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Flexural strengthening of damaged RC T-beams using self-compacting concrete jacketing under different sustaining load

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HIGHLIGHTS

- Damaged RC beams are strengthened by SCC jacketing under different sustaining load.
- Flexural behavior of the damaged beams after strengthened are experimental studied.
- Effects of sustaining load on beams cracking, stiffness, capacity are clarified.

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ABSTRACT

An experimental test is proposed in the present study to investigate the flexural behavior of damaged reinforced concrete (RC) beams strengthened by self-compacting concrete jacketing under different sustaining load. Eight RC T-beams with primary damages are designed and strengthened under different sustaining load. Then, the flexural testing test is employed to investigate the structural behavior of the strengthened beams. The influences of the sustaining load on beam response are clarified. The prediction method for the flexural capacity of the strengthened beams is also discussed. Results shows that the strengthening method proposed in the present study improves effectively the flexural behavior of beams, both in the stiffness after concrete cracking and the flexural capacity of the beams. Especially the flexural capacity, which becomes about twice as great. The interface treatment by surface roughening and rebar planting can provide effective bond strength between the substrate-new concrete. Sustaining load increase slightly the stiffness and the flexural capacity of beams until exceeding a critical value. The critical load was about 30% of the yield moment of beam before strengthening in the present test. The prediction of flexural capacity had high accuracy by the plastic limit analysis method and neglecting the strain-lag effects caused by the sustaining load during the strengthening process.

1. Introduction

To improve the performance of old structures and satisfy the higher requirements of the new design codes, many reinforced concrete (RC) bridges have to be strengthened for extending their service life [1,2]. Different techniques have been developed recently for the strengthening of RC members with deficiencies [3–6]. Reinforced concrete jacketing, epoxy bonding the fiber reinforced polymer (FRP) composites and external post-tensioning are the most commonly methods used for strengthening [7–14]. Nowadays, some new materials, such as the functionally graded material (FGM), are also discussed for the strengthening of RC structures [15–18]. All these methods have their advantages and also several drawbacks [19]. The FRP composites, for example, has light weight, high strength and stiffness, no risk of corrosion and speedy application, but it is high cost, impossible in application on humid surfaces and at low temperatures, insufficient in fire resistance, and lack of vapor permeability [20–22]. The FGM has high strength, stiffness, low weight and durability, but it is expensive and difficult for widely used in civil engineering [23–25].

Compared with the FRP composite, the reinforced concrete jacketing is cheap, has sufficient fire resistance and can be used in the wet environment, but it requires labour-intensive and time-consuming procedures. Another disadvantages are the size and mass increases, stiffness modifications and alteration of dynamic characteristics of structures [26]. To reduce the weight, the concrete jacketing is usually thinly designed and the reinforced steels are densely arranged in the jacketing. This is difficulty in casting of concrete, resulting in any durable impacts related to

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segregation, delamination, blocking, and bleeding [27,28]. To cater for these problems, the self-compacting concrete (SCC) is developed in the recent years [29,30]. SCC has high fluidity and can therefore spreads through congested reinforcement, reaches to all confined parts of the formwork with only own weight instead of vibration and completely fills the formwork to form a uniform dense concrete [31,32].

The success of SCC jacketing on the strengthening of reinforced structure depends on bond behavior between the old concrete and the new casted SCC [33,34]. A lot of works have been performed to study the bond strength between old-new concrete as traditional vibrated concrete [35–37]. It has been reported that bond strength between old and new concrete is affected by various factors, such as compressive strength of old-new concrete, surface preparation, bonding agents, curing conditions, moisture content and stress state at the interface [38–40]. Recently, some studies have also been proposed to investigate the effects of these factors on bond stress for new overlay self-compacting concrete [40,41]. Nowadays, however, very few works are existed to observe the flexural behavior of RC structures strengthened by SCC jacketing.

In practical engineering, the dead weight of beams, the construction loads and the likes can not be absolutely removed during the strengthening of bridges. In the case of quick strengthening of bridges, some more ancillary facilities, such as the crash barriers and the pavement, may also be reserved. Therefore, bridge strengthening could usually be performed under a certain of sustaining load [42]. Additional, the reasons of bridge strengthening could usually be the low bearing capacity, which can not bear the increased load and traffic [43]. Therefore, some greater load could apply on these bridges, leading to some initial damages during the service history [44,45]. Nowadays, Chalioris et al. [46–48] investigated the behavior of damaged reinforced concrete beams strengthening by SCC jacketing. The effects of the sustaining load on the strengthening by SCC jacketing is still not well understood.

