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A Study on Effective Length of Slender Column with Elastic Restraints

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Abstract

The bottom slender columns are widely used in modern high rise buildings because of the existence of floor with opening, and the effective length will deeply affect bearing capacity of the column. This paper presents a new methodology for calculate the effective length of the bottom slender columns based on the equivalent model. The elastic restraints of beams are considered as lateral support spring, and the effective length of the column is determined through buckling analysis of the column fixed at bottom and elastic supported at top. A case study of high rise building with 20 m bottom slender column was conducted as follows: A horizontal force was applied on the floor supporting of the slender column top, and the lateral displacement of the column could be calculated through whole structure analysis in design procedure, therefore, the spring stiffness can be figured out through the applied horizontal force divided by the displacement. Then, eigenvalue buckling analysis was conducted on the column by using software ANSYS. The buckling mode shape were checked and the lowest buckling mode was solved, the buckling critical load could be obtained by multiplying the critical load coefficient by compression stress of the member. Finally, the effective length factor could be determined by comparing the bearing capacity of the bottom slender column with bearing capacity of that column with hinge joint at both ends. The results indicate that the effective length factor of the bottom slender column based on the proposed method is 21% larger than that in the design code. The weakness in bearing capacity of the bottom slender column should be considered during design.

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1. Introduction

At present, more and more tall buildings appear in the downtown of city. These buildings function as commercial, office, hotel, even residential spaces. As to meet large space requirements of public commercial function in the bottom of buildings, some bottom columns at the corner of floor opening in real buildings possess large length, such as 14.3 m long circular column in Port Center of Guangzhou Harbor project, 31 m long rectangular column in Shenzhen Aerospace Technology Square. These columns not only show large slenderness ratio, but also are fixed at the foot while elastic supported by the beams at the head. The columns are referred as to bottom slender column.

The bearing capacity of bottom slender columns will deeply influence by the effective length[1]. Many studies on the buckling analysis of compressive column were conducted. Bendito et al. presented a new equation for the effective length factor for reinforced concrete columns with elastic restrains on both ends, taking in accounting the inelastic behavior of the concrete columns cracking, yielding, and second order effects[2]. Pinarbasi conducted the stability analysis on the leaning columns with pinned conditions and elastic restrains on both ends, analysis results show that all iteration algorithms yielded exactly the same results in all studied problems[3]. Trahair and Rasmussen studied the elastic buckling of thin wall steel columns with either rigid or elastic restraints by using finite element method[4]. Laudiero et al. conducted nonlinear finite element analysis of pultruded fiber-reinforced plastic profiles subjected to pure compression[5]. The abovementioned studies focus on either the elastic restraints of columns through parameter of beam-to-column rigidness ratio, or small cross section size. For bottom slender columns in the real project, the cross section width is usually large than 1 m, and the elastic restraints is usually related to the applied rotations. This paper studies the effective length of bottom slender columns by buckling analysis.

2. Analytical method of slender column

2.1. General buckling equation and related boundary conditions

“Code for design of concrete structures”[6] formulates the effective length of frame column based on elasticity stability theory. Boundary constraint conditions are determined by the deformation characteristics of beam and column. The value of the effective length of bottom storey column on cast in-situ floor is equal to the storey height.

In the real condition, column height may be equal to or beyond two storey height, and this type of columns is of the bottom slender column. If the storey height is used for calculation, the effective length of column will be smaller [7]. At present, there are no specific regulations about these columns.

2.2. Determination of effective length of slender column

The effective length of bottom slender column is determined by two mutually perpendicular centroid axes. In the real conditions, the restraints of bottom slender column is complicated because the buckling condition of each member will be influenced by other members[8]. There are three buckling analysis methods to get the effective length of bottom slender column: integral model method, partial member model method and independent member method.

For integral model method: Structure with bottom slender column is modeled for buckling analysis, as shown in Fig. 1(a). The buckling mode of the integral model method is close to practical mode. In general, the model is complicated and expend too much computing resources.

For partial member model method: The restraint members around cross-floor and the reinforcement and cross section will be considered in model, as shown in Fig. 1(b). The restraints of other columns are not considered in this method.

For independent member method: Firstly, ascertain the length of bottom slender column with the whole floor or restraints of cross beam system at both ends AB. Secondly, the restraining stiffness of every direction of column is considered, and ascertain the elastic stiffness of the restraints, K1, K2, K3, as shown in Fig. 1(c). The method for determining the spring stiffness is as follows: Unit force along global coordinate system is applied on each restriction node of column. The horizontal displacement under unit force could be calculated. The percentage of unit force to displacement would be the elastic stiffness of other members to column. Finally, the bottom slender column