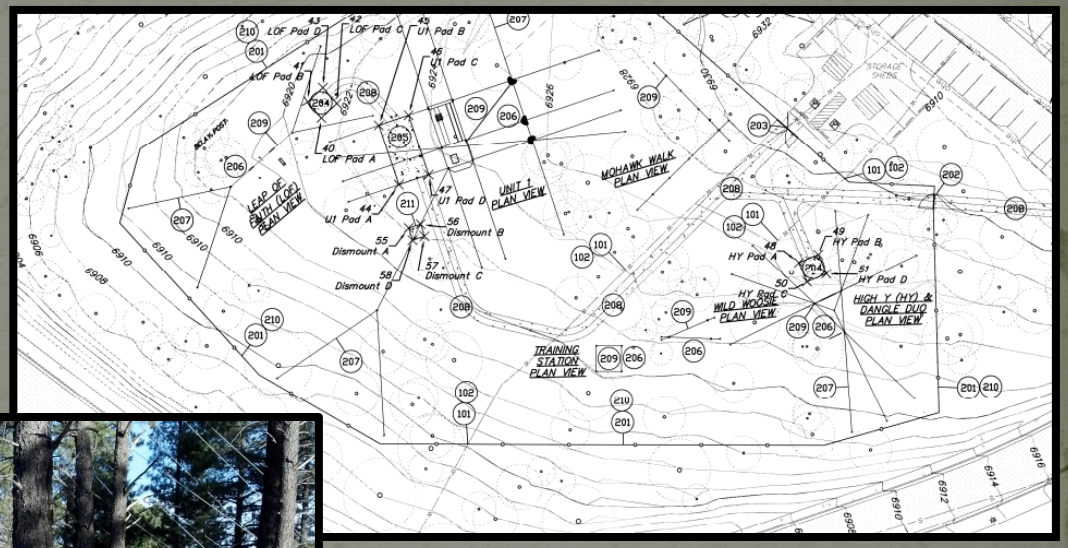
- Constraints Given by Owner
  - Dimensions
  - Only a two pole system
  - Rear deck
  - No guy wires
  - Belay cable
  - Use available materials



Drawn By: Amber Heft

Existing Conditions

- Even surface
- Thin layer top soil
- Limestone underneath top soil



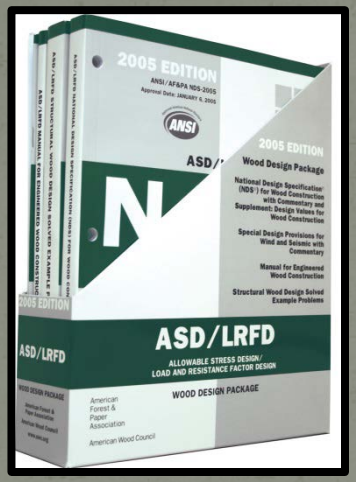
Previous Plan Set, Existing Conditions and Demo Plan

Photographer: Austin Hopper

Scope of Work: Task 1

- Project Management
  - Client
    - Met with/contacted Amber Heft approximately once a month
  - Technical Advisors
    - Weekly meetings with John Tingerthal and/or Thomas Nelson (Hubbard Merrell Engineering)
  - Team
    - Met on an average twice a week for project support
  - Capstone Course Meetings
    - Presented on project advances and arising issues to Dr. Odem every other week

Scope of Work: Task 2



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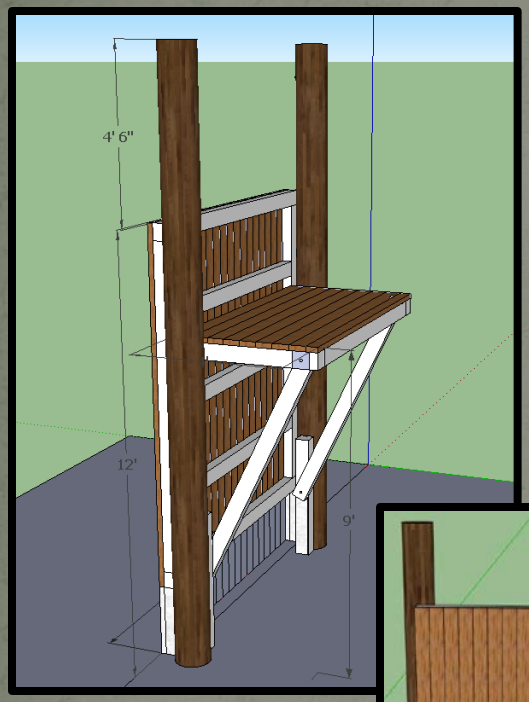
- Obtain Existing Documents and Required Codes
  - Geotechnical Report
  - As-Builts of Current Challenge Course
  - City of Flagstaff Building Codes
  - Association for Challenge Course Technology (ACCT)
  - ASCE 7-10 Minimum Design Loads for Buildings and other Structures
  - ASD/LRFD, Manual for Engineered Wood Construction (2005 Edition)
  - International Building Codes (IBC)
  - International Residential Codes (IRC)

