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Tensile behavior of half grouted sleeve connection at elevated temperatures

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HIGHLIGHTS

- The compressive behavior of cementitious grout at elevated temperature was studied experimentally.
- Tensile behavior of half grouted sleeve connection at elevated temperature was studied experimentally.
- When the temperature elevated, the failure mode and rebar breakpoint location of half grouted sleeve connection may change.
- At high temperature, the bonding length of rebar, enough at room or low temperature, may become to be not enough.

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ABSTRACT

Half grouted sleeve connection is widely used in joining rebars in precast concrete structures. However, its mechanical behaviors at elevated temperatures remain to be a topic with little research. This paper presents experimental results of 12 half grouted specimens and 12 single rebars under static tension at different temperatures. The tensile properties of half grouted sleeve connection were found to be directly affected by the temperature, and some characteristics are different from that of the rebar. The results showed that the half grout sleeves exhibited two types of failure, namely rebar fracture and rebar pullout due to bonding failure. The mechanical properties of specimens were similar to that of single rebars. When the temperature elevated, the failure mode and rebar breakpoint location may change. The bonding length that would be sufficient at room or low temperature, becomes insufficient at 600 °C. Suggestions about the bond length are given to avoid rebar pull out from the grout due to bond failure at elevated temperature.

1. Introduction

Precast concrete structure is one of the main structural styles in the process of building industrialization, and is also one of the development trends of the construction industry. The technology of grouted sleeve connection is mainly used for the connection of steel rebar in precast concrete element. It has a history of more than 40 years. According to the joint form, grouted sleeve connection can be divided into full grouted sleeve connection and half grouted sleeve connection. The latter, by contrast, is currently more popular in practice. Fig. 1 shows the common designs of half grouted sleeve connection used in precast concrete member [1].

In recent years, the fire accidents in the world and its losses have been unabated. Research on fire resistance of structures becomes an urgent task, which has attracted the attention of many scholars all over the world. The behavior of precast concrete structure and the realization of safety objective under elevated temperature are problems that civil engineers have to tackle directly. As one of the most widely used components, the properties of half grouted sleeve connection at elevated temperature play an important role in the performance of members and systems. Tensile behavior of half grouted sleeve connection at elevated temperatures was studied in the present paper. It can provide necessary foundation and reference from the study and analysis of the performance of precast concrete members or structural systems under fire or at elevated temperature.

Starting in 1983 when the American Concrete Institute included the grouted sleeve connection as one of the main rebar connection technologies, a series of studies on the grouted sleeve connection

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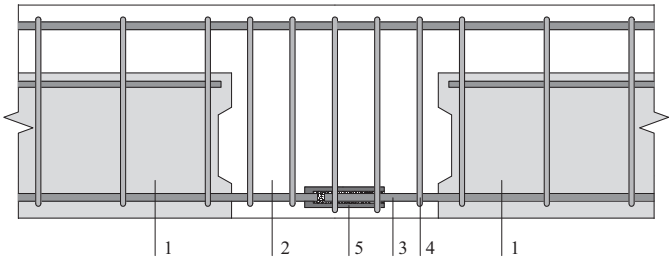
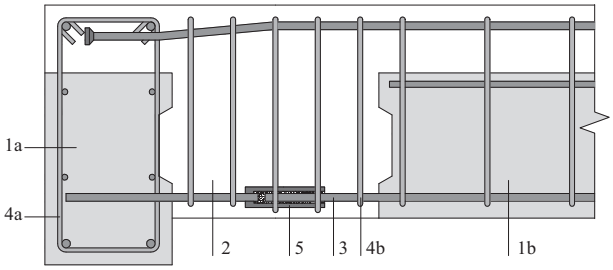


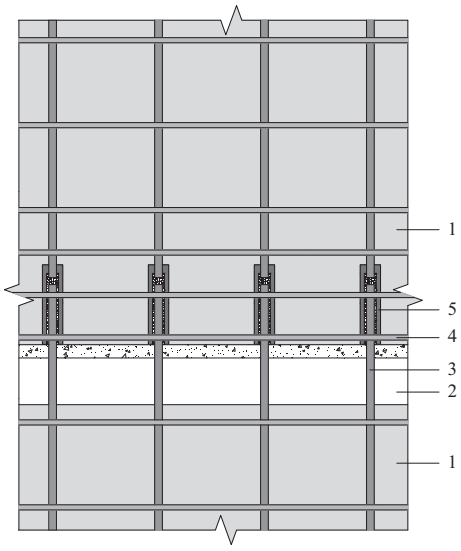
1-Precast concrete 2-Cast-in-situ concrete 3-Connected rebar
4-Stirrup 5-Grouted sleeve with half thread end

