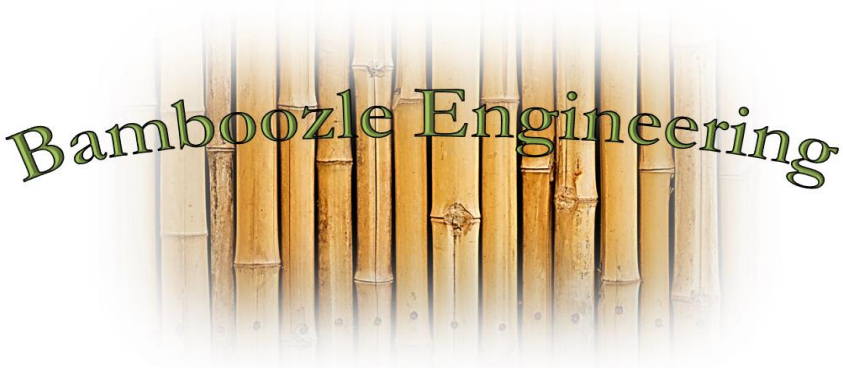
CENE 486C : Bamboo Bridge Design



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Purpose

- Design a Bamboo replacement bridge for the Flagstaff Urban Trail System (FUTS) to improve the aesthetics of the site area
- Construct a physical scale model that reflects design and architecture (not for loading)
- Analyze the feasibility and practicality of utilizing bamboo as a structural material

Figure 1: Existing Structure Facing South

Background - Project Location

Figure 2: Vicinity Map of Project Site, Google Maps

Background - Existing Structure

- Existing structure is a pedestrian bridge made of treated lumber
- Structure spans across a stream and joins two segments of the F.U.T.S.
- Proposed design must conform to these dimesions

Figure 3: Dimensions of Existing Structure

Exclusions

- *Footings Design*
  Includes geotechnical engineering analysis or earthwork associated with manipulating the pre-existing concrete footings

- *Material Testing*
  Due to availability of reliable theoretical values, mechanics of materials testing will be excluded

Figure 4: Pre-existing Footing at Project Site

Design Constraints and Criteria

Constraints

- Design structure using bamboo
- Weather resistant design
- Fixed span length and footing size

Criteria

- Material Strength/Stress Properties
- Durability (material warping)
- Aesthetics
- Cost

Figure 5: Laminated Bamboo Beams [8]

