Student
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Course
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Design project report for Engineering Mechanics

Introduction

Understanding materials in mechanics is critical in the application of the materials in the in mechanics. This fact has led to the investigation of a truss bridge to establish why it is permanently deflected under a load that is higher than the allowable specification (Ashby). The test majorly entails establishing the causes of failure of a truss bridge due to loading. The test will majorly entail loading of the truss bridge and collect data relevant for the compilation of the Young's modulus, yield stress and ultimate tensile stress. These tests will be done severally so as to increase the accuracy of the data obtained. This document presents the raw data obtained, the failure report and the material testing discussion.

The experiments aim at familiarizing with the relationship between load and deflection of the various beams that make up the truss bridge. It also aims at exploring the theory of young's modulus of the materials that comprise the beams. The experiments that will be undertaken are the bend testing rig, the deflection of a cantilever and deflection of a simply supported beam. The bending test will involve loading of masses on a shaft supported between clamps of a rig and measuring the load-deflection relations. The deflection of a cantilever experiment will involve deflection of a cantilevered beam for steel and aluminum. Finally, the deflection of a simply supported beam experiment entails investigating the deflection of a simply supported beam for steel and aluminum.

Executive Summary

The tests endeavor to explain the failure of the truss bridge using engineering principles. The bridge experienced permanent deflection under a load that is higher than the allowable specification. The test methods involved testing of the tension of metallic materials. The test was done at room temperature with the metals forged into beams. The test mainly was aimed at establishing the Young's modulus, yield stress and ultimate tensile stress of the beams making the truss bridge. The members of the truss were made from annealed stainless steel grade 405 (Modulus of Elasticity = 200 GPa, Yield Strength = 170 MPa, Ultimate Tensile Strength = 415 MPa). The length of the truss was found to be approximately 80 meters, and the height to be approximately 6 meters. Each truss bay is equal in size (International). The bottom chord members consist of 40x40 mm square sections, and all other truss members are 80x80 mm square sections.

The exceptions to this tests were made for the individual members where it was imperative to conclude that the members would operate with their allowable stress and strain zones. The members were also assumed to be non-elastic hence they could experience fracture

when their elastic limits are exceeded. Room temperature was considered to be 10 to 38°C. The values were all converted to the SI units.

The labs mainly aimed at testing the two members of the bridge; the tensile and the compression members. The two different beams (cantilever and the simply supported) were tested under different loads obtaining the load deflection hence establishing that the bridge permanently deflects under load is higher than the allowable specification. The results from the test calculation of young's modulus accurately. This test proved useful in determining Young's modulus of the material of the beams and hence offer superior results as compared to the tensile test. The stress both in the (90x90) tension members and the (80x80) compression is higher than the one allowed by the material properties. A higher compression higher than the yield point caused deformation of the diameter hence distorting cross-sectional area of the member while the tension reduced the diameter of the member.

The calculations for Young's modulus to establish the yield point of the material was able to establish that the bridge would succumb to masses introduced at the center of the bridge. The finding was because yield point would easily be exceeded when compression force was introduced.

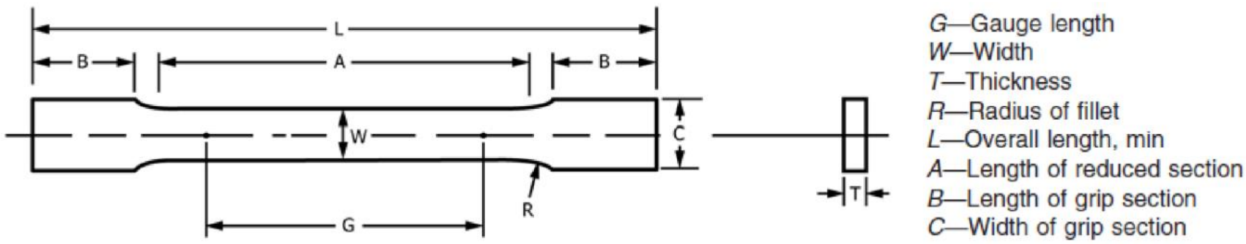
Materials Testing Discussion

To test the behavior of the materials of the member of the truss bridge, we do a compression test and tensile test (Peixoto, Sousa and Restivo). The main elements to be tested were the Young's modulus, yield stress and ultimate tensile stress of potential materials to be used to construct a new bridge. The bending experiment was effective in obtaining accurate values for the calculation of the Young's modulus. The simply supported was a little bit undesirable.

