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Compression behavior of concrete columns confined by high strength steel wire

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HIGHLIGHTS

- Experimental tests of high strength wire (HSW) confined concrete columns.
- Different stress–strain behavior compared with FRP or ordinary steel confined concrete columns.
- Existing stress–strain models inapplicable to HSW confined concrete columns.
- New stress–strain model developed that is applicable to both HSW and ordinary steel spiral confined concrete columns.

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ABSTRACT

Experimental investigations were undertaken on high strength wire (HSW) confined concrete columns. Fifteen columns were tested with the variation of confinement pressure that was achieved by changing the winding spacing of HSW. The stress–strain response, peak strength and strain, ultimate strain, and failure modes of the columns were investigated. The experimental results showed that winding HSW is an effective and efficient method of column jacketing that can significantly increase column strength and ductility. The failure mode of HSW confined concrete columns showed successive fractures of HSW with increased ductility and abundant warning compared with fiber reinforced polymer (FRP) jacketed columns. The test results show that the existing framework for stress–strain modeling of ordinary steel spiral confined concrete columns is generally applicable to HSW confined concrete columns. However, the parameters of the stress–strain model must be revised to suit the significantly different characteristics of the new confining material. Using the test results from this work and other data collected from the literature, an improved stress–strain model is developed which is applicable not only to HSW confined concrete columns but also to ordinary steel spiral confined concrete columns. The proposed model shows an improved performance compared with existing models reported in the literature.

1. Introduction

Convenient, inexpensive, effective and reliable techniques are required for strengthening, repairing, or retrofitting (all referred to as rehabilitation) of reinforced concrete (RC) columns. Additional external lateral confinement in the form of jacketing has been proven an effective method to enhance strength and ductility of existing RC columns. The current jacketing technology can generally be divided into three groups: RC jacketing, steel jacketing, and fiber reinforced polymer (FRP) jacketing. Numerous types of steel jackets have been reported and used in the construction industry, such as steel plate [1–3], steel cage [4–6], steel strip [7–10], and steel wire [11–15]. All these types of jackets have been found effective for RC column jacketing, as long as intimate and sufficient confinement to concrete can be provided. The selection of jacketing materials and techniques depends on availability of materials, local expertise, construction cost and duration, availability of design and construction guidelines, and knowledge or experience of local industry.

Winding steel wire on external face of RC columns (referred to as steel wiring hereafter) has been found a convenient and effective way of column jacketing [11–15]. Steel wiring is generally similar to the conventional steel spiral (stirrups, links, hoops, etc., all referred to as spiral hereafter) confinement. The early work by Richart et al. [16,17] investigated the strength of spiral confined circular concrete columns and proposed the classical model for confined concrete strength that has been the basis of most current design models of confined columns. In the past thirty years, numerous studies on spiral confined concrete were conducted. Desayi et al. [18] studied the stress–strain curves of concrete confined in various pitches of steel circular spirals. Ahmad and Shah

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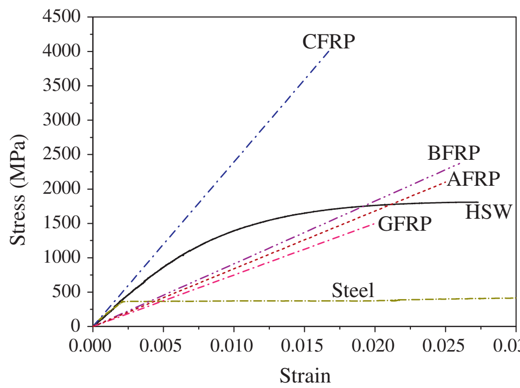

Fig. 1. Stress–strain relationship of confining materials.

Fig. 2. High strength steel wire (HSW).

[19] investigated the influence of compressive strength, aggregate type, and the spacing and yield strength of hoop reinforcement on spiral confined concrete. Mander et al. [20,21] tested and modeled the longitudinal stress–strain behavior of the nearly full-size confined concrete with spiral reinforcement. Assa et al. [22] investigated response characteristics of concrete cylinders confined by spiral steel, involving two different kinds of high strength steel. Li et al. [23] tested high-strength concrete columns confined by various amounts and strengths of spiral reinforcement. Sheikh and Toklucu [24] investigated monotonically loaded short concrete columns reinforced with spirals or hoops, with the variations of amount, type, and spacing of lateral steel, and specimen size.