Design Alternatives

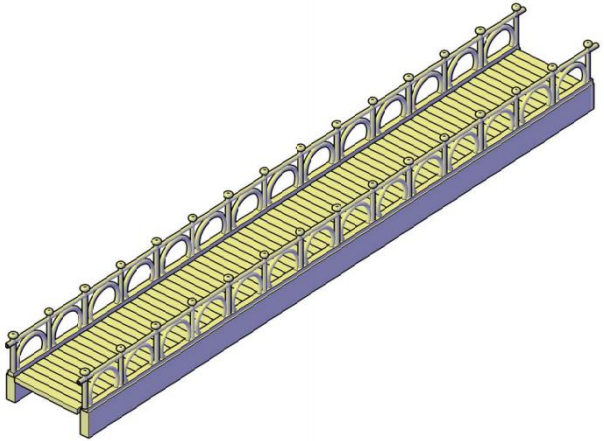


Figure 6: Design Alternative A

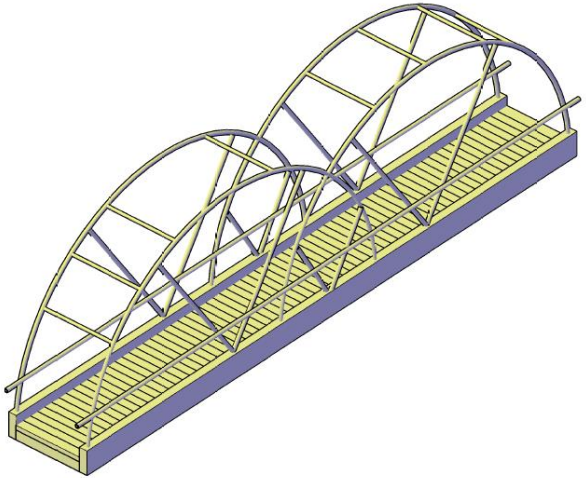


Figure 7: Design Alternative B

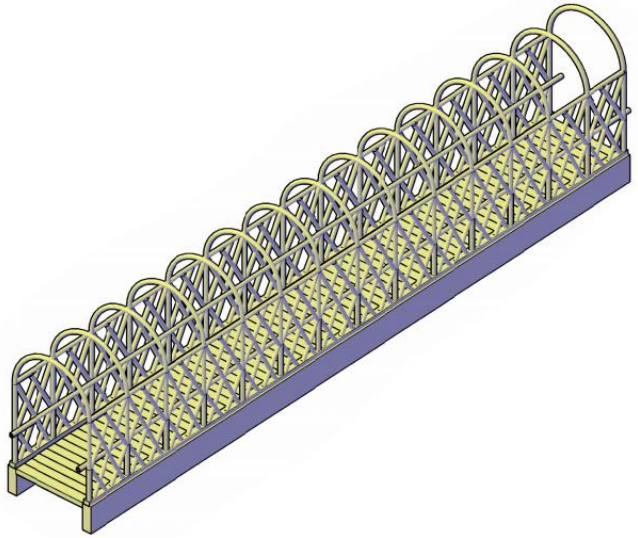


Figure 8: Design Alternative C

Final Design – Structural and Architectural

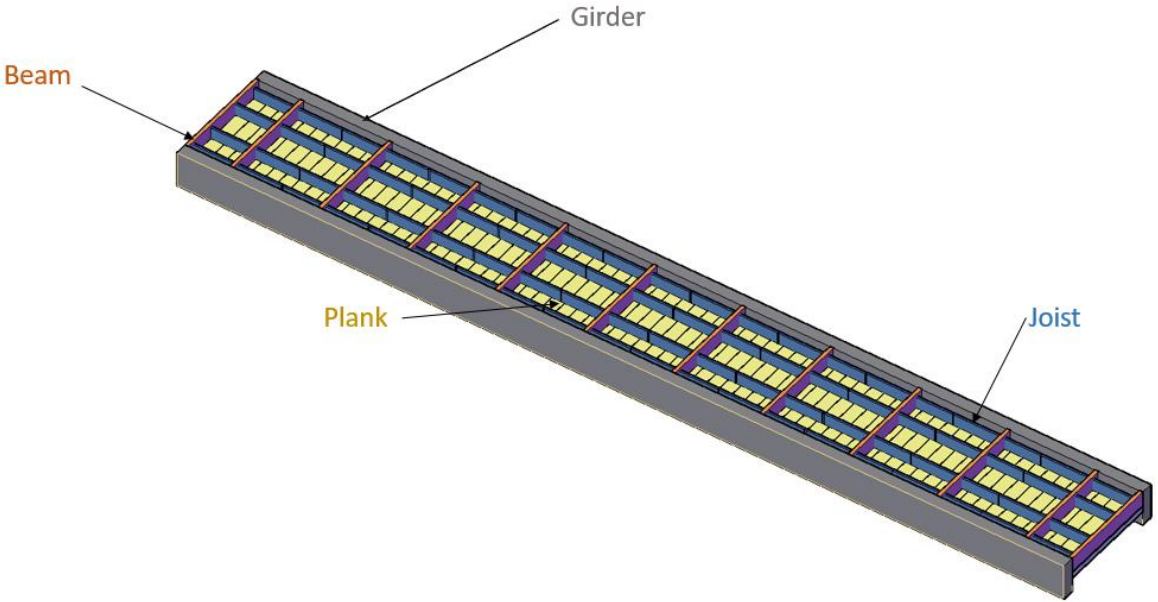


Figure 9: Bottom View of Structural Design

Table 1: Color Coded Member Cross-Section Dimensions

Member Attributes	B (in)	H (in)
Plank	*11.25*	*1.5*
Joist	*1.5*	*7.25*
Beam	*1.5*	*11.25*
Girder	*14*	*48*

Testing and Analysis - Loading

- Designed for 50 lb/ft^2 of live load
- Designed for 40 lb/ft^2 of snow load

Material Properties	
Density (lb/ft^3)	42
MOE (kips/in^2)	1319
Allowable Bending Stress (kips/in^2)	12.8

