Slenderness limit of the weak axis in the design of rectangular reinforced concrete non-sway columns

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Most design codes (Model Code 90, ACI-318-2008 and Eurocode–2-2004) suggest that the effect of a geometrical imperfection ought to be taken into account in the most unfavorable direction when designing slender reinforced concrete columns. If the bending plane of the beam–column is related to the strong axis, this imperfection acting in the opposite direction results in the column being subjected to axial load and biaxial bending, complicating the design procedure and increasing computational costs considerably. Such standards do not indicate when this geometrical imperfection generates a notable loss of resistance in the column. This paper proposes the geometrical slenderness of the weak axis (λg/β) as the variable that determines whether or not to consider the influence of such imperfection. This paper denominates this boundary value the “slenderness limit of the weak axis” (λg,weak), and this is associated with a loss of resistance of 10% of the bending moment of the unbraced columns with respect to non-sway columns. An approximated equation of this limit is proposed using the results of a numerical simulation. The equation is valid for rectangular columns with doubly symmetric reinforcement and both normal and high strength concrete, and also for short-term and sustained loads.

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1. Introduction

In general, reinforced concrete columns in buildings or industrial facilities are subjected to axial load and uniaxial bending moment. Cross sections are typically square or rectangular. The stiffness of the column in each bending direction varies due to the reinforcement distribution which is symmetric at opposite faces and parallel to the strong axis of bending, and is also different if the section is rectangular. This arrangement produces a strong axis perpendicular to the bending plane with higher stiffness than that of the weak axis parallel to the bending plane. Therefore, such columns are subjected to axial load and uniaxial bending with respect to the strong axis.

In this case, the behavior of the column can be affected by the flexibility of the weak axis, as a geometrical imperfection in the perpendicular direction to the principal bending plane means that the column is subjected to biaxial bending which reduces the load capacity of the column considerably. Furlong [1] stated that second order effects in columns subjected to biaxial bending are greatly influenced by the previous flexibility, producing a coupling of second-order effects from both bending directions. According to Bonet et al. [2], the rectangular columns subjected to uniaxial bending with respect to the strong axis, and with an axial load close to the critical axial compression of the column, experience an important loss of load capacity. Such authors affirm that the behavior of a column under axial load and uniaxial bending with respect to the strong axis depends on whether the bending of the column in the weak axis is neglected or not, Fig. 1(a). If the column is non-sway, the relative critical axial load corresponds to that of the strong axis (Vcr, strong). Moreover, if the column is unbraced and the eccentricity tends to zero, the behavior of the column is affected by the weak axis and the relative critical axial load corresponds to that of the weak axis (Vcr,weak). This behavior was experimentally observed by Pallarés et al. [3].

Menegotto [4] pointed out that when the geometrical slenderness of both axes of bending is very different (λg, strong ≠ λg, weak), Fig. 1, the interaction of the weak axis of bending can cause an important reduction in the bending capacity of the column with respect to the strong axis, due to second-order effects. In this case, in order to analyze the behavior of the column, if the interaction diagram is linearized or simplified (as indicated in Eurocode 2 [5]) by calculating the first order relative bending moments of each bending direction in an uncoupled way in (µyi, strong, µyi, weak), an unsafe situation can result, Fig. 1(b). This author affirms that there is no criterion in the literature to evaluate or quantify the importance of this effect.

In fact, in the literature, most authors have studied the behavior of pinned–pinned columns with square sections subjected to biaxial bending. Only Mavichak and Furlong [6], Kim and Lee [7] and Pallarés et al. [3] have investigated the influence of the weak axis on the behavior of the column under biaxial bending.