These existing works used conventional steel bars and wires that have low yield strength. Currently, high-strength steel wires (HSW) with strength of more than 1500 MPa are common. These wires are very suitable for column jacketing as they are small in diameter and can be easily wound on column surface. The high strength is particularly advantageous as it provides a much higher confinement with the same winding work. HSW is made by twisting high strength steel filaments in a helix. The surface of HSW is galvanized to prevent corrosion. Fig. 1 shows typical stress–strain relationship of HSW in comparison with that of mild steel and FRP. It is clearly seen that HSW exhibit a nonlinear stress–strain behavior with a short yield plateau at its peak strength. Compared with FRP, it is more ductile, less expensive, and less sensitive to high temperature and fire.

Few investigations on column jacketing with HSW have been reported in the literature. Yang et al. [12–14] and Sim and Yang [15] developed a simple strengthening procedure using wire rope and longitudinal T-shaped steel plate and concluded that the wire rope and steel plate enhanced the strength, ductility and other seismic performance of the columns. However, the existing investigations were largely qualitative in nature that demonstrated the effectiveness of HSW for column jacketing. Extensive quantitative studies for development of design guidelines were scarce. Although, strength and stress–strain models are available for ordinary steel spiral confined concrete columns, their suitability for design of HSW confined concrete columns is questionable. Therefore, this work aims at a quantitative investigation on the technology and development of design oriented stress–strain model for HSW jacketing.

2. Experimental program

2.1. Material properties

The HSW used in this work is shown in Fig. 2. The wire is made by twisting together nineteen single high strength steel filaments. The nominal diameter and net cross-sectional area of the HSW are 3.0 mm and 5.37 mm^2, respectively. The diameter of a single steel filament is 0.6 mm. Tension tests were conducted to measure the mechanical properties of the HSW. The measured stress–strain curves are shown in Fig. 3 and the properties are provided in Table 1. HSW exhibits a nonlinear stress–strain behavior and ruptures suddenly at its ultimate strain.

The epoxy-based SJK-03 adhesive was used as the rendering material. SJK-03 adhesive is commonly used to bond steel plate for strengthening concrete structures. It has a high tensile strength and provides high tensile bond to concrete. The steel wires become an integral jacket after solidification of the adhesive. Table 2 summarizes the mechanical properties of SJK-03 adhesive provided by the manufacturer.

2.2. Specimen design

Fifteen circular concrete cylinders with a diameter of 150 mm and height of 300 mm were made as test specimens. All specimens were cast in one batch of concrete to avoid variation of concrete strength. The average cylinder compressive strength of concrete at the time of testing was 36.4 MPa. One day after casting, the specimens were removed from the molds and cured. The main parameter in this investigation is the winding spacing of the HSW that varies from 10 mm to 40 mm by an increment of 10 mm. Fig. 4 shows the winding details. Other details of the specimens are given in Table 3. The specimens were labeled as follows: the first letter indicates the circular section (C = cylinder), the two middle digits indicate the

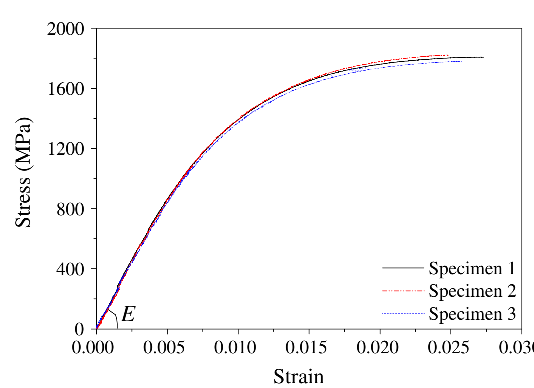

Fig. 3. Measured stress–strain curves of HSW.

Table 1
Mechanical properties of HSW.

Specimen no.	Nominal area (mm^2)	Maximum load (N)	Ultimate strength (MPa)	Elastic modulus (GPa)	Ultimate strain (%)
1	5.37	9707.9	1807.8	151.4	2.730
2	5.37	9780.5	1821.3	152.9	2.486
3	5.37	9558.3	1779.9	148.6	2.579
Average	5.37	9682.2	1803.0	151.0	2.598