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Team Beam Lab Report

Introduction to Engineering Practices and Principles I

ENGR 1201-001

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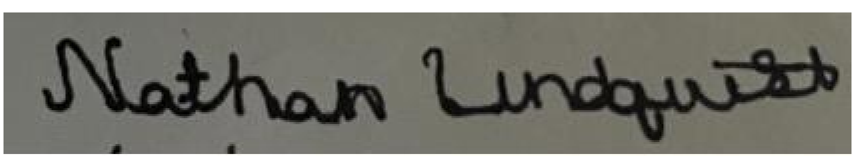
11/07/2021



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Introduction

We, as individuals, were assigned a task to design three viable beams (I-beam, H-beam, and hollow box beam). The beams were to be constructed of 24-inch-long basswood lumber and must have had a cross-section that was configured like an I-beam, an H-beam, or a hollow box beam. Each individual beam needed to contain a cross-section that was symmetrical about the centroid axes and had to be made into a center-loaded, simply-supported configuration that was able to withstand a load of 300lb on the X-axis and 150lb on the Y-axis. The overall cross-section of each individual beam should not have exceeded 2 inches by 2 inches. The weight of each individual beam should not have exceeded 270 grams. The span length of each beam needed to be 18 inches. Each individual beam's X-axis deflection should not have exceeded 0.225 inches and Y-axis deflection should not have exceeded 0.240 inches. The beam could not exceed a price of $10.50 with glue joints priced at $.50 per joint. Each beam could only be built using clamps, tools, and Elmer's Carpenter's Wood Glue provided by the instructor. It could be assumed that the modulus of elasticity of basswood lumber is$1.46 * 10^6$psi and the density of basswood lumber is$28 lbm/ft^3$.

Given these requirements each individual designed three beams and we researched and performed calculations that allowed us to conclude that Thomas Fulbright's I-beam was the optimum solution.

Theory

Beams are usually horizontal structural components; they can be vertical. Beams are designed to withstand loads that are vertical to its horizontal axis. Several factors impact the strength of a beam such as the material the beam is constructed of, the span length, represented by a L, which is the length between the beam supports, and the type of supports used to support the beam. Beams are usually categorized by their cross-section which is the shape of the beam when looking at the end of the beam. A beam's load, represented by a P, is defined as the force that a beam can withstand and is measured by the amount of force applied and the location and way the force is applied to the beam. The type of load used in the testing of this beam was single-point load which is a concentrated load. The type of support used in the testing of this beam was simple-support which is a beam that has supports on each end. There are several concepts that help in designing a beam: the area moment of inertia, modulus of elasticity, the deflection (Gill, Lindsay, Fennel 2021, Week 8).

The area moment of inertia is represented by an I. The area moment of inertia is defined as how resistant the beam is to bending or deflecting. To calculate the area moment of inertia of an I-beam one needs to gather the following information:

- The web thickness, represented by W_t, is the width of the vertical center cross-section.
- The flange thickness, represented by F_t, is the length of the horizontal top and bottom sections.

- The outside base, represented by B, which is the total horizontal length.
- The inside base, represented by b, which is the total horizontal length subtracted by the web thickness.
- The outside height, represented by H, which is the total vertical length.
- The inside height, represented by h, which is the total vertical length subtracted by the flange thickness.

The equation for the area moment of inertia of an I-beam is $\frac{(B*H^3)}{12} - \frac{2(b*h^3)}{12}$.

The modulus of elasticity which is represented by an E. The modulus of elasticity is defined as the inherent stiffness of the material.

Deflection which is often represented by a Δ symbol. Deflection is defined as the amount of bending a beam shows when the load is applied. To calculate the deflection of an I-beam one needs to gather the following information:

- The load, represented by P.
- The span length, represented by L.
- The modulus of elasticity, represented by E.
- The area moment of inertia, represented by I.

The equation for the deflection of an I-beam is $\frac{P*L^3}{48*E*I}$

Methods

In order to construct our beam, we set out to use several calculations that would contribute to the design of each beam. The calculations were a crucial part of the beam design as it ensured the beam would theoretically pass every test given to it and meet the design specifications. The first narrowing factor used to construct the beam was to not allow anything over a 2 inch by 2 inch surface or a cost greater than $10.50. Given these two strict specifications, we were able to construct a beam within a reasonable time. When designing this beam, we were under the assumption that the least amount of deflection would be best when a load was applied. So our calculations were based mainly off of the Δx of the beam. Seeing as the moment of inertia was indirectly proportional to the deflection across the x-axis, we set out to design a beam with a large moment of inertia. To obtain a large moment of inertia, one must create a tall beam. The beam created for this project was the maximum height as we believed it would yield the best results regarding the deflection. The materials used for this experiment were a 5/16" X 1-½" basswood web along with two ¼" X 1-½" flanges. This took up almost all of our space as well as the cost of the beam. The first calculation of the beam needed is the moment of inertia. For an I-beam, this is found through the formula below in equation 1.

