ABSTRACT

When designing a reinforced concrete column, most codes specify that second-order effects must be taken into account when the column slenderness exceeds a lower limit, usually associated to a certain loss of non-slender column carrying capacity. These lower slenderness limits depend on a few structural parameters related with stress, stiffness, end restraints, and loads applied on the column. However the provisions of codes of practice are very different in qualitative and quantitative aspects. In this paper, simplified analytical expressions are presented for the lower slenderness limits, associated with a 10 % and 5 % loss of bearing capacity for slenderness effects, of rectangular columns (with 3 different symmetrically reinforcements). These limits have derived from the principles of structural mechanics of reinforced concrete and take into account the most important parameters intervening in the behavior of slender concrete columns, such as end restraints, axial load, first-order end eccentricities, ratio between permanent and instant load, creep factor, load path and amount and distribution of the reinforcement. It was necessary to obtain an analytic formulation of the interaction diagram M-N of a section, for the considered reinforcement distributions, which allows to obtain the bending moment and axial load that cause the section failure according to a certain amount of reinforcement. Another key point for the formulation of the slenderness limits was to obtain the analytical expression of the second-order moment (from a senoidal approach of the end eccentricity law) taking into account the effects of long term actions. The results obtained with the proposed analytical expressions have been compared with those resulting from a non linear numerical analysis done in isolated columns and unbraced structure columns, obtaining a very good correlation. The numerical analysis has been done with the non linear analysis model CONS, that allows to consider the second-order effects by taking into account the non linear behavior of materials and geometry, the creep effects and an incremental load. Using the CONS model and an incremental analysis of the loss of bearing capacity of a big number of columns with different values of the variables intervening in the lower limits of slenderness has been obtained, through an incremental process of the columns length, a graphic relationship between the slenderness and the loss of bearing capacity of every column compared to a non-slender column with the same characteristics). From the values obtained with the CONS non linear analysis model and the values obtained with the proposed expressions has been done an analysis of the influence of the variables intervening in the second-order problem in order to obtain those less adjusted to the formulations. In order to justify the use of the equations suggested for the determination of the slenderness lower limit, it was/has been done a comparative analysis between the values obtained, by applying the different codes, in some of the analyzed structures and those obtained by applying the formulations proposed in this paper. The obtained results show that most columns of conventional reinforced concrete buildings, currently considered slender, are under the lower limit of slenderness and could be designed ignoring second-order effects. To conclude, it is also presented a proposal of the path to follow in future studies about the lower limits of slenderness, which are basically the formulation of these equations for other reinforcement distributions, cross section geometries, materials and structural typologies.