



Effect of internal axial loads on the stability of sway-permitted prismatic columns



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ABSTRACT

The stability of prismatic columns subjected to internal axial loads is a common issue during engineering analysis and design. Because of the big difference between the effects of internal loads and end loads, the traditional effective length method is not applicable. Current codes do not provide design method for this issue and engineers require the ability to analysis and design this kind of columns efficiently. Using the concept of negative stiffness, a relationship between end loads and internal axial loads applied on sway-permitted prismatic columns is established so that the internal loads can be considered equivalent to end loads and the critical value can be obtained easily by Euler formula. A practical method to determine the second-order effect is also developed. Eigenvalue buckling and elastic nonlinear analyses are performed to examine the proposed method and the comparison results indicate it has high accuracy.

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1. Introduction

Research on column buckling is longstanding. Since Euler's classic work in the eighteenth century, a lot of studies have been conducted, which covered a wide range of factors that influence column stability, including end restraint, initial imperfection, load eccentricity, material nonlinearity, residual stress, and column interaction [1]. But only a few literatures mentioned the effect of internal axial loads on buckling, which is actually a common problem existing in many structures, such as the frame of mill building provided with bridge crane (Fig. 1), the boundary column of steel plate shear walls, the chord member of steel trusses (Fig. 2) and the mega column of frame-core tube structures (Fig. 3). These columns usually have constant cross sections and are loaded axially both at ends and at interior points. The traditional effective length method is not applicable because of the big difference between the effects of internal loads and end loads. Analyses of such problems are still cumbersome and time-consuming, requiring the use of equilibrium method or finite element method (FEM) programs.

Literatures on stability problems pertaining to internal axial loads are limited. Based on equilibrium method, Timoshenko [2] analyzed

the stability of prismatic bars with one intermediate load and bars subjected to distributed axial loads. Using the same method, Chen [3] determined effect length factors for prismatic columns with single corbel load, but only fixed and hinged bases were involved. Aristizábal-Ochoa [4] proposed a matrix approach for determining the stability and second-order response of semi-rigid frames, which can also be used for columns with distributed axial loads. British Standard, BS 5950-1 [5] suggests a rough value of 1.5 as the effective length factor for the crane column shown in Fig. 1(a). But this value is identical with the factor for the column without corbel load and cannot fully reflect the influence of end restraint stiffness and crane height. Chinese Standard, GB 50017-2003 [6], provides a formula for effective length factors of the chord member shown in Fig. 3, but only the case of single internal load is involved. Besides these, some studies on spliced and stepped columns have been conducted (e.g. Lindner [7], Girão Coelho [8,9], Simão [10] and Pinarbasi [11]), which are generally associated with internal axial loads. Lindner [7] conducted full scale tests on different types of splices, and combining with FEM analysis, a buckling curve for columns with midspan splice was presented. Girão Coelho [8,9] examined the effect of splices on column behavior and developed a relationship between spliced columns and prismatic Euler columns to simplify the design procedure. In order to determine effective lengths for two-segment stepped crane columns, Simão [10] proposed a geometrically nonlinear model and formulated it using equilibrium method. The findings suggested the upper and lower segments be treated

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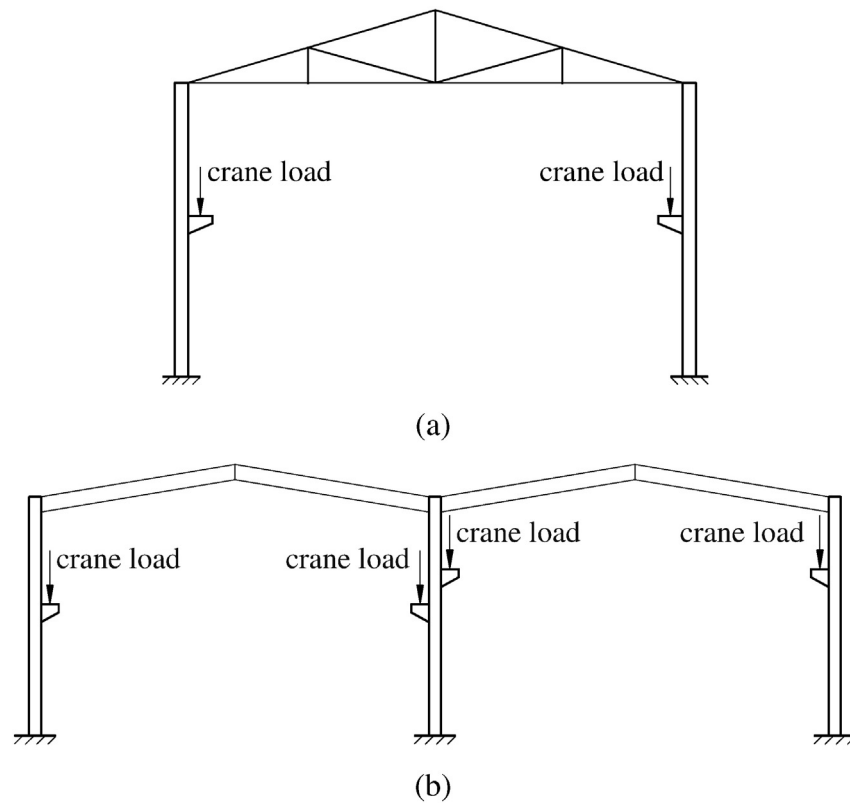


