Improving of Damaged Reinforced Concrete Beams (RC) Failure Behavior Using Externally Bonded UHPFRCCs System

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Introduction

- CARDIFRC strip [1] and GUSMRC strip [2-3] bonding systems of UHPFRCCs have been successfully utilized for RC beam retrofitting owing to their high compatibility with the parent material of damaged reinforced concrete beams.
- Despite improvements, some of the retrofitted beams experienced sudden shear failure due to mid-span over-strengthening, attributed to the high strength of materials and the used retrofitting patterns of GUSMRC [2-3] and CARDIFRC [1]

Research Aim

To develop a new retrofitting pattern using the UHPFRCCs strip bonding system to prevent sudden shear failure in RC beams.

Methods and Materials

In this study, 18 CBs were cyclically loaded at different levels (25%, 50%, and 75% Pu) to analyze flexural behavior **(Fig. 1)** and then retrofitted with 16 mm and 20 mm UHPFRCC strips (T16 and T20) using the new UHPFRCCs configuration **(Fig. 2).**

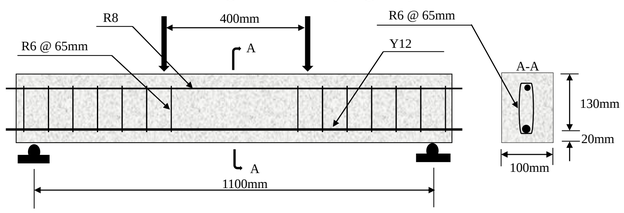

Fig. 1 : Reinforcement details of control beams (CB).

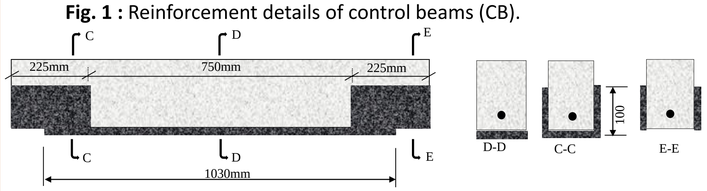

Fig. 2: New UHPFRCCs retrofitting pattern [Type B]

Figures and Results

In this study, the flexural and shear behaviors (Figs. 3 and 4), flexural capacity (Fig. 5), deflection capacity (Fig. 6 and 7) and damage rating (Table 1) of the 18 RC beams before and after retrofitting were evaluated.

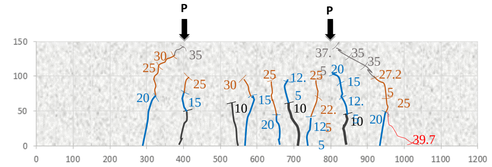

Fig. 3: Crack patterns observed in damaged CBs at failure load [Load (kN), Distance (mm)].

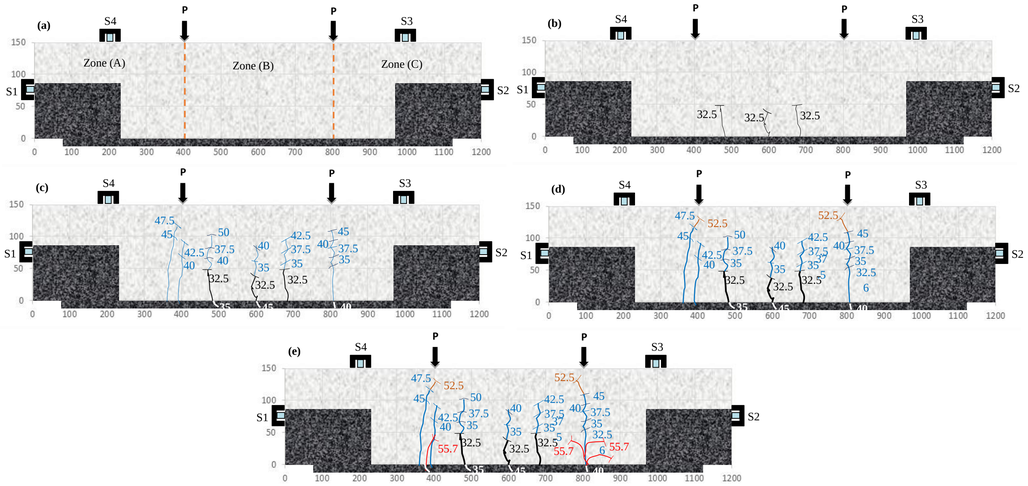

Fig. 4: Crack patterns of retrofitted beams at different damage stages: (a) Stage I - micro-cracking, (b) Stage II - first visible crack, (c) Stage III - flexural cracks, (d) Stage V - localized damage, and (e) Stage VI - failure [Load is in kN, distance in mm].

