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Faculty of Engineering & Informatics

Moment-Curvature Behaviour of Hybrid Reinforced Concrete T-Beams

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Outline

- Hybrid Reinforcement System
- Aim and Objectives
- Description of the Analytical Programme
- Sensitivity Study
- Validation
- Parametric Study
- Conclusions

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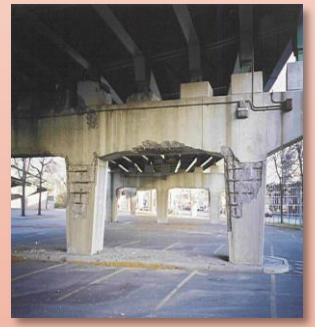
Hybrid-Reinforcement System

Steel

Steel reinforcement corrosion is responsible for most types of failure in concrete structures



high maintenances cost

FRP

The linear elastic behaviour

The low modulus of elasticity

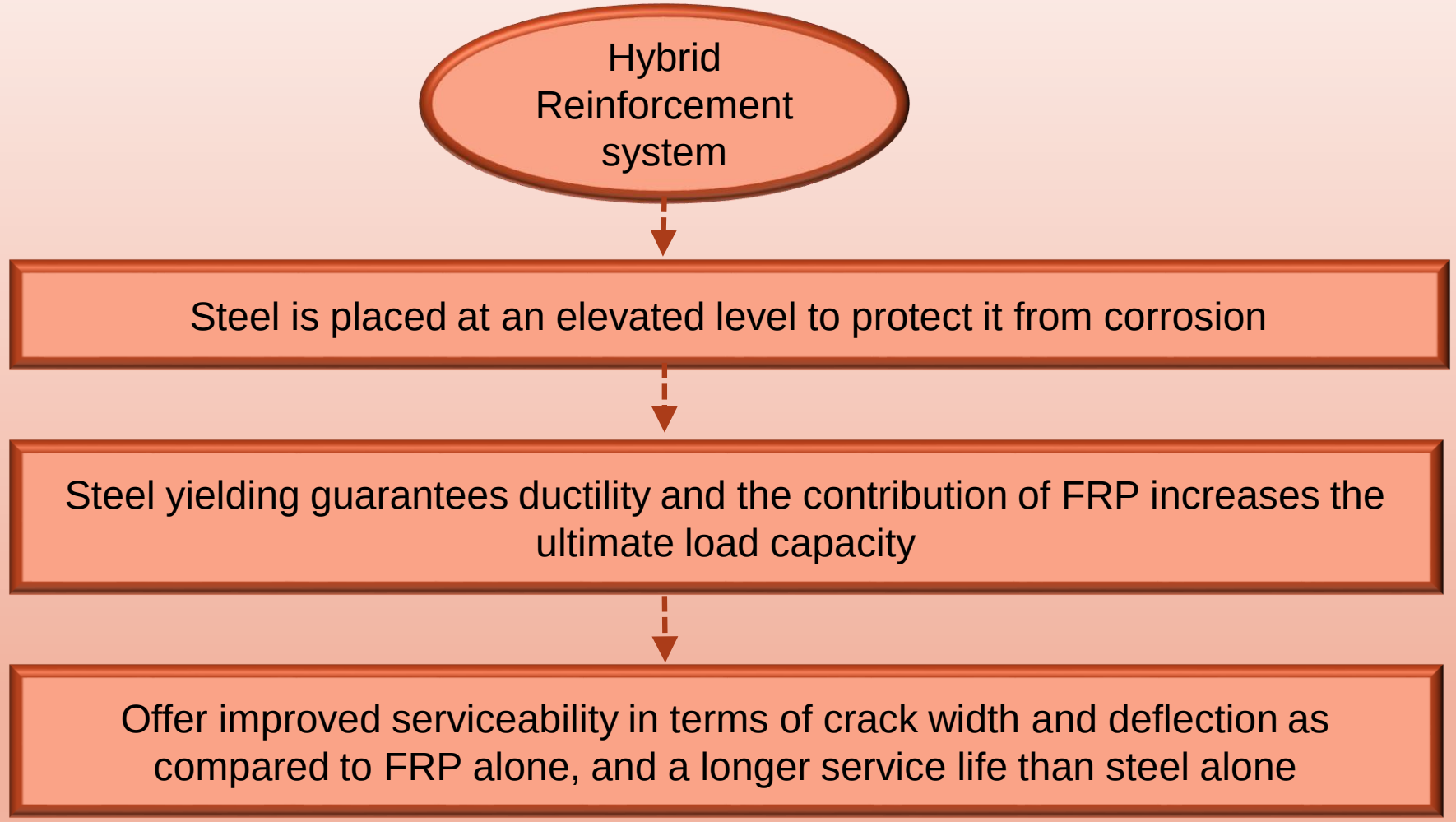
Brittleness of FRP-RC structures

Larger deflection and wider cracks as compared to steel-RC beam

Affects the ability of continuous FRP-RC structures to redistribute moment

Unexpected failure occurs with a small or insufficient warning

Hybrid Reinforcement System

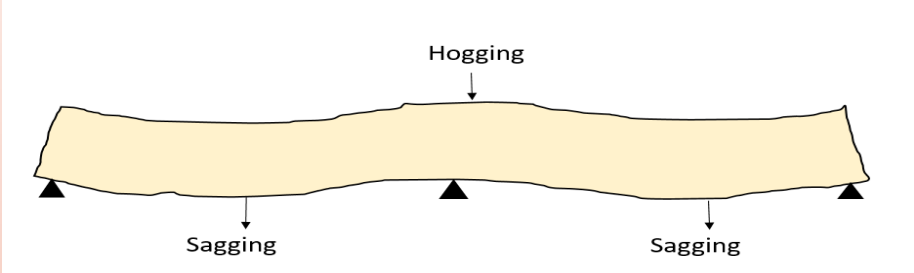


Aim and Objectives

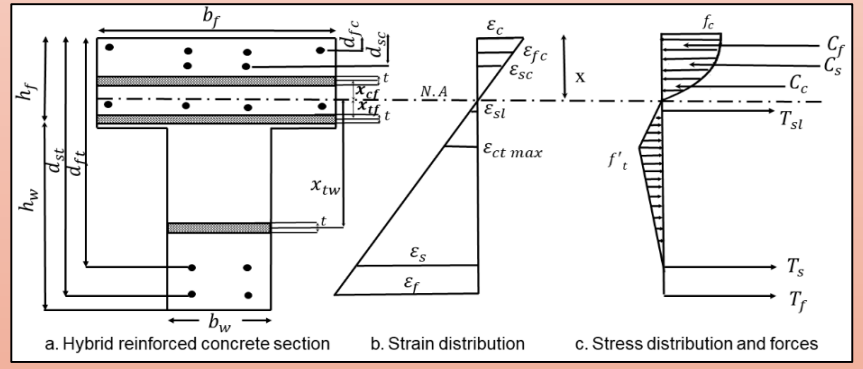
Study the moment-curvature behavior of HRCT-beams…why?

Develop an analytical techniques program to find the moment-curvature relationship of HRCT-beams