Table 2: Material Properties

Plank Loading	
Self-Weight (lb/ft)	4.921875
Live Load (lb/ft)	70.3125
Snow Load (lb/ft)	37.5
Total Distributed Load (lb/ft)	112.7344

Joist Loading	
Self-Weight (lb/ft)	3.171875
Live Load (lb/ft)	150
Snow Load (lb/ft)	80
Plank Dead Load (lb/ft)	10.5
Total Distributed Load (lb/ft)	243.6719

Beam Loading	
Self-Weight (lb/ft)	4.921875
Live Distributed Load (lb/ft)	974.6875
Total Distributed Load (lb/ft)	979.6094

Girder Loading	
Self-Weight (lb/ft)	237
Live Distributed Load (lb/ft)	487.7145
Total Distributed Load (lb/ft)	724.7145

Figure 10: Member Loading Analysis

Testing and Analysis - Results

- Designed to maximum allowable bending stress
- Checked individual member deflections

Plank Analysis	
Max Moment (kip-in)	0.676406
Max Bending Stress (kips/in^2)	0.160333
Deflection (in)	0.009725

Joist Analysis	
Max Moment (kip-in)	17.90988
Max Bending Stress (kips/in^2)	1.36294
Deflection (in)	0.209513

Beam Analysis	
Max Moment (kip-in)	72.00129
Max Bending Stress (kips/in^2)	2.275596
Deflection (in)	0.225432

Girder Analysis	
Max Moment (kip-in)	5372.406
Max Bending Stress (kips/in^2)	0.999332
Deflection (in)	2.340213

Legend
Exceeds Requirements
Meets Requirements
Calculated Cells
Input Cells

Deflection Limits (in)	
Plank	0.0666667
Joist	0.2333333
Beam	0.2333333
Girder	2.3433333

Figure 11: Beam Stress and Deflection Analysis

Connections

Connection Design

- Z-MAX (Zinc) coating and epoxy paint for corrosion/weather resistance
- Spacers to be used for slab connections

2x12 Beam Hanger	
	
Allowable Load (kips)	Design Load (kips)
4.9	3.43

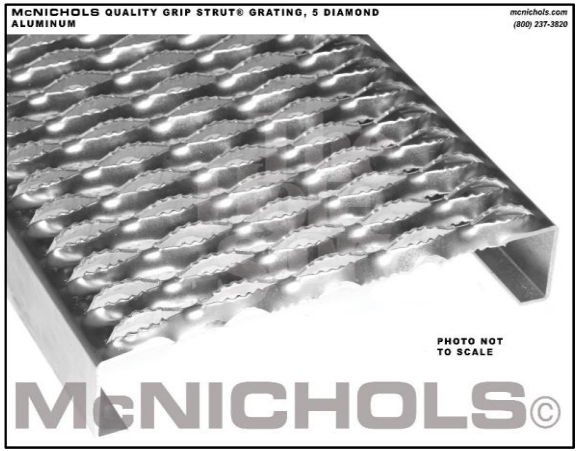
Figure 12: Beam Hanger [1]

2x8 Joist Hanger	
	
Allowable Load (kips)	Design Load (kips)
1.68	0.85

Figure 13: Joist Saddle Hanger (PFD28B) [1]

Decking Options

Steel Grating



Allowable Load (psf)	Design Load (psf)
300	115

Figure 14: Grating used for Decking [11]

Bamboo Decking

Allowable Deflection (in)	Design Deflection (in)
0.067	0.01

Figure 15: Planks used for Decking [8]

