University of Texas at Austin

CE 314K

Properties and Behavior of Engineering Materials

Sample Writing Assignment

Fall 2007

The following example provides guidance for interpreting the instructions in the *CE 314K Technical Writing Guide*. A memo and lab report based on a scenario for Lab 1 are provided.

Scenario

Assume that you are an engineer working for Polymer Testing Services, Inc. Your company has just been hired by Six Flags to develop the project specifications for a new bungee jumping attraction for their San Antonio theme park. The design engineer for the project has determined that the bungee cord for the project must be able to withstand repeated loading cycles to a maximum stress of 265 psi and that the secant modulus of elasticity must be between 800 and 1200 psi. Your supervisor, Steve Armstrong, has asked you to perform a series of laboratory tests to determine if the standard bungee cord manufactured by Titan Rubber Supply is sufficient to meet the project specifications. Assume that the rubber specimen you tested in the laboratory was manufactured by Titan Rubber Supply.

Document your laboratory results in a short memo to Mr. Armstrong. In addition, document any observations that you made during the laboratory that may limit the usefulness of the bungee cord material for the proposed application.

Lab Report

Document the detailed results of your tests in a laboratory report. Address the following four topics in the discussion of results. Note that the step numbers refer to the laboratory procedure.

1. Calculate engineering and true stress-strain values for data collected in steps 9 and 10. Plot the data in one figure and compare the values. Discuss if the observed response was elastic or inelastic. Discuss if the observed response was linear or nonlinear.
2. Calculate the secant modulus of elasticity for the rubber at the maximum stress based on the engineering stress-strain curve.
3. Determine the average value of Poisson's ratio from the measured data. You can determine the transverse strain from the measured values of the diameter using Eq. 1:

$$\varepsilon_y = \frac{\Delta D}{D_o} \qquad \text{Eq. 1}$$

   where ΔD is the change in diameter, and D_o is the original diameter. Does the average measured value for Poisson's ratio agree with the expected value? If the value estimated from your data is not expected, identify possible sources of error in the measured data.
4. Use the data collected in steps 4 though 8 to discuss the behavior of the material when subjected to repeated loading cycles. Identify any trends in the data that may impact the suitability of this material for an engineering application.

In addition, document the measured response of the test specimens using the following appendices:

- Appendix A – Measured Load and Elongation Data
- Appendix B – Calculation of Stress and Strain
- Appendix C – Repeated Loading

CE 314K
Laboratory 1
Behavior of Rubber in Tension

Example Writing Assignment

Name:	Lena Marie Elwood
Date:	18 January 2006
Lab Session:	Monday PM Lab Session
Technical Teaching Assistant:	John Schnitzer
Lab Partners:	Jason Smith, Eugene Wong, Julia Ramirez

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POLYMER TESTING SERVICES, INC.

TO: Steve Armstrong
FROM: Lena Marie Elwood, Engineer
DATE: 18 January 2006
RE: Tests of Bungee Cord for New Attraction at Six Flags San Antonio

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I have conducted a series of materials tests on the standard 0.5-in. diameter bungee cord manufactured by Titan Rubber Supply and have concluded that this material is suitable for the proposed attraction at Six Flags in San Antonio, TX.

Based on the project specifications, I have assumed that the maximum axial stress expected in the field is 265 psi. I tested the bungee cord material in the laboratory to an axial stress of 272 psi. The absence of any distress in the material indicates that this is a safe load level. Using the maximum levels of stress and strain, I calculated the secant modulus of elasticity to be 1000 psi. This value also satisfies the project specifications.

The laboratory tests indicated that the aluminum end fixtures used to grip the cord easily cut the surface of the bungee material. There were also a few minor nicks and cuts along the length of the sample. These observations may indicate that the end grips could limit the useful life of the bungee cords. Therefore, I recommend that the bungee cords used at the Six Flags attraction be inspected carefully on a daily basis. If the inspector observes any tearing of the cord material, the cord must be replaced immediately. If requested, I would be happy to develop an improved design for the end grips to provide a longer-term solution to this potential problem.

Please contact me if you need any additional information or would like a copy of the complete report documenting my laboratory experiments.

Laboratory Report: Behavior of Rubber in Tension

Introduction

The primary objective of this experiment was to perform a series of tests to determine if a given type of rubber met the project specifications for a bungee jumping attraction at the Six Flags theme park in San Antonio. Load and elongation data were measured while subjecting a rubber specimen to tensile loads. These data were then converted to stress and strain. Poisson's ratio and the secant modulus of elasticity were then calculated from the stress and strain data.

Procedure

The test specimen was a rubber strap with a circular cross section of approximately 0.5 in. diameter. Aluminum clamps were used to grip the ends of the specimen. The top was supported on a horizontal steel rod, and a hangar assembly was attached to the bottom grip. During the first phase of testing, the specimen was loaded in uniaxial tension by placing weights on the hangar assembly in 10-lb increments. Before applying the first weight, a 10-in. gage length was marked on the specimen so that elongation could be monitored during the test. The diameter of the specimen was also measured during each load step. The maximum applied load was 50 lb. The specimen was also unloaded in 10-lb increments. During the second phase of testing, the specimen was loaded and unloaded five times to a maximum load of 50 lb.

