Construction and Building Materials 78 (2015) 50–59

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Axial behavior of ferrocement confined cylindrical concrete specimens with different sizes

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HIGHLIGHTS

- Studied the axial behavior of ferrocement confined cylinder with different sizes.
- Single layer mesh ferrocement cannot provide significant confinement.
- Atleast two layer mesh needs in ferrocement jacket to provide necessary confinement.
- A strength model is proposed for ferrocement confined concrete.

ARTICLE INFO

Article history:
Received 9 July 2014
Received in revised form 24 October 2014
Accepted 5 January 2015
Available online 16 January 2015

Keywords:
Concrete cylinders
Size effect
Wire mesh
Ferrocement
Strength model

ABSTRACT

This paper presents an experimental study on the axial behavior of ferrocement confined cylindrical concrete specimens. The present study also intends to investigate the effect of specimen size on the confinement action of ferrocement jacket. Three types of 27 concrete cylinders with diameters of 150, 100, and 75 mm are cast and tested under axial compression. Each type of specimens is confined with single layer and double layer welded wire mesh ferrocement jacket having a constant thickness of the jacket. The experimental results demonstrate the effectiveness of ferrocement confinement in enhancing the strength, ductility and energy absorption capacity of concrete specimens. The confinement action is found more effective in case of smaller specimens. A post-peak descending branch in the axial stress–strain curve is observed in all the confined specimens. The stress–strain behavior and the failure pattern indicate that single layer mesh ferrocement jacket cannot provide significant confinement; at-least two layer mesh is required for substantial confinement. A new analytical model for the strength of ferrocement confined circular concrete specimen is proposed based on the test results of this work and verified with the recent experimental data obtained from the literature.

1. Introduction

Concrete is a widely used construction material all over the world. However, it often suffers deterioration due to various environmental (like earthquake, flood) and structural (like overloading) factors. A variety of materials and methods have been tried by the engineers to increase the strength and ductility of unsafe or deteriorated concrete structures. The materials and techniques applied for such strengthening activities should be structurally effective; and also cost effective as cost effectiveness is another major concern for developing countries.

Fiber reinforced polymer (FRP) is widely used nowadays as a confining/strengthening material for upgrading the strength of concrete members. However, FRP is very expensive, and its installation also requires highly skilled labor. Installation of FRP in hot and humid weather is very difficult and need special measures during its installation [1,2]. On the other hand, ferrocement is very cost effective technology in developing countries as its raw materials are easily available in these countries [3]. Ferrocement is a form of RC using closely spaced single or multiple layers of mesh and/or small-diameter skeletal rods completely infiltrated with, or encapsulated, in mortar [4]. Although, ferrocement is an old technology, it is extensively used as a construction material with advanced technology in both developed and developing countries due to its ease of fabrication [5]. It could be one of the promising materials for confining the concrete elements due to its improved structural properties [6,7].

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http://dx.doi.org/10.1016/j.conbuildmat.2015.01.044
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Many researchers have recommended the use of external ferrocement jacketing as a potential confinement material for concrete column. Sandowich and Grabowski have studied both axial and eccentric load behavior of circular composite columns made of ferrocement pipes filled concrete column and reported a ductile behavior of such columns [8]. Balaguru has investigated the axial load behavior of wire mesh composite plain concrete cylinder and observed an enhanced strength and ductility of the confined concrete [8]. Singh and Kaushik studied the effectiveness of ferrocement confinement for repairing both circular and square short concrete columns and achieved an enhanced strength and ductility of the jacketed specimens [10]. Walliudin and Raffeeqi studied the order of casting of ferrocement for confining the plain concrete. The methods of confinement studied were: (i) mesh layer cast integrally, (ii) mesh layers in precast shell, and (iii) wrapped mesh layer on precast core. They have observed that the confinement is 100% effective when the ferrocement jacket cast integrally with the concrete core [11]. Ramesh studied the confinement behavior of ferrocement in confining steel fiber reinforced concrete. The study achieved an improved ultimate strength by about 10%, but 200% ultimate strain compared with the similar ferrocement confinement of normal core concrete [12]. Mourad investigated the behavior of externally confined plain concrete with welded wire mesh ferrocement [13]. He studied the effect of different attaching methods of wire mesh around the concrete specimens. Kondraivendhan and Pradhan have investigated the behavior of ferrocement confined cylindrical concrete specimens of different grade and observed that the strength enhancement varies with the grade of concrete [14]. Xiong et al. investigated the strength and ductility of plain concrete encased with ferrocement including skeletal steel bars and compared with FRP confined concrete [15]. They concluded that the ferrocement confined concrete is more ductile under axial load than that of FRP confined concrete. Kaish et al. proposed some improved square ferrocement jacketing to strengthen square RC columns [16]. The performance of those improved square ferrocement jacketed square RC columns under concentric compressive load was verified later by Kaish et al. [17]. Kaish et al. have also investigated the behavior of ferrocement encased square RC columns under eccentric load [16,18]. Ho et al. have proposed a strengthening method for circular RC columns using high-performance ferrocement (HPF) composites [19].