Lateral Bracing

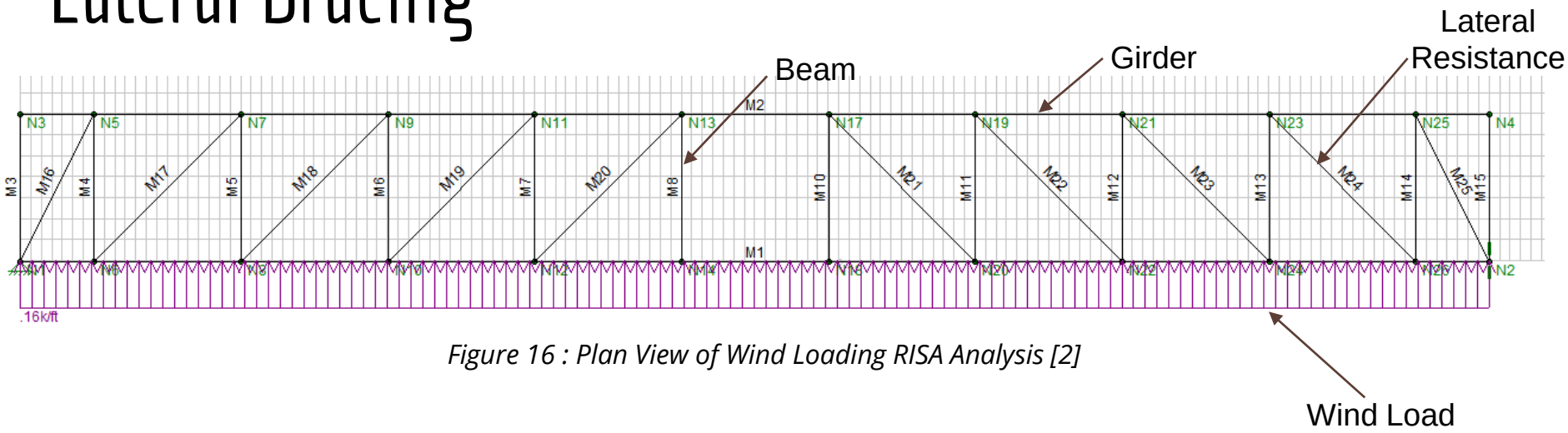


Figure 16 : Plan View of Wind Loading RISA Analysis [2]

Table 3: Maximum Load on Lateral Bracing Structure

	Member		*Load [k]*
1	M20	max	.783
		min	.783
1	M21	max	.783
		min	.783

Mike 13

Construction Cost

Table 4: Material Price Comparison

Material Price Comparison									
Supplier	**Lumber Material**	**Joist 2"x8"x8'**	**Quantity**	**Beam 2"x12"8'**	**Quantity**	**Girder 14"x48"x70.3'**	**Quantity**	**Total Cost**	% Diff
Home Depot	Douglas Fir	$8.26	40	$13.55	10	$8,973.75	2	$18,413.41	**343%**
LAMBOO	Bamboo	$72.50	40	$112.50	10	$38,763.00	2	$81,551.00	

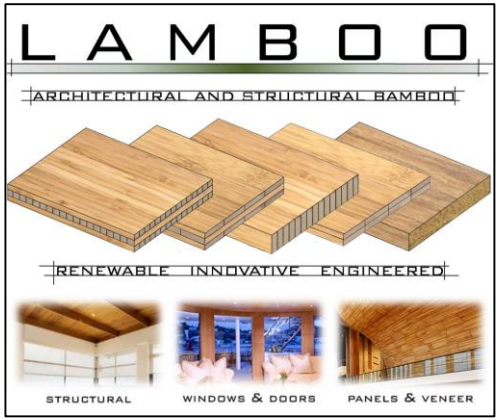


Figure 17 : Laminated Bamboo [9]

Table 5: Total Construction Cost

Total Construction Costs	
Lamboo Materials	$81,551.00
Decking Materials	$4,210.37
Strucutral Connection Materials	$1,040.31
Lateral Bracing Connections	$425.34
Total Costs	**$87,227.02**

Figure 18 : Dimensional Lumber, Douglass Fir [10]

