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Behaviour of high-strength concrete columns confined by spiral reinforcement under uniaxial compression

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HIGHLIGHTS

- 18 HSC columns confined by spiral reinforcement were tested to investigate the factors influencing behaviour of confined concrete, including strength of concrete, spacing of transverse reinforcement and specimen height.
- The specimen height to core concrete diameter ratio ranges from 2 to 4.
- Four stress-strain of confined concrete models were compared with the experimental results.

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ABSTRACT

This paper presents the results of an experimental program investigating the behaviour of confined high-strength concrete. Eighteen high strength concrete circular columns confined by spiral reinforcement were tested under axial compression. The test variables included concrete compression strength, the spacing of the spiral reinforcement and specimen height. The influence of the size of the effect on the behaviour of the confined concrete was investigated. Four confined concrete models which are defined in the literature were used to predict peak stress and strain of the core concrete (Mander et al., 1988; Fafitis & Shah, 1985; Razvi & Saatcioglu, 1999; Legeron & Paultre, 2003). A comparative study of the stress-strain model with the test results indicated that the models used in this study all produced a conservative prediction for the ductility of confined high strength concrete. The model proposed by Fafitis & Shah 1985 can make a more accurate prediction with standard deviation 3.92% and 21.88% in peak stress and strain, respectively, compared to predictions made by other models.

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1. Introduction

In recent years, high strength concrete has been widely used in buildings, bridges and other structures. The use of high strength concrete in columns can significantly reduce the size of the column and consequently reduce the dead load on the foundation system. Moreover, the available floor space for a building can be increased due to the reduction in column size. With greater elastic modulus, the use of high strength concrete can increase the stiffness of the structural member, resulting in a reduction in deformation with the same load. High-strength concrete possesses excellent resistance to low temperatures, rust and permeation, due to the increased density of the microstructure. The technical and economic benefit of using ultra-high-strength concrete is apparent, with its good mechanical properties and durability [1]. However, the high strength concrete is significantly more brittle than conventional strength concrete [2]. This can result in failure occurring suddenly under high loads. The challenge using high strength concrete is to address the problem of the brittleness in this material.

According to the theory of the multiaxial stress state, the maximum strength of confined columns is greatly enhanced by the lateral pressure. A relationship for the maximum strength of confined concrete f_{cc}, under the triaxial stress state can be described as:

$$f_{cc} = f_{co} + 4.1 f_l$$

where f_{co} = maximum strength of unconfined concrete in a member; and f_l = lateral pressure [3]. Sheikh & Uzumeri [4] proposed the concept of effectively confined concrete area. The arching action is assumed to act in the form of parabolas with an initial tangent slope of 45. Mander et al. used the concept of the effectively confined concrete area to calculate the confinement effectiveness coefficient, K_e [5]. The confinement effectiveness coefficient describes the circular spirals:

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$$K_e = \frac{1 - \frac{s'}{2d_s}}{1 - \rho_{cc}}$$

where s' = clear spacing between spiral; d_s = concrete core dimension to center line of perimeter spiral; ρ_{cc} = ratio of area of longitudinal reinforcement to area of core of section. The effective confinement index $K_e\rho_h f_{yh}/f'_c$ is used to assess the confinement efficiency of reinforcement concrete columns, where ρ_h is the volumetric ratio of the transverse reinforcement, f_{yh} is the tie yield strength, and f'_c is the cylinder strength of plain concrete. There have been some investigations reported in the literature describing the ductility and post-peak behaviour of the reinforced concrete columns. In order to develop adequate ductility of the columns using high strength concrete, more lateral confinement is required. These studies investigate the influence of various parameters on the strength and ductility of confined concrete.