Fig. 1. Mill buildings: (a) single span; (b) two span.

as separate beam-columns, and the effective length factors for each segment were present. Using variational iteration method, Pinarbasi [11] carried out buckling analysis for two-segment stepped columns with internal axial loads and presented approximate buckling loads in tabular forms. These research mainly focused on two-segment columns, and equilibrium method was the dominant approach. Although there are some similarities between stepped column and prismatic column with internal axial loads, the equilibrium method is impractical for the later partially because of the overly complicated differential equations. FEM can generally provide reasonable results for buckling problems, but it is time-consuming and troublesome for designer and fabricators to use because preliminary design commonly requires reiterative calculations, especially when the analysis model is large.

In terms of sway-inhibited prismatic columns, Tian [12] established a relationship between end loads and internal axial loads using the concept of equivalent negative stiffness, so the critical buckling loads can be obtained easily by Euler formula. This paper extends the earlier work to sway-permitted columns. Equivalent factors are presented and a practical method to determine the second-order effect is also developed. The findings would be useful for engineers and fabricators aiming to achieve

more efficient and economic designs for prismatic columns subjected to internal axial loads.

Outrigger Truss

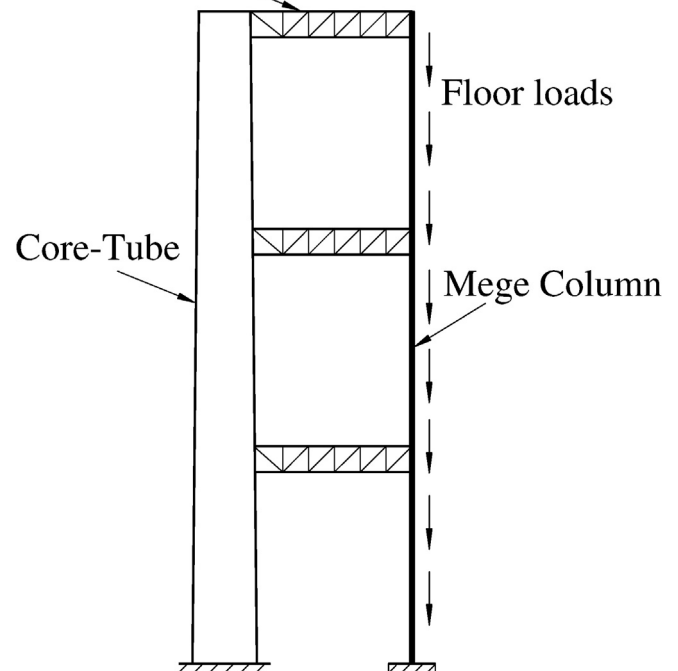


Fig. 3. Frame-core tube structure.

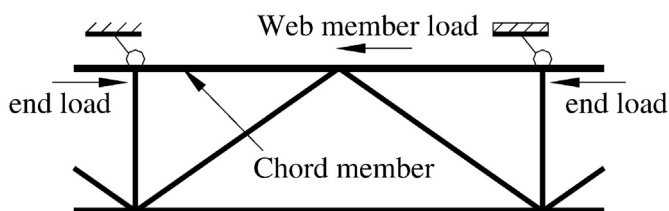


Fig. 2. Chord member of steel trusses.

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