$I_x = (b_o h_o^3)/12 - (2b_i h_i^3)/12$ Equation (1)

Using equation (1) along with our selected wood sizes yielded

$I_x = (1.5in * 2in^3)/12 - (2 * (1.5in - 5/16in) * (2in - 2(1/4in))^3)/12 = 0.6660in^4$

This was the result for the x-axis moment of inertia for the I-beam. The next calculation is for the y-axis of the beam. Equation (2) explains the calculation of such a beam.

$I_y = (2b_f h_f^3)/12 + (b_w h_w^3)/12$ Equation (2)

In the case of our designed beam, the results of these calculations are below.

$I_y = (2 * 1/4in * 1.5in^3)/12 + (1.5in * 5/16in^3)/12 = 0.1444in^4$

Once we calculated the moments of inertia, we calculated the deflection across the x-axis. This can be found by using equation (3).

$\Delta x = (P_x L^3)/(48EI_x)$ Equation (3)

In our experiment, solving for the deflection across the x-axis was as follows:

$\Delta x = (300lbf * 18in^3)/(48 * 1.46 * 10^6 psi * 0.6660in^4) = 0.037in$

In order to find the deflection across the y-axis, we use equation (3) but replace the force exerted on the beam's x-axis with that of the y-axis and replace the moment of inertia with that of the y-axis. Our value for the deflection on the y-axis is calculated below.

$\Delta y = (150lbf * 18in^3)/(48 * 1.46 * 10^6 psi * 0.1444in^4) = 0.086in$

Another important component we had to take into consideration is the volume of the beam. In order to calculate the volume, we needed to first calculate the area. Since this beam is in the shape of an I, we broke it into three pieces and then added them together. We calculated the area of the flanges and the web, added them together, and then multiplied the total by the length of the beam. See the formula for volume in equation (4) below.

$volume_{I-Beam} = (2f_b f_h + w_b w_h) * L$ Equation (4)

Using equation (4), we calculated our beam's volume to be

$V = (2(1/4in)(1.5in) + (5/16in)(1.5in)) * 24 = 29.25in^3$

Another important design specification that must be accounted for is the efficiency of the beam. The efficiency must be greater than 1.20 in order to receive full credit for the project. The efficiency of the beam is based on the max weight available and the actual weight of the beam. With this in mind, we must first calculate the weight of the beam. The formula for the weight is given in equation (5) where V is volume, P is density, and m is mass.

$V * P = m$ Equation (5)

Our calculations of the beam are as follows:

First, we had to convert the density from lbf/ft^3 to g/in^3. See calculations below.

$P = 28lbf/ft^3 * 1ft/12in * 1ft/12in * 1ft/12in * 1lbm/1lbf * 1kg/2.2lbm * 1000g/1kg = 7.3653g/in^3$

With the density calculated, we can now find the mass of the beam using equation (5).

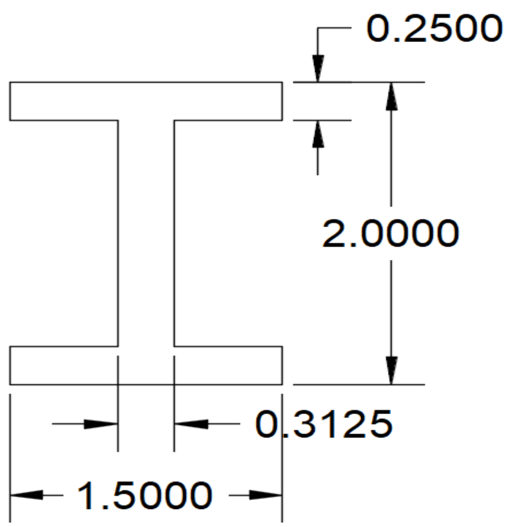
$7.3653g/in^3 * 29.25in^3 = 215.4356g$

Given that the maximum weight of the beam should not exceed 270g, we can now make our calculations of the efficiency of our beam given in equation (6).

