Excellent Engineers

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Introduction:

For this project, we designed a truss intended to withstand a concentrated load at the center of the truss. While following the design specifications, we constructed a design prototype that consisted of a length of 23 inches, a height of 6.875 inches, and beam members of width 0.7 inches. Our design had a total of 5 base beams, 6 (smaller) link beams, and 7 rectangular gusset plates. We then programmed a calculator on Google Sheets to solve for forces, stresses, internal loads, buckling, shear, cross-sectional areas, and tensile strength of members and connections within our truss design. After completing our design, we built the truss using oak wood and Gorilla Glue as the base materials. Our truss turned out to weigh 17.2 lbs and withstood a total of 872 lbs as it failed due to glue shear stresses. In this report, we will specify our truss design by including our experimental calculations, technical engineering drawings, final calculations of all forces, predictions, final results, and our conclusion/recommendations.

Experimental Material Property Data and Calculations:

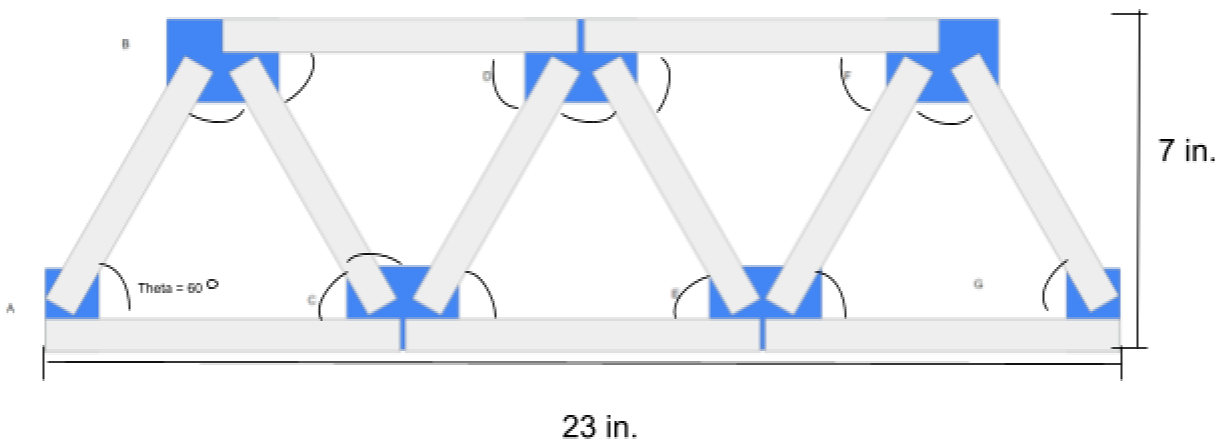
There were two types of wood, oak and pine, and two types of glue, Elmer's and Gorilla, made available for the construction of the truss. To obtain experimental values of the properties of these materials, tests were run in a lab environment. For the wood, data was collected on the tensile and shear strength, elastic modulus, and density. For the glue, data was collected on the shear strength. The results are as follows:

- Oak Wood
  - Average Tensile Strength: 17,873 psi
  - Average Shear Strength: 2,872 psi
  - Elastic modulus: 1.8 Mpsi
  - Density: 0.024 lb_f/in^3
- Pine Wood
  - Average Tensile Strength: 14,327 psi
  - Average Shear Strength: 1,492 psi
  - Elastic modulus: 1.5 Mpsi
  - Density: 0.014 lb_f/in^3
- Elmer's Glue
  - Average Shear Strength w/ Oak: 869 psi
  - Average Shear Strength w/ Pine: 727 psi
- Gorilla Glue
  - Average Shear Strength w/ Oak: 1265 psi
  - Average Shear Strength w/ Pine: 1086 psi

After examining the results of the material testing, a few observations can be made. First, oak is the overall stronger wood, being able to withstand much more force than pine. Second, Gorilla glue is a much more effective adhesive than Elmer's glue, especially when paired with oak wood.

