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Shear strengthening of fire-damaged reinforced concrete beams using bolted-side plating

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Abstract

Six reinforced concrete (RC) beams were fabricated and exposed to fire in accordance with the international standards ISO834 temperature curve, four of which were retrofitted employing the bolted side-plating (BSP) technique. The shear tests of two control beams and four beams strengthened with BSP after fire were carried out. The influence of the plate depth and bolt spacing on the shear strength, ductility and stiffness was investigated. The testing results indicated that the BSP method can significantly increase the shear capacity of fire damaged RC beams and improve the overall shear and flexural performance. The strengthening effect increases as the increase of plate depth and the decrease of bolt spacing. When the external load is very large, local buckling of steel plate will occur under the combined action of bending and shearing. Both longitudinal and transverse slips coexist on the plate–RC interface of BSP beams. The bolt spacing exerts an important influence on the degree of partial interaction between the plate and the concrete. In the design of BSP reinforcement, the relative relation between the number of anchor bolts and the plate depth should be taken into consideration.

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Keywords: Shear strengthening; Fire damaged; Reinforced concrete beam; Bolted side-plating (BSP).

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1. Introduction

Considering the mechanical properties of concrete and steel bars degrade seriously after elevated temperature, the fire-damaged reinforced concrete beams does not satisfy the bearing capacity and serviceability[1, 2]. As building fires often occur and RC beams after fire can be well retrofitted, the damaged concrete beams are very necessary to be repaired and reinforced after fire[3, 4]. The bolted-side plating (BSP) is a technique where the steel plates are attached to the two side faces of the RC beams using anchor bolts[5]. Compared to other strengthening methods by gluing carbon fibre reinforced polymers[6] (CFRPs) or steel plates[7], the RC beams strengthened by the BSP technique were enhanced in both tensile and compressive reinforcement thus immune from reducing the ductility of RC beams and the brittle over-reinforced failure, the premature peeling failure at the end of the plates and CFRPs was also suppressed[8].

At present, although the systematic researches on the field of anchored steel platescholars have been carried out, most of them mainly concentrated in the application at room temperature, there are few research results for BSP method to strengthen the fire-damaged beam. Oehlers et al.[9] established the relationship between the degree of partial interaction and the shear stiffness of the anchor bolt connection by comprehensive experimental and theoretical studies. Su and Siu[8] developed a procedure to predict the nonlinear load-deformation response of bolt groups by theoretical analysis and numerical simulation; and two deformation-based parameters were introduced to quantify the degree of partial interaction, thus a theoretical model was proposed for longitudinal and transverse slips. Li and Su[10] tested seven BSP beams with different plate depths and various bolt spacing, and introduced the effect of the interfacial slip into the computation of flexural bearing capacity thus developed a simplified design method. However, the comprehensive work on the shear performance of BSP beams is still barely found in literature. Barnes et al.[11] compared the shear capacity of RC beams with bolted and glued steel plates on the side faces, and proposed a simplified theoretical model for the computation of shear capacity.

Therefore, the BSP technique would be adopted to strengthen the fire-damaged RC beam in this paper. Specifically, the shear tests of 2 control beams and 4 beams strengthened with BSP after fire were carried out.

2. Experimental program

In tests, six RC beams were fabricated, with cross section of 200 mm × 400 mm, concrete cover of 30 mm, and length of 2600 mm, as shown in Fig. 1. The 4D22, 2D12, and d6@200 was employed respectively as tensile reinforcement, compressive reinforcement, and stirrups. The notations 'D' and 'd' denoted the high-yield deformed steel bars and the mild steel round bars respectively. The material properties of the steel bars and the steel plates were tabulated in Table 1, and the average cube strength of the concrete was 32.3 MPa. The chemical anchoring system provided by Hilti Corporation was employed to anchor the steel plates to the RC beams. The anchor bolt was Grade 8.8, and the tensile and shear strength were 400 MPa and 320 MPa respectively.

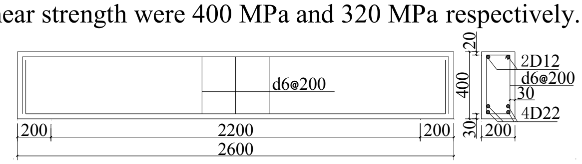

Fig. 1. Details of specimens (dimensions in mm)

Table 1. Mechanical properties of steel.

Sample	Diameter(mm)	Yield strength(MPa)	Young's modulus (GPa)
d6	6	307	201
D12	12	429	189
D22	22	418	193
Steel plate	--	302	303