The novelty of the present work is to study the Flexural strengthening of damaged RC T-beams using local Self-Compacting Concrete jacketing under different sustaining load. Eight RC T beams are designed and tested in flexural for primary damage. Then, the beams are strengthened with steel rebars and self-compacting concrete under different sustaining load. And, the flexural loading test is employed to investigate the structural behavior of the strengthened beams, such as beams cracking, failure mode and ultimate flexural capacity. The influences of the sustaining load on beam response are clarified. And, the prediction of flexural capacity of the strengthened beams is discussed. Several conclusions are then drawn based on the proposed study.

2. Experimental program

2.1. Specimens

Eight T-beams with the similar section dimension and reinforcement steel are designed and manufactured. These beams are 5.0 m length, 0.45 m high, and 0.12 m wide. The flange of the T-beam is 0.6 m wide and 0.065 m high. The beams are reinforced by six 14 mm deformed bars at the bottom, two 12 mm and seven 6 mm deformed bars in the top, six 6 mm deformed bars in the web, and 6 mm stirrups with the spacing of 100 mm. Two pairs of the six bottom longitudinal bars are bent up at the position of 0.8 m and 1.4 m from the beam ends, respectively. Three pairs of 14 mm diagonal bars are also arranged in the flexural-shear span of the beams. Details of the beams are shown in Fig. 1.

All these beams are casted with the commercial concrete from the same concrete truck. Sand and gravel form river and the 42.5 ordinary Portland cement are used for the concrete. The weight ration of water, sand and gravel to cement is 0.45, 1.48 and 3.22, respectively. Three concrete cube samples with the side length of 150 mm are reserved. The average 28-day concrete compressive strength for these beams is 34 MPa. All the reinforcement steel used in the present test is HRB 335. The mechanical properties of reinforcement steels are listed in Table 1.

2.2. Primary loading test

The reasons of bridge strengthening could usually be the low bearing capacity, which can not bear the increased load and traffic. Therefore, some greater load could apply on these bridges, leading to some initial damages during the service history. To simulate this condition, a primary loading test is performed on the beams to make some initial damages before the reinforcement.

The beams are simply supported with the clear distance of 4.8 m. The first load is applied by twenty-four 25 kg weights in each side of beams. The following loads are step-applied by the two jacks at the middle region of beams. The distance between the two jacks is 0.8 m. The increased load in each load step is 5 kN, which is measured by two load cells on the jacks. The applied load transfer to cantilever beams, the anchor bolts, and anchor on the ground. The vertical deflections at the midspan, and the two quarter spans are measured by three digital dial gauges. The propagation of crack is also measured during the loading test. Details of the primary loading test are shown in Fig. 2.

The primary loading is stopped just as the yielding of the beams. This case is determined by the load-deflection response as the rapid growth deflection appears. The corresponding flexural moment at the midspan is defined as the yield moment of beam. In the present test, the yield moment ($M_{y,0}$) of these eight beams is about 185 kN m, which is treated as a basic data used in the reinforcement of beams.

2.3. Strengthening design

After the initial damage, these beams are strengthened under different sustaining load. The beam is strengthened by four 14 mm deform bars in the bottom, two 6 mm deform bars in the web and 6 mm stirrups with spacing of 100 mm. Nine 6 mm

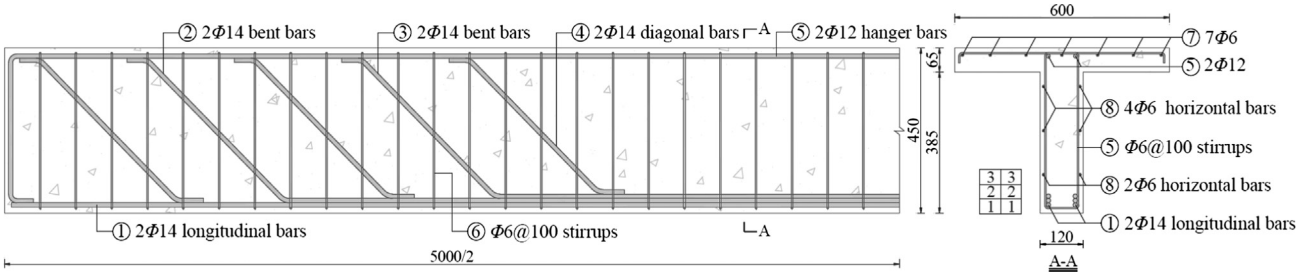

Fig. 1. Section dimension and reinforcement steel of the beam (Unit: mm).