Scope of Work: Task 3

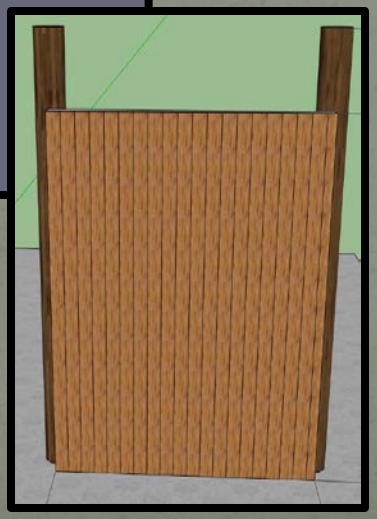
- Analyze Available Materials from Owner
  - Utilizing materials already possessed by NAU
  - A list of available materials, quantities, and sizes
  - Identify each material's use and capability
  - Researched material properties
- Determine Materials Needed to Complete Project
  - Identify Quantities
  - Identify Specifications
  - Identify availability of materials

Photographer: Austin Hopper

Scope of Work: Task 4



Drawn By: Austin Hopper



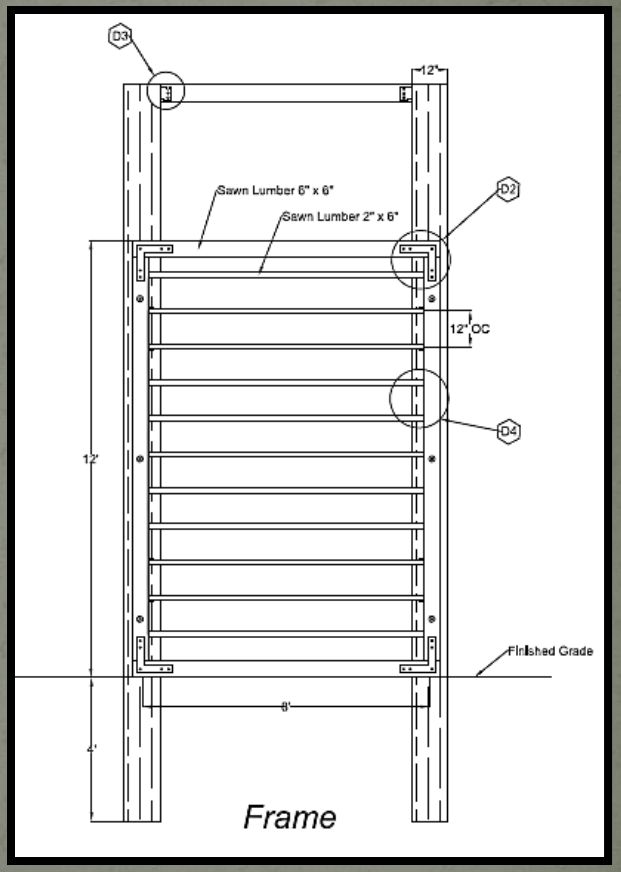
- Develop Architectural Design
  - Using constraints given by owner a rough sketch was created using Google SketchUp, including:
    - Dimensions
    - Rear deck
    - Posts
    - Front face
- Receive Approval of Owner to Proceed with Design

Scope of Work: Task 5

- Structural Design
  - Structural Analysis
    - Live load, snow load, wind load, dead load
    - Calculations done by hand and RISA
    - Poles act as fixed supports in the rock and under worse-case loading
  - Structural Member Design
    - Sizing of members
    - Strength, durability, deflections
    - Wood capacities
    - Connection analysis
    - Load and Resistance Factored Design (LRFD)
  - Foundation Requirement Analysis
    - Bearing Capacity
    - Depth of Poles
    - Strength of Limestone
    - Material Type