$Efficiency\ Ratio = (Design\ Mass\ (maximum))/(Actual\ Design\ Mass)$ Equation (6)

In our case, the efficiency was greater than 1.20 so we were able to receive full credit.

$Efficiency\ Ratio = 270g/215.4356g = 1.25$



Drawing (1)

After calculating all this data, we came to the conclusion that the proposed beam passed all of the tests and would be submitted for construction. The building process of the beam is to simply use Elmer's wood glue and flow a single beam of glue down each joint of the beam. In the case of the I-beam, that would be a total of two joints, one between the web and the flange of both sides. After letting the glue dry and harden, we must test the beam to ensure that all the requirements are met for the constructed beam. In order to test the beam, we must apply a specific load to the center point of the beam. The beam had a span of 18 inches with the total length of the beam being 24 inches. To properly test the beam, place the stand for the beam 3 inches from each side of the beam to support it. This will give us the span required. Next measure the size of the width that you will be using to apply the pressure to the beam. Then subtract that from the total length of the beam and divide the result by two. This will determine the position to place the load in the center of the beam. Using a car jack rigged to a metal stand, along with a transducer we can apply various amounts of a controlled load. A transducer is a device that measures physical quantities and converts it into an electrical signal. In our case, it will take the pressure applied and display it in pound-force for us to monitor. A caliper was then used to measure the deflection across each axis. The caliper was in imperial units and measured 0.001 inch per tick mark on analog display. The result of a full revolution of the needle was 0.1 inch. This was used to accurately measure the deflection of the beam. As the testing progressed, we moved up the weight in 50 pound-force increments and took deflection measurements until we reached our maximum weight at 300 pound-force. After gathering the data, the beam was rotated 90 degrees to measure the y-axis deflection. In order to do this, some extra wood was placed longways across the I-beam in order to apply pressure to both flanges. After placing the maximum load of the y-axis, we measured the deflection to ensure that the beam passed the requirements.

Results

The results from our lab were almost identical to what we were expecting. Our I-Beam seemed to pass all of the tests down to how our calculations went. The only thing that seemed that we over expected was the weight. We had calculated the weight to be slightly heavier than it tested to be. In accordance to figure 1 The results from the lab are able to be seen in tabular form.

fig (1)

	Given Values	**Theoretical Values**	**Test Results**	**Difference Percentage**
x - axis Deflection	.225 in	.037 in	.095 in	87.87%
y - axis Deflection	.240 in	.086 in	.129 in	40%
Weight (grams)	270 grams	215.4356 grams	205 grams	4.96%

Discussion

After taking a closer look at the results, we found that our I - Beam deflected more upon the x and y axis that we anticipated. One of the reasons that this deflection could have differed could be from the dexterity of the glue joints. In our theoretical calculations, we did not add in the strength of the glue or how they would impact the deflection. Overall the deflection of the beam stayed within the region of the guidelines for the lab and passed the test. If given the chance to recalcalculate, we could add in the type of glue and amount used. This could help with finding weak points and give a closer calculation on the deflection. When looking at the test results, our beam had passed in every way which is good and shows our calculations were close enough to correct to provide a strong enough beam.

Conclusions

In this assignment, we were able to learn to develop a team and work together as a group to perform a task well. Because of this, we are more professionally developed than before. In the experiment, we designed a beam to withstand a force of 300 pound-force without deflecting more than 0.225 inches. The beam constructed allowed the beam to withstand much more weight and only deflected 0.095 inches with the maximum load. This is considered a success as we planned to have a safety factor of 2.5. This means that the beam could withstand 750 pound-force before exceeding the x-axis deflection. As we can see the difference in the beams calculated above was high meaning that the beam was not constructed under perfect conditions. This is understandable as nothing in the real world is perfect. This beam was a success as it allowed us to work in a group setting and create a beam that would withstand the design specifications.

References

Gill, Gwendolyn, and Lindsay Kevin. “Beam Theory.” Week 8 - Oct. 11-17: Beams: HOW THE WORLD GETS BUILT! Canvas - University of North Carolina at Charlotte, 2021. https://uncc.instructure.com/courses/156101/files/13229697?wrap=1

Appendix

https://uncc.instructure.com/courses/156101/pages/beam-testing-video?module_item_id=3787743

Test data file: ///C:/Users/User/Downloads/Team%204%20Beam%20Test%20Results.pdf