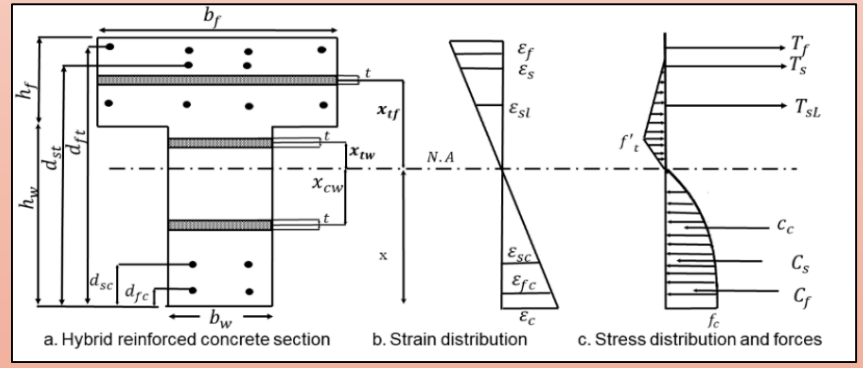
Description of the Analytical Program



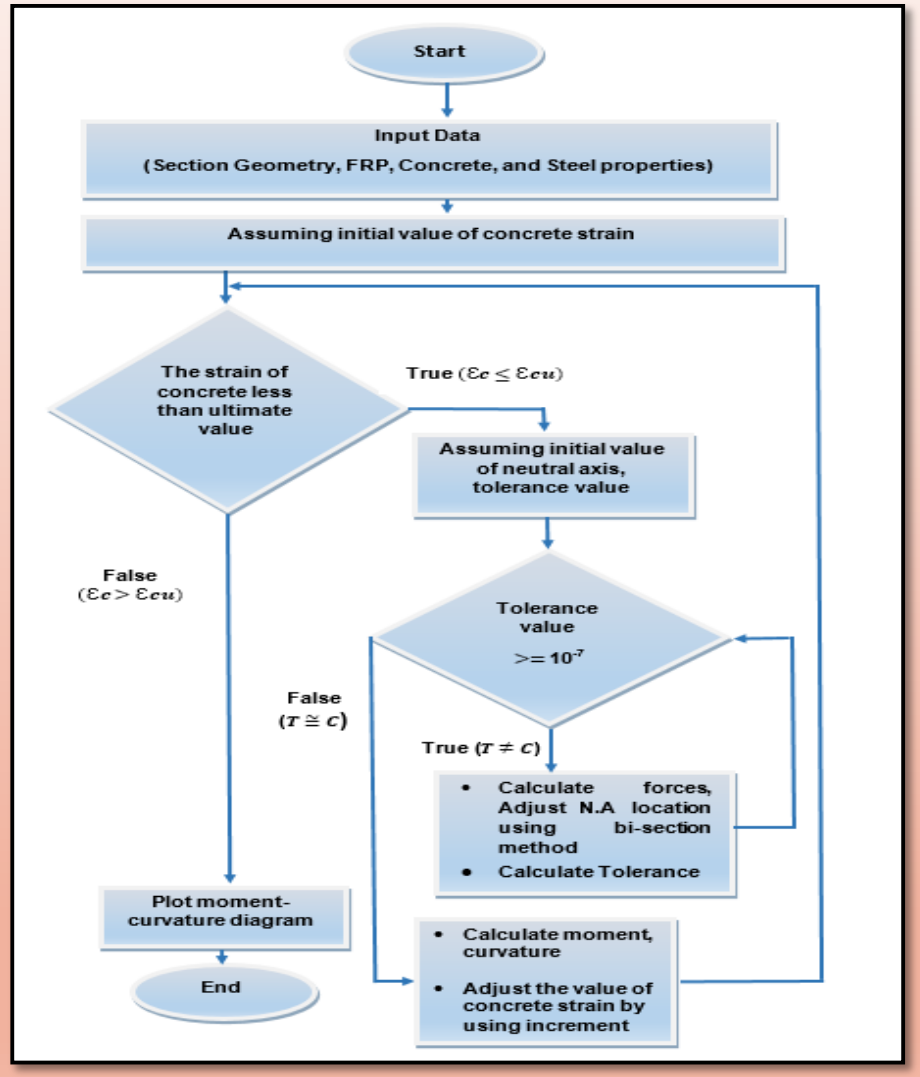
Deformed Continues beam



Sagging moment section when N.A in flange

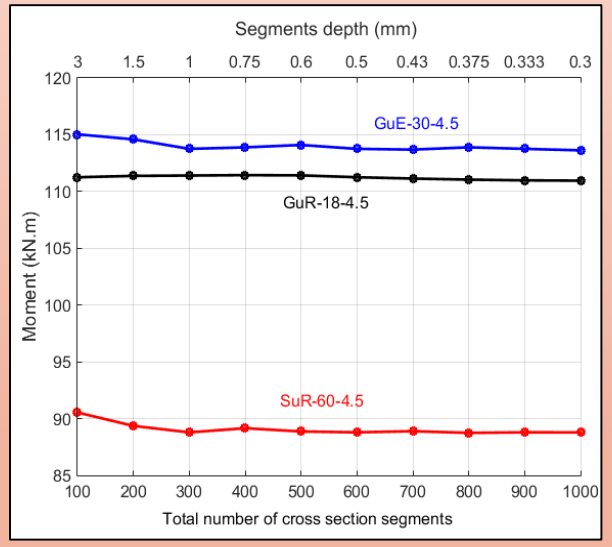


Hogging moment section when N.A in web



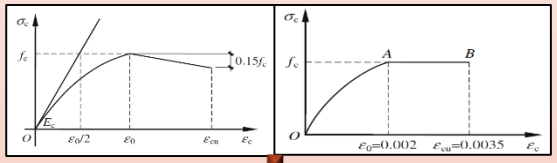
The flow chart of the analytical programme