Schedule - Executed

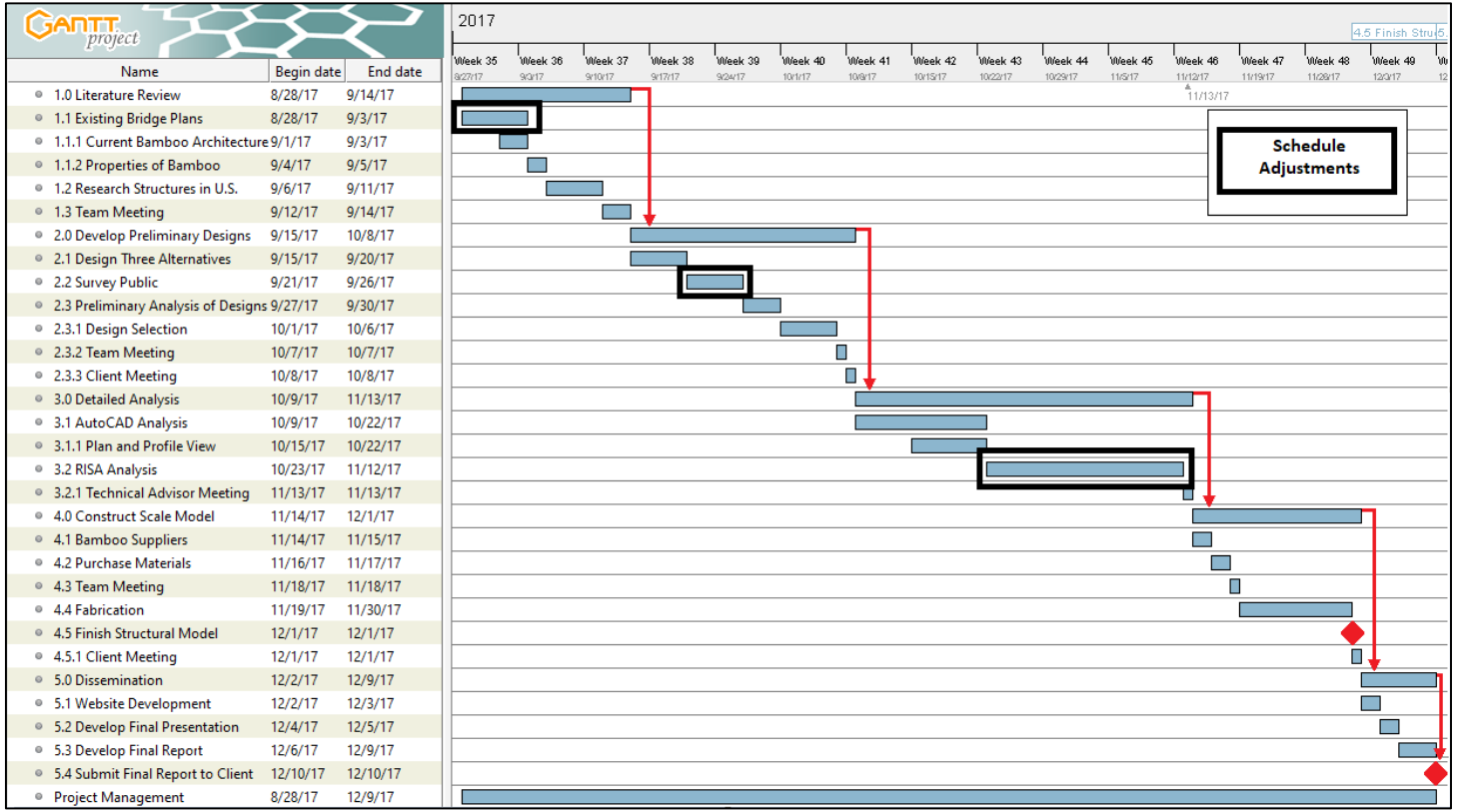


Figure 19: Executed Gantt Chart Schedule

Cost of Engineering Services

Table 6: Cost of Engineering Design Costs

COST ANALYSIS					
Position	**Hourly Rate (USD)**	**Total Hours**		**Costs**	
Senior Engineer	$194.00	150	106	$29,100.00	$20,564.00
Project Engineer	$67.00	191	157	$12,797.00	$10,519.00
Project Manager	$90.00	165	141	$14,850.00	$12,690.00
EIT	$50.00	211	172	$10,550.00	$8,600.00
		717	**576**	**$67,297.00**	**$52,373.00**
		% Diff	**-20**	**% Diff**	**-22**

Impacts of Design

Economic

- Bamboo production/manufacturing
- Decrease lumber market

Social

- Influencing architectural designs
- Encourages citizens of Flagstaff to use the FUTS

Environmental

- Bamboo grows naturally and quickly
- Decrease in steel/lumber production

Figure 20: Sports Hall in Thailand, [6]

Figure 21: Raw Bamboo Stalks, [7]

Scale Model

Figure 22: Scale Model Construction Finish

Table 7: Scale Model Cost

Scale Model Materials Costs	
Home Depot	$38.85
Michaels	$92.04
Total Cost	**$130.89**

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