

## Shear Strength between HPC and Rolled Steel Plate after Elevated Temperatures

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**Abstract.** This paper had developed C100 high-performance concrete (HPC). Mechanical properties of high-performance concrete after evaluated temperatures were investigated. Besides, this paper had summarized the extrinsic characteristics of HPC after evaluated temperatures, which was effectively applied in evaluating the temperature experience of concrete structures. Shear strength between HPC and rolled steel plate after evaluated temperatures was experimentally studied with the facilities of specially designed loading device. Mathematical model of shear strength was proposed, which can be used in both engineering and numerical simulation.

### Introduction

Since the second half of the 1990s there is a renewed interest in the modeling of concrete at high and very high temperature [1-2]. Studies on bond stress between concrete and deformed bars show that bond stress is made up of three components namely: (1) chemical adhesion; (2) friction; and (3) mechanical interaction between concrete and steel [3-4].

Due to the complexity of the external loads of concrete structures, the damage of the three mentioned components which has not been determined explicitly is different. For example, the loss of chemical adhesion after evaluated temperatures can not be well reflected by traditional test method. The understanding and the modeling of the interfaces is actually one of the challenges of Civil Engineering. It concerns as well the classical techniques in masonry (including antique monuments) as the new techniques used either in assembling or repairing structures or developing new reinforced concrete adapted to strong solicitations [5]. Experimental study of the interaction between concrete and a bar subjected to a pull out force shows that bond evolve progressively from perfect adhesion to dry friction type [6]. Chemical adhesion, one of composition of bond strength at the interface of concrete and steel, is affected by concrete mix proportion, age of the concrete substrate, curing conditions and other factors. Campione pointed out that the chemical adhesion between concrete and steel bar should less than 1.2MPa [7]; Xu completed a series of experiments and found that the chemical adhesion should be 0.4~0.6MPa [8], Gao recommended the chemical adhesion should be 1~3MPa [9]. Inspection of the literature found by different scholars, there are some discrete in the research results on the same subject. Moreover, previous experience has been only studied the shear strength at room temperature, but little research has been done after evaluated temperatures.

Furthermore, finite element software ANSYS, ABAQUS have access to contact analysis [10-11]. However, the interface parameters are often selected based on experience. In view of the particularity and complexity of the bond-slip relationship, this paper presents an experimental study on the chemical adhesion between HPC and rolled steel plate after evaluated temperatures. The result of this paper can provide necessary parameters for strengthen concrete structures after fire or finite element simulations.

### Shear-off specimen design

HPC mix proportion are listed in table1.

Table 1 Mix proportion of C100 concrete

A variety of materials consumption per cubic meter of concrete/(kg.m-3)								Slump/m
Slag cement	Slag	Silicon	Water	Sand	Grave (5~15mm)	Super plasticizer		m
420	120	60	162	615	1140	9.526		200

Mixing process is as follows: First put into cement, slag, silica fume, sand and gravel, stirring about 2min, mix evenly by adding half of the water, then add the other half of the water and the water-reducing agent, stirring for 3~4min before the discharge. Through relevant tests, the concrete produced by the ratio and the mixing process above has good workability and durability.

Specimen with dimension of 100mm×100mm×150mm was casted in a special mold. Two 5mm thick steel plate were pasted on both left and right surface of the specimen. After the form removal, the specimens were cured in water (20±3 °C) in the conservation room. 28 days later, they were placed indoors for natural drying. Another month later, the specimens were tested. Specimens were divided into 4 groups (G1~G4), each group including 6 specimens corresponding to 6 temperature conditions. Fig.1 demonstrates the shear specimen.



Fig.1 Cementation shear specimen

### Shear strength after elevated temperatures

Shear strength test was carried out on TSY-2000 electric hydraulic pressure testing machine, see Fig.2. The schematic diagram is displaced in Fig.3.



Fig.2 Test equipment

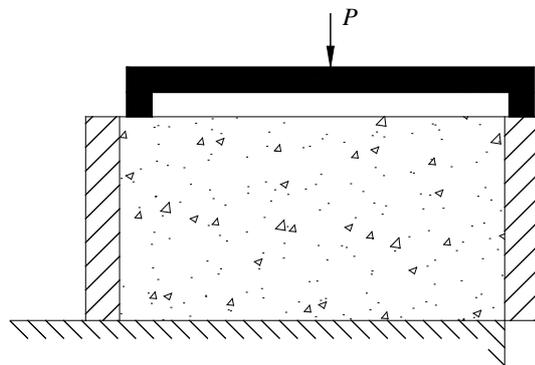


Fig.3 Schematic diagram

Vertical load P was recorded while the plate had been sheared off. The loading rate should less than 0.5kN/sec. The average bond shear strength of concrete can be obtained with the following formula:

$$\tau_a = \frac{P}{2A} \quad (1)$$

The variations of shear strength with the evaluated temperatures are shown in Fig.4t. Shear strength can be seen with a significant linear relationship with the evaluated temperatures.