Scope of Work: Task 6

- AutoCAD Drawings
  - Detailed construction drawings
  - Including:
    - Location
    - Dimensions
    - Materials
    - Specifications
    - Foundation Requirements
  - Reviewed by Technical Advisors



Drawn By: Austin Hopper

Scope of Work: Task 7

- Compose Project Report
- Creation of Website
- Presentation Preparation
- Submission of Construction Documents
  - John Tingerthal P.E. – NAU faculty

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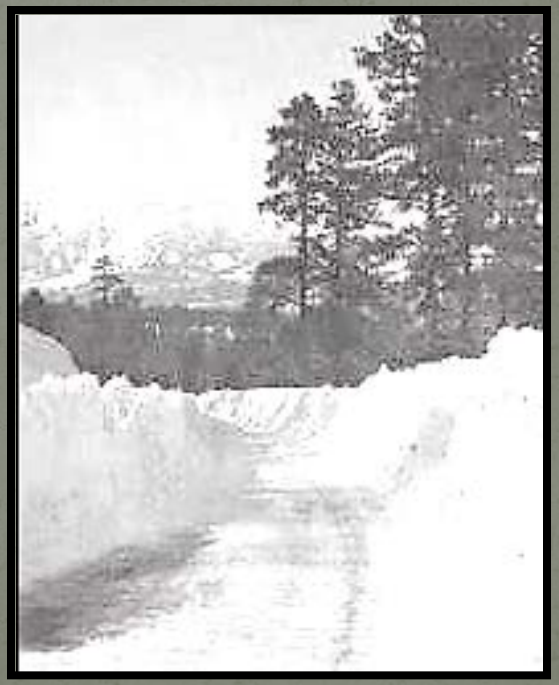
Final Design

- Loading
  - ASCE 7-05
  - Flagstaff Region Standards for Wind and Snow Load
- Values
  - Wind (90 mph)– 24.4 psf
  - Dead Load – 7 psf
  - Snow Load – 48 psf
  - Live Load – 100 psf



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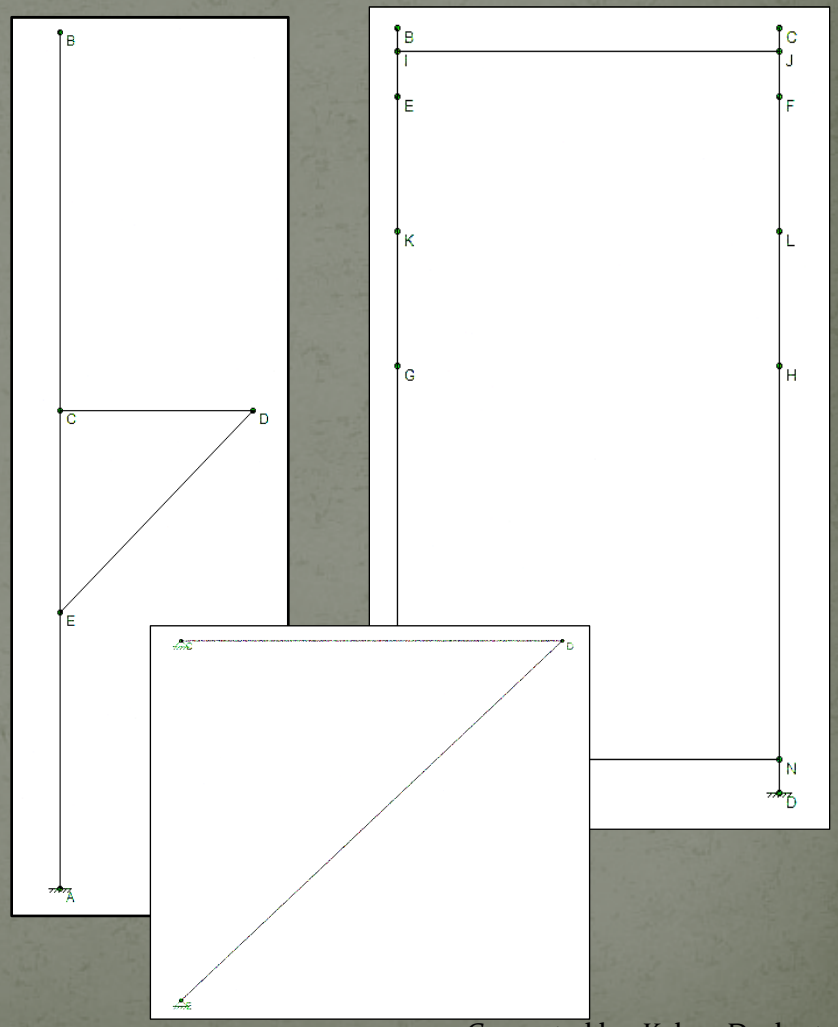
Final Design