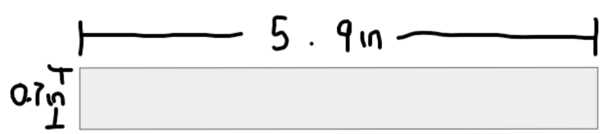
Technical Engineering Drawings:

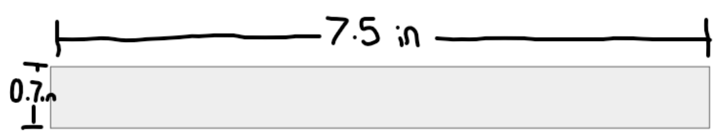
Truss Complete View:



- All angles are 60 degrees between members

Members/Beams:

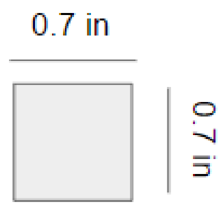




<u>Members: AB, BC, CD, DE, EF, FG:</u>
Base Length: 5.9 in
Height: 0.7 in
Cross-Sectional Area: 4.13 in^2

<u>Members: BD, DF, AC, CE, EG:</u>
Length: 7.5 in
Height: 0.7 in
Cross-Sectional Area: 5.25 in^2

Cross-Section of Members:



Width: 0.7 in

Height: 0.7 in

Cross-Sectional Area: 0.49 in^2

<u>Gusset Plates(B,C,D,E,F)</u>

