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Paper #161: Performance of composite local glass fibre sheets and epoxy on flexural strengthening of reinforced concrete beams

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Introduction

- Change in Indonesian Seismic Code→ some areas in Indonesia increase the seismic loading, therefore existing structures need to be evaluated.
- Some structures need to be retrofitted → the structural elements such as Beam may experience flexure deficiency.
- Retrofitting RC for Flexure→ commonly use glued CFRP method at tension surface

Introduction

- CFRP and Epoxy →Import material and expensive→alternatif materials locally available
- The main problem for glued CFRP is delamination from concrete surface→ need technique to prevent premature failure.
- The paper presents “performance of local composite woven roving GFRP with epoxy as strengthening material and the effect of end anchorages

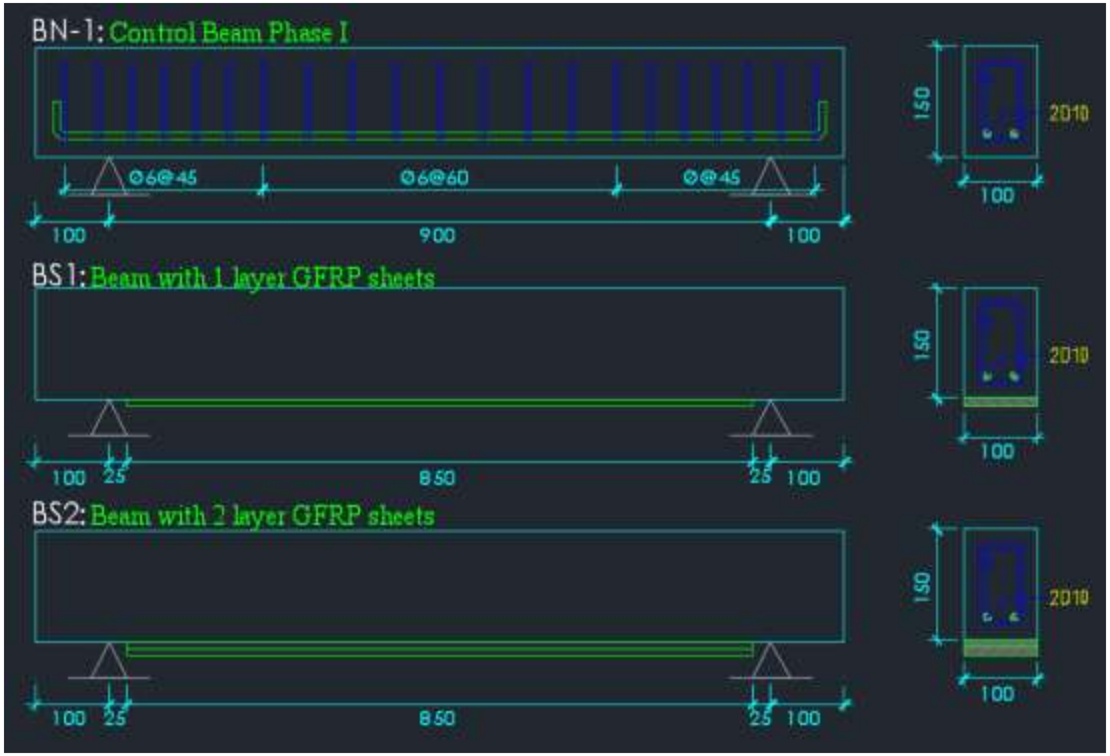
Experimental Program

Material Properties

- Compressive concrete strength (f'c) for phase I is 31.99MPa and phase II is 21.13 Mpa.
- Epoxy (©Avian) with f_{au} and E_{au} is 51.43 MPa and 20192.2 Mpa, respectively
- Composite GFRP sheet has f_{fm} of 123.33 MPa and E_{fm} of 5535.4 MPa
- Rebar diameter 10 mm and 6 mm has fy of 389 Mpa

