Experiment Four
Column Buckling Test

Introduction

4.1 Objective:

The purpose of this experiment is to verify the Euler buckling equation for steel columns of various lengths subjected to different end conditions.

Apparatus:

Materials and Equipment

a. Columns of various lengths made from different materials
b. Column buckling machine
c. Load equipment
d. Dial indicators

4.3 Background

There are usually two primary concerns when analyzing and designing structures: (1) the ability of the structure to support a specified load without experiencing excessive stress and (2) the ability of the structure to support a given load without undergoing unacceptable deformation. In some cases, however, stability considerations are important especially when the potential exists for the structure to experience a sudden radical change in its configuration. These considerations are typically made when dealing with vertical prismatic members supporting axial loads. Such structures are called columns. A column will buckle when it is subjected to a load greater than the critical load denoted by P_{cr}. That is, instead of remaining straight, it will suddenly become sharply curved as illustrated in Figure 1.

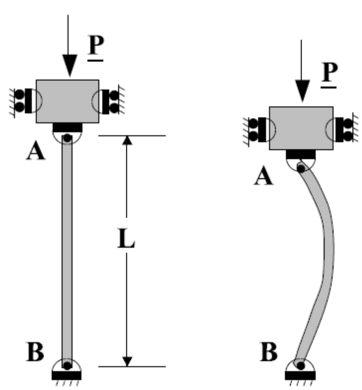
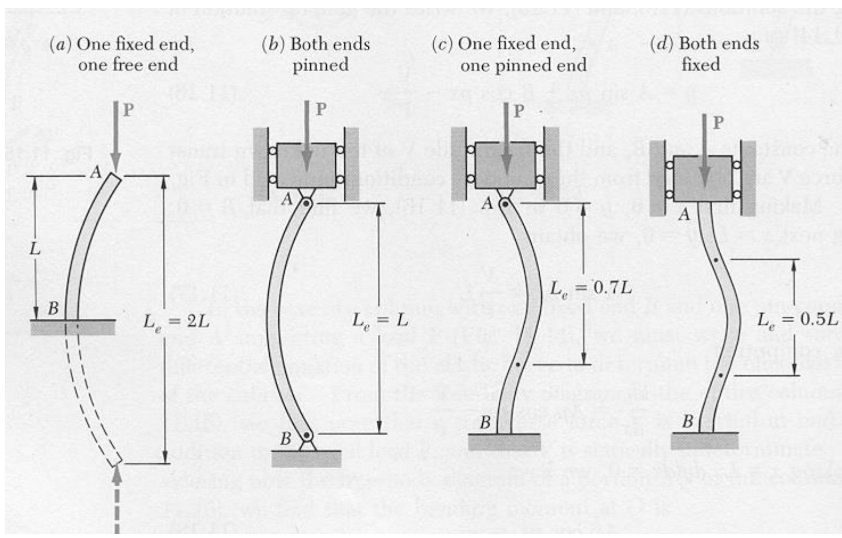


Figure 1. A column will buckle when a critical load is reached.

The critical load is given in terms of an effective length by :

$$P_{cr} = \frac{\pi^2 E I}{L_e^2} \qquad \textbf{(4.3-1)}$$

where E is the elastic modulus, I is the moment of inertia, and L_e is the effective length.
The expression in Equation (4.3-1) is known as Euler's formula. The effective length depends upon the constraints imposed on the ends of the column. Figure 2 shows how the effective length is related to the actual length of the column for various end conditions.



The critical load is computed by making $I = I_{min}$ in Equation (4.3-1). Thus, if buckling occurs, it will take place in a plane perpendicular to the corresponding principal axis of inertia.
The radius of gyration, r, is often introduced into Euler's formula. This quantity is given by

$$r = \sqrt{\frac{I_{min}}{A}} \qquad \text{And} \qquad P_{cr} = \frac{\pi^2 E A}{(L_e/r)^2} \; .$$

Where A is the cross sectional area of the column. Substituting Equation (4.3-2) into (4.3-1), Finally:

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{\pi^2 E}{(L_e/r)^2} \; .$$

In Above Equations, the quantity (L_e / r) is called the slenderness ratio of the column.
For long columns, with a large slenderness ratio, Euler's formula is adequate for design purposes. However, for intermediate and short columns, where failure occurs essentially as a result of yield, empirical formulas are used to approximate test data. These empirical formulas are specified on the basis of material tests conducted by engineers working in that field. The American Institute of Steel Construction, for example, sets the design standards for structural steel in the United States.

Preparation for the lab:

1. Calculate the projected critical load for the pin-supported columns to be tested for 10”, 12”, 15”, 18” and 20”.
2. All columns are rectangular shape of 0.75” x 0.075”
3. Create and prepare a data sheet for the laboratory indicating the following information on the table.
    a. Length
    b. Predicted critical load,
    c. Measured mid span deflection,
    d. Failure mode (elastic or inelastic)
4. What are your dependent variables, independent variables, and controlled variables?

Procedure

The number of columns tested will be sizes from 10” to 20” using 10”, 12”,15”,18”
Only one end condition, two different end conditions [see Figure 2, cases (b), (c),] would be tested.

The most critical factor in this lab is to ensure that the columns are loaded in a perfectly horizontal and secured position. Any angular rotation (especially in the case when both ends are fixed) will result in erroneous results. Care should also be taken in adjusting the collar on the post for each column. It is important to stop the loading of the column as soon as the critical load has been reached to avoid permanent damage to the column.

For each column tested:

1. Measure and record the dimensions of the column on the worksheet.
2. Calculate the expected buckling load for the end conditions at hand. The steps for doing this are outlined on the worksheet.
3. Orient the satin chrome blocks on the loading frame for the end conditions chosen. V-notches should face away from the mounting surface (towards the column) for pinned ends and towards the mounting surface (away from the column) for fixed ends.

4. With the end conditions selected, adjust the capstan nut
6. Gradually apply increment of load, and must be rechecked each time the column is changed.
5. The loading beam should then be adjusted to the desired column as follows:

The stop for the loading beam when the column start to change mode of bucking.

After the column is in position, the dial indicator is installed in the brackets and fastened to the center post. The indicator bracket should be moved up or down the post so that the indicator point contacts the column at its midpoint. The indicator may then be zeroed by loosening the black plastic knob that holds the indicator on the frame and then moving it gently toward the column until the needle on the small scale is zero. The large scale is zeroed by rotating the outside bezel until the large needle is on zero. One revolution on the large scale is 0.100 in. (2.54 mm) and is equal to 1 on the small scale. Each graduation of the large scale is 0.001 in. (0.025 mm). Extreme care should be exercised in handling the dial indicator.

After each increment of load, record the load and deflection on the data sheet. Suitable increments for the loading of the column may be obtained by rotating the hand wheel.

Required:

From graph and data collected find:

1. Find average bulking critical loads from measurements and provided equations.
2. Plot average critical load and deflection as function of column length.
3. Using Euler's equation and the average critical load data for 18" column find modulus of elasticity for each material.
4. Use Johnson's equation and the average critical load for 12" column and solve for Yield strength of the materials.
5. Graphically show the Euler's equation diverges from your data as the column length decreases.
6. Repeat above 5 for Johnson's equation and show the divergence is in the increase side.
7. Provide critical load verses length.
8. In a table compare are your theoretical values with experimental values. You can make three columns, Laboratory Data, Expected values, and percent errors.

DISCUSSION:

1. What are possible sources of error?
2. Were your errors within reasonable limits (< 10%)?
3. Why are the failed specimens shaped as they are?