Results and Discussion

All data measured in this laboratory are presented in Appendix A. Engineering data calculated from the measured data and the equations used to calculate the engineering data are provided in Appendices B and C.

Stress-Strain Response

The engineering and true stress-strain values were calculated for the rubber specimen, illustrated in Figure 1. At the maximum applied load of 50 lb, the engineering stress is 272 psi and the true stress is

351 psi. The corresponding values of engineering strain and true strain are 0.272 and 0.240, respectively. Both the engineering and true stress-strain curves exhibited nonlinear responses. At low levels of applied load, the values of engineering and true stress and strain are nearly the same. However, the differences increased as the magnitude of the applied load increased. As expected, the true stress exceeded the engineering stress, and the engineering strain exceeded the true strain for all levels of applied load. Although the stress-strain curves plotted in Figure 1 indicate that the rubber experienced a slight amount of permanent elongation, the specimen returned to its original length after approximately 5 minutes. Therefore, the observed response may be classified as being elastic. These trends in the measured data were expected based on published information (Young et al., 1998).

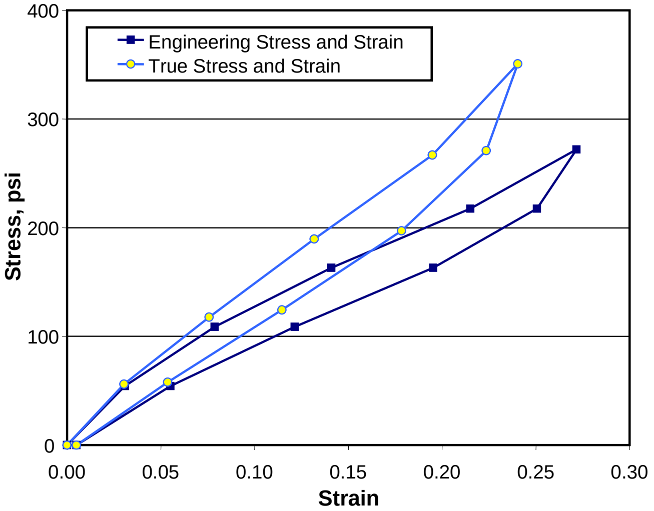

Figure 1: Measured Stress-Strain Curves for Rubber Specimen

Modulus of Elasticity

Because the stress-strain curve for rubber is nonlinear, the modulus of elasticity depends on the applied load. For this application, the secant modulus was determined using the maximum stress. As shown in Figure 2, the secant modulus of elasticity for this material is 1000 psi.

Poisson's Ratio

The average value of Poisson's ratio calculated from the measured data was 0.48, which is consistent with published values (Mamlouk and Zaniewski, 2006). However, the value appears to depend on the level of the applied load (Figure 3). For low levels of applied load, the value of Poisson's ratio tended to be 0.5, or larger. As the applied load was increased, Poisson's ratio decreased. This variation in Poisson's ratio was not expected. Additional tests are required to determine whether these variations are representative of the rubber tested in this laboratory, or whether the variations may be attributed to errors in measuring the response of the specimen.

