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Experimental tests of slender reinforced concrete columns under combined axial load and lateral force

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ABSTRACT

The use of high strength concrete (HSC) in columns has become more frequent since a substantial reduction of the cross-section is obtained, meaning that slenderness increases for the same axial load and length, producing higher second order effects. However, the experimental tests in the literature of reinforced concrete columns subjected to axial load and lateral force focus on shear span ratios, according to Eurocode 2 (2004), clause 5.6.3., $(M/(V \cdot h))$ lower than 6.5. This gap in the literature limits technological development for the construction of these structural elements. This paper presents 44 experimental tests on reinforced concrete columns subjected to constant axial load and monotonic lateral force. The aim of this is to gain greater knowledge of the types of elements which will also be of use in calibrating the numerical models and validating the simplified methods. The test parameters are strength of concrete (normal- and high-strength concrete), shear span ratio, axial load level and longitudinal and transversal reinforcement ratios. The strength and deformation of the columns were studied, and an analysis of the simplified methods from Eurocode 2 (2004) and ACI-318 (2008) concluded that both are very conservative.

1. Introduction

In the ultimate state, the inelastic behavior of a structure is conditioned to the progressive appearance of plastic hinges, so much so that the design of the structure must aim to make yielding appear first in the beams and later in the columns in order to guarantee the overall stability (weak beam–strong column). However, in the column–foundation connection (both for building and bridge piers) the appearance of the plastic hinge is possible in the ultimate state of the structure. Moreover, the use of high strength concrete (HSC) in columns is becoming increasingly frequent given that a substantial reduction of the cross-section is obtained, producing an increase in slenderness for the same axial load and length and resulting in higher second order effects. There are several tests in the literature ([1–4] among others) that demonstrate that the columns made with HSC are more brittle than NSC columns. Those authors suggest more experimental research in relation with the resistance capacity and deformation of HSC columns in order to analyze the reliability of the numerical models and simplified design methods.

From the point of view of structural safety, both strength and ductility have the same significance. Traditionally, the design of structures focuses on providing the elements with enough resistance for the design forces corresponding to U.L.S (ultimate limit states) and provides enough stiffness to verify S.L.S (service limit states). In addition, the required ductility is guaranteed by specific design criteria and reinforcement arrangements defined in the different design codes: ACI-318 [1], EC-2 [5] and EC-8 [6].

These design methods are developed from the large amount of tests within the bibliography quantifying the deformation capacity of elements under flexure, both for monotonic and cyclic loads. In general, studies focusing on monotonic loads aim to investigate the capacity of the force redistribution for dead or live combinations of loads, whereas tests for cyclic loads study the behavior for a seismic event. As can be observed in the distribution of the 1125 tests summarized in Chapter 6 of bulletin number 25 from the F.I.B. (Fédération Internationale du Béton) [7] for elements under monotonic and cyclic loads (Fig. 1(a)), and from the database for PEER (Pacific Earthquake Engineering Research Center) [8] with 306 cyclic tests (Fig. 1(b)), most of the experiments focus on a shear span ratio λ_V lower than 6.5 ($\lambda_V = L_s/h = M/(V \cdot h)$), Panagiotakos and Fardis [9], where L_s is the distance between point of zero and maximum moment M, V is the shear force and h is the overall depth of the cross section. There are several reasons that justify the need to study slender reinforced concrete columns subjected to constant axial load and monotonic (or cyclic) lateral force. The first of these is that the use of concrete with a higher capacity implies the construction of slender columns, while the second is that second order effects (P–Δ effect) have a major influence on the deformation capacity of the columns, Bae and Bayrak [10]. A third

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