P-Delta effect for a cantilevered column

Test Problem

Name:	P-Delta effect for a cantilevered column
Description:	Calculation and verification of the P-Delta effects of a cantilevered column.
Program:	SAP2000
Version:	14.2.4
Model ID:	109

This test problem calculates and verifies the P-Delta and Large-Displacement effects associated with the lateral deflection of a fully fixed cantilevered column. The Scilab numerical-computation software is used to verify selected values.

On this page:

Model description

The fully fixed cantilevered-column model has the following properties:

- Length: L = 10m
- Cross-section: 0.1m x 0.1m square
- Concrete modulus: E = 30GPa
- Axial load: F_v = 4kN (compression)
  F_v is chosen as 70% of the critical buckling load, where $P_{cr} = {}^2 EI / 4L^2 = 6.168kN$
- Lateral load: F_H = 0.045kN
  F_H is chosen to cause an elastic deflection of 0.06m, where $= PL^3 / 3EI$

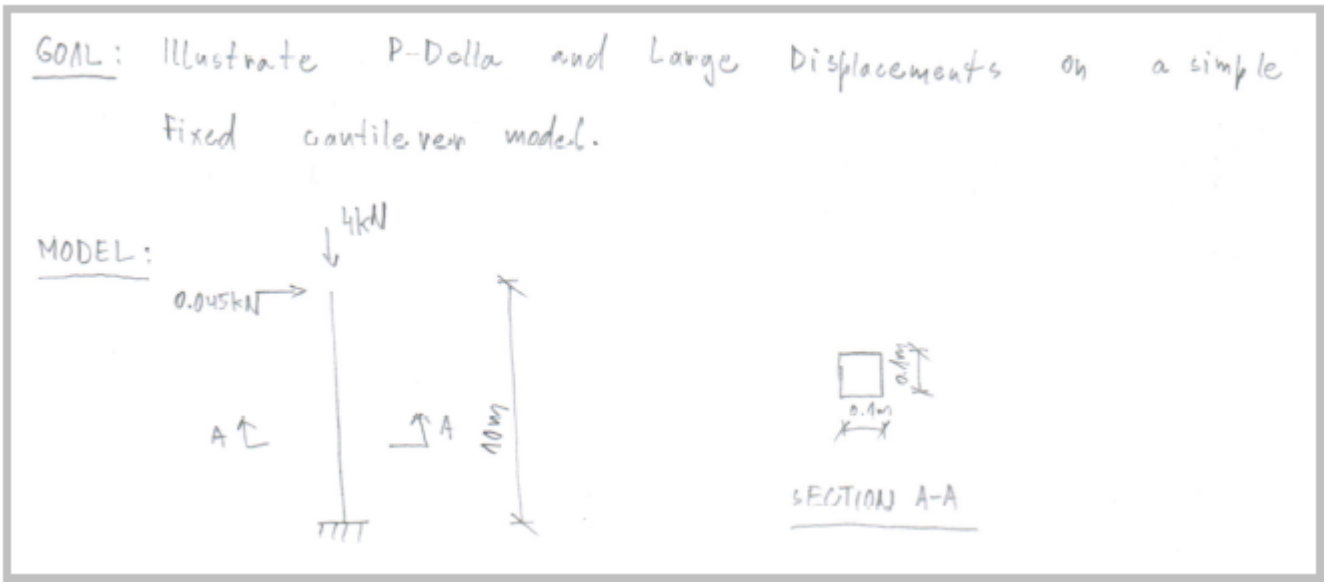

Figure 1 - Cantilevered-column buckling parameters

Results

Results obtained from SAP2000 and Scilab are summarized in the tables below. The analysis process integral to Scilab software utilizes the stiffness and geometric matrices described in Dr. Edward L. Wilson's text Static and Dynamic Analysis of Structures. Additional details are included in the attached Scilab input file .

Lateral tip displacement

Load Case	SAP2000 Value [m]	Scilab Value [m]
STATIC (linear)	0.06m	0.06 m
NLSTATIC1(1) (nonlinear with P-Delta, 1 step)	0.1677 m	0.1677 m
NLSTATIC1(10) (nonlinear with P-Delta, 10 steps)	0.1671 m	not calculated
NLSTATIC2(1) (nonlinear with P-Delta and large displacements, 1 step)	0.1676 m	not calculated
NLSTATIC2(10) (nonlinear with P-Delta and large displacements, 10 steps)	0.1675 m	not calculated

Base moment

Load Case	SAP2000 Value [kN-m]	Scilab Value [kN-m]
STATIC (linear)	0.45 kN-m	0.45 kN-m
NLSTATIC1(1) (nonlinear with P-Delta, 1 step)	1.121 kN-m	1.324 kN-m
NLSTATIC1(10) (nonlinear with P-Delta, 10 steps)	1.120 kN-m	not calculated
NLSTATIC2(1) (nonlinear with P-Delta and large displacements, 1 step)	1.120 kN-m	not calculated
NLSTATIC2(10) (nonlinear with P-Delta and large displacements, 10 steps)	1.120 kN-m	not calculated

Screenshots

Figure 2 presents a realization of the cantilevered-column model, subjected to a 6kN axial force. Stiffness and response are evaluated at 100 increments.