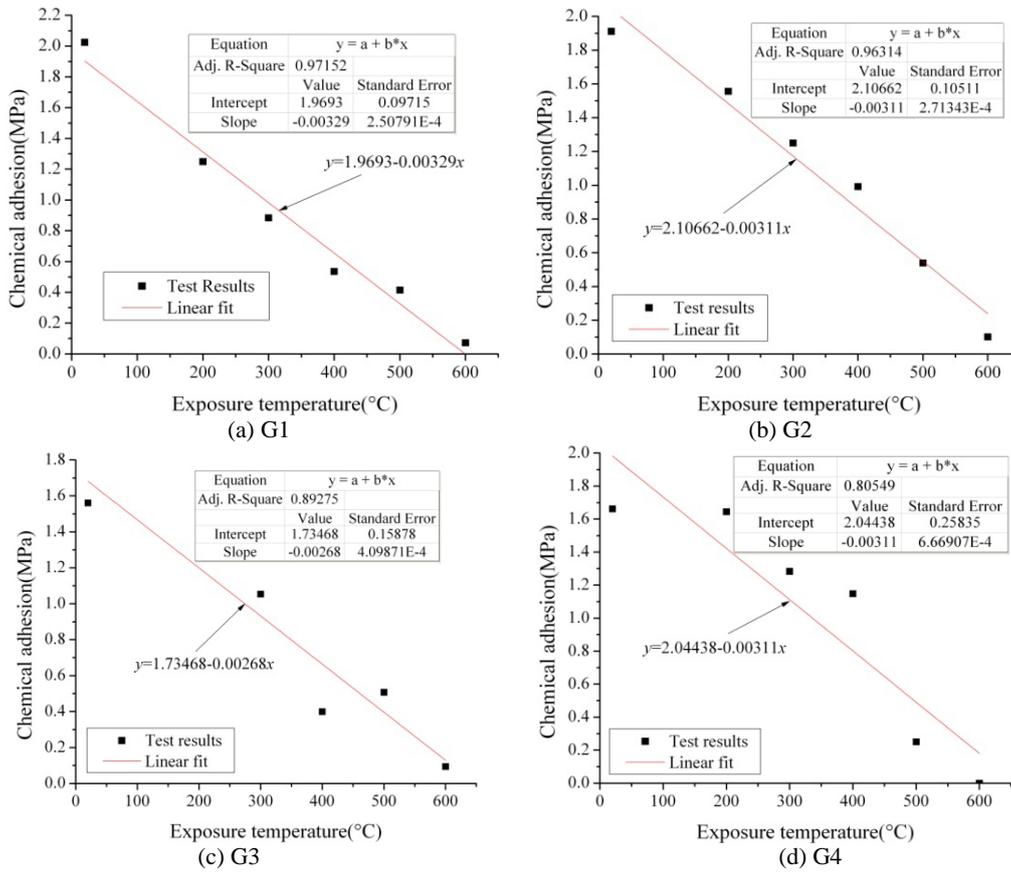


Fig.4 Shear strength variation with evaluated temperatures

Shear strength between HPC and rolled steel decreases with increasing temperatures. The trends can be expressed as a linear function:

$$\tau_a = a + b \times T \quad (2)$$

Where T is the experienced temperature, the range of a is 1.73468~2.10662, while the range of b is -0.00311~-0.00268. However, test results show that the rolled steel plate would be off because of uneven expansion when the experienced temperature is higher than 400 °C, which would result in an increase of the coefficient of variation. Therefore, in the conservative consideration, the author recommended that bond-slip problem should no longer include in the focus of adhesion when the exposed temperature is higher than 400 °C.

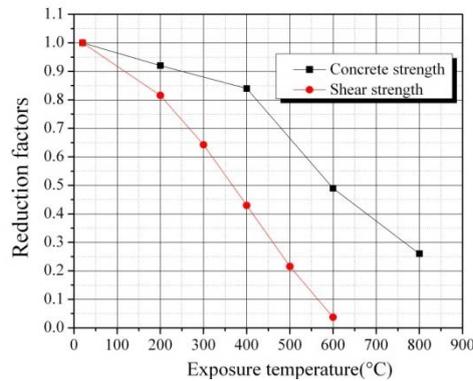


Fig.5 Reduction factors of concrete strength and shear strength after evaluated temperatures

Reduction factors of concrete strength and shear strength are graphically presented in Fig.5. It can be seen from the picture that reduction factors of concrete strength and shear strength were reduced as the exposure temperature was increased. The reduction factors of concrete strength versus temperature decrease slightly before 400 °C, yet sharply at temperatures greater than 400 °C. Besides, the reduction factors of shear strength should always lower than that of concrete strength after evaluated temperatures.

## Conclusions

In this paper, shear strength between HPC and rolled steel plate after evaluated temperatures was experimentally studied. Based on the test result and relative analysis, the following conclusions are obtained:

1. Compressive strength of HPC would decrease with increasing temperatures.
2. Shear strength between HPC and rolled steel decreases with increasing temperatures. Bond-slip problem should no longer include in the focus of adhesion when the exposed temperature is higher than 400 °C.
3. The decrease trends of shear strength between HPC and rolled steel can be expressed as a linear function.
4. The reduction factors of shear strength should always lower than that of concrete strength after evaluated temperatures.

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