(a) Butt-jointed beam



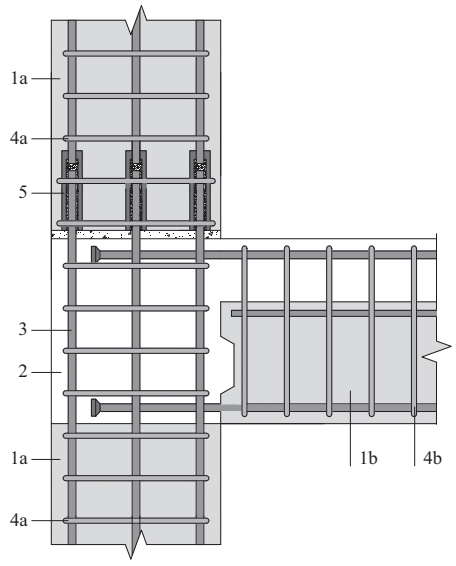
1a-Precast concrete of main beam 1b-Precast concrete of secondary beam
2-Cast-in-situ concrete 3-Connected rebar 4a-Stirrup of main beam
4b-Stirrup of secondary beam 5-Grouted sleeve with half thread end

(b) Secondary beam jointed with main beam



1-Precast concrete 2-Cast-in-situ concrete 3-Connected rebar
4-Horizontal rebar 5-Grouted sleeve with half thread end

(c) Jointed Wall



1a-Precast concrete of column 1b-Precast concrete of beam
2-Cast-in-situ concrete 3-Connected rebar 4a-Stirrup of column
4b-Stirrup of beam 5-Grouted sleeve with half thread end

(d) Beam jointed with column

Fig. 1. Half grouted sleeve connections used in precast concrete structure.

was carried out by many scholars. For example, Einea et al. (1995) completed unidirectional tensile test of grouted sleeve connection under different tectonic conditions. It was found that the tensile bearing capacity of grouted sleeve connection was related to the inner tectonic parameters and increased with the strength of the grouting and the length of rebar [2]. Kim (2000) improved the sleeve recommended by Einea et al. and performed the low cycle repeat tests of two joints made of precast concrete beams and columns. The material properties and pouring quality of grouting have great influence on the performance of grouted sleeve connection [3]. Goh (2009) conducted axial tensile experiments and found that as the age of grouting material develops (1d, 3d, 9d), the strength of grouted sleeve connection increases, and so do the rebar bond strength and bearing capacity [4]. Kim (2012) designed and made two different full grouted sleeve connections. Based on the axial tensile tests, he found that reducing the diameter of sleeve and increasing the length of rebar anchorage could improve the bond property of steel bars [5]. Sayadi et al. (2014) found that providing interlocking mechanism in the elastic segment of sleeve actually decreases the bond strength of splice sleeve and load carrying capacity of beams [6]. Ameli et al. (2016) pointed out that the precast subassemblies had a lower displacement ductility capacity than the control specimens, while improved seismic response was observed when the splice sleeve connectors were placed inside the footing rather than the column end [7]. Ling et al. (2012, 2014, 2016) studied the tensile properties, influencing parameters and mechanism of rebar grouting sleeve connections with different sleeves [8–10]. Huang et al. (2017) completed the experimental study and computational analysis on mechanical properties of half grouted sleeve connection, and observed that there were three categories of failure mode, namely rebar fracture, bond failure and thread failure [11].

The high temperature properties of rebar and its connection directly affected the behavior of reinforced concrete structure at elevated temperature. Niu et al. (1990) presented the constitutive expression of rebar related to temperature, based on the experiments under high temperature [12]. Yan et al. (2003) summarized the performance of rebar and concrete under high temperature and after high temperature [13]. Wang et al. (2005) developed the degradation curve of the rebar strength affected by the temperature based on mechanical property tests [14]. Li et al. (2012) completed the property tests of mechanical sleeve connection, and suggested design specifications of the yield strength, yield strain and elastic modulus at elevated temperature [15]. Kodur et al.