Construction and Building Materials 125 (2016) 585–594

Contents lists available at ScienceDirect

Construction and Building Materials

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

Experimental investigation of reinforced concrete beams with spiral reinforcement in shear

Nasim Shatarat [a,*], Hasan Katkhuda [b], Mu'tasim Abdel-Jaber [a], Maha Alqam [a]

[a] Civil Engineering Department, The University of Jordan, Amman, Jordan
[b] Civil Engineering Department, The Hashemite University, Zarqa, Jordan

HIGHLIGHTS

- Shear behavior of twenty eight reinforced concrete beams was investigated.
- The beams included continuous rectangular spiral shear reinforcement.
- Results showed improved shear capacity and ductility compared to closed stirrups.
- The optimum inclination angle for spiral stirrups was 80°.

ARTICLE INFO

Article history:
Received 15 June 2016
Received in revised form 16 August 2016
Accepted 19 August 2016

Keywords:
Rectangular spiral reinforcement
Shear
Reinforced concrete
Beams
Stirrups inclinations
Shear span-to-depth

ABSTRACT

The use of continuous rectangular spiral shear reinforcement as transverse reinforcement is experimentally investigated by testing 28 reinforced concrete beams in a static four-point bending setup. In this paper two shear span-to-depth ratios (2.5 and 3.0), three spacing (125, 150 and 200 mm) and five inclination angle of stirrups (62, 70, 75, 80 and 85°) are adopted. The behavior of the shear-critical beams is studied through monitoring the load–deflection curves, ultimate load values, vertical deflections measurements and crack propagation during static tests. The experimental shear capacity of the beams are compared with analytical values from the design shear formulas of ACI 318M-14 code. Test results clearly indicate that using rectangular spiral shear reinforcement improved the shear capacity and ductility of beams compared with traditional individual closed stirrup beams. Furthermore the results showed that the optimum inclination angle for spiral stirrups is 80°. Accordingly, using rectangular spiral shear reinforcement is recommended because it improves the shear capacity and ductility in beams and can reduce the total cost due to labor costs.

1. Introduction

All reinforced concrete beams require shear reinforcement. Usually the shear reinforcement is individual vertical stirrups or continuous spiral reinforcement. The theoretical shear strength of a member is provided by concrete and shear reinforcement if the external applied shear force exceeds the shear strength of the member provided by concrete only [1–4]. However, it is required to provide minimum shear reinforcement in all beams to avoid brittle fracture even if external applied shear force does not exceed the shear strength of the member provided by concrete only.

The use of continuous spiral reinforcement can be considered more effective in construction compared to individual vertical stirrups due to the fact that spiral reinforcement is made of spirally shaped cage that can be quickly installed into place which reduces the time and labor costs significantly. While the individual stirrups bending and installation is a time consuming operations which lead to increase in the ultimate cost due to labor cost. Furthermore, the single closed stirrup installation requires the formation of two end hooks for anchorage. These two hooks are extra amount of material that increase the total cost. The use of spiral reinforcement in reinforced concrete elements was studied by many researchers [5–9]. They reported that the spiral reinforcement enhances the strength and ductility capacity due the confining of concrete core. Also, the application of spiral reinforcement in circular reinforced concrete elements under seismic loading has been extensively investigated [10,11]. The use of additional circular spirals near the potential plastic hinge regions in columns confirmed that the concrete is very effectively confined leading to significant

* Corresponding author at: The University of Jordan, School of Engineering, Civil Engineering Department, Amman 11942, Jordan.
E-mail address: n.shatarat@ju.edu.jo (N. Shatarat).

http://dx.doi.org/10.1016/j.conbuildmat.2016.08.070
0950-0618/

enhancements in both the load capacity and ductility of columns [12].

Reinforced concrete beam-column joints, columns and infilled frames with rectangular members and rectangular spirals as shear reinforcement have already been tested under cyclic loading [13,14]. The experimental results of these tests showed that the spiral reinforcement improved the overall seismic performance and increases maximum loading, energy absorption and ductility capabilities of beam-column joints.