Young's modulus

The following are the dimensions of the beams used in the experiment material

Material	Nominal Thickness (T) mm	Gauge Length (G) mm	Width (W) mm
MS Blackform	1.6	80	12
SS 304	1.5	80	12
Al 5005	1.6	80	12
Al 5052	1.6	80	12



The beams were deflected in agreement with the Euler-Bernoulli beam theory. The principles would be considered for both the set ups of the experiment. The cantilever beam had the maximum deflection occurs at the free end of the beam, and in the simply supported beam it occurs at the center of the beam. To calculate the maximum deflection of the cantilever and the simply supported beam the below equations can be used.

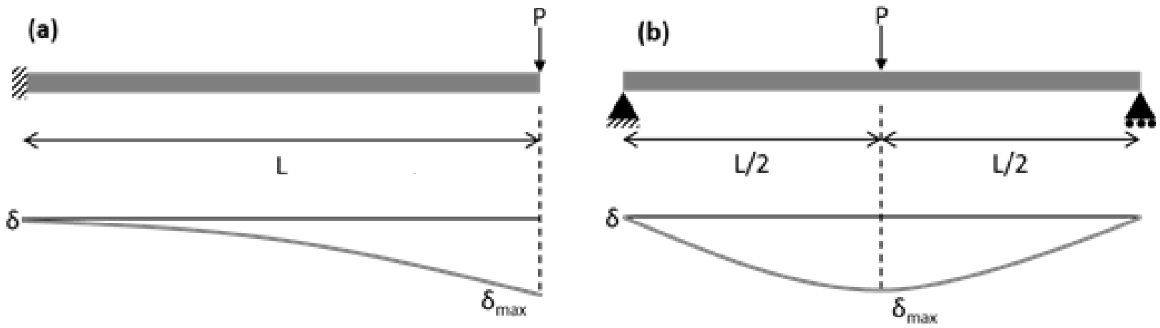
$$\delta_{max} = \frac{PL^3}{3EI} = \left(\frac{L^3}{3EI}\right)P$$

$$\delta_{max} = \frac{PL^3}{48EI} = \left(\frac{L^3}{48EI}\right)P$$

$$I = \frac{bh^3}{12}$$

L is the length of the beam (mm)
E is Young's modulus (GPa or N/mm2)
P is the load (Newtons)
I is the 2nd moment of inertia (mm^4)

The figure below represent the deflection experienced in the two experiments.



Young's modulus represents the slope of the line in a stress-strain curve. To determine the young modulus from the tests we plot the relationship between the load and the resulting deflection and hence obtain the slope of the graph. Treating the plot a linear relationship y = bx + c we obtain the following equations.

$$b = L^3/3EI$$

$$b = L^3/48EI$$

From the experiment, we first calculate the second moment of inertia so as to be able to obtain the deflection

Beam	Width(mm)	Height(mm)	Length(mm)	Cross-sectional area(mm^2)	I (mm^4)
Aluminium	19.2	3.1	150	2880	47.67
Steel	19.2	3.1	200	3840	47.67

