LESSON 10: COLUMN BUCKLING II – THEORETICAL K-VALUES

Monday, September 19, 2016

LESSON OBJECTIVES

1. Identify bracing.
2. Know that columns in braced situations must have \( K \leq 1 \) and that columns in unbraced situations must have \( K \geq 1 \).
3. Describe and illustrate the fact that \( KL \) is the length over which the buckled column completes a half-sine.
4. Describe and illustrate the effects of positional and rotational restraint on \( KL \).
5. Estimate \( KL \) in braced and unbraced situations, based on the theoretical values of Table C-A-7.1 (pp. 16.1-511).
6. Compute the nominal and allowable loads for columns, based on the controlling slenderness, when the boundary conditions are different for each axis.
7. Assess the adequacy of a column using the ASD method.
8. Assess the adequacy of a column using the LRFD method.

LABS THIS WEEK: BRING EARBUDS OR HEADPHONES. STD. LAB ATTIRE FOR STEEL FABRICATION

THEORETICAL K-VALUES. From AISC Commentary Appendix 7.2: Table C-A-7.1 (pp. 16.1-511)

<table>
<thead>
<tr>
<th>Approximate Values of Effective Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucketed shape of column is shown by dashed line.</td>
</tr>
<tr>
<td>( \text{Theoretical } K \text{ value} )</td>
</tr>
<tr>
<td>( \text{Recommended design value when ideal conditions are approximated} )</td>
</tr>
<tr>
<td>End condition code</td>
</tr>
</tbody>
</table>

IN-CLASS PROBLEM:

The frame shown has infinitely stiff beams (an idealization). For Elevation 1, it is rigidly-connected, but unbraced. For Elevation 2, it is simply-connected (pin-connected), but it is clearly braced. Compute the nominal (\( P_n \)) and allowable (\( P_n/\Omega \)) loads for the column \( b \). The building has a rigid diaphragm (slab not shown for clarity). Use Theoretical K values from Table C-A-7.1.

Given: All Columns – \( F_y = 50 \text{ksi}; A = 10 \text{in}^2; r_x = 5 \text{in.}; r_y = 2 \text{in.} \)

Story Height = 200"

![Plan View](image1)
![Elev. 1](image2)
![Elev. 2](image3)
Required Reading
- Textbook (Segui), pp. 109 to 121.

Reference (Skim and Search)
- AISC Commentary Appendix 7 (pp. 16.1-509 to 16.1-514)

Homework (Due Wednesday. Standard homework assignment – presentation counts)
- Go to AISC Commentary Appendix 7 (pp. 16.1-509 to 16.1-514). Note that the theoretical K-values are given, along with “Recommended design values when ideal conditions are approximated.” Use the “Recommended design values when ideal conditions are approximated” unless otherwise noted.

1. Conceptual K-Value Questions. Provide a sketch, the answer, and a very brief justification for the answer.
   a. For the columns below, give the range of values that K can possibly take if the girder-ends are rigid connections and the frame is braced; i.e., what is K if the girder is infinitely stiff? What is K if the girder has zero flexural stiffness? These values define the range of possible values. Example: 0 < K < 100 (this example is obviously wrong)

   ![Rigid Connection Diagram](image)

   b. For column buckling, what is the theoretical K value for column AB if beam BC has infinite flexural stiffness? Given: pinned base supports, rigid beam-column connections.

   ![Pinned Base Supports Diagram](image)

   c. For column buckling, what is the theoretical K value for column AB if beam BC has zero flexural stiffness? Given: pinned base supports, rigid beam-column connections.

   ![Pinned Base Supports Diagram](image)

   d. For column buckling, what is the theoretical K value for column AB if column AB has infinite flexural stiffness? Given: fixed base supports, rigid beam-column connections.

   ![Fixed Base Supports Diagram](image)

   e. For column buckling, what is the theoretical K value for column AB if beam BC has infinite flexural stiffness? Given: pinned base supports, rigid beam-column connections, pin-ended brace between A and C.
2. Develop a Column Strength Calculation Workbook in Excel. First, view the tutorial video. A link for the tutorial video is found on the course webpage. It is also found on the network at P:\ceedrive\CE311\Lesson 10 (FYI, the network version is clearer than the Youtube version. That’s just the nature of Youtube). Each student will begin with a starter file, specifically for that student, found in a directory on the network that is specific to that student (e.g., a student named Gus Bates would find his starter file at P:\ceedrive\CE311\Lesson 10\GusBates and the file would be called Bates Lesson 10 Basic Column Strength.xlsx). To “submit” this assignment, simply do the work, saving it right where it is on the network. After the submission deadline, Prof. Kurtz will open and grade whatever file is in the student’s directory. See below.

3. Use your Column Strength Calculation Workbook for this problem, submitting a paper copy. In addition to this (spreadsheet-based) calc sheet, you will also need to submit hand calculations to determine the applied (ASD) $P$ and the factored (LRFD) $P_w$, based on the appropriate load combinations.

Problem: For Column AB, determine:

a. the nominal buckling strength $P_n$

b. the ASD allowable strength $P_n/\Omega$

c. the LRFD design strength $\phi P_n$

Then:

d. Determine if the column is adequate according to ASD.
e. Determine if the column is adequate according to LRFD.

Note: generally, ASD and LRFD provide the same level of safety, but LRFD “fears live loads.” This fact explains the previous two answers.

Given: The applied axial load on the column consists of:

- Dead, $D = 10$ kips (includes all dead loads, including the column self-weight)
- Live, $L = 225$ kips
- Snow, $S = 50$ kips
- Roof Live, $L_r = 40$ kips

W12x40 columns, HUGE girders (consider them to have infinite $EI$), pinned base (foundation), RIGID (moment-resisting) connections for View 1, simple (non-moment-resisting) connections for View 2. $F_y=50$ ksi for all.

Columns are 12-feet long, but the key to this problem is determining the correct K-values; study the views very carefully, determining which axis corresponds with rigid connections and which corresponds with pinned connections. Use theoretical K values.

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1 Each file contains electronic markers that are specific to each student

2 If you feel up to it, you could certainly make an Excel calculation sheet that performs Load Combination calculations, automatically. Or, just do them manually.
3D View: Note the column orientations, carefully.