Structures 5 (2016) 152–160

Contents lists available at ScienceDirect

Structures

journal homepage: www.elsevier.com/locate/structures

On the improvement of buckling of pretwisted universal steel columns

Farid H. Abed *, Mai Megahed [1], Abdulla Al-Rahmani [1]

Department of Civil Engineering, American University of Sharjah, P.O. Box 26666, Sharjah, UAE

ARTICLE INFO

Article history:
Received 1 August 2015
Received in revised form 21 October 2015
Accepted 29 October 2015
Available online 6 November 2015

Keywords:
Pretwisting
UC sections
Buckling
FE simulation
Columns

ABSTRACT

This paper investigates the improvement in elastic buckling capacity of pretwisted columns using Linear Perturbation Approach. Three different Universal Column (UC) sections of various lengths were considered in the proposed study assuming fixed–fixed and pinned–pinned end conditions. Linear perturbation analysis was first verified by comparing the critical loads of the simulated straight columns with analytical results. Numerical analysis was then extended to simulate the buckling improvement of pretwisted columns considering four different lengths of 4 m, 5 m, 6 m and 7 m, and a range of twisting angles between 0° and 180°. The results showed that the initial twisting has positively impacted the axial capacity of the pretwisted columns. This noticeable improvement is supported by the significant increase in the buckling capacity for the three UC sections, particularly at angles of twists between 120° and 150°.

1. Introduction

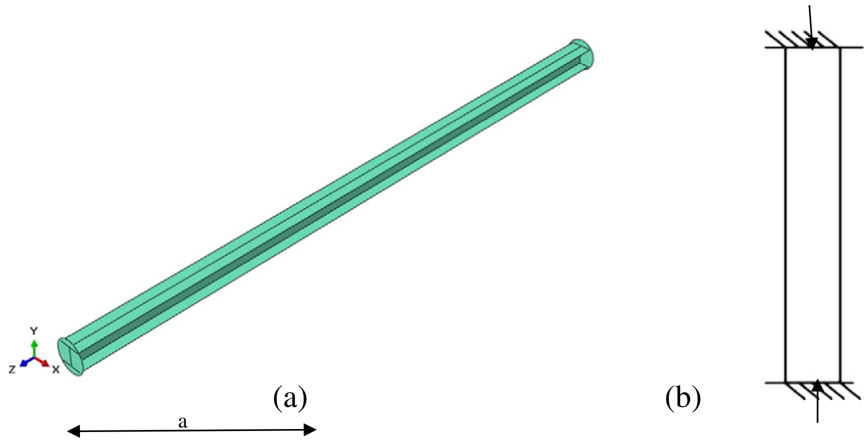
Steel structures are increasingly used in constructions as they proved to be more user- and environmental-friendly, more time efficient and less labor intensive than reinforced concrete. Steel is a recyclable material that can be reused when a building is demolished, leaving behind minimal waste, thus, preferable for sustainable construction. Furthermore, the uniformity and stability of steel as it does not creep or shrink with time unlike reinforced concrete makes it more desirable to be used in construction. However, one of the main disadvantages of a steel column is the susceptibility to buckle under compression before achieving the design strength. Buckling is a mode of failure that is mainly observed in compression members due to structural instability. The critical buckling load carried depends mainly on the slenderness of the member being investigated. For stocky members, a larger buckling load would be required to witness the deformed buckling mode. As a matter of fact, stocky compression members may fail mainly due to compressive yielding instead of buckling. Compressive yielding may occur if the stresses built within the compression members exceeded the yielding stress of the steel being used. However, for slender members, to be more specific, the stress just before buckling is below the proportional limit such that the member is still elastic [12].

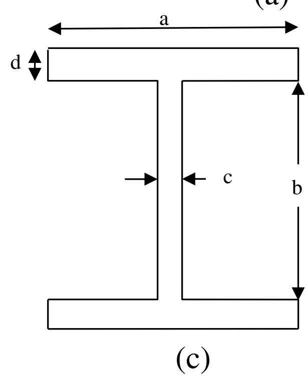
Inducing a natural pretwist along the length of a column section makes the column have a different resistance at every point along its centroidal axis. It is well-known that a column usually buckles around the weak axis, but with pretwisting, the buckling mode of the column may no longer be perpendicular to the weak axis. Pretwisting is known to induce a coupling effect on the weak and strong flexural planes of a column. Hence, a pretwisted column in 3D-space has its strong flexural plane weakened and its weak flexural plane strengthened, leading to a net favorable effect on the buckling strength of the pretwisted column. Thus, the buckling load recorded with the first mode shape of the pretwisted column is relatively higher than that of the non-pretwisted column [15]. Another interesting definition of pretwisting would be; the rotation of the principal axes as a function of the centroidal axes of the cross-section along the column's length [3].