- Computer Analysis-RISA 2D
  - LRFD Calculations
  - Includes:
    - Material Strengths
    - Material Specifications
    - Loading Types
    - Load Combinations
  - Outcomes
    - Three Separate Models
      - Side View Model
      - Truss Model
      - Front View Model



Generated by: Kelsey Deckert

Final Design

- Computer Analysis-RISA 2D

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

Joint Reactions (By Combination)

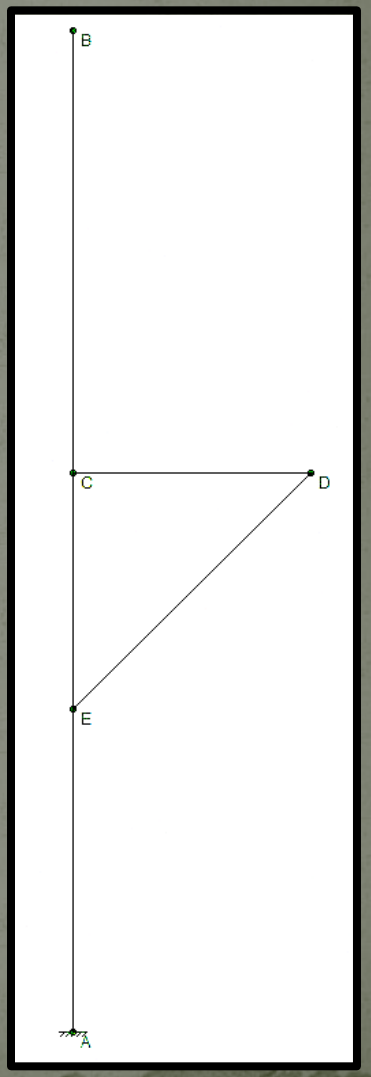
	L...	Joint Label	X [k]	Y [k]	MZ [k-ft]
1	13	A	-2.112	2.138	16.947
2	13	Totals:	-2.112	2.138	
3	13	COG (ft):	X: 2	Y: 9.5	

Member Section 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

Member Section Deflections (By Combination)

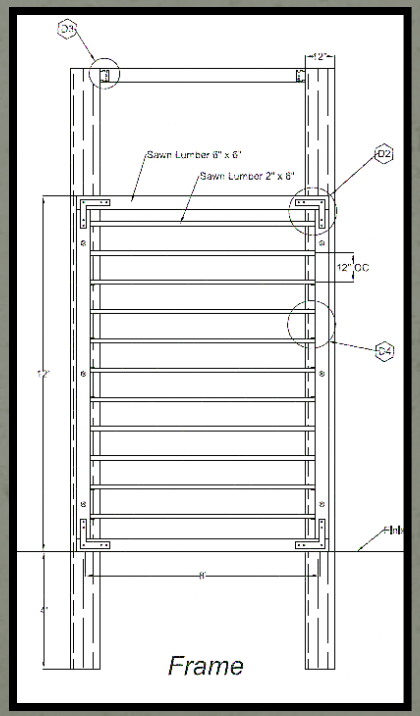
	L...	Member Label	S...	x [in]	y [in]	(n) L/y ...
1	13	AB	1	0	0	NC
2			2	-.001	-.224	911.209
3			3	-.002	-.743	274.733
4			4	-.002	-1.348	151.349
5			5	-.002	-1.956	104.32
6	13	Cd	1	.884	-.002	NC
7			2	.884	-.149	3322.968
8			3	.884	-.292	1967.515
9			4	.884	-.416	3103.439
10			5	.885	-.534	NC
11	13	DE	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

