Bending behavior of composite reinforced concrete beam repaired with UHPFRC

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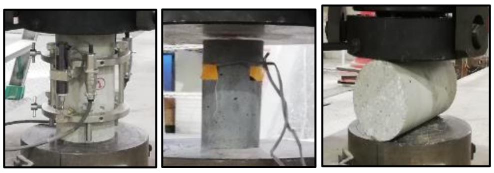
1. Introduction

Due to the big influence of transportation network in development because of economic and communication role impact. Evaluation to the existing bridges is necessary. Concrete bridges are the most common and expensive one. The bearing capacity to the aging bridges and their working life is reduced from the time it had been constructed. Due to many reasons such as environmental actions, time dependent phenomena like creep, prestressing steel relaxation, and degradation caused by the corrosion, the existing bridges needed to upgrading to be able to carry out the new demands of the traffic loads. Upgrading by repair /or strengthen to exceed the structure life service needs to check the bond strength between two materials. Using normal concrete (NC) as repair material has a weak bond with NC as a substrate. Repair existing structures with limited dead loads makes the need for advanced materials with high mechanical properties is essential. Ultra-high-performance steel fiber concrete (UHPFRC) is a cementitious composite with outstanding mechanical and durability properties. Its durability and tensile strength combination make UHPFRC a good material for minimizing structural cracking. Structure deterioration happens because of cracks which allow to chemicals to attack the concrete casing corrosion and decrease section efficiency. This paper study the flexural behavior of reinforcement concrete beams with top repaired UHPFRC, and the effect of interface condition. to represent the bond behavior at the interface between the NC-UHPC slab, which needs to be upgraded; the reinforcement concrete (RC) bridge slab.

Table 1 Material properties

Properties	Concrete	UHPFRC
Compressive strength	41 MPa	117.3 MPa
Modulus of elasticity	33 GPa	49.5 GPa
Tensile strength	2.9 MPa	11.1MPa



Compressive Test　　Tensile Splitting
Fig. 2 Material tests

2. Experimental program

Two top repaired beams were tested under four -point bending test. RC-UHPFRC composited beams cased with repaired thicknesses 20, and 50 mm[1]. The beam cross-section was 200 mm in total depth, 400 mm in width, and a shear span of 550 mm (Fig. 1). The distance between the two concentrated loads was 150 mm. Three steel reinforcement bars D13 in the tension side were used, with yielding strength 345MPa, and two bars (D06) in compression side. UHPFRC contains 3% of steel fibers and water-reducing agent. The mechanical properties of concrete and UHPFRC are listed in Table1, Fig.2. The RC beams with ordinary concrete were cast in the steel mold. The concrete surface was set in a smooth condition. After 2 weeks UHPFRC layer was casted. It was kept

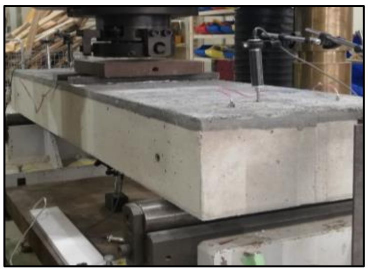


Fig. 3 Bending test setup for BU-20

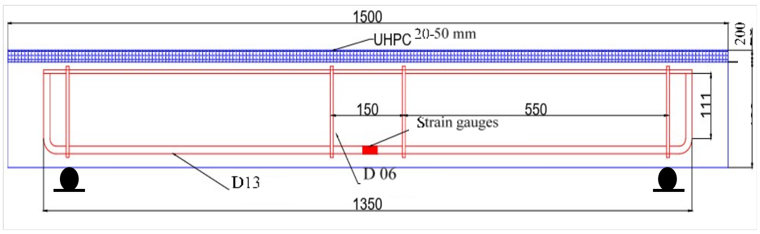


Fig. 1 Beam dimensions (in mm)

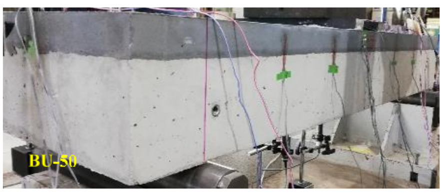


Fig. 4 Flexural test setup for BU-50

Keywords; RC beams, Ultra- high performance fiber reinforcement concrete, flexural behavior, top repaired beams
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at laboratory room temperature for a week before testing. The structural behavior of the beams was observed and monitored by recording the loads, vertical displacement and the strain changes at UHPFRC. The applied load was obtained with control machine, it increased up to the failure. The vertical displacement was measured by two gauges (LVDT) down the middle span for the maximum displacement and at both supports to calculated the opposite direction displacements. One strain gauge was placed at the top mid span of UHPFRC and two were placed on the beam side at the repaired layer as shown in Figs. 3 and 4. Reference specimen (B0) without repaired is analyzed by FEM using nonlinear software Diana.

