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Effects of spiral confinement to the bond behavior of deformed reinforcement bars subjected to axial tension

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ABSTRACT

When grouted pipe splice connections are employed, the structural performance of the connected precast concrete components is significantly influenced by the bond behavior between the main reinforcing bars and the surrounding grout. Owing to this important characteristic, the bond behavior, in particular the local bond-stress slip relationship and the bond strength, of the main steel reinforcement bars embedded in grout needs to be investigated accordingly. This paper presents the bond behavior of main deformed steel reinforcement bars confined by a grouted spiral connection. A total of 36 pullout specimens were tested under increasing axial tensile load to investigate the effects of spiral confinement to the connected main steel bars. Parameters covered in this study were spiral diameter and spiral pitch distance. The experimental results showed that the spiral configurations influence the bond performance due to the effect of confinement generated by the spiral diameter and pitch distance. As compared to spiral pitch distance, the spiral diameter provides more dominant confinement effect which subsequently increases the bond strength significantly.

1. Introduction

One of the major concerns that commonly arise with regard to the use of prefabricated precast concrete components is the quality of connections in joining the loose components together [1]. Many designers prefer to have a precast connection that has the same features of cast-in-place connection [2]. In this regard, the America Concrete Institute (ACI) has published different connection details to emulate equivalent cast-in-place rigid quality in the precast concrete construction [3]. Apart from mechanical rebar splicing systems such as Lenton and Erico, grouted splice vertical duct connection is one of the precast connections that is able to provide full continuity for continuous construction. On the other hand, still there is not enough supplementary information in the ACI code regarding the design of mechanical splice connections. Moreover, according to the related literature, majority of technical details are usually private and confidential except the basic feasibility evaluation of splice connections that has been recently published by Tokyo Steel Corp [4], Jansson [5], Coogler et al. [6] and Ling et al. [7]. To develop new splice connections, it is very essential to know the interactions and also internal stress distribution among the splice bars and the surrounding materials. It is also essential to make the relevant information accessible, in particular the local bond stress–slip relationship which is considered as the main objective of the study.

Grouted pipe splice connections are usually used in connecting precast concrete components and usually the bond development has strong effect on the interaction between the grout and splice bars. In fact, the mechanism of load transfer between the precast components depends on the quality of adequate bond between the connected reinforcement bars in the grouted splice connections [8]. Fig. 1 shows a typical example of connecting precast wall components using grouted splice connection. To avoid load eccentricity in the splice joints, rebar lapping in the grouted connection is avoided. Hence the rebars are connected using the end to end bar splice connections, as shown in the figure.

Research on the factors that affect the bond has developed greatly over the last 55 years, in which the detailed investigation of bond started with the research works by Rehm [10] in 1961. Experimental works by Goto [11], had demonstrated the bond action between concrete and steel deformed bar, which provides the understanding of the force transfer, the behavior of interlocking mechanisms and cracks between the embedded reinforcement bars and the grout. Other research studies on bond include the works by Jorge et al. [12], Ogura et al. [13] and Haskett et al. [14], Huanzi [15] and Azizinamini et al. [16]. As a result of numerous research works, considerable modifications have been

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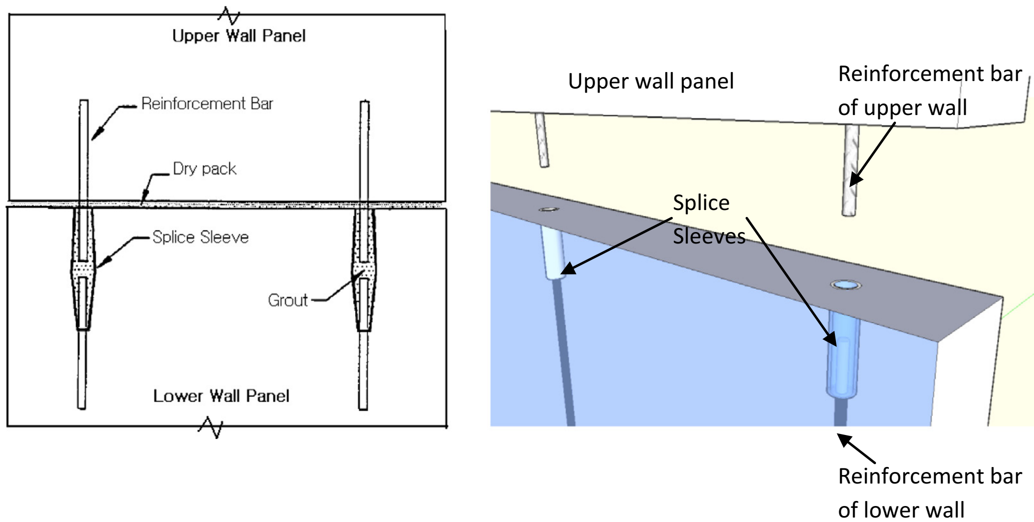

