CEEN 3320 - Behavior & Properties of Engineering Materials

Laboratory Experiment No. 1

Measurement techniques

Engineers rely on data from a wide variety of sources to design the things that make up our physical world and to ensure compliance with established specifications.

The vast majority of this data comes from a variety of measurements. The depth of a concrete footing, the speed of a shaft in an engine, and the voltage across a resistor in an electronic circuit are all examples of measurements we as engineers rely on to facilitate the design process.

It is important (in many instances critically so) that the data generated from these measurements is as close to the "true" value as our instruments and techniques will allow. In the vast majority of cases, this "truth" is unknown so we rely on instruments that have been *calibrated,* or checked against a standard or known value, to provide us with an accurate assessment of whatever parameter we are interested in measuring.

Even though we have instruments that are properly calibrated we still face the challenge of choosing the correct measurement device, and once chosen, using it correctly. Engineers and scientists use the terms *resolution, precision, accuracy and bias* to describe very specific aspects of a device's capability, and we as engineers need to understand what each means and how it impacts our decisions.

Resolution

Resolution (also referred to as *sensitivity*) is the smallest portion of an interval we can measure or distinguish on an object or specific parameter being measured, or on the instrument we are using. For instance, a measuring tape may be marked in 1/16" increments, and we can confidently say that we can distinguish the halfway point between these markings, giving us an *implied* maximum resolution of 1/32" while the *stated* maximum resolution is 1/16". In contrast, the resolution of a digital device such as a caliper or balance is fixed at the number of decimal places the display presents.

It is important to note that resolution is not the same thing as *accuracy*. The measurement could be in error by much more than the devices resolution due to improper calibration, instrument wear, and changes in temperature or defective manufacturing to name just a few possibilities.

Accuracy

Accuracy is a measure of how close a measurement is to truth. It can also be defined as the absence of *bias*, or the tendency to diverge from the true value in one direction. Figure 1.18 on page 28 of the text shows a graphical representation of accuracy, precision and bias. It follows that the greater the bias, the less accurate the measurement.

$$bias = \overline{\theta} - \theta_0$$

Precision

Precision is a measure of the variability of repeat measurements or trials. We may, for example, measure the length of a steel beam several times and each time obtain a slightly different result. The *variance* of the readings can be caused by a number of reasons such as small differences in how you use the instrument each time, operator experience and expertise, etc. Variance (***var***) is a statistical measure calculated as follows:

$$\mathrm{var} = \frac{\sum(\theta - \overline{\theta})^2}{(n-1)}$$

where θ is the difference of each measurement and $\overline{\theta}$ is the mean of all measurements. It follows that the larger the variance, the less precise the data.

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Measurement Techniques

OBJECTIVE:	**To determine the most suitable measuring tool for each specific task, proper use of those tools and proper data recordation**
EQUIPMENT:	**Load Cell, Data Acquisition System, Dial Caliper, Digital Caliper, Dial Gauge, Ruler, Measuring Tape, Potentiometer, Proving Ring, Static Weights for Calibration, Wood Test Specimens, Steel Test Specimens, Balance**
ASTM REF:	**E 29-06**
TEXT REF:	**Materials for Civil and Construction Engineers, 2nd ed.**
	Chapter 1, sections 1.1-1.7; Experiment 1, pp. 466-469.

PROCEDURES:

Part A- Measurement of Length and Depth (Data Sheet 1)

1. **Select a wood test specimen and record its length, width and depth to the maximum resolution of the tape measure. Record the mass using the balance.**
2. **Determine the length, width and depth of the aluminum cube using dial and digital calipers. Record the mass using the balance**
3. **Determine the length and diameter of the concrete cylinder. Record the mass using the balance.**
4. **Select a tensile test specimen and record the gage length and diameter using both the dial and digital caliper.**
5. **Select a stack of paper and measure thickness using the micrometer.**
6. **Determine the thickness of the aluminum plate using the dial gauge. Repeat using the linear potentiometer.**

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Part B- Measurement of Force (Data Sheet 2)

1. **Develop a calibration curve for the proving ring by placing a series of increasing static weights on the load platen and record the displacement of the proving ring shown on the dial gage.**
2. **Select each object of unknown mass and place on the proving ring. Record the proving ring deformation.**
3. **Place the proving ring in the Riehle Universal Test Machine such that it is resting on the bottom bolster. Place the load cell on top of the proving ring. Apply load very slowly through the load cell to the proving ring and record both load cell and proving ring data at several points of the load cycle. Continue loading to a maximum value of 1,000 lbf.**

Report:

1. **Prepare a report which briefly describes the tests completed and results obtained.**
2. **Using the table of values determined in Part A, steps 1-3, calculate the unit weight and specific gravity of each material. Comment on these results.**

$$G_s = \frac{\gamma}{\gamma_w} = \frac{m}{\mathrm{V}\,\gamma_w}$$

3. **Prepare a plot of proving ring load (y axis) vs. proving ring deformation (x axis) from data obtained during Part B, step 1. Perform a linear regression analysis of the proving ring data to determine the calibration equation. Comment on the results.**
4. **Using data from Part B, step 3, prepare a plot of the calculated proving ring load (y axis) vs. the load measured by the load cell (x axis). Comment on results.**
5. **Calculate the submerged mass of the metal cube (weight under water).**

Part A - Data Sheet 1

	Length	**Width**	**Depth**	**Diameter**	**Mass**
Wood Specimen				▨	
Tensile Test Specimen		▨	▨		▨
Tensile Test Specimen		▨	▨		▨
Aluminum Cube				▨	
Aluminum Cube				▨	
Concrete Cylinder		▨	▨		
Paper	▨	▨		▨	▨
Aluminum Plate	▨	▨		▨	▨
Aluminum Plate	▨	▨		▨	▨

Part B - Data Sheet 2

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Calibration Mass					
Proving Ring Dial Gauge Reading					
Object					
Proving Ring Dial Gauge Reading with Unknown Mass					
Load Cell Reading From Data Acquisition System					
Proving Ring Dial Gauge Reading					
Proving Ring Load (Calculated)					
Mass of Object (Calculated)					