Engineering Structures 83 (2015) 154–162

Contents lists available at ScienceDirect

Engineering Structures

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

Non-proprietary bar splice sleeve for precast concrete construction

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ARTICLE INFO

Article history:
Received 18 April 2014
Revised 24 October 2014
Accepted 27 October 2014
Available online 22 November 2014

Keywords:
Development length
Bond strength
Bar splice
Precast concrete
Confinement

ABSTRACT

Over the last few decades, the use of precast concrete components have been significantly increasing in building and bridge construction due to their quality, durability, and speed of construction. Precast components need to be fully connected to ensure the integrity, serviceability, and durability of the completed structure. Several proprietary grout-filled sleeves are currently being used to splice reinforcing bars of the adjacent precast components. These sleeves require very tight tolerances in precast production to ensure the alignment of the spliced bars, which usually results in using larger and more costly sleeves than needed. The objective of this paper is to introduce a non-proprietary bar splice sleeve that accommodates current production tolerances in addition to being economical and easy to produce. The design method of the proposed splice sleeve and the analytical investigation conducted using FE analysis are discussed. The experimental investigation conducted using two alternatives of the proposed bar splice sleeve is presented. Eighteen specimens for splicing #8 and #9 bars were tested using different sleeve lengths. Test results indicated that the proposed bar splice sleeve have adequate capacity to fully develop reinforcing bars while being simpler to use and more economical than current proprietary splice sleeves.

1. Introduction

Precast concrete construction usually requires connecting precast concrete components, such as wall panels, columns, and pier caps, to form the completed structure whether it is a building or bridge. Several proprietary grout-filled sleeves are currently being used to splice the reinforcing bars of adjacent components. Examples are NMB Splice Sleeve, Sleeve Lock by Dayton Superior, and Lenton Interlok. In these connections, sleeves are inserted around the reinforcing bar in one component during fabrication, while reinforcing bars are extended from the other component at the same location of the sleeves as shown in Fig. 1. During construction, the components are erected by inserting the projected bars from one component into the sleeves in the other component. Then, the sleeves are, then, filled with high strength non-shrink grout using grout vents and grout pump as shown in Fig. 1. Proprietary sleeves are designed to allow a maximum tolerance of ½” or less in the alignment of the spliced bars, which is a challenge to many precast producers. In these cases, they use the sleeves designed for one or two bar diameters larger than the diameter of the spliced bars to provide additional tolerance, which results in less efficient and more costly splicing.

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http://dx.doi.org/10.1016/j.engstruct.2014.10.045
0141-0296/

The main objective of this paper are to introduce a non-proprietary bar splice sleeve that accommodates current production practices with respect to tolerances in addition to being easy to produce and more economical than existing proprietary sleeves. This includes developing an expression for calculating the required sleeve length as function of the bar diameter, grout strength, and desired tolerance. The paper is organized as follows: (a) previous research on the effect of transverse confinement on the bond strength of reinforcing bars is presented; (b) the concept and design of the proposed splice sleeve is discussed; (c) experimental investigation conducted to evaluate the proposed design is demonstrated as well as the analysis of test results; (d) theoretical investigation conducted sing finite element (FE) modeling is presented; and finally (e) research conclusions and recommendations are summarized.

2. Previous research

The structural performance and durability of reinforced concrete members are highly dependent on the bond strength between reinforcing steel bars and the surrounding concrete. Bond strength is a function of the confinement provided by the concrete itself and transverse reinforcement that surrounds reinforcing steel bars. Transverse confinement plays an important role in determining the required development length and/or splice length.

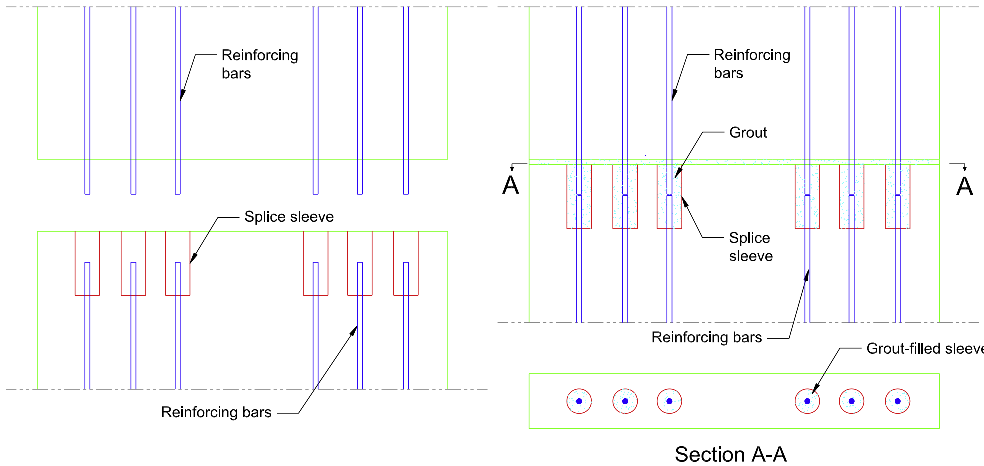

Fig. 1. Two precast concrete components before (left) and after (right) connecting using bar splice sleeves.