Length: 2.37 in

Height: 1.75 in

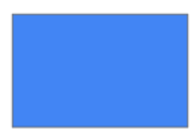
Area: 4.1475 in^2

<u>Gusset Plates (A,G)</u>

Length: 1.13 in

Height: 1.75 in

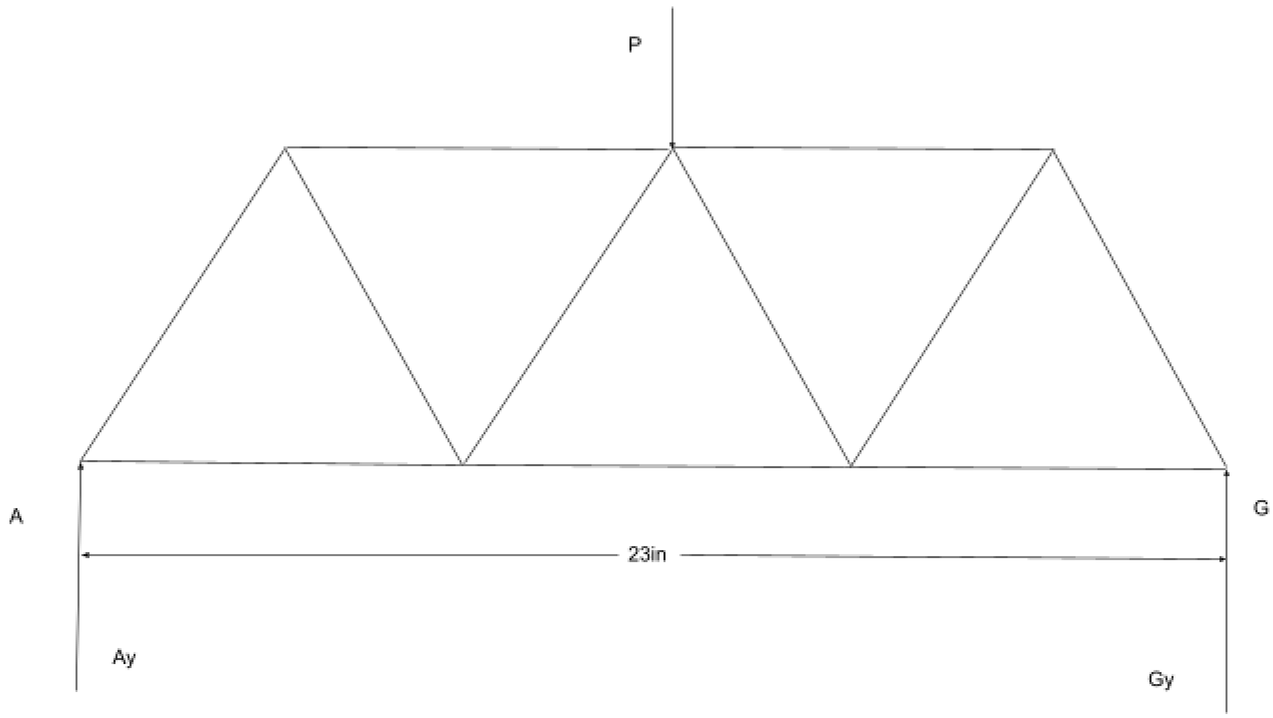
Area: 1.9775 in^2



Calculations:

[Truss Calculator - Google Sheets]

Support reactions:



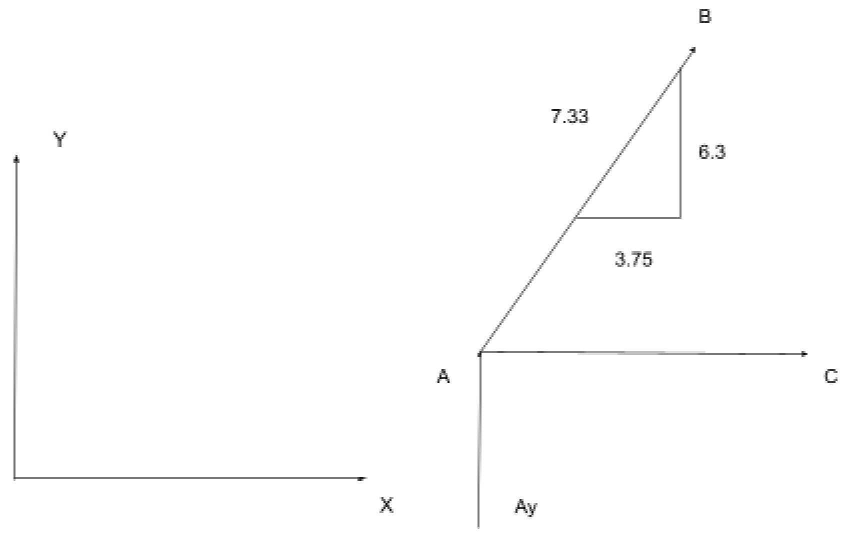
$$\Sigma F_x = 0$$

$$\Sigma F_y = 0$$
$$A_y + B_y - P = 0$$

$$\Sigma M_A = 0$$
$$23in \times B_y - 11.5in \times P = 0$$

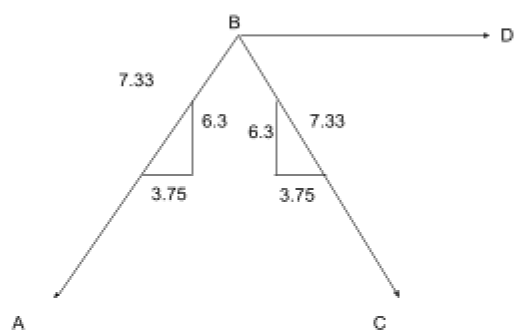
$B_y = P/2$
$A_y = P/2$

Internal Cross-Sectional Forces:



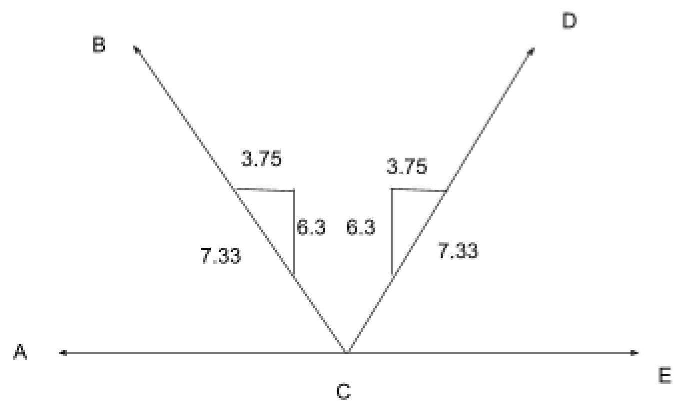
$$\Sigma F_x = 0$$
$$\frac{3.75}{7.3} \times F_{AB} + F_{AC} = 0$$
$$0.296 \times P = F_{AC}$$

$$\Sigma F_y = 0$$
$$A_y + \frac{6.3}{7.33} \times F_{AB} = 0$$
$$-0.577 \times P = F_{AB}$$



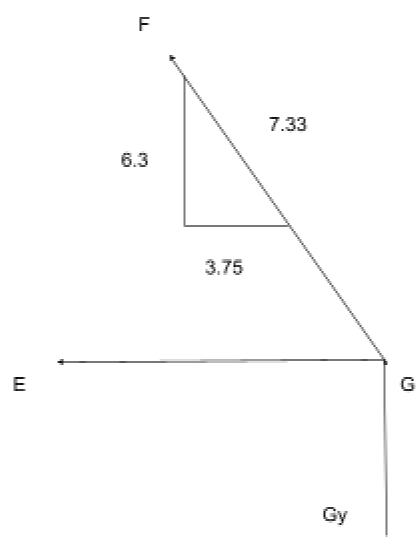
$$\Sigma F_x = 0$$
$$-\frac{3.75}{7.3} \times F_{AB} + \frac{3.75}{7.3} \times F_{BC} + F_{BD} = 0$$
$$-0.592 \times P = F_{BD}$$

$$\Sigma F_y = 0$$
$$-\frac{6.3}{7.33} \times F_{BA} - \frac{6.3}{7.33} \times F_{BC} = 0$$
$$0.577 \times P = F_{BC}$$



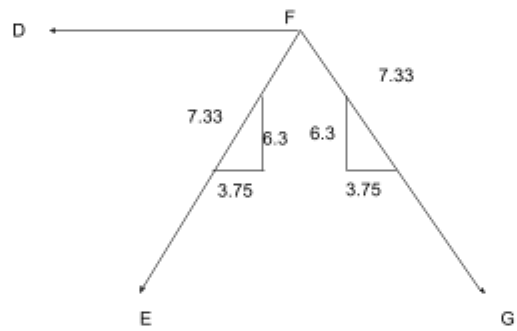
$$\Sigma F_x = 0$$
$$-F_{CA} - \tfrac{3.75}{7.3} \times F_{CB} + \tfrac{3.75}{7.3} \times F_{CD} + F_{CE} = 0$$
$$0.296 \times P = F_{CE}$$

$$\Sigma F_y = 0$$
$$\tfrac{6.3}{7.33} \times F_{CB} + \tfrac{6.3}{7.33} \times F_{CD} = 0$$
$$-0.577 \times P = F_{CD}$$



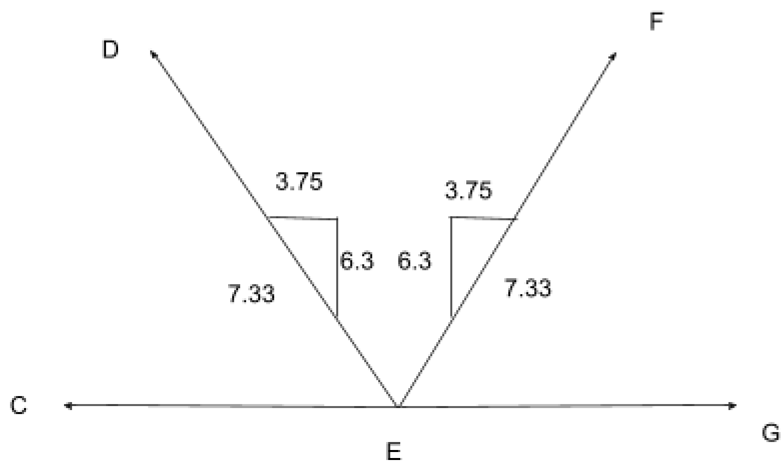
$$\Sigma F_x = 0$$
$$-\tfrac{3.75}{7.3} \times F_{GF} - F_{GE} = 0$$
$$0.296 \times P = F_{GE}$$