$$19.2 \times (3.1)^3 / 12$$

$$47.6656mm^4$$

From the above readings we can calculate the second moment of inertia

$$I = \frac{bh^3}{12}$$

$= (0.02)\,(0.003)^3/\,12$

$=4.5 \times 10^{-11}\ m^4$

To obtain the maximum deflections

$$\delta_{max} = \frac{PL^3}{3EI}$$

$= (2.5)\ (0.2)^3/3(207 \text{ x } 109)\ (4.5 \text{ x } 10^{-11}m^4)$

$= 0.000716$ m

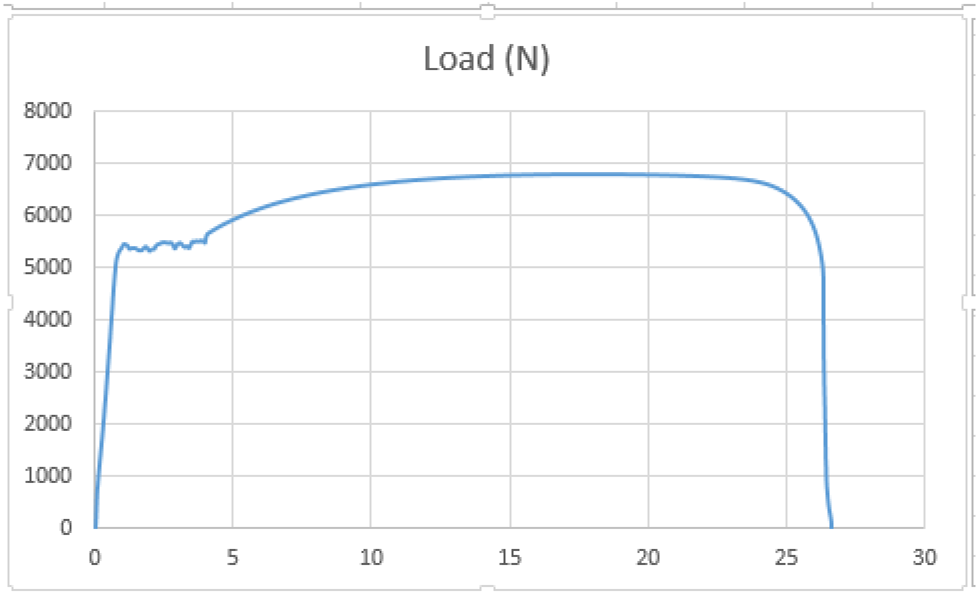
$= 0.716$mm

The deflection obtained can be used to determine the Young's modulus of the material of the beams.

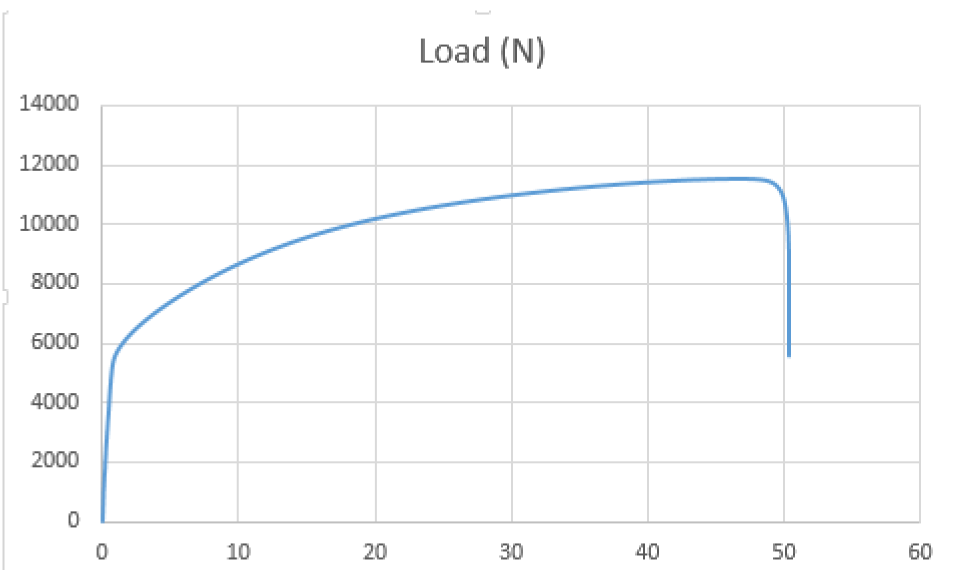
Property	Your value	Unit
Young's modulus	46.025	GPa
0.2 % proof stress	283.07	MPa
Ultimate tensile stress	348.54	MPa
Engineering strain at the point of necking	22.26	%
ductility	33.4599	%

To design the beams we plot the respective extensions of the beams against the loads.