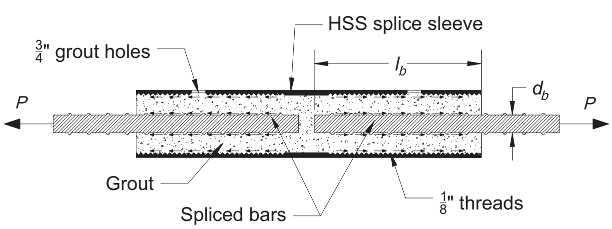

Fig. 2. Proposed bar splice sleeve and force transfer mechanism.

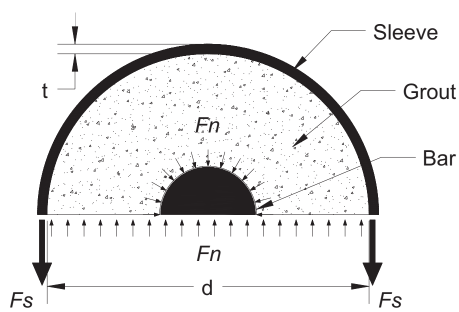

Fig. 3. Equilibrium of forces in the proposed bar splice sleeve.

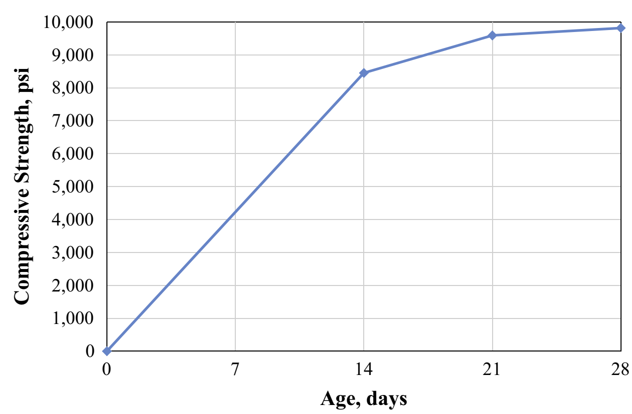

Fig. 4. Grout compressive strength development with time.

Transverse confinement have been studied extensively in several experimental and analytical investigations.

Untrauer and Henry [10] reported that the bond strength between the steel and concrete increases in proportion to square root of normal pressure and concrete strength. Normal pressure was applied to the faces of concrete specimens subjected to pullout forces. Orangun et al. [7] developed an expression for calculating the development and splice lengths for deformed bars with or without transverse reinforcement. These expressions were based on a nonlinear regression analysis of test results for beam specimens with lap splices that reflect the effect of splice length, concrete cover, bar diameter, concrete strength, and transverse reinforcement. The developed expression for the effect of transverse reinforcement was the basis for the current development length requirements in the ACI 318 [2]. Soroushian et al. [9] studied the effects of confinement by transverse reinforcement and compressive strength of concrete on local bond stress-slip characteristics of deformed bars using pullout testing. They reported that the ultimate bond strength increases almost proportionally with the square root of the concrete compressive strength. Confinement of concrete by transverse reinforcement did not directly influence the local bond behavior of deformed bars. Adajar et al. [1] established a new, simple and economical technique of connecting vertical bars in precast concrete shear walls by performing an experimental investigation using a combination of lapping bars and confining spirals. The effect of bar size, length of lapped bars, spacing of vertical bars, lug height of steel sheath, and pitch of spiral steel were studied. The main bars were spliced in grout-filled ducts that were surrounded by steel lapping bars and spiral. They concluded that the ultimate strength of the splices used in their investigation is equal to the tensile strength of the spliced bar when the lapping distance equals or exceeds 25 times the bar diameter. Sheikh and Toklucu [8] reported that the spiral reinforcement reached its yield strain before the confined concrete reached its maximum compressive strength, and the ultimate strength of the member increased with increased spiral yield strength. Also, they recommended using high strength wires to enhance reinforcement confinement of concrete. Einea et al. [4] evaluated the bond strength of reinforcing bars as a function of grout compressive strength and the level of confinement by studying the variables that affect the bond strength of reinforcing bars confined with steel pipes. They reported that a development length as short as seven time the bar diameter can be achieved by confining the high strength grout surrounding the bars. Darwin et al. [3] concluded that the fourth root of the concrete strength provided an accurate representation of the effect of concrete strength on bond