Experimental Program

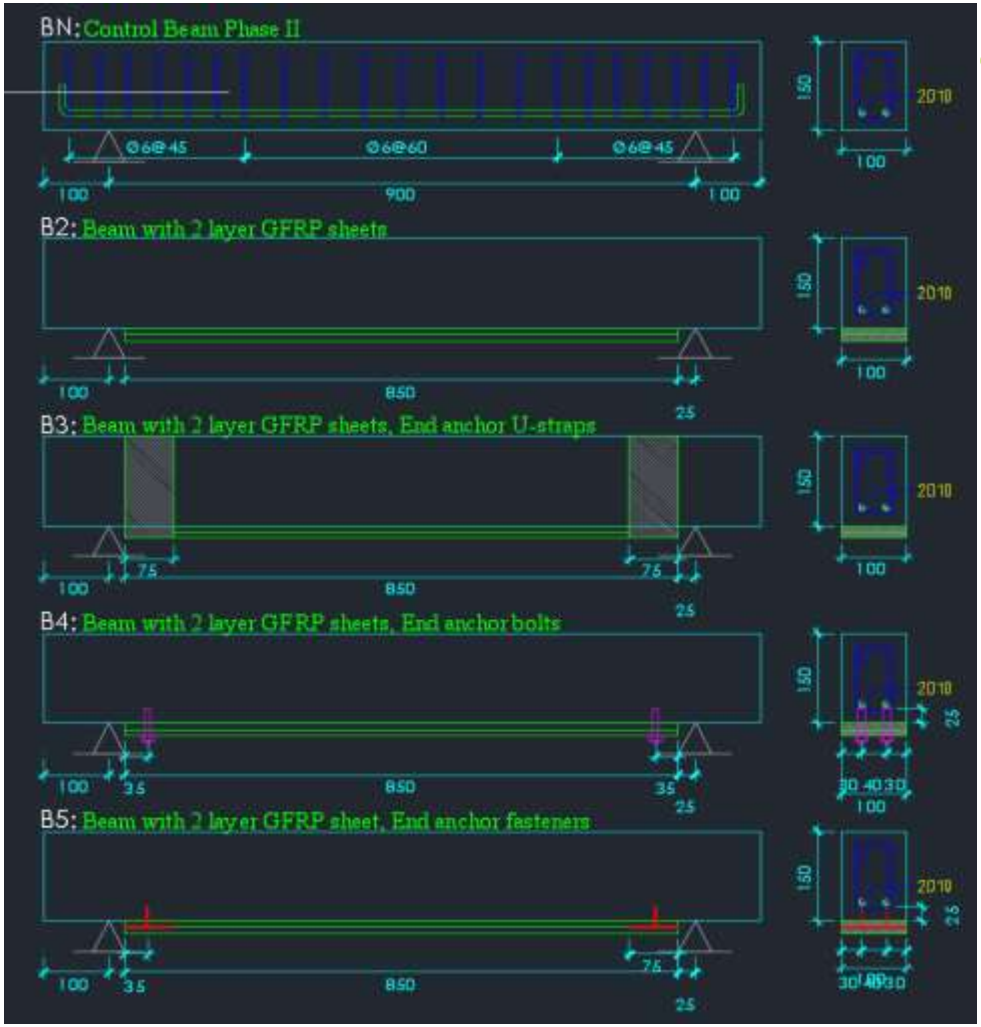
Specimen Detail



- Phase-I to study the effect of GFRP layers number (0, 1 and 2 layers)
- Each parameter was consisted of 3 beams