There are not enough studies on the topic of pretwisting and its effect on the buckling of structural compression members. However, the study of the nature of pretwisting and its applications has been introduced into the literature a long time ago. Celep [3] investigated the stability of an elastic cantilever column with a linear viscous internal damping system exposed to evenly distributed vertical and follower loads. Galerkins' technique was then applied to solve the prevailing differential equations of motion to determine the flexural deformation in both planes of a pretwisted slender column. Yang and Yau [16] studied the stability of pretwisted bars having assorted end torques. Two types of torques were investigated; quasi tangential and semi-tangential, on an originally straight bar but with an applied rotation angle. Tabarrok et al. [15] solved the equilibrium equations of buckling analysis of a pretwisted column utilizing the concept of total potential energy and the associated boundary conditions. Steinman et al. [14] studied the effect of pretwisting on statically determinate and indeterminate columns. To work out the buckling equations of a pretwisted column, the general stability equations applied for a spatial rod were used as a part of the derived differential equations. Exact numerical solutions to the controlling fourth-order differential equations were achieved through simple iterative approach. The input data to the

* Corresponding author.
E-mail address: fabed@aus.edu (F.H. Abed).
[1] Master Student.

http://dx.doi.org/10.1016/j.istruc.2015.10.012





Section Name	a (mm)	b (mm)	c (mm)	d (mm)
UC100×100×17	100	84	6	8
UC152×152×30	152.9	138.8	6.5	9
UC150×100×21	100	130	6	9

(d)

Fig. 1. Geometric description of the UC sections used in the current study; (a) FE model, (b) fixed-fixed column, (c) cross-section, and (d) dimensions used in FE analysis.

iterative approach were the calculated buckling loads, coefficients of the various mode shapes involved and analytical forms of the failure mode shapes anticipated. Serra [13] used Fourier series to analytically prove that inducing a rotation angle to the geometry of a column positively impacts its critical buckling load. Recently, Sahu and Asha [10] studied the stability analysis of ply-laminated composite pretwisted panels using finite element analysis with 8-node quadratic shell elements. Specifically, they have studied the effect of different parameters such as

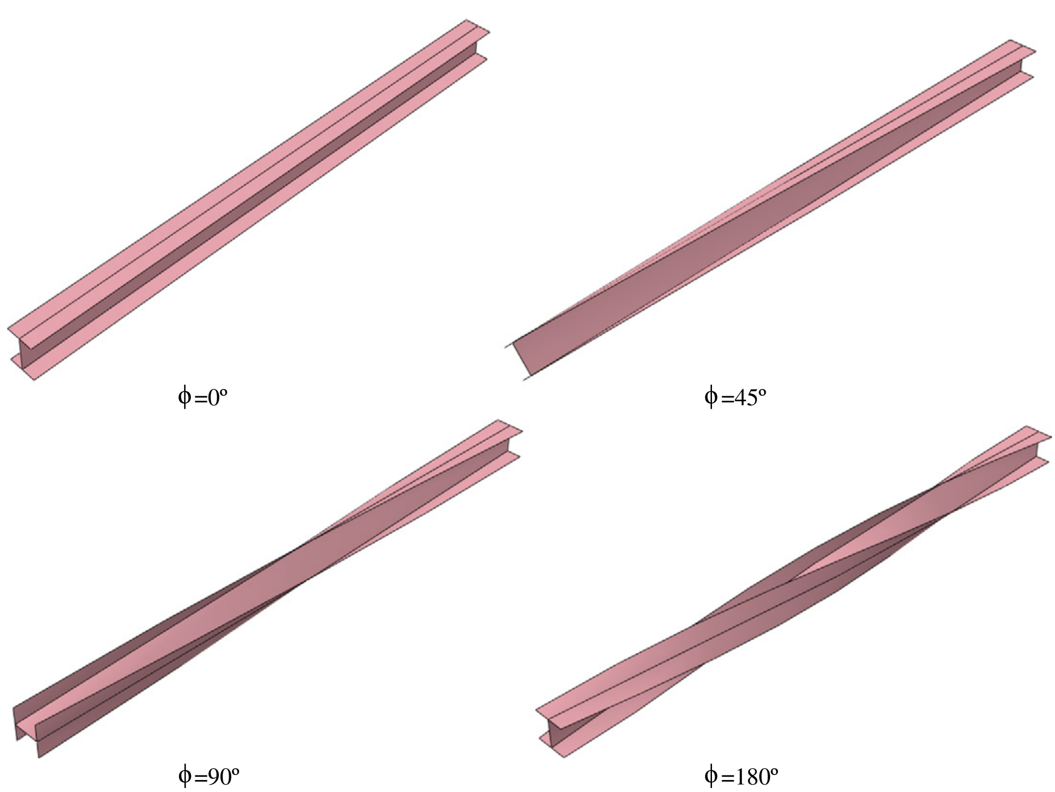


Fig. 2. Samples of pretwisted geometries for UC100 × 100 × 17 columns at selected angles.