

The effect of concrete compressive strength to the strengthening efficiency of RC beams using CFRP in slits

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Abstract

The near-surface mounted technique (NSM) is one of the most effective techniques to strengthen concrete structures, mainly in bending and shear. ABAQUS software has been used to establish a numerical model for the mechanical behavior of a RC beams strengthened by CFRP NSM. In this paper, three rectangular CFRP strengthened RC beams were simulated using ABAQUS and tested in four-point bending scheme in order to investigate the impact of concrete compressive strength to the strengthening efficiency. The results showed that increasing the Concrete compressive strength induced a positive impact to the peak load. Further changing the compressive strength influence the failure criteria of the tested specimens.

Key words-Strengthening technique, Near Surface Mounted, Concrete compressive strength, ABAQUS.

I. INTRODUCTION

The near-surface mounted technique (NSM) is one of the most effective techniques to strengthen concrete structures, mainly in bending and shear. It consists on inserting the reinforcement material in the concrete cover of the element to be strengthened. The use of fiber reinforced polymers (FRP) as reinforcing material in the context of the NSM technique has been intensively studied in the last 15 years allowing its widespread application [1]. A number of experimental studies have been conducted on NSM CFRP RC beams, which have led to the identification of four debonding failure modes. Concrete cover separation has been found to be more often than interfacial debonding in NSM CFRP RC beams, further the desired debonding failure mode at the NSM FRP-to-concrete interface is the cohesion failure in a thin layer of concrete near the adhesive-to-concrete interface. This failure model can be achieved if the surfaces of concrete and CFRP are appropriately treated and a proper adhesive is used [2]. Fig. 1 Summarizing, FRP possible failure modes reported by [3].

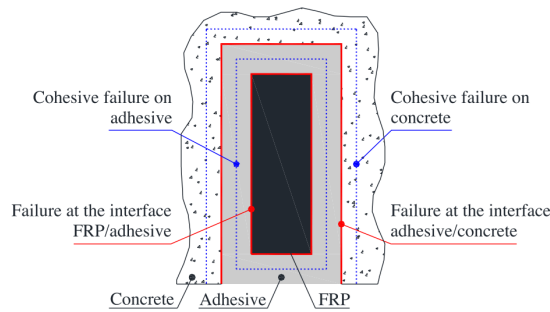


Fig. 1. Four possible failure modes associated with debonding phenomenon.

Several factors a like Groove surface, groove geometry,

TABLE I
INPUT PARAMETER TO CFRP STRIPS

Young's Modulus (Mpa)	Poisson's Ratio	Yield Stress	plastic strain
		(Mpa)	(Mpa)
164000	0.3	2461	0

FRP axial stiffness, FRP section geometry, and bonding length may affect the efficiency of this strengthening technique [3]. There is an important parameter determining the strengthening efficiency and beam performance and capacity when strengthening RC beams with CFRP material.

As for the externally bonded reinforcement, concrete plays a critical role on the performance of the NSM strengthening technique. By default, the maximum pullout force (F_{fmax}) increases with the concrete compressive strength (f_c) up to a threshold value a parametric study was carried out to assess the impact of concrete compressive strength on peak load, medium span deflection, and failure pattern. The impact of the concrete compressive strength was investigated, and the FEM analysis result was analyzed and discussed [4], [5], [6].

II. MATERIAL AND METHODS

A. Specimen details

The beam dimensions were 150 mm c 200 mm height and 1500 mm length with clear span of 1300 mm. The concrete properties and steel reinforcement area were the same for all beams; two 8 mm diameter bars were provided at the top and two 12 mm diameter bars were provided at the bottom, as shown in Fig. 1.

Stirrups of 8 mm diameter were spaced 120 mm near the ends and 135 mm near the center of the span for shear reinforcement. The groove was cut with a concrete saw,

TABLE II
IMPORTANT RESULTS OF SPECIMEN WITH DIFFERENT CONCRETE GRADE

Beam ID	Pu(KN)	%Pu(%)	Med span deflection (mm)	Failure mode
BS-15-C50	130	80	7.8	SHEAR
BS-15-C40	95	31	12.8	Flexural
BS-15-C30	92	27	13.1	Flexural

