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Performance of Reinforced Concrete Beams Retrofitted by a Direct-Shear Anchorage Retrofitting System

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Abstract

Reinforced concrete beams can be effectively strengthened by FRP plates or attaching steel plates on the soffit. The performance of this type of composite beam is controlled by the interaction at the steel-concrete interface. In this study, a total of three full-scale reinforced concrete beams, strengthened with steel plates in use of different types of strengthening methods, were tested, including one reinforced concrete beam without strengthening. In this program, a new simplified anchoring system (direct shear bolting-plate system) has been proposed for strengthening a reinforced concrete beam. Its behavior was compared to the available test results from the commonly used strengthening methods. The experimental results shows that this modified anchoring system is capable of effectively reducing the debonding failure between concrete and steel plates and controlling crack development after steel yielding. It was also found that the direct shear anchoring system is more effective in increasing the flexural strength of a reinforced concrete beam and reducing the longitudinal slipping between structural components, which was eventually for increasing the capability between concrete beams and steel plates to work together.

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Keywords: Direct-shear；Anchorage；Strengthened； Debonding；Reinforced concrete beam

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1. Introduction

The emergence of building reconstruction and reinforcement industry is for satisfying the change in the functional usage of existing buildings, strengthening or repairing concrete structures due to material deterioration and structural damage [1]. In Chinese Standard[2], two common retrofitting methods are recommended for building repairing and strengthening: (1) enlargement of the cross section area by casting new concrete with reinforcement, (2) attaching steel plates or fibre reinforced polymer plates (FRP) for enhancing the cross section strength. However, utilization of the first method is very limited due to the difficulty in construction and exhausting labour requirement. On the other hand, the plate bonding approach is already established as a simple and convenient repair method for building reconstruction. For example, the FRP plate bonding technique has been broadly employed with an advantage of strengthening a structure without obstructing its in-service function. However, FRP composites consist of carbon or glass fibers (GFRP and CFRP) embedded into a resin matrix[3], and cannot withstand a high temperature, as the glass transition temperatures of the bonding adhesive normally lie in the range 50-90 ℃[3, 4]. The degradation of the bonding adhesive leads to the debonding failure between FRP plates and a concrete beam.

The alternative technique is to employ steel plates externally bonded onto the soffit of a reinforced concrete beam with epoxy and/or anchor bolts. This retrofitting approach was first used to strengthen defective concrete structures in South Africa in 1967[5]. Then Swamy[6] and Hussain[7] investigated the influences of steel plate thickness, concrete strength and end anchorage to the structural performance of strengthened concrete beams. Swamy et al.[8, 9] also studied the durability and shearing behavior of reinforced concrete beams with steel plates bonded externally, and finding that this retrofitting method is effective in strengthening of damaged structural components. However, references[7, 10, 11] indicated that the reinforced concrete beams externally bonded with steel plates by adhesives are more likely to observe the intermediate crack-induced interfacial debonding (IC debonding) (peeling-off failure at flexural cracks) between concrete and steel before development of their full bearing capacities. This is caused by concrete cracking in the initial stage of loading[11]. For solving this problem, the anchoring plate bonding method was proposed to against the peeling-off failure, recommended in the references [12, 13]. The present work will perform a number of experimental tests on the RC beams strengthened by two different anchoring plate bonding methods: direct-shear anchoring plate bonding approach and conventional anchoring plate bonding method, corresponding to two types of anchor rods (bolts), respectively. The first anchoring approach is newly developed by Quan et al. [14] as a modification of the conventional anchoring approach (the latter one). Therefore, it may be interesting to use the experimental tests to find out the difference of these two approaches in strengthening the RC beams.

2. Experimental Program

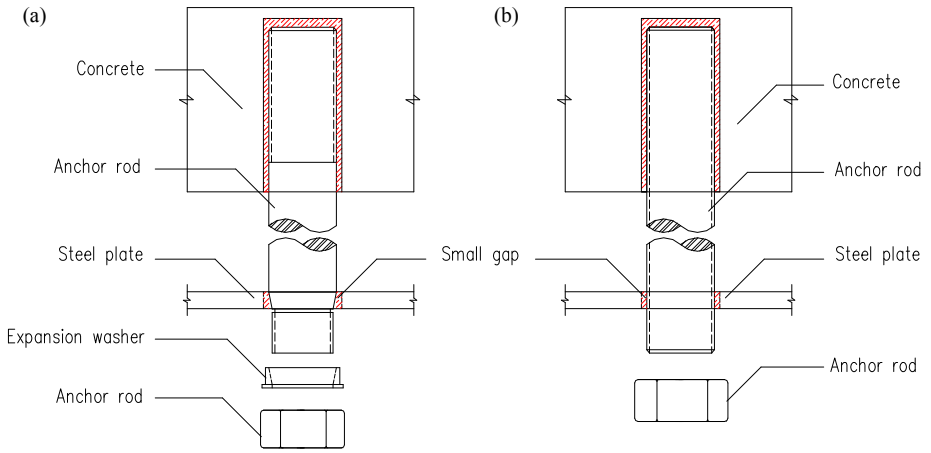

Fig. 1. Installation details of anchoring rods: (a) Direct-shear anchorage system; (b) Conventional anchorage system