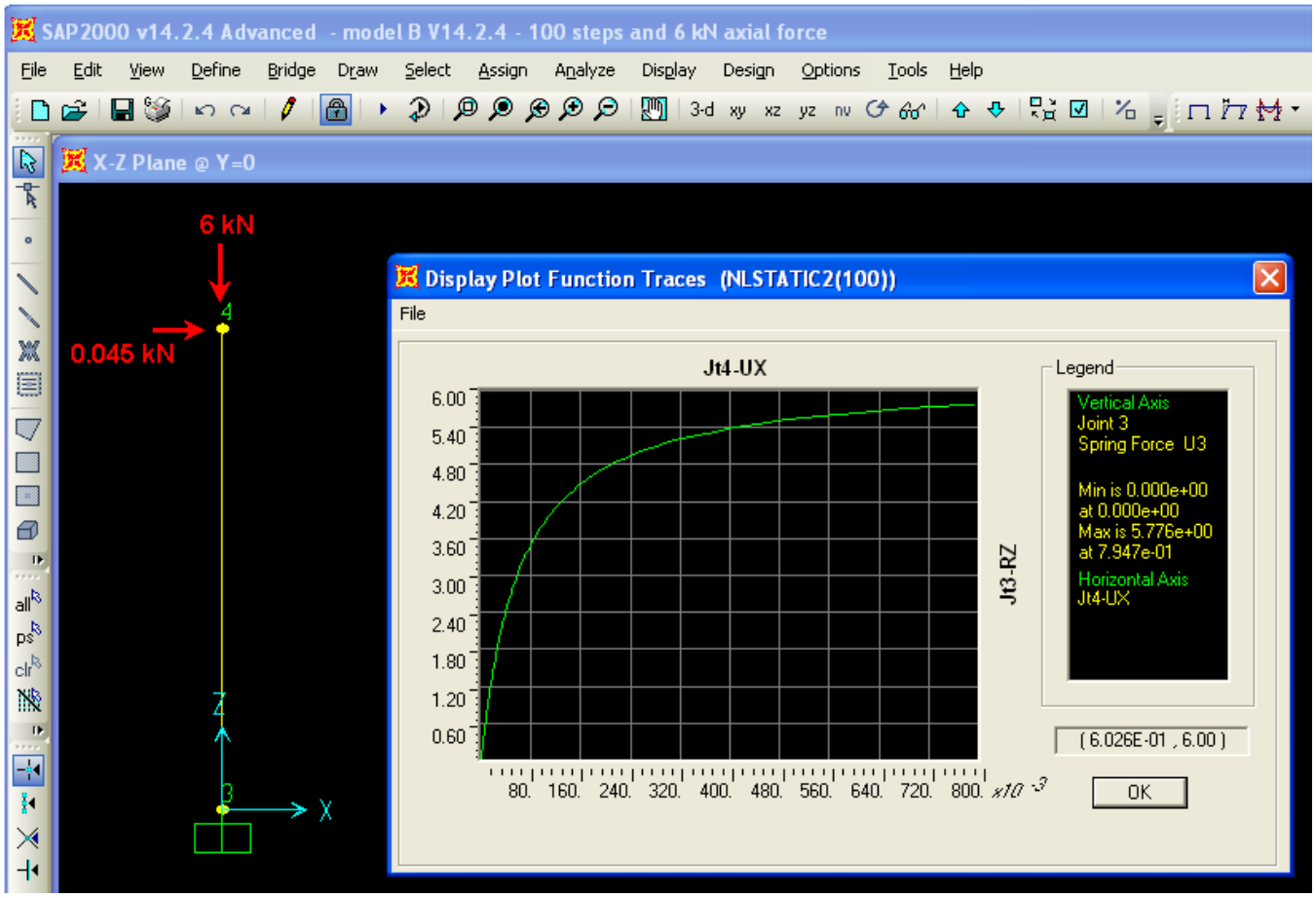

Figure 2 - Buckling analysis for a cantilevered column

Discussion

- Results from SAP2000 and Scilab indicate agreement between displacement values. A slight discrepancy exists between the moment values returned.
- When considering Large-Displacement effect, smaller lateral displacements result. There is no geometric limitation for the application of P-Delta effect, which projects laterally from the column tip in a straight line. Large-Displacement effect, however, is bound by column length. As column rotation increases, the tip displaces along a curvilinear profile. As a result, given Large-Displacement effect, axial displacement should be larger.

References

- Wilson, E. L. (2004). *Static and Dynamic Analysis of Structures* (4th ed., pp. 120-121). Berkeley, CA: Computers and Structures, Inc.

See Also

- Interpreting buckling analysis results for different initial conditions

Attachments

- SAP2000 V14.2.4 model (zipped SDB file)
- Model variation with 100 steps and a 6kN axial force (zipped SDB file)
- Hand calculations (PDF)
- Scilab input and output files (zipped OUT and SCE files)