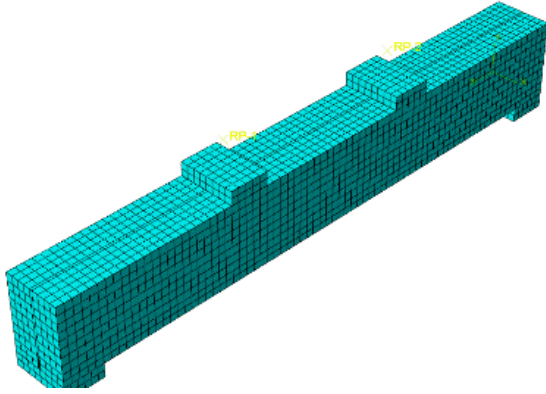


Fig. 2. 3D FE mesh of RC strengthened beams

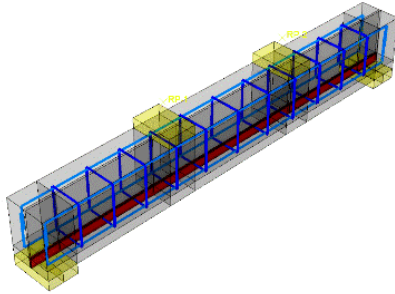


Fig. 3. FEM of reinforcements parts assembly

and the groove dimension is given in Fig. 2, where BS-15 represents type A and BS-30 represents type B.

B. Material

All the three tested specimen has the same material properties except for the concrete compressive strength. The compressive strength of the concrete was determined to be 40 MPa for Specimen BS-15-C40 witch was experimentally investigated by the author [7], the concrete compressive strength of other two specimens BS-15-C30, and BS-15-C50 was 50 MPa ,and 30 MPa respectively. The concrete's structural behavior was defined the different concrete compressive strength using the Chinese code design of concrete structure [7], more details reported in Lubliner's theoretical framework [8]. The steel reinforcing modulus of elasticity employed in the analyses was $E_s=200$ GPa. The stress vs strain curve of steel reinforcement is assumed to be elasto-plastic. The reinforcement is handled as a uniaxial material along the whole portion of the element.

The CFRP strips had thicknesses of 3 mm, ultimate strengths of 2461 MPa, and modulus of elasticity of 164

GPa, according to the manufacturer's specifications. A two-component epoxy adhesive with tensile strength of 46.3 MPa, 83.3 MPa compressive strength, and 2.508 GPa modulus of elasticity was used.

C. Numerical Model

Three rectangular reinforced concrete beams by different concrete compressive strength were analyzed using ABAQUS software. A perfect bond was assumed between steel reinforcing bars and surrounding concrete, as well as between CFRP strips and concrete soffit. The Interaction module of the ABAQUS program specifies the mechanical interactions between the model's parts the embedded region interaction technique was used to describe the concrete-steel reinforcement bars and stirrups, with the concrete serving as the host and the steel reinforcement serving as the embedded region. As a result of the inconsistency of the traction separation models in this scope and the different values suggested by the researchers as reported in the study [8], the tie interaction was chosen to represent the relationship between the CFRP and concrete since it is the easiest contact in application. To imitate the loading configuration, two loading plates were tied to the concrete top surface, as illustrated in Fig. 2. A boundary condition was implemented and the supports were attached to the bottom concrete surface using the tie interaction.

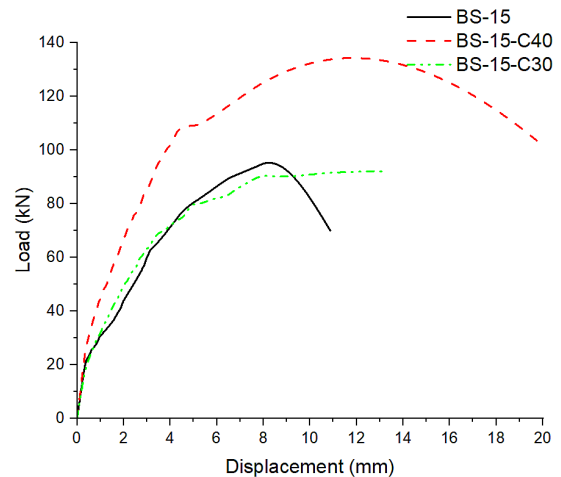


Fig. 4. Load vs Displacement curves for specimen BS-15-C50B, BS-15-C40, BS-15-C30.

III. RESULT DISCUSSION

The load-deflection curve depicted in Fig. 4 describe the impact of the concrete compressive strength to the efficiency

of the strengthening system. The maximum load was increased remarkably in the specimen BS-15-C50 which has a compressive strength of 50 MPa. Further the failure mode was changed to shear failure instead of flexure at the specimen with lower compressive strength.

The direct influence of this parameter is when the failure is at the concrete layer adjacent to the concrete surface bonded to the CFRP strips, due to the translation of the tensile stresses from the CFRP strips through the concrete. since the concrete is weak in resisting the tensile force the influence of the concrete strength is marginal artificial, in other words if the CFRP strips in not rather well bonded the influence of the concrete strength is marginal due to the debonding at the CFRP, EPOXY interface.

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