3. Results of beam tests and discussion

Figure 5 shows the load- deflection curves at the center of the beam span, for the tested beams additional to B0 FEM analysis.

BU-20 was repaired with top 20mm UHPFRC layer. The first flexural crack was formed, when the load approached 35 KN (around 28% of the ultimate load). As the load increased, new flexural cracks formed. At load reached to 114.34 kN and, the first longitudinal steel reinforcement yielded which the cracks started between the UHPFRC- NC. At load 119.28 kN and 10.103 mm the second longitudinal steel bar reached to its yield strength. With increasing the loading the cracks get visual, and wider. it concentrated at the middle span at the maximum bending moment zone to the beam. At load 123 kN the third longitudinal steel bar yielded. After yielding of the steel bars, the deflection of the middle span increased. Observed sound was heard at 127.89 kN due total debonding in the left side of the beam was occurred. Fig.6. A sudden fall in the load occurred at 127.89kN but the beam kept hold as a rigid body. The concrete was crushed under the left plating load at compression side when the deflection was 69.1 mm. The beam failed by flexure as shown in figure 5,6. After the test finished the pull off test were occurred on the NC-UHPFRC at not delaminated part. The shear bond strength 1.7 MPa the failure mode was at concrete failure. Fig.8

BU-50 was repaired with top 50mm UHPFRC layer. the first flexural crack was formed when the load approached 32.6 KN (around 23% of the ultimate load). At load reached to 105.06 kN, first the longitudinal steel bar yielded, with fine cracks shown. At load 116.26 kN the second longitudinal steel reinforcement reached to the yield strength. At load 122.62 kN the third longitudinal steel reinforcement reached to yield strength. After yielding the steel bars flexure cracks were visual and wider at mid-pan. Loading was continued to see the ultimate behavior with a sudden fall in the load occurred at 142.1 kN, where total opening at all the interface surface was observed. At 27.8mm deflection the beam failed by flexure as shown in figure 5,7.

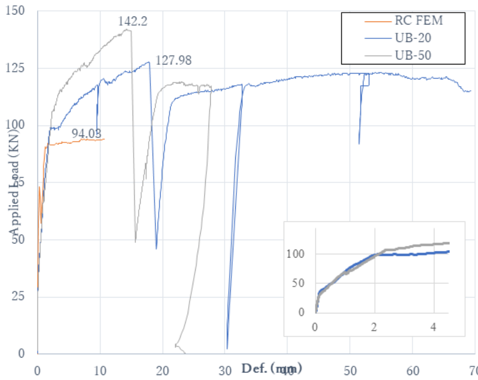

Fig. 5 Load – Deflection curves

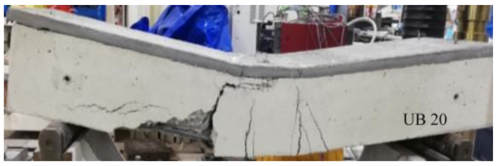

Fig. 6 Failure mode for BU-20

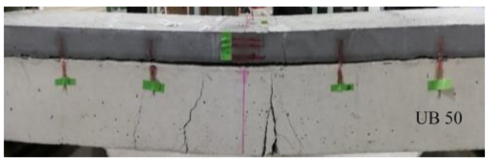

Fig. 7 Failure mode for BU-50

Fig. 8 BU-20 pull off test

4. Conclusions

In this paper, the bending behavior of the beam is investigated for top-repaired UHPFRC with different thicknesses. The results show that using UHPFRC increased bending capacity compared with reference beam. But BU20 behavior had delay in cracking, yielding load, with larger deflection after yielding, but the cracks were wider than BU50 at the same load stage. In further investigation, finite element modeling simulation to this study is needed to be able to change the parameters such as rough surface for site case study `bridge deck` evaluation later on.

Reference

1. Haber, Zachary B., et al. Field testing of an ultra-high performance concrete overlay. United States. Federal Highway Administration. Office of Infrastructure Research and Development, 2017.