METHOD FOR MEASURING CRITICAL BUCKLING LOAD OF CANTILEVER COLUMNS

B. Blostotsky[1] and E. Efraim[1]

[1]*Department of Civil Engineering, Ariel University, Ariel, Israel*

e-mail: efraime@ariel.ac.il

1. Introduction

The critical sway buckling load is the upper limit of the allowed vertical columns loading. This load is defined by the columns configuration, cross-sections of the columns as well as configuration and stiffness of the end connections. Motivation to determine accurate value of critical force is caused by its using as follow:
- critical load is maximal allowable load for given configuration of columns and can be used as criterion of perfection or efficiency of the structure;
- it is used in calculation prescribed by standards for design of structural elements under combined action of compression and bending [1];
- it is used for verification of theoretical analysis of stability at various end conditions of columns [2].

There are two types of non-destructive testing of frames for critical load: dynamic [3] and static. In static method the lateral deformation of frame caused by compression forces in columns due to their initial imperfection is measured [4]. Load acting on a column is limited by plastic deformations and it is always lower than critical load. At columns and frames testing in sway mode the vertical loading is performed by using of additional weights [5], directly via a lever system [6] or using special mechanism as gravity load simulator [7]. To determine a critical load, the extrapolation is performed using Southwell's diagram or other applications [8]. The accuracy of the method depends on closeness of initial imperfect form with buckling mode shape.

The aim of the present work is developing of more exact non-destructive experimental method for determination of critical load of frame in sway mode. Increasing in accuracy is achieved by conducting experiments in diapason of vertical loads includes the critical load as well as by using of loading system without friction. The method allows performing measurements during the tests under loads that exceeds the frame critical loads without losing its stability. Technological advantage of this method is the ability to create loading correspond to critical loads of real full-size columns.

2. The idea and brief description of the method

Figure 1 presents the setup scheme for testing of cantilever column (A) fully restrained at the base and unbraced upper end. The traction element (B) (cable) has a pinned connection to the free end and includes the traction device (C) or additional weights for producing of tension force. In the initial position, the cable is positioned at an angle γ_0 to the column. Under the action of force P in the cable the column bends and the cable turns. At a certain value of traction force, the cable holds a vertical position and the force in the cable is equal to the critical force of the column. This statement is proved by the analysis of deformation of the column-cable system from which follows that at $\gamma = 0$ the force is equal to the critical force of cantilever column in sway mode

(1) $$P = P_{sw} = \frac{\pi^2 EI}{4L^2}.$$

The problem of determination of critical force for the system column-traction element with initially inclination of cable at at $\gamma = 0$ has been considered by Timoshenko [9]. A similar result can be obtained in case of a column of variable cross-section and a column with initial curvature, provided that $y \ll \gamma d$, where y

is a deviation of the free end of the column relative to the base due to initial curvature. In this case, the angle of deflection of the cable should be reckoned relatively to the line connecting a column base to its free end at unloaded state.

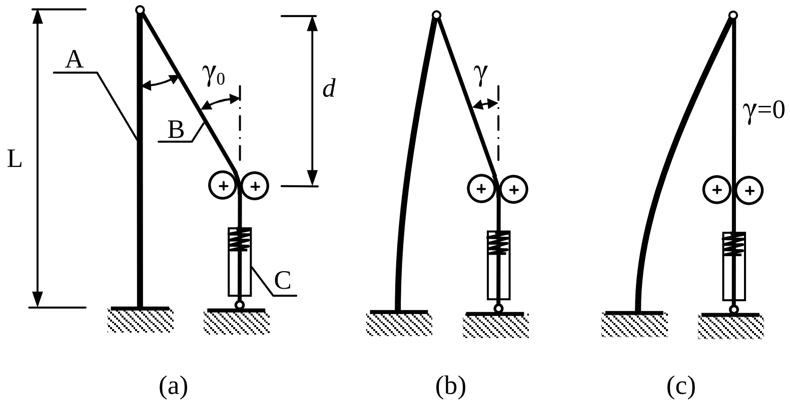

Figure 1: Setup scheme for testing of sway column: (a) - the initial position without traction force; (b) - intermediate state at any traction force; (c) - the state of system includes a column with lost lateral stiffness.

The physical meaning of the coincidence of the force in the traction cable with the column's critical buckling load is that for $\gamma=0$ the loading and the deflection form of the column correspond to loading and shape of the cantilever prismatic rod with loss of stability in sway mode. Using as a criterion of loss of stability in sway mode the condition of equality to zero of lateral stiffness [10], it can be asserted that a condition $\gamma=0$ corresponds to this criterion. At the same time the general stability remains as force P is less than critical force of column-cable system.

The advantages of the proposal method are:
- possibility of testing a column at a critical load for sway mode and also exceeding this load;
- elimination of friction influence in the loading system caused by the movement of the column's loaded end.

The efficiency and reliability of the method is confirmed by laboratory studies of column models. The results of the study are recommended for use in laboratory and industrial testing of columns and sway frames.

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