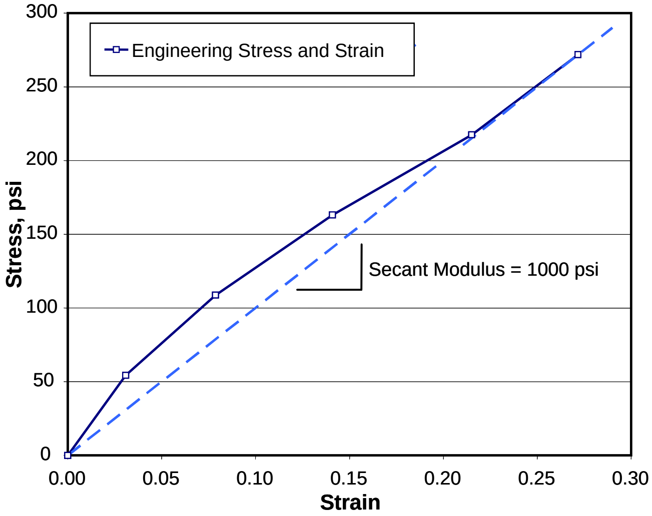

Figure 2: Secant Modulus of Elasticity

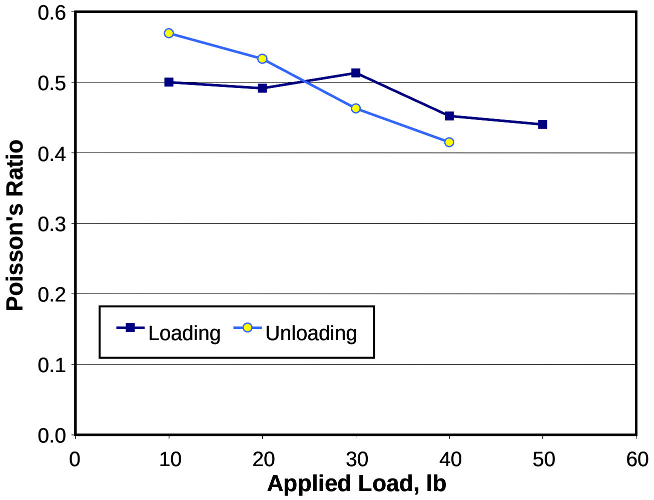

Figure 3: Variation of Poisson's Ratio with Applied Load

Repeatability of Measurements

The rubber specimen was subjected to five loading cycles between 0 and 50 lb. During the first three cycles, the length of the specimen increased in each subsequent cycle (Figure 4). However, the length of the specimen appeared to stabilize during the fourth and fifth loading cycles, since the variation in the measured lengths was essentially zero for these cycles. After completing the loading cycles, the specimen initially exhibited a residual increase in length. However, the specimen returned to essentially its initial length after a period of approximately five minutes. The conclusion from this set of tests is that the response of the rubber is time dependent. The long molecule chains of the polymers that form the rubber take time to straighten and relax during loading and unloading. In contrast, the measured diameters did not exhibit a clear trend with the number of loading cycles (Figure 5). Without additional tests, conclusions cannot be drawn.

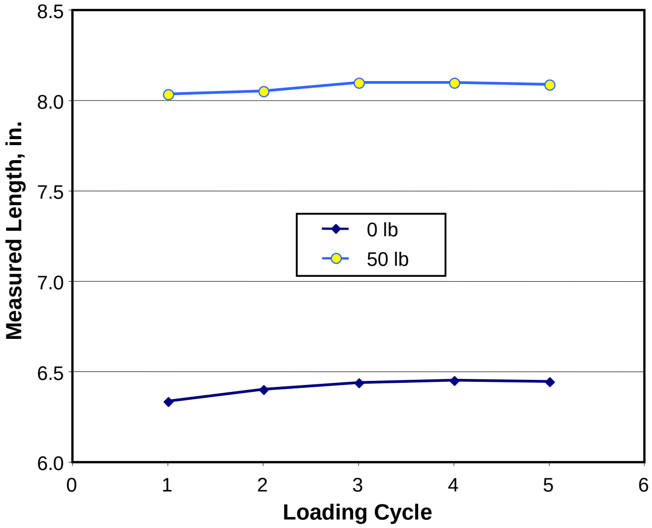

Figure 4: Variation of Measured Length with Number of Loading Cycles

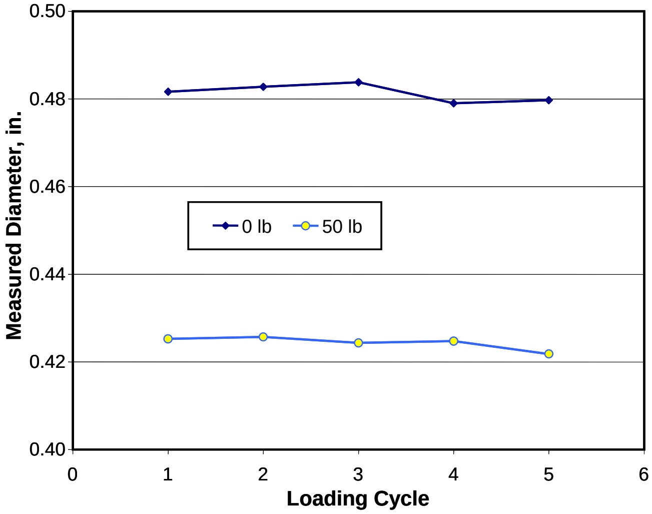

Figure 5: Variation of Measured Diameter with Number of Loading Cycles

The laboratory group experienced some problems while making the measurements. The marks on the surface of the rubber used to identify the gage length were wider than the scale on the ruler used to measure the length of the specimen. Therefore, readings taken by different engineers could easily vary by 0.02 to 0.05 in. for a given load. The laboratory group also experienced problems with the micrometers. After a considerable amount of practice, each member of the group was able to read the micrometer to within 0.0002 in. for a given configuration of the specimen. However, additional variations in readings were expected because some group members tightened the barrel more than others. In spite of these difficulties, the measured data appear to be reliable.

Conclusions

As expected, the rubber specimen exhibited nonlinear, elastic stress-strain response when subjected to tensile loads. The loading and unloading curves were not the same; therefore, the material is characterized as exhibiting hysteresis. At all levels of applied load, the values of true stress exceeded the corresponding values of engineering stress and the values of engineering strain exceeded the corresponding values of true strain. The experiments were remarkably repeatable, with most error being due to the inexperience of the researchers and inconsistency in measurement techniques used by different researchers.

Appendix D: References

Mamlouk, M.S. and Zaniewski, J.P. (2006). *Materials for Civil and Construction Engineers*, Second Edition, Pearson Prentice Hall, 576 p.

Young, J.F., Mindess, S., Gray, R., Bentur, A. (1998). *The Science and Technology of Civil Engineering Materials*, Prentice Hall, 384 p.