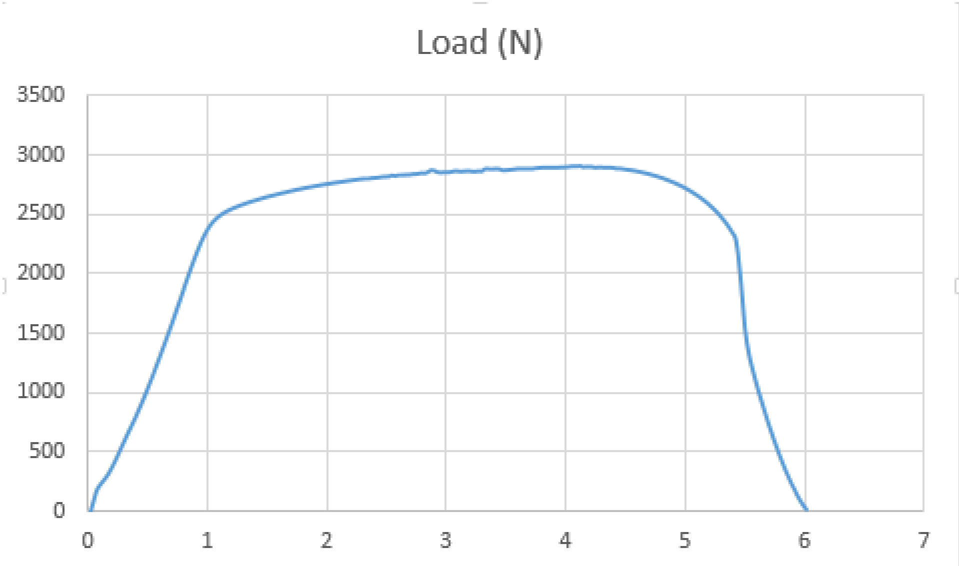
MS Blackform



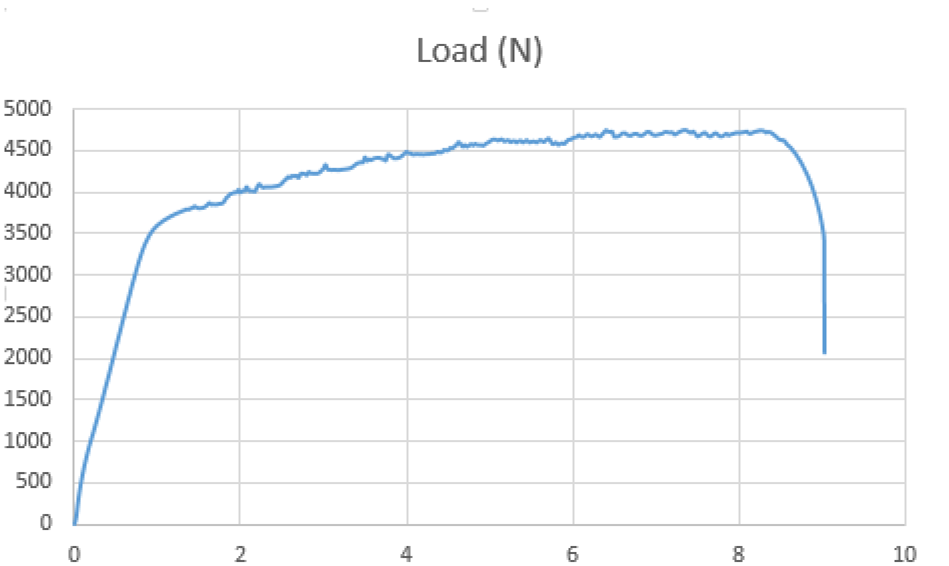
SS 304



Al 5005



Al 5052



Yield stress and ultimate tensile stress

The tensile test is used to measure the mechanical properties of the beams. It relates the effects of a tensile load on the elongation (change in length) of the bridge beams. To fully analyze the material of the beams we monitor their behavior under tension and compression (G, Totten and MacKenzi). The assumption for the tension and compression worked for the value of the material constant. The stress and deformation formula developed are applied to the members of the bridge in tension and compression hence establishing the effect of loading on the beams. The compressive strength of the materials is different from their tensile strength. From the stress-strain plots, the modulus of the elasticity is the same for tension and compression. But from the results, the compressive strength of aluminum was two times that of steel. Compression test was conducted without unloading hence the beams behavior was almost the same in the compression and the tension.