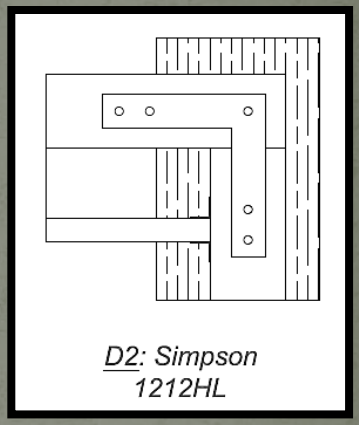


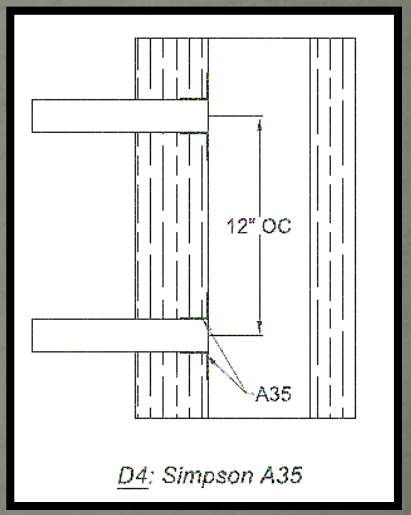
Generated by: Kelsey Deckert

Final Design

- Wood Strength
  - Poles
    - Type 3 Cedar Transmission Poles
      - 12 in diameter at bottom
      - 11.5 in diameter at top
      - 20.5 feet overall
      - 16.9 kip-ft reaction per pole
      - 2.12 kip shear at ground
  - Face
    - 4” x 6” lumber frame
    - 12’ tall by 8’ wide
    - 2” x 6” joists (12” OC)
    - Simpson A35 and 1212HL
    - Trex Decking



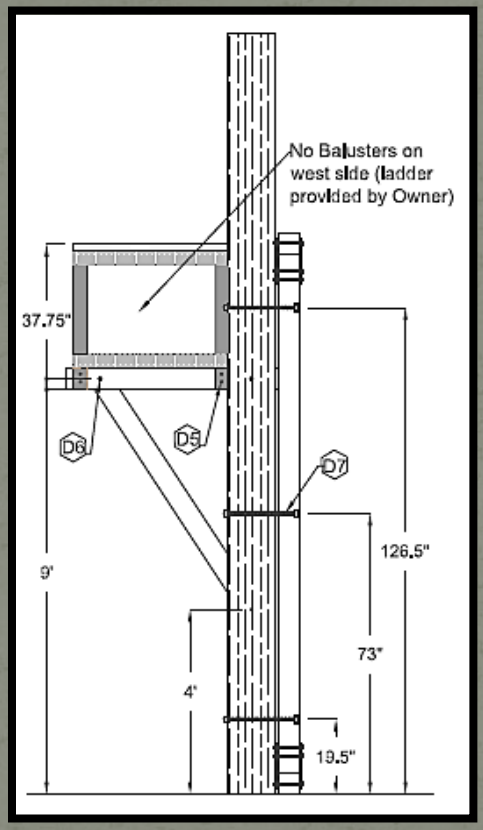


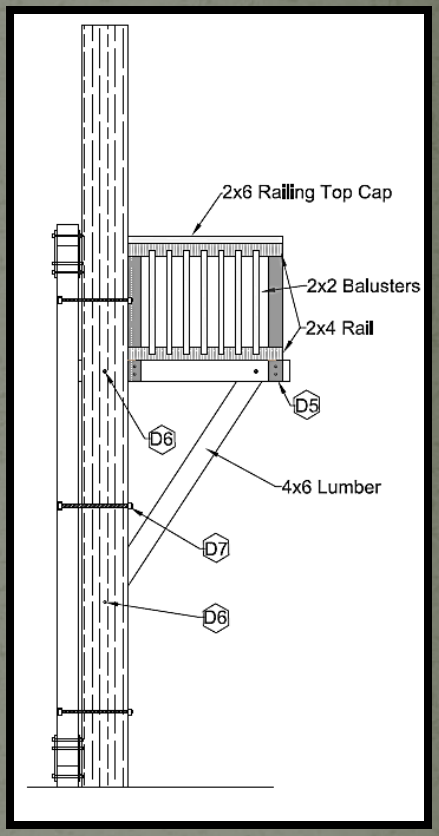


Drawn by: Austin Hopper

Final Design

- Wood Strength
  - Deck Supported by Truss
    - 4” x 6” lumber frame and truss
    - 8’ x 4.5’ back deck
    - 36” tall railing
    - 2” x 6” joists
    - Trex Decking
    - Tested with 5 kip load on outer edge, only 1.1” deflection