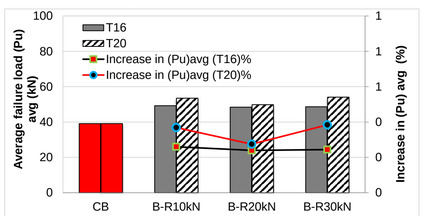

Fig. 5: The average failure load of beams before (CB) and after retrofitting (Type B)

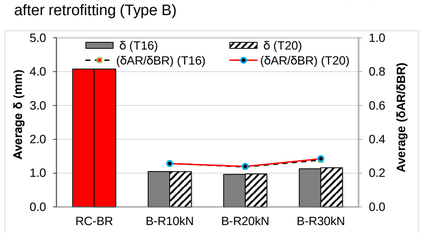

Fig. 6: Average mid-span deflections of beams before (CB) and after retrofitting (Type B) at failure load (40 kN)

Table 1: Damage rating at various load levels for all beams based on tolerable crack width limits [ACI and ICRI, 2008]

Load level	Control Beam (CB)	Retrofitted Beam (Type B)
10 kN	$(w_{max})_{avg} \leq 0.1$ mm	---
	A very slight damage	No -damage
20 kN	$(0.1 < (w_{max})_{avg} \leq 0.3$ mm	---
	A slight damage	No -damage
30 kN	$0.3 < (w_{max})_{avg} \leq 0.5$ mm	$(w_{max})_{avg} \leq 0.1$ mm
	A moderate damage	A very slight damage
40 kN	$0.5 < (w_{max})_{avg} \leq 3$ mm	$(w_{max})_{avg} \leq 0.1$ mm
	A severe damage	A very slight damage
100%Pu	$0.5 < (w_{max})_{avg} \leq 3$ mm	$0.5 < (w_{max})_{avg} \leq 3$ mm
	A severe damage	A severe damage

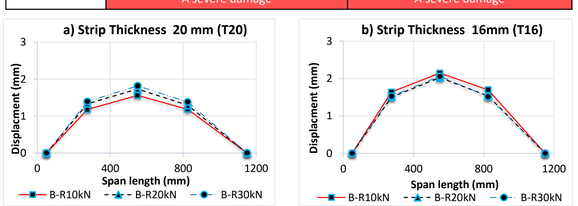

Fig. 7: Effect of retrofitting thickness on the deflections of beams at failure load (40 kN)

Discussions

- The shear failure possibility for Type B retrofitting was 0.0% (Fig. 4).
- Type B retrofitting increased the failure load by 24.37% to 38.39% (Fig. 5).
- Average mid-span deflection of Type B beams at 10, 20, 30, and 40 kN was 21%-23.6%, 16.6%-19.9%, 20.7%-24.9%, and 23.6%-28.5% of control beams, respectively (Fig. 6).

Conclusions

- The damaged RC beams were successfully retrofitted with Type B, achieving up to a 38% increase in failure capacity.
- Recommendation: Retrofit beams using the proposed pattern in Fig. 8 to further enhance flexural failure and capacity.

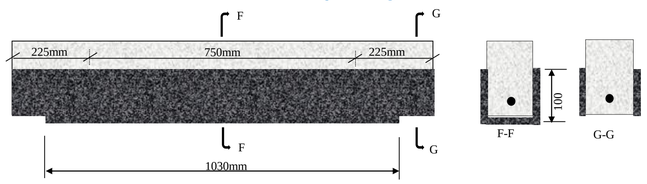

Fig. 8: Recommended UHPFRCCs retrofitting pattern [Type C]

References

[1] Alaee, FJ, Karihaloo, BL (2003). Retrofitting of reinforced concrete beams with CARDIFRC. *Journal of Composites for Construction*, 7(3), 174-186. https://doi.org/10.1061/(ASCE)1090-0268(2003)7:3(174).

[2] Aldahdooh, MAA, Bunnori, NM, Megat Johari, MA (2013). Evaluation of ultra-high-performance-fiber reinforced concrete binder content using the response surface method. *Materials & Design*, 52(0), 957-965. http://dx.doi.org/10.1016/j.matdes.2013.06.034.

[3] Aldahdooh, M, Bunnori, NM, Johari, MM, et al. (2016). Retrofitting of damaged reinforced concrete beams with a new green cementitious composites material. *Composite structures*, 142, 27-34. https://doi.org/10.1016/j.compstruct.2016.01.067.