Some stress-strain models of confined concrete have been proposed previously. Nagashima [6] developed a stress-strain model for confined concrete based on the test results of 26 prism specimens of ultra high and high strength concrete of strengths 118 MPa and 59 MPa (Φ100*200), respectively [6]. Razvi & Saatcioglu [7] developed a confinement model for high and normal strength concrete on the basis of the "equivalent uniform confinement pressure" concept proposed by Saatcioglu & Razvi [20]. The data includes a total of 46 near full-size columns of concrete strengths ranging from 60 to 124 MPa, 124 tests of high strength concrete columns conducted by others and 96 tests of normal strength concrete columns. The type, volumetric ratio, spacing, yield strength and arrangement of the transverse reinforcement, as well as concrete strength and section geometry were taken into account in model [7]. Cusson & Paultre [8] proposed a confined model based on results from 30 high strength concrete tied columns and 20 high strength concrete tied columns tested by Nagashima et al. [6]. The influence of distribution of the longitudinal reinforcement, yield strength, spacing, configuration, volumetric ratio of transverse reinforcement and concrete compressive strength on the strength and ductility of the confined concrete were investigated. Legeron & Paultre [9] proposed a confined model based on results from more than 200 circular and square large-scale columns. Li, Park & Tanaka [10] proposed a stress-strain model for confined high strength concrete based on experimental results in which the compressive strength of the concrete ranged from 32.5 to 82.5 MPa. Bjerkli, Tomaszewicz & Jansen [11] proposed a stress-strain model using results from a large number of plain and confined high strength concretes, with compressive strength concrete ranging from 65 to 115 MPa. Martinez et al. [12] described the response of high-strength concrete columns which were confined with steel spirals, when subjected to the short term compressive loading. Seventy-eight short columns without protective concrete cover over the spirals and 16 specimens without protective concrete cover were tested. Fafitis & Shah [13] proposed analytical explanation for the stress-strain curves of confined high-strength concrete based on experimental data. Seven confined models reported in the literature, Fafitis & Shah [13], Martinez et al. [12], Bjerkli et al. [11], Li et al. [10], Razvi & Saatcioglu [7], Legeron & Paultre [9] and Mander et al. [5] can be applied to the circular columns.

The model proposed before can be classified into two catagories based on the shape of cross-section (square and circle), while, the localization occurred in the compression failure of concrete was

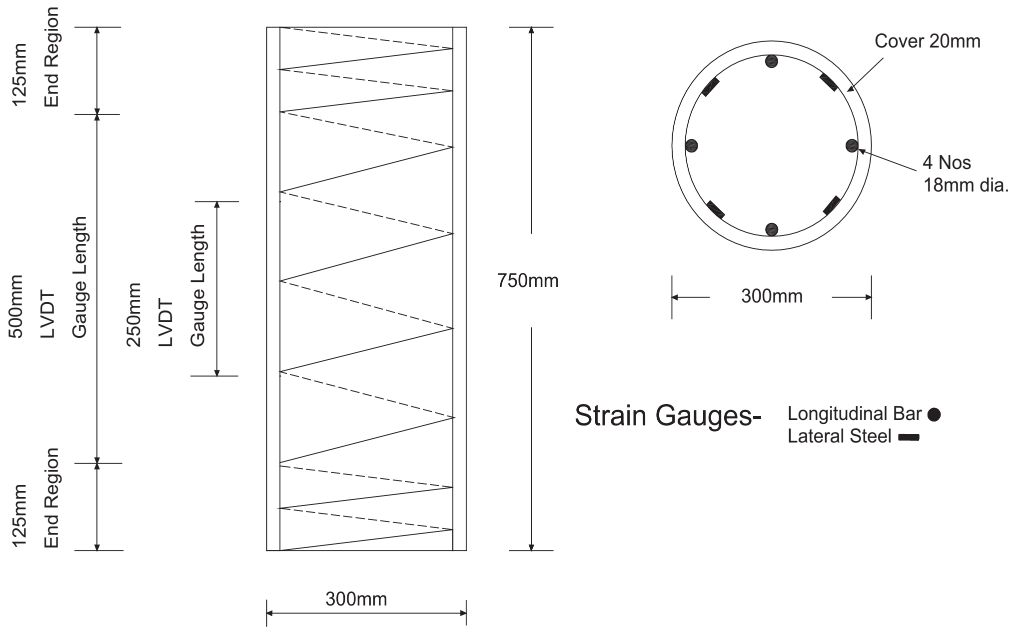

Fig. 1. Details of column specimens and instrumentation.

Table 1
Mix proportions.

Mix	Cement kg/m^3	Water kg/m^3	Coarse Aggregate kg/m^3	Sand kg/m^3	Silica Fume kg/m^3	GGBS kg/m^3	Super Plasticizer kg/m^3	28 Days Cylinder compressive Strength f'_c, MPa	28 Days Cube compressive Strength f'_c, MPa
A	350	175	1200	800	50	100	5	79.45	85.20
B	540	150	1140	760	60	0	6	92.61	101.30
C	560	112	1020	680	80	160	16	109.78	118.30

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