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Theoretical behavior of HSC sections under torsion

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ABSTRACT

The main purpose of this study is to propose a simple computational computing procedure in order to predict the global behavior of high-strength concrete beams under pure torsion.

A computational procedure was developed and validated for normal-strength concrete beams and presented in a previous study. This procedure is revised and corrected in this article so that high-strength concrete beams can also be covered. Theoretical predictions are compared to some experimental results available in the literature.

It is shown that the proposed computing procedure gives good predictions for the global behavior of high-strength concrete beams with hollow rectangle cross sections under pure torsion.

1. Introduction

In recent decades, high-strength concrete (HSC) or high performance concrete became a competitive material in many situations and its use has increased.

HSC possesses some characteristics and properties that may differ from the ones of normal-strength concrete (NSC) [1]. Such differences become more and more important as strength increases. Experimental tests with non-reinforced HSC elements have, for example, shown that such elements may in many cases be characterized by their linear elastic behavior up to stress levels that go close to maximum stress. Therefore, the HSC stress (σ)–strain (ε) curve decreases at a much greater rate than the corresponding NSC curve and thus shows the greater brittleness of HSC when compared to NSC.

However, several studies carried previously on HSC beams under flexure [2–7] have shown that the low deformability of HSC does not necessarily result in a low deformability of the correspondent structural members. Shear and torsion failures are normally associated with brittle behaviors. However, shear and torsion may not necessarily lead to brittle failures. A good choice of longitudinal and transversal reinforcement will induce some shear ductility. Cladera and Marí have recently studied shear failures in beams with and without stirrups [8–10] and they proposed a simplified shear design method to be used in codes. There are not many research works on torsion of concrete beams. Some of the recent published works deal with the complex algorithms of theoretical computing of concrete structures [11–13]. This article aims to find a simple algorithm, that would allow the prediction of the behavior of reinforced concrete (including HSC) sections under pure torsion up to failure, with special attention to T (Torque)–θ (Twist) relationships. At this point, it should be mentioned that the authors of the current article have already proposed a first calculation procedure, elaborated and validated only for NSC beams [14]. This paper described the different theoretical models and criteria used to characterize the states of behavior within a theoretical analysis to torsion applied to NSC beams with rectangular cross sections (plain and hollow). A computing procedure was also developed – with the help of spreadsheet EXCEL and using VBA (Visual Basic for Applications) – to predict the behavior of the beams referred above. Bernardo and Lopes [15] showed that this computing procedure does not give good predictions when applied for HSC beams under torsion. Thus, a new theoretical approach is presented in this paper in order to include HSC beams.

The theoretical approach divides the whole loading history into three regions (states). Each state identifies a particular type of the behavior of beams under torsion as observed in experimental tests. Such states can been characterized as follows:

– linear elastic analysis in non-cracked state (State I): Theory of Elasticity, Skew-Bending Theory and Bredt's Thin Tube Theory;
– linear elastic behavior in cracked state (State II): Space Truss Analogy with a 45° angle for concrete struts, taking into consideration the linear behavior of materials;

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