Experimental Program

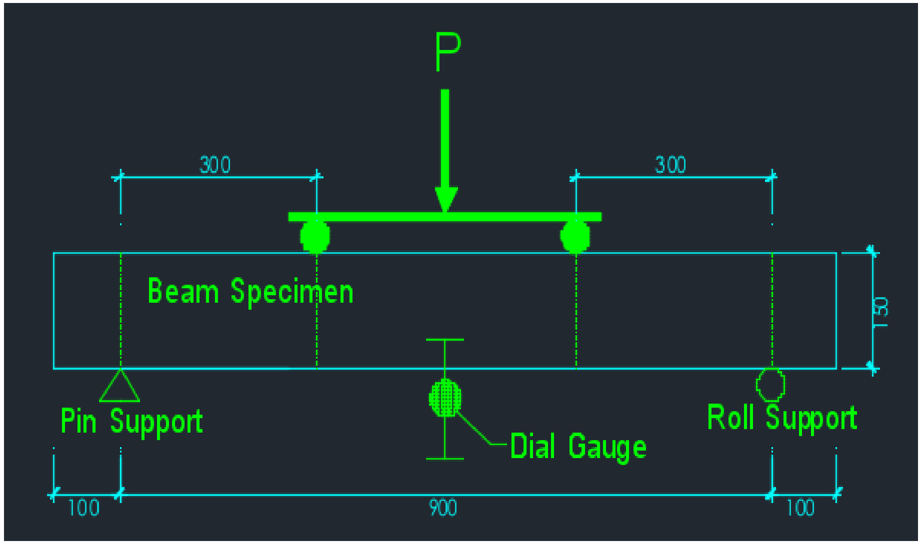
Specimen Detail phase II



- Phase-II to study the effect of end anchor on 2 layers GFRP sheet:
  - BN: No GFRP Layer
  - B2 : No end anchors
  - B3 : End Anchor GFRP U-straps
  - B4 : End anchor Bolts
  - B5 : End anchor GFRP fasteners

Experimental Program

Test Setup



- Load applied incrementally at 2.5 kN
- 2 dial gauges at midspan beams to measure beam deflections

RESULTS and DISCUSSION:

a) Failure modes and ultimate capacity

Specimen ID	Phase	Variations	Ultimate Loads (Pult) kN	Failure Modes
BN1	I	Control specimen Phase I	52,5	Flexure
BN2			54,0	Flexure
BN3			55,0	Flexure
BS11		One-layer GFRP	58,0	Flexure, GFRP Rupture
BS12			61,0	Flexure, GFRP Rupture
BS13			60,0	Flexure, GFRP Rupture
BS21		Two layers GFRP	62,5	Flexure, GFRP debonding
BS22			60,5	Flexure, GFRP debonding
BS23			60,0	Flexure, GFRP debonding

- All beams failed in flexure
- Beams with 1 layer, GFRP Rupture before flexure
- Beams with 2 layer, GFRP debonding before flexure

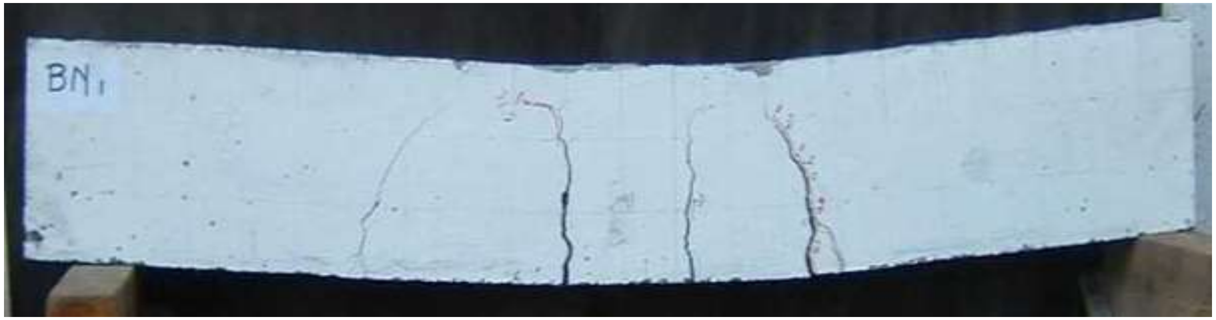
RESULTS and DISCUSSION:

a) Failure modes and ultimate capacity

Specimen ID	Phase	Variations	Ultimate Loads (Pult) kN	Failure Modes
BN1		Control specimen	51.5	Flexure
BN2				
BN3				
B21				
B22				
B23				
B31				
B32				
B33				
B41				
B42				
B43				
B51		Two layerss GFRP with end anchor of GFRP fasteners	63.0	Flexure, GFRP rupture
B52			69.0	Flexure, Anchorage rupture, GFRP debonding
B53			69.0	Flexure, Anchorage rupture, GFRP debonding

- All beams in phase II failed in flexure with higher loads
- Beams with U-straps, Anchor Rupture/delamination before flexure.
- Beams with Anchor Bolts, All GFRP performs well to reach their capacity→GFRP Ruptures
- Beams with GFRP fasterner→ mostly anchor rupture and debonding→ slow debonding.

RESULTS and DISCUSSION:
a) Example beam failure for phase I

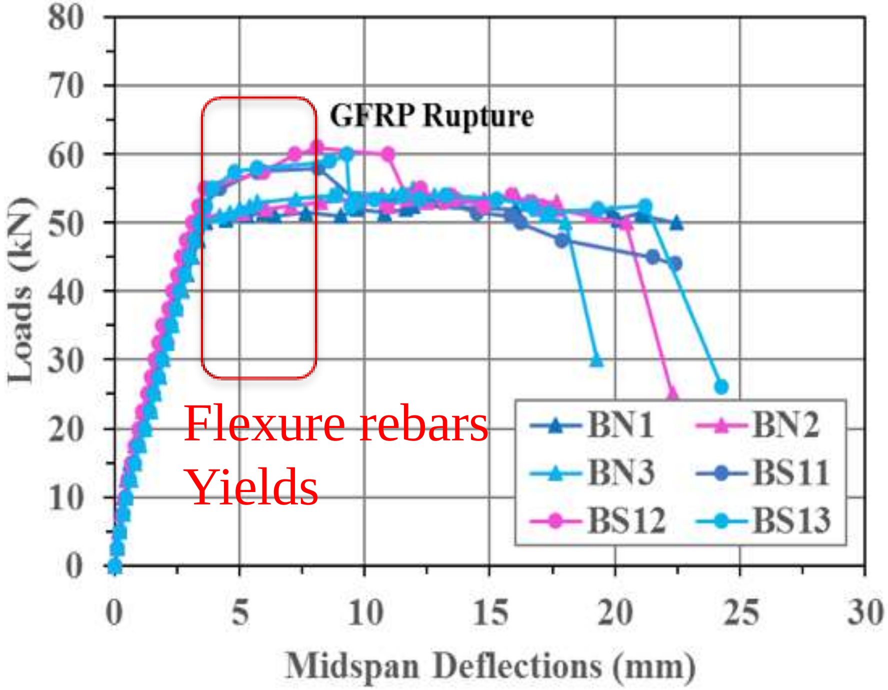


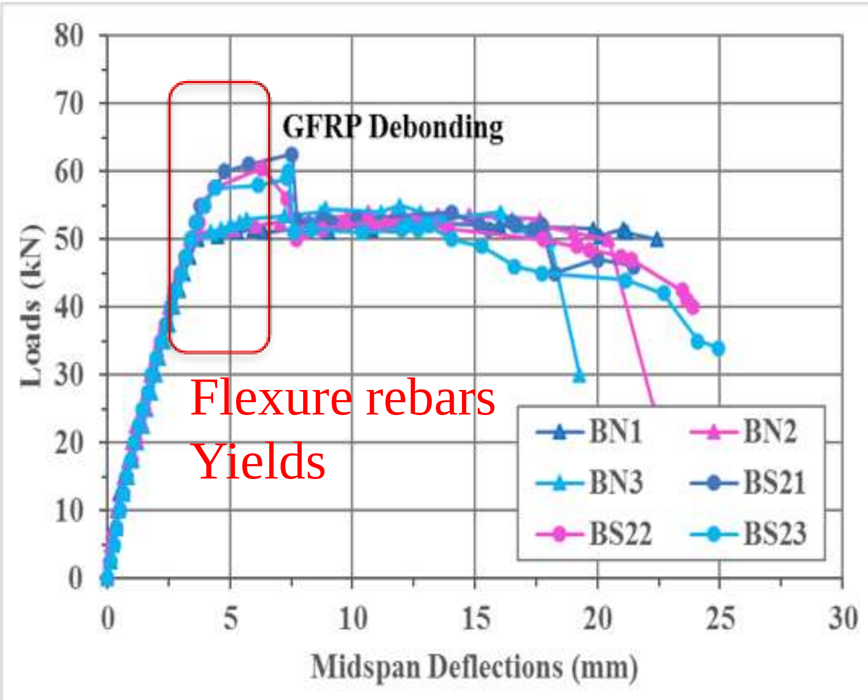
BN: Control beam

BS1: Beam with 1 layer GFRP, GFRP Rupture

BS1: Beam with 2 layer GFRP, GFRP Debonding

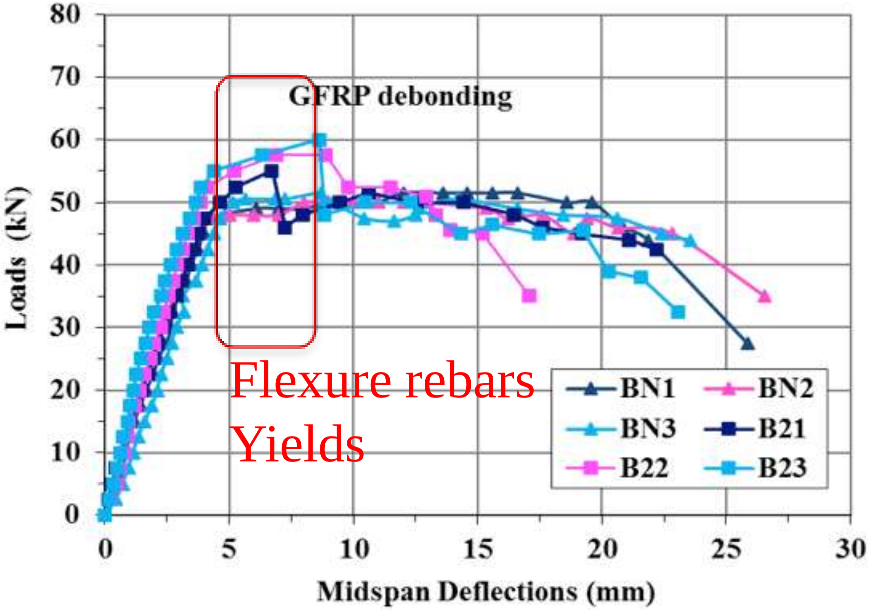
RESULTS and DISCUSSION:
b) Beam Deflection for Phase-I:

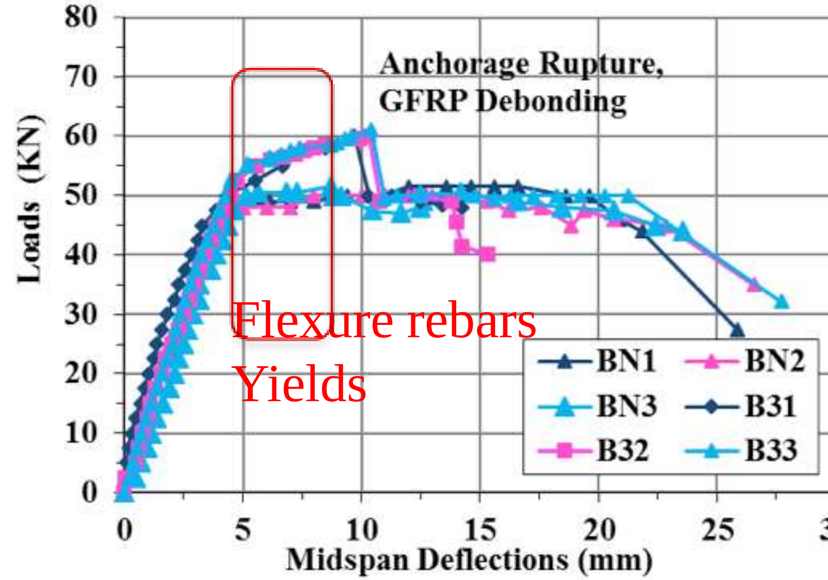




- All beams show yielding of flexure reinforcement
- Yield loads of strengthening beams higher than normal beam (control beam)
- After failure of strengthening materials due to rupture or debonding, the beams behave as control beams.

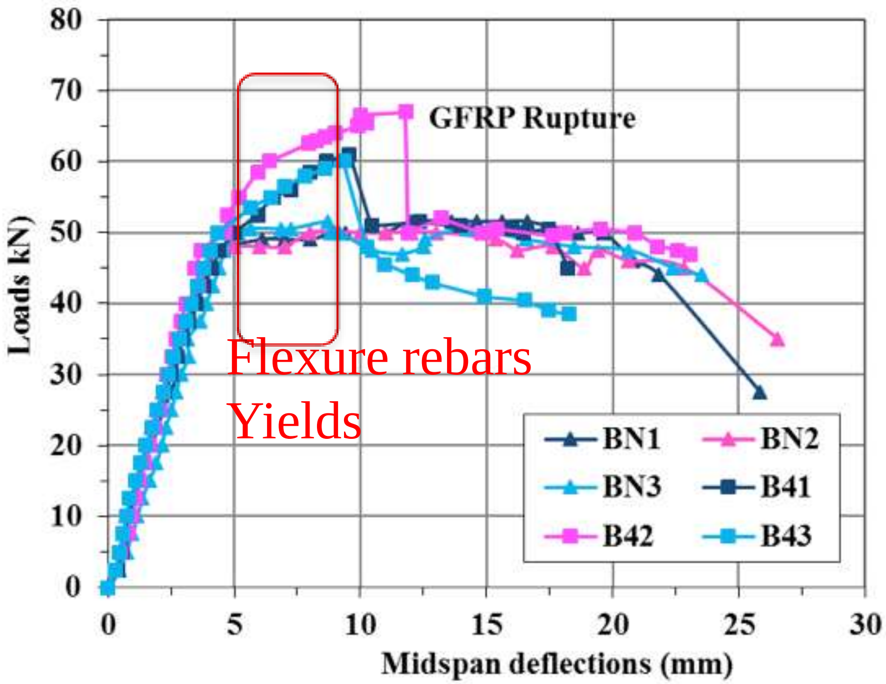
RESULTS and DISCUSSION:
b) Beam Deflection for Phase-II:

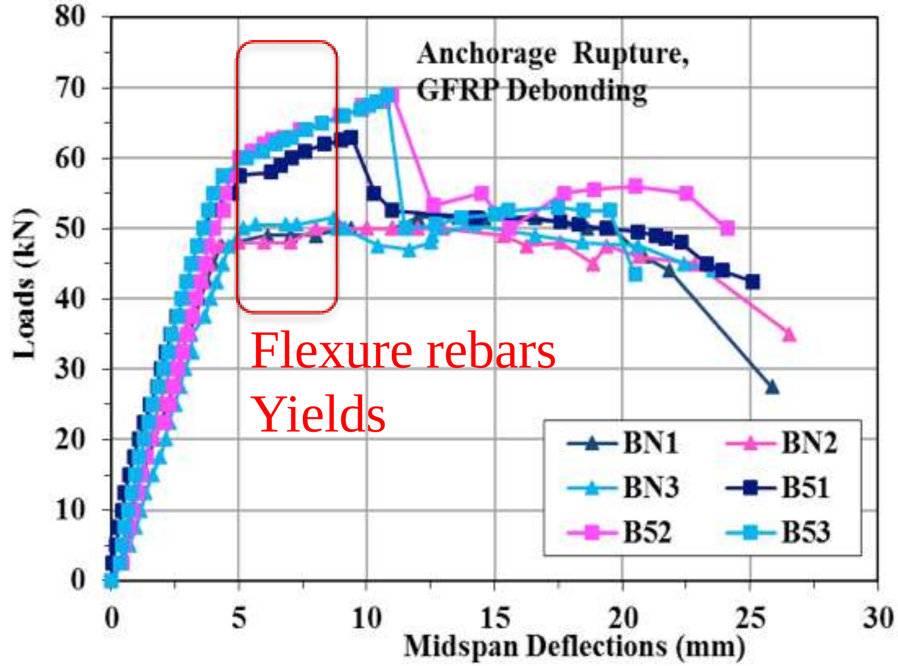




- Load-deflection curve BN *vs* B2 (no end anchor) and BN *vs* B3 (with U-strap)
- P-δ Behavior of beams similar to beams in phase I

RESULTS and DISCUSSION:
b) Beam Deflection for Phase-II:





- Load-deflection curve BN *vs* B4 (with anchor bolts) and BN *vs* B5 (with GFRP fasteners)
- P-δ Behavior of beams similar to beams in phase I

Results & Discussion

c) Beam Capacity:

Beam ID	Phase	Loads (Pult) kN	M_{ult} (kNm)	$M_{ult,avg}$ (kNm)
BN1	I	52.5	7.88	8.08
BN2		54.0	8.10	
BN3		55.0	8.25	
BS11		58.0	8.70	8.95
BS12		61.0	9.15	
BS13		60.0	9.00	
BS21		62.5	9.38	9.15
BS22		60.5	9.08	
BS23		60.0	9.00	

Beam ID	Phase	Loads (Pult) kN	M_{ult} (kNm)	$M_{ult,avg}$ (kNm)
BN1	II	51.5	7.73	7.65
BN2		50.0	7.50	
BN3		51.5	7.73	
B21		55.0	8.25	8.63
B22		57.5	8.63	
B23		60.0	9.00	
B31		60.0	9.00	9.05
B32		60.0	9.00	
B33		61.0	9.15	
B41		61.0	9.15	9.45
B42		67.0	10.05	
B43		60.0	9.00	
B51		63.0	9.45	10.05
B52		69.0	10.35	
B53		69.0	10.35	

- Increase no. of layers, increase nominal moment of beams (data of phase I)
- Type of end anchors affects the ultimate beam flexure capacity (data of phase II)

Conclusion

- For the beams without end anchors, the full strength of GFRP can only be achieved in one-layer GFRP specimens. Up to two-layers GFRP sheets, the debonding failure occurred at the interface between concrete and epoxy results in GFRP delamination.

- The beam flexural capacity can be increased by 10.8% and 13.4% of the control beams for one and two layers of GFRP sheet, respectively.

Conclusion

- In the presence of end anchors performance of GFRP improved. End anchors changes the initial GFRP delamination from cut-off end to the middle beam span.
- The flexural capacity increased by 31.4%, 18.3% and 22.9% of the 2nd phase control beams, respectively for fastener, U-strap and bolts anchor's types.


thank you
danke
謝謝
ngiyabonga
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gracias
спасибо
Баярлалаа
рахмат
bedankt
dziękuje
obrigado
sukriya
kop khun krap
go raibh maith agat
mochchakkeram
tapadh leat
terima kasih
grazie
arigatô
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