Fig. 1. Grouted splice sleeve connection in precast concrete wall panels [9].

introduced to bond clauses in design codes worldwide [17]. Detailed evaluation of bond strength and bond behavior is complicated, as the magnitude of bond strength is influenced by a wide range of factors. For example, the CEB-FIP Model Code 90 [18], includes not less than 10 parameters which influence the anchorage bond behavior.

Confinement has been attributed as one of the governing parameters that provide significant improvement in the anchorage bond that could lead to a reduction in the required embedment length of the connected steel bars [19–22]. To provide confinement to the connected main bars, various methods such as transverse reinforcements [23], spirals [24,25], cylindrical pipes [19,25–28], square hollow sections [29] and wrapping of fiber reinforced polymer (FRP) sheets [1] surrounding the anchorage bar zone have been adopted. Confinement is known to control the spread of the splitting cracks, either by bridging or by resisting the expansion of materials surrounding the main steel bars. This effect increases the bond strength between the deformed bars and the surrounding grout and as a result a shorter embedded length for the main bars.

In Malaysia, the effect of spiral confinement on the bond strength of deformed steel bars was experimentally investigated by Hoseeini and Rahman [24,25]. The confinement was provided by means of spiral, similar to the proprietary grout filled splice sleeves that are widely used in precast concrete construction. In Denmark and Sweden respectively, similar research works for splicing tensile reinforcement bars using spiral sockets were carried out by Efsen [30] and Tepfers [31–33]. Research results by Efsen showed that spiral sockets were able to cause the spliced reinforcement bars rupture outside the splice. Tepfers [32] investigated the strength of tensile reinforcement splices confined by spiral reinforcement where every overlap has a separate spiral. The splices were tested in reinforced concrete beams and the results showed that the confining spiral contributed to the increase in splice strength significantly.

Grouted spiral connections can be used as the horizontal joint for connecting precast concrete wall-to-wall, wall-to-base, column-to-column and column-to-base. Higher bond strength provided by the spiral confinement has led to a reduction in the embedded length of the connected main reinforcement bars. Shorter embedded length facilitates the installation of precast concrete components and grouting of the connections. The proposed grouted spiral connections can be adopted in Industrial Building Systems (IBS) and can become a substitute to other types of mechanical spliced connections.

The objectives of this paper are:

1. To investigate the effects of spiral diameter and spiral pitch distance in providing the confinement.
2. To investigate the effects of confinement contributed by the steel spiral in improving the bond strength of deformed steel bars in the grouted splice connection.

2. Descriptions of test specimens

A complete grouted spiral connection consists of spiral reinforcement cage, two main reinforcement bars and non-shrink grout. Sections 2.1–2.4 discuss the components and material involved in making the connection.

2.1. The spiral reinforcement cage

The fabrication of the spiral reinforcement cage involved a spiral reinforcement that was welded to four (4) number of high yield steel (Y) deformed bars in 10 mm diameter, denoted as 4Y10 (see Fig. 2). The 4Y10 splice bars were welded to the external diameter of the spiral to provide the tensile resistance mechanism within the grouted connection.

2.2. Main reinforcement bar

The geometrical details of main reinforcement bar connected by the grouted spiral connection are shown in Fig. 3. It is a deformed bar and high yield (Y) steel with a diameter of 16 mm, denoted as Y16. The details of the deformed shape are: rib height = 1 mm, rib spacing, c = 10 mm and rib inclination, β = 63.5°.

2.3. Grouted spiral connection

Fig. 4(a) and Table 1 show the details and Fig. 4(b) shows the preparation of the grouted splice connection in joining the two main Y16 reinforcement bars. In this connection, the main reinforcement bars are inserted into the spiral and then grouted with the aid of PVC pipe.

The grouted splice connections are categorized in three series namely S25, S35, and S45, with the spiral diameter of 25 mm, 35 mm, and 45 mm respectively. Each group had three different pitch distances that were 15 mm, 25 mm, and 35 mm.