Other application of spiral stirrups is in concrete-filled steel tubular stub columns [8,9,15]. Hamidian et al. [16] investigated the axial compressive behavior of reinforced concrete-filled steel tube columns using spirally reinforced concrete with different pitch spacing. The test results indicated that using spiral reinforcement in the columns and reducing the pitch spacing enhance the post-yield behavior. Ding et al. [17] presented an experimental comparison between concrete-filled square steel tubular stub columns confined by spiral stirrups, traditional square concrete-filled steel tubular stub columns, and inner stiffened square concrete-filled steel tubular stub columns. Liang et al. [18] studied the axial compressive load-carrying capacity and behavior of square composite steel and concrete columns confined by multiple interlocking spirals. The variables of the specimens included type and spacing of the lateral reinforcement, and shape of the structural steel section. The test results showed that the columns with multiple spirals achieved higher axial load-carrying capacity and deformability. Yang et al. [19] examined the shear behavior of three two-span reinforced concrete T-beams that have been reinforced using wire ropes with high-strength as shear reinforcement. The test results showed that using such system enhanced the ductility of beams.

Recently the use of rectangular continuous spiral reinforcement in reinforced concrete beams with rectangular cross-sections has been studied. De Corte and Boel [20] tested 24 beams to assess

Fig. 1. Traditional individual closed stirrups and rectangular spiral stirrups.

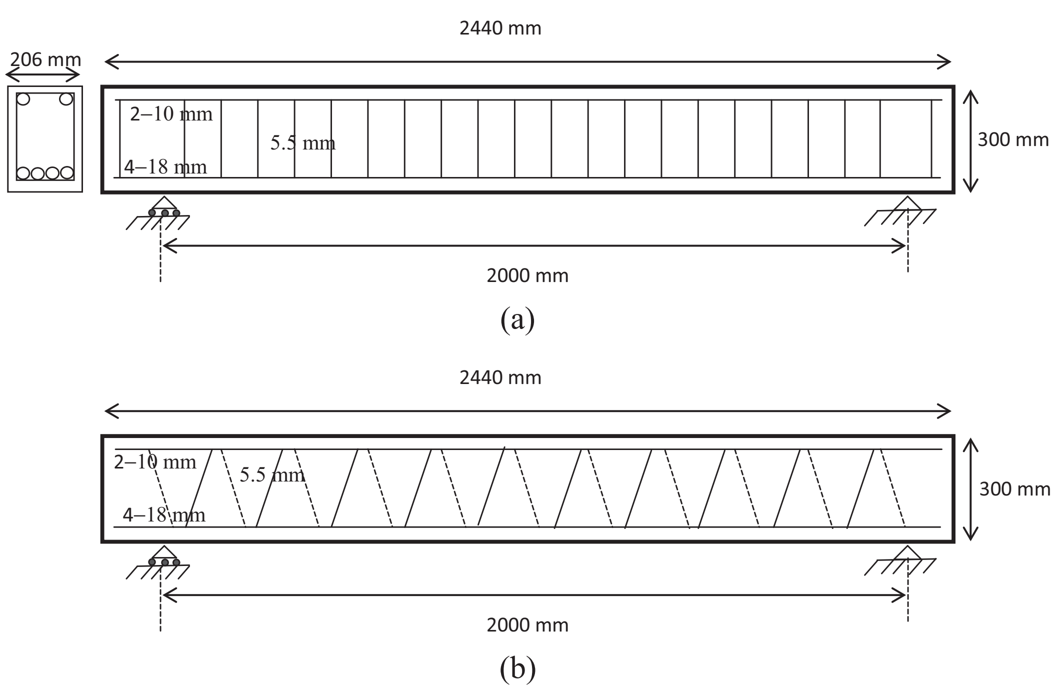

Fig. 2. (a) Beam details using single stirrups; (b) Beam details using rectangular spiral reinforcement.