$$\Sigma F_y = 0$$
$$G_y + \tfrac{6.3}{7.33} \times F_{GF} = 0$$
$$-0.577 \times P = F_{GF}$$



$$\Sigma F_x = 0$$
$$\tfrac{3.75}{7.3} \times F_{FG} - \tfrac{3.75}{7.3} \times F_{FE} + F_{FD} = 0$$
$$-0.592 \times P = F_{FD}$$

$$\Sigma F_y = 0$$
$$-\tfrac{6.3}{7.33} \times F_{FG} - \tfrac{6.3}{7.33} \times F_{FE} = 0$$
$$0.577 \times P = F_{FE}$$



$$\Sigma F_y = 0$$
$$\tfrac{6.3}{7.33} \times F_{ED} + \tfrac{6.3}{7.33} \times F_{EF} = 0$$
$$-0.577 \times P = F_{ED}$$

Beam:	Force in beam in terms of P:
AB	-0.577P
AC	0.296P
BC	0.577P
BD	-0.592P
CD	-0.577P
CE	0.296P
DE	-0.577P
DF	-0.592P
EF	0.577P
EG	0.296P
FG	-0.577P

Normal Stress In Beams:

$\sigma = F/A$
Average tensile strength of oak: 17873 psi

Beam:	Force In Beam In Terms of P:
AB	$17873\ psi = 0.577P/0.49\ in^2$ P=15200 lbs
AC	$17873\ psi = 0.296P/0.49\ in^2$ P=29600 lbs
BC	$17873\ psi = 0.577P/0.49\ in^2$ P=15200 lbs
BD	$17873\ psi = 0.592P/0.49\ in^2$ P=14800 lbs
CD	$17873\ psi = 0.577P/0.49\ in^2$ P=15200 lbs
CE	$17873\ psi = 0.296P/0.49\ in^2$ P=29600 lbs
DE	$17873\ psi = 0.577P/0.49\ in^2$ P=15200 lbs
DF	$17873\ psi = 0.592P/0.49\ in^2$ P=14800 lbs
EF	$17873\ psi = 0.577P/0.49\ in^2$ P=15200 lbs
EG	$17873\ psi = 0.296P/0.49\ in^2$ P=29600 lbs
FG	$17873\ psi = 0.577P/0.49\ in^2$ P=15200 lbs

Safety Factor:

Smallest P is 14800 lbs
$SF = P_{max}/P_{actual}$
$SF = 14800lbs/1000lbs = 14.8$

Buckling for Compressive Members:

$\frac{\pi^2 EI}{(KL)^2} = Critical\ Buckling\ Load$

$I = \frac{bh^3}{3} = \frac{.7 \times .7^3}{3} = .0803\ in^4$

$E_{oak} = 1800000\ psi$

K = 1, pinned pinned connection

Beam:	Length of Beam (in):
AB	7.331609646
BD	7.5
CD	7.331609646
DE	7.331609646
DF	7.5
FG	7.331609646

Beam:	Critical Buckling Load (lbs):
AB	P=26500
BD	P=25300
CD	P=26500
DE	P=26500
DF	P=25300
FG	P=26500

Shear Stresses:

Gorilla Glue Shear Strength:1265 psi

$\tau = F/A$

Shear Glue Stress				
	Area of contact with gusset plate			
	Left Side of Beam (in^2)	Right Side of Beam (in^2)	Left Side of Beam P	Right Side of Beam P
AB	0.616	0.616	$1265\ psi = 0.577P/(0.616 \times 2)\ in^2$ P=2700lbs	$1265\ psi = 0.577P/(0.616 \times 2)\ in$ P=2700lbs
AC	0.791	0.791	$1265\ psi = 0.296P/(0.791 \times 2)\ in^2$ P=6760lbs	$1265\ psi = 0.296P/(0.791 \times 2)\ in$ P=6760lbs
BC	0.616	0.616	$1265\ psi = 0.577P/(0.616 \times 2)\ in^2$ P=2700lbs	$1265\ psi = 0.577P/(0.616 \times 2)\ in$ P=2700lbs
BD	0.791	0.791	$1265\ psi = 0.592P/(0.791 \times 2)\ in^2$ P=3380lbs	$1265\ psi = 0.592P/(0.791 \times 2)\ in$ P=3380lbs
CD	0.616	0.616	$1265\ psi = 0.577P/(0.616 \times 2)\ in^2$ P=2700lbs	$1265\ psi = 0.577P/(0.616 \times 2)\ in$ P=2700lbs
CE	0.791	0.791	$1265\ psi = 0.296P/(0.791 \times 2)\ in^2$ P=6760lbs	$1265\ psi = 0.296P/(0.791 \times 2)\ in$ P=6760lbs
DE	0.616	0.616	$1265\ psi = 0.577P/(0.616 \times 2)\ in^2$ P=2700lbs	$1265\ psi = 0.577P/(0.616 \times 2)\ in$ P=2700lbs
DF	0.791	0.791	$1265\ psi = 0.592P/(0.791 \times 2)\ in^2$ P=3380lbs	$1265\ psi = 0.592P/(0.791 \times 2)\ in$ P=3380lbs
EF	0.616	0.616	$1265\ psi = 0.577P/(0.616 \times 2)\ in^2$ P=2700lbs	$1265\ psi = 0.577P/(0.616 \times 2)\ in$ P=2700lbs
EG	0.791	0.791	$1265\ psi = 0.296P/(0.791 \times 2)\ in^2$ P=6760lbs	$1265\ psi = 0.296P/(0.791 \times 2)\ in$ P=6760lbs
FG	0.616	0.616	$1265\ psi = 0.577P/(0.616 \times 2)\ in^2$ P=2700lbs	$1265\ psi = 0.577P/(0.616 \times 2)\ in$ P=2700lbs

Safety Factor:

Smallest P is 2700lbs

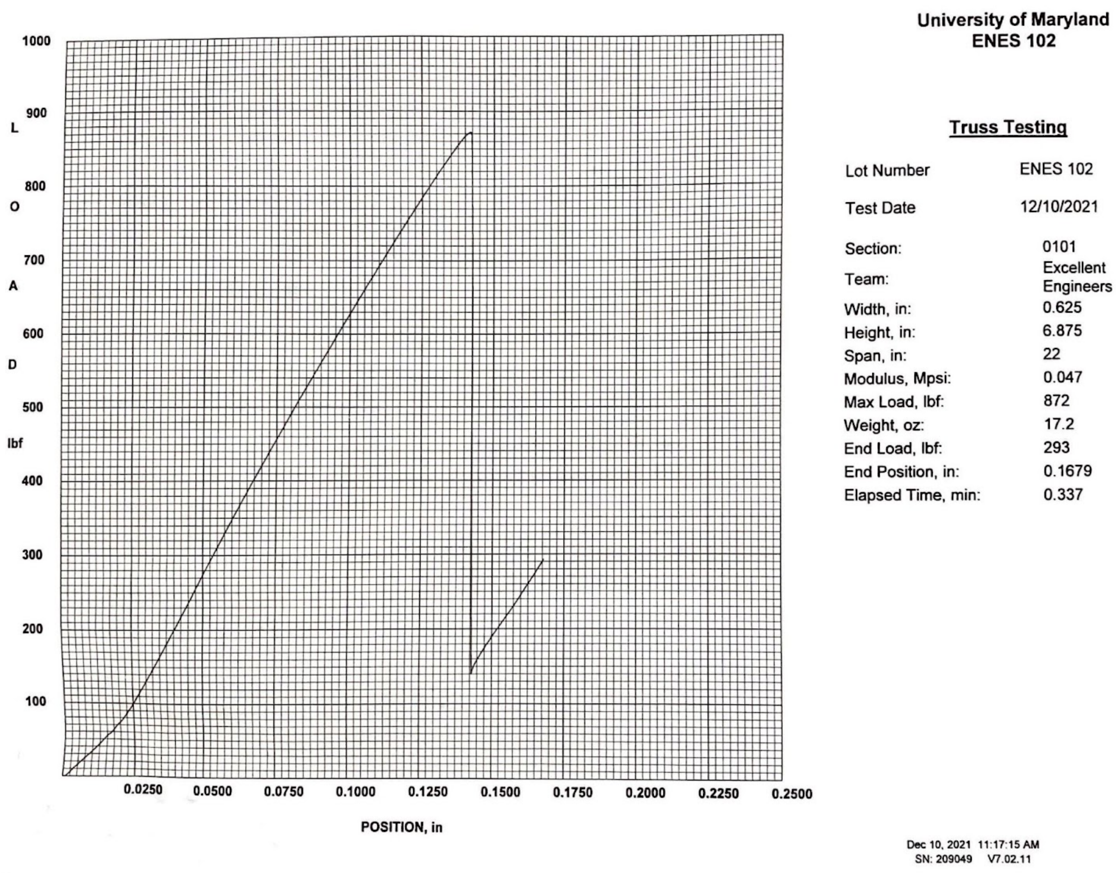
$SF = P_{max}/P_{actual}$

$SF = 2700/1000 lbs = 2.7$

Predictions:

Maximum load: Smallest P calculated: 2700lbs

Test Results:



<u>Strength to weight ratio:</u> 50.698 lbf/oz
<u>Failure:</u> Glue shear

Discussion of Results:

The truss was capable of holding a maximum load of 872 lbf until glue shear occurred. Possible reasons for the structural failure are:

1. The truss was not a perfect symmetry along the y-axis. Because, on the testing machine, the load point was slightly shifted from the middle joint to one side of the truss, it resulted in an uneven distribution of load, causing an unpredicted structure failure.
2. The amount of glue necessary for each gusset plate wasn't measured. So there could be places where less than the required amount of glue is applied. Also, we could not immediately put the clamps on, because first, we applied glue and all the gusset plates on both sides of the truss. This took us approximately 25 to 30 minutes, and then we put the clamps on. This may have affected the glue strength.
3. The angle between the members of the truss structure was not accurate, which is also a reason behind the uneven distribution of load. When putting the clamps on the truss members moved while tightening the clamp, changing the angles between the members. We used the blueprint for accurate angles but not tools to hold the members down, so the members may have moved when applying glue or attaching the gusset plates. Human error is also a possible reason for inaccurate angles.

Conclusions and Recommendations:

Our truss project designed to withstand a predicted load of 1000 lbf was only capable of holding 872 lbf, with a strength to weight ratio of 50.698 lbf/oz, and the type of failure is glue shear. The uneven distribution of load was probably the main reason behind failure. In future projects we should:

1. Make sure the angles between the members are accurate and symmetric over the y-axis, the center joint of the truss. Also, we should use tools or supports to hold the members down at the correct angles so that they don't move when applying glue, putting on clamps, or moving the truss for any reason.
2. Make sure there is no gap left when applying glue between members and gusset plates. Also, put the clamps on immediately after applying glue to get maximum glue strength.
3. Use supports to stop the truss from moving when putting on clamps on the gusset plates.