The modulus of elasticity, yield stress and the ultimate stress become equal.

From the strain and stress on the original length of the beam length of the sample obtained from the truss and equaled the elongation of the beam (the change in length of the beam) divided by the original length of the beam. Since both strain and stress have units of length, the strain has dimensionless units and is expressed mainly in meters and millimeter. Commonly strain can be expressed as engineering strain as a percent strain or percent elongation (M).

Engineering strain = engineering strain x 100%

The plot of the stress vs. strain diagram results in a curve that is usually linear and follows the relationship. This linear relationship is based on Hooke's Law and has a yield point represents elastic deformation. Removal of the load in the region of the beam, the member will regain its original shape without permanent deformation. The gradient of the curve is the modulus of elasticity or Young's Modulus, which is similar to a spring constant. Materials differ in the young modulus due to the difference in the bonds, a material's Young's modulus is not affected by microstructure but is entirely affected by the bond strength holding the atoms in the structure. When the load increases the stress level is increased to the point beyond the elastic limit, if the stress exceeds the yield stress and permanent deformation of the beams take place. The permanent deformation is known as the plastic deformation owing to the kind of behavior in the structure. It's difficult to determine the exact point where the change from elastic to plastic behavior occurs. The 0.2% offset method is usually used to estimate this point. A parallel line to the elastic curve is drawn through the strain, and the point of intersection with the stress-strain curve defines the yield stress. The ultimate tensile stress is the maximum stress in the engineering stress-strain diagram. The beams will ultimately experience extensive plastic deformation after excessive loading, and then eventually undergo localized deformation known as necking before ultimate failure. The region is as a result of deformation instability and after its formation, hence any deformation is restricted to this region. At this point the true stress required to pull the beams to failure constantly increasing until fracture. But, since the stress is calculated using the original cross-section of the beams after necking occurs the value of the engineering stress decreases. The beam's ductility is characterized either by the strain to failure or the percentage change in length. If significant necking occurs before fracture, the percentage change in dimension of the beams will be a clear measure of ductility of the beams.

Conclusions

The experiments aim at establishing the ductility of the beams to be used in the truss bridge. The relationship between load and deflection of the beams that make up the truss bridge. The experiment was able to test the theory of young's modulus of the materials that make up the beams. The experiments so far undertaken involved the bend testing rig, the deflection of a cantilever and deflection of a simply supported beam. The bending test involved loading of masses on a beam supported between clamps of a rig and measuring the load-deflection relations. The deflection of a cantilever experiment involved deflection of a cantilevered beam for steel and aluminum. Finally, the deflection of a simply supported beam experiment entailed investigating the deflection of a simply supported beam for steel and aluminum

Young's modulus, is a measure of the deformation of a the beams material in response to an applied force causing stress to the beams, is a fundamental variable to consider when designing and mechanical engineering systems like bridge or buildings. Young's Modulus is the gradient of the stress-strain curve. We designed and used clamps to hold the beams so as to measure the Young's modulus of aluminum and steel beams. The beams were held taut at one end with clamped blocks, and the other end is suspended with the load to cause stress and strain so as to provide data for the design. The application of mass to the beams stretches the beam and causes the beam to deflect. The amount of the deflection is proportional to the load applied to the beams. The strain is found by the deflection of the beam divided by the initial length of the beam while; the stress can be found using the amount of force applied divided by the cross-sectional area of the beam. The stress-strain graph is then plotted, and the Young's Modulus is determined using the slope of the graph.

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