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Bond behavior of spirally confined splice of deformed bars in grout

Seyed Jamal Aldin Hosseini *, Ahmad Baharuddin Abd. Rahman, Mohd Hanim Osman, Aziz Saim, Azlan Adnan

Department of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia

HIGHLIGHTS

- A spiral combined with splice bars as an alternative grouted connection.
- Significant increase in bond strength for rebars connected by the spiral connection.
- More effective confinement and higher bond strength with smaller spiral diameters.
- Similar trends of bond behavior observed in axial and flexural pull-out tests.
- Lower bond strength in flexural specimens compared to axial pull-out specimens.

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ABSTRACT

This paper presents the bond behavior of deformed steel reinforcement bars connected by a grouted spiral connection. The bond behavior investigated in this study comprised the mechanism of force transfer, the bond-slip relationship due to the effects of spiral diameter and the comparison of bond stresses between axial and flexural pull-out tests. A total of 36 pull-out specimens and 12 beam specimens were tested until bond failure. The results show that the bond performance between rebars and grout improved significantly due to the confinement provided by the spiral. Reducing the spiral diameter increases the confinement effect and subsequently increases the bond strength. The results also show that the bond strengths obtained from the flexural tests are within the range of 0.74–0.79 times the bond strength of the axial pull-out tests. However, both test results show similar trend of bond behavior with respect to variation in spiral configurations.

1. Introduction

There have been great developments in the factors affecting the bond over the past 40 years and as a result, design clauses related to bond in different worldwide design codes have been considerably modified [1]. There are some complications in detailed bond strength evaluation since the bond strength magnitude is affected by numerous factors. For instance, no less than 10 parameters, which affect anchorage, are included in the CEB-FIP Model Code 90 [2].

A governing issue known as confinement has significantly influenced the anchorage bond and reduced the required connected steel bars embedment length [3–6]. The confinement technique has successfully control the development of splitting cracks either by bridging or by the resistance provided by the expansion materials surrounding the steel bars.

The confinement of grout is proposed herein by providing closely spaced steel spirals as transverse reinforcement. The circular spiral provides a continuous confining pressure, which approximates uniform lateral fluid pressure around the circumference [7]. One benefit of such circular spirals is that they are widely available.

Research on the spiral connection has also been carried out by Housing and Development Board (HDB) of Singapore [8]. The spiral connection system was developed to provide a safe, reliable, cost effective connection system for splicing precast components. It embraces the theory of 'concrete confinement and shear action' to generate the required strength for connecting reinforcement bars efficiently. The connection system has undergone rigorous tests by HDB to meet the high performance standards. This connection is used for connecting precast concrete components such as wall-to-wall and column-to-column In this joint system, HDB has adopted the use of reinforcement with enlarged ends. Fig. 1 shows the spiral connection produced by HDB and its application in joining precast concrete components [9].

* Corresponding author.
E-mail address: Hosseini_s_jamal@yahoo.com (S.J.A. Hosseini).

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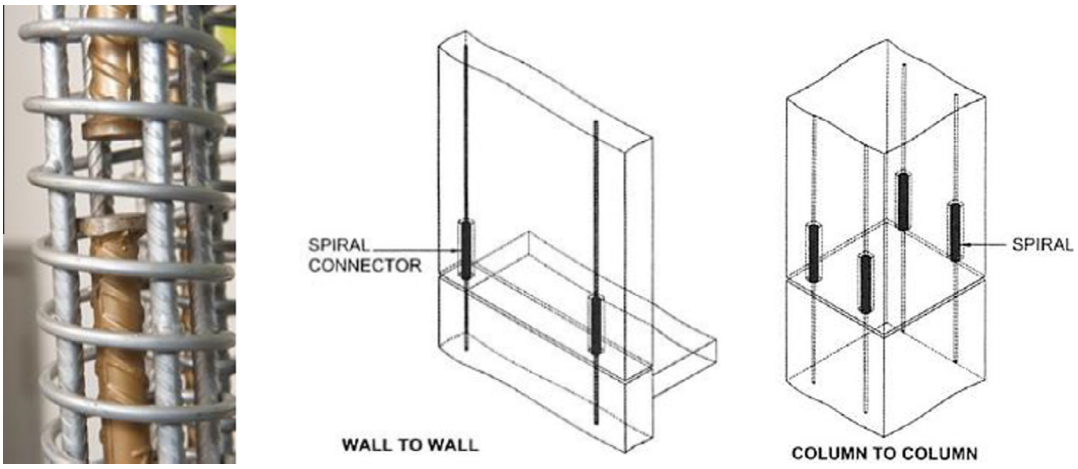

Fig. 1. HDB spiral connection [8] and its application in precast concrete wall-to-wall and column-to-column connections [9].

The main objectives of this paper are:

(i) Understanding the mechanism of force transfer in the spiral connection.
(ii) Understanding the behavior of bond stress–slip in the main reinforcement bars due to the effects of passive confinement provided by the spiral.
(iii) Investigating the performance of bond stresses between the axial and flexural pull-out effects.

1.1. Research significance

In Malaysia, grouted sleeve connections are the most popular method of connecting precast column-to-column or column-to-base. For example, the column-to-column or column-to-base connection is carried out by inserting the sleeves available in the upper column into the protruding starter bars of the lower column, see Fig. 2. The sleeves and starter bars are then grouted. In this joint, a long embedded length of about 40 times bar diameter [10] is normally required for each protruding starter bar. As a result of long embedded length, there is a possibility that the main bar is not positioned exactly at the center of the sleeve and could be in contact with the sleeve wall. As a result, the bar is not fully grouted and this reduces the anchorage capacity and the full strength of the main bar could not be exploited.

Fig. 2. Grouted sleeve connection.

There is a growing need for short bar development length in lap splices of deformed reinforcing bars in grout, because apart from the problem of long embedded length of normal grouted sleeve connections available mechanical splices are either expensive or require special equipment and installation procedures.

The spiral connection is part of the proposed short splicing method, where the confinement provided by the spiral increases the bond strength very substantially. The spiral connection can be used in Industrial Building Systems (IBS) as an alternative to other types of mechanical splice connections.

In terms of cost, the spiral connection uses mild steel spiral that is welded to Y10 high steel splice bars, which is considered inexpensive. The other advantage, the splice connection is not cast together with the precast components in the factory. Only a cavity or sleeve is required and formed in the precast component. To join precast components on site, the spiral connection is inserted into the cavity and then grouted with non-shrink grout.

As the success of the grouted connection rely heavily on the performance of the reinforcement bond strength, this paper presents the effects of spiral connections to the behavior of bond-slip relationship as obtained from axial pull-out tests and also flexural pull-out tests which emulate the true behavior of the connection in actual condition of flexural members.

1.2. Previous research

Confinement can improve the strength of concrete significantly. The influence of confinement on the ductility and compressive strength of concrete confined by transverse ties and spiral has been reported by many researchers [11–15].

Pessiki and Pieroni [16] and Graybeal and Pessiki [17] conducted studies on concrete confined by steel spirals. The specimens were subjected to compression. Their findings showed that the yield strain of the spiral confinement occured before