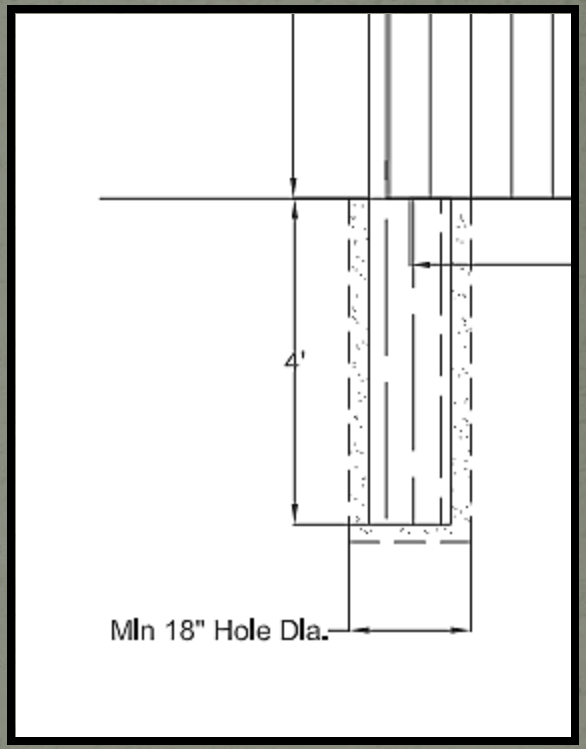




Drawn By: Austin Hopper

Final Design

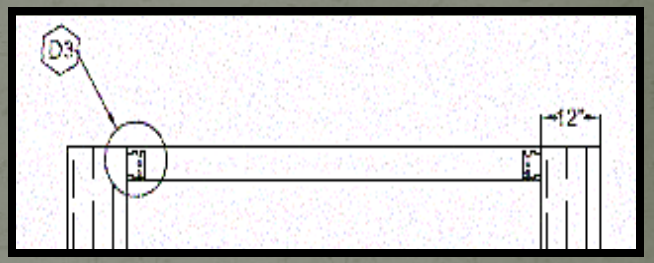
- Foundation
  - Compacted soil, concrete, and polyurethane foam considered
  - Bearing capacities of limestone
  - Depth based on ACCT standards
  - Diameter of hole based on Rainbow Technology Manual

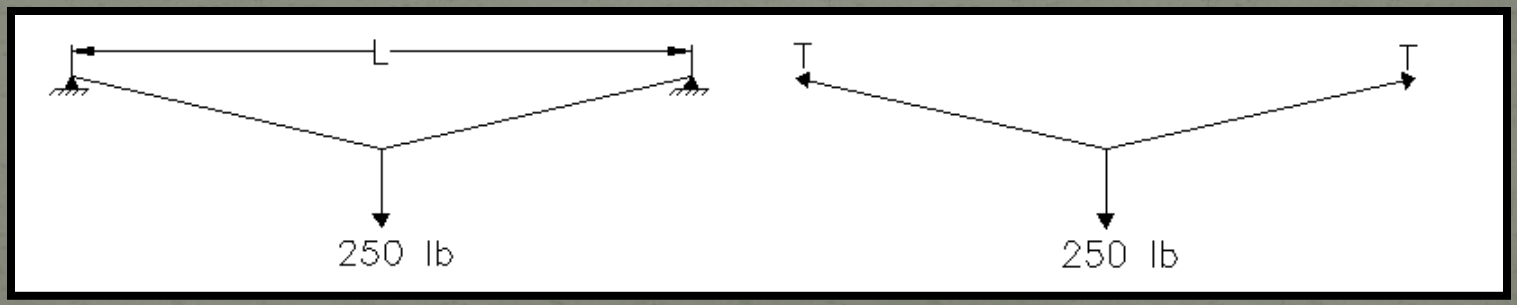


Drawn by: Stephanie Sarty

Final Design

- Belay Cables
  - Designed from ACCT standards
  - Sag over 5%
  - 250 lb design load (50 lbs over required)
  - Eye bolt attachment
    - 4” curved washer to reduce wood bearing
- Wood strut added to reduce deflections