As demonstrated above, ferrocement is an established material for rendering external confinement for axially loaded concrete members. However, the available research on ferrocement as a confining material is not much compared to the research carried out on other strengthening materials and techniques. Although ferrocement is a very old material, but still there is a big gap in scientific knowledge to use it as a confining material for concrete structures. The size effect of concrete specimens on the confinement action of ferrocement jacket is still not investigated. This gives the necessity of investigating the effect of specimen size on the effectiveness of ferrocement confinement. Moreover, there are only three confinement models available in the literature for ferrocement confined plain concrete, two of those were proposed for woven mesh ferrocement jacket and the rest was for welded mesh including steel bars [9,11,15]. However, most of these models are very complicated to use practically for design purpose. Additionally, skeletal steel bars are not used in the ferrocement jacket all times. Thus, a simple strength model is also required for concrete confined with welded mesh ferrocement jacket that have no skeletal steel bars. This study is intended to further the understanding of the confinement mechanism of ferrocement (made of welded wire mesh) jacketing for concrete members. A simple analytical model is also proposed finally to predict the strength of ferrocement confined cylindrical concrete specimens.

2. Experimental program

The experimental study was carried out on 27 concrete cylinders of three different sizes. The height and diameter of the cylinders were 300 mm, 200 mm, 150 mm; and 150 mm, 100 mm, 75 mm, respectively. Nine cylinders were prepared for each size; three of them were kept non-jacketed (denoted as NJ); three were jacketed with ferrocement having a single layer wire mesh; and the rest three were jacketed with ferrocement having a double layer wire mesh. The thickness of the external ferrocement jacket was kept constant (12.5 mm) for the jacketed specimens of all sizes. The external jacket was consisted of single or double layer welded wire mesh infiltrated with mortar. In general, 150 mm diameter specimens are designated as LS, 100 mm diameter specimens are designated as MS, and 75 mm diameter specimens are designated as SS. Fig. 1 demonstrates the details of the test specimens. The specifications of the specimens are shown in Table 1.

2.1. Materials

2.1.1. Cement

The cement used to prepare the specimens was local made Dragon brand cement. The strength class of cement was 32.5 N CEM-II conforming to EN 197.

2.1.2. Aggregates

The coarse aggregate used was 12 mm downgrade crushed stone. Its specific gravity and water absorption capacity was 2.62% and 1.05%, respectively.

The fine aggregate used was locally available coarse river sand. The specific gravity and water absorption capacity of sand were 2.58% and 0.95%, respectively. The same sand was used in preparing mortar for ferrocement after conforming ACI 549.1R-93 [20]. Both the fine and coarse aggregate used in mixing concrete were saturated and surface dried.

2.1.3. Wire mesh

The wire mesh used as reinforcement for ferrocement jacket was welded wire mesh. The opening of the mesh (grid size) was 12.5 mm square opening. The diameter of wires in the mesh was 0.85 mm. The yield strength of individual wires of the mesh was 415 Mpa.

2.2. Mix design

2.2.1. Concrete mix

The concrete mix was designed to obtain a concrete strength of 20 MPa at 28 days. The design amounts of materials in the mix were 400 kg/m^3 cement, 1026 kg/m^3 coarse aggregate, 624 kg/m^3 fine aggregate, and 180 kg/m^3 free water.

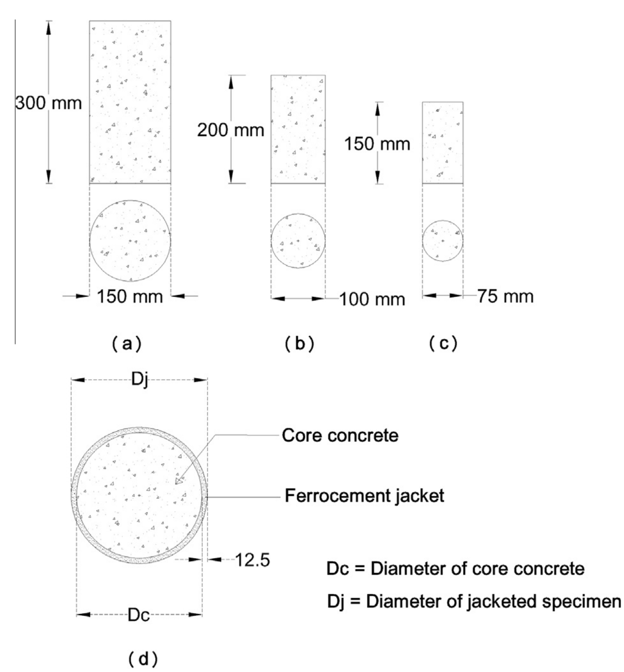

Fig. 1. Details of the test specimens.