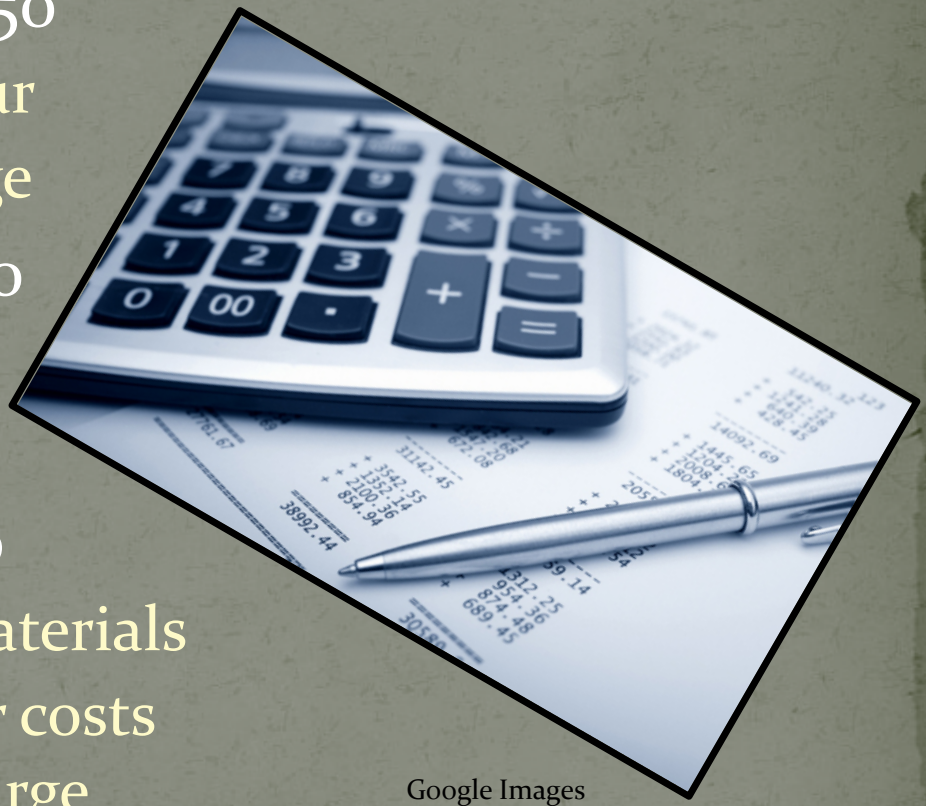




Drawn by: Kelsey Deckert

Cost Estimate

- Engineering Design: $29,150
  - 3 engineers at $50 per hour
  - Cost Plus Fixed Percentage
- Construction Costs: $6,440
  - Physical Labor: $1,878
  - Subcontracting: $1,500
- Total Project Cost: $35,590
  - NAU already has some materials
  - Design and physical labor costs are being done free of charge



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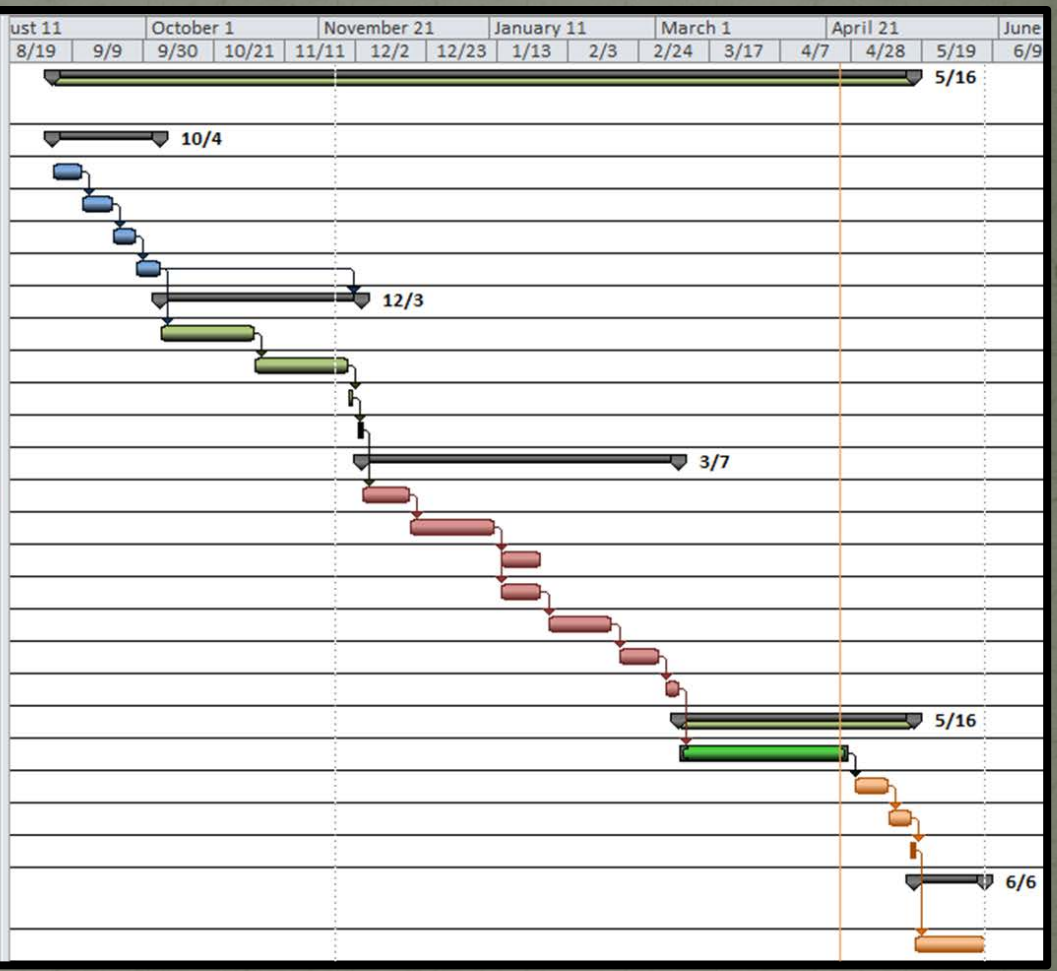
Schedule

	Task Name	Start	Finish
1	**Project Management**	**Mon 9/3/12**	**Thu 5/16/13**
2	**Project Understanding**	**Mon 9/3/12**	**Thu 10/4/12**
3	Meeting with Owner	Mon 9/3/12	Tue 9/11/12
4	Meeting with Advisor	Wed 9/12/12	Thu 9/20/12
5	Research Current Codes	Fri 9/21/12	Thu 9/27/12
6	Obtaining Existing Documents	Fri 9/28/12	Thu 10/4/12
7	**Architectural Design**	**Fri 10/5/12**	**Mon 12/3/12**
8	Rough Calculations	Fri 10/5/12	Thu 11/1/12
9	Preliminary Drawings	Fri 11/2/12	Thu 11/29/12
10	Meeting with Owner	Fri 11/30/12	Fri 11/30/12
11	Meeting with Advisor	Mon 12/3/12	Mon 12/3/12
12	**Structural Design**	**Tue 12/4/12**	**Thu 3/7/13**
13	Analyze Available Materials	Tue 12/4/12	Mon 12/17/12
14	Structural Analysis	Tue 12/18/12	Fri 1/11/13
15	Structural Member Design	Mon 1/14/13	Fri 1/25/13
16	Foundation Requirements	Mon 1/14/13	Fri 1/25/13
17	Construction Drawings	Mon 1/28/13	Fri 2/15/13
18	Specifications	Mon 2/18/13	Fri 3/1/13
19	Meeting with Advisor	Mon 3/4/13	Thu 3/7/13
20	**Submission to PE**	**Fri 3/8/13**	**Thu 5/16/13**
21	PE Review	Fri 3/8/13	Fri 4/26/13
22	Required Alterations to Design	Mon 4/29/13	Wed 5/8/13
23	Meeting with Advisor	Thu 5/9/13	Wed 5/15/13
24	**Submission to NAU**	Thu 5/16/13	Thu 5/16/13
25	**Construction Support**	**Fri 5/17/13**	**Thu 6/6/13**
26	Support	Fri 5/17/13	Thu 6/6/13



Generated by: Austin Hopper

Impacts

- Environmental
  - Disturbing the ground
  - No trees will be removed
  - No endangered species known to area
- Political
  - Improves the image of NAU to future students and families
- Economic
  - Aim to make course affordable to all social groups
- Global
  - Course only impacts Flagstaff and surrounding vicinity
- Regulatory
  - Course does not impact guidelines
- Contemporary Design
  - Designed with “green” materials
    - FSC Certified Wood

Thank you

Photographed by: NAU Construction Management

Questions?