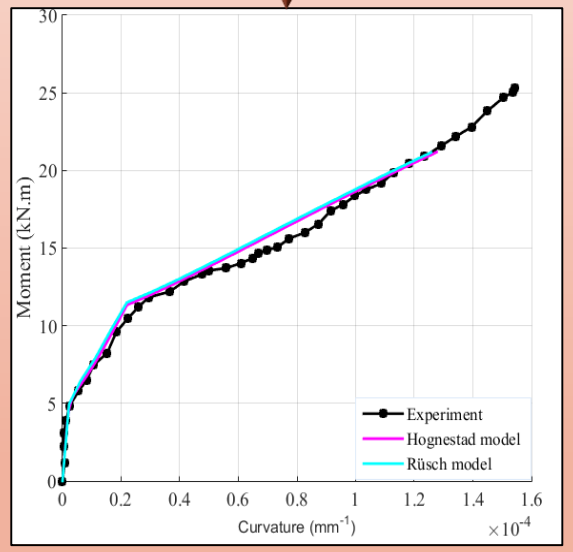
Sensitivity Study



Effect of segments number in concrete section

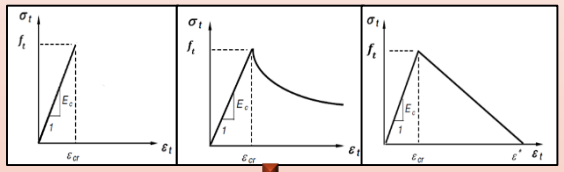
Hongested model Rüsch model

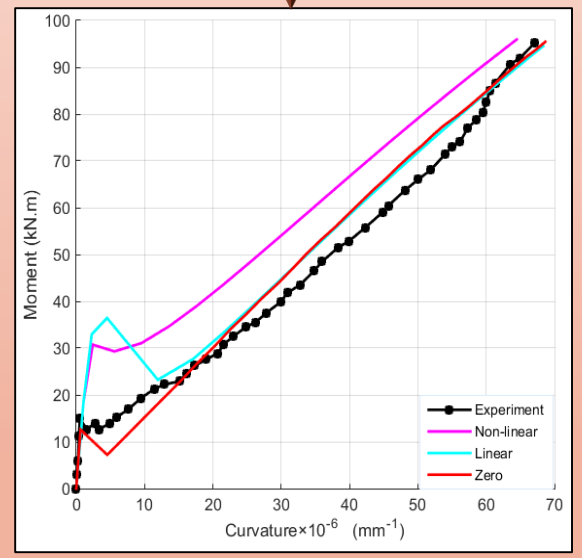




Effect of concrete compression models (A1, Aiello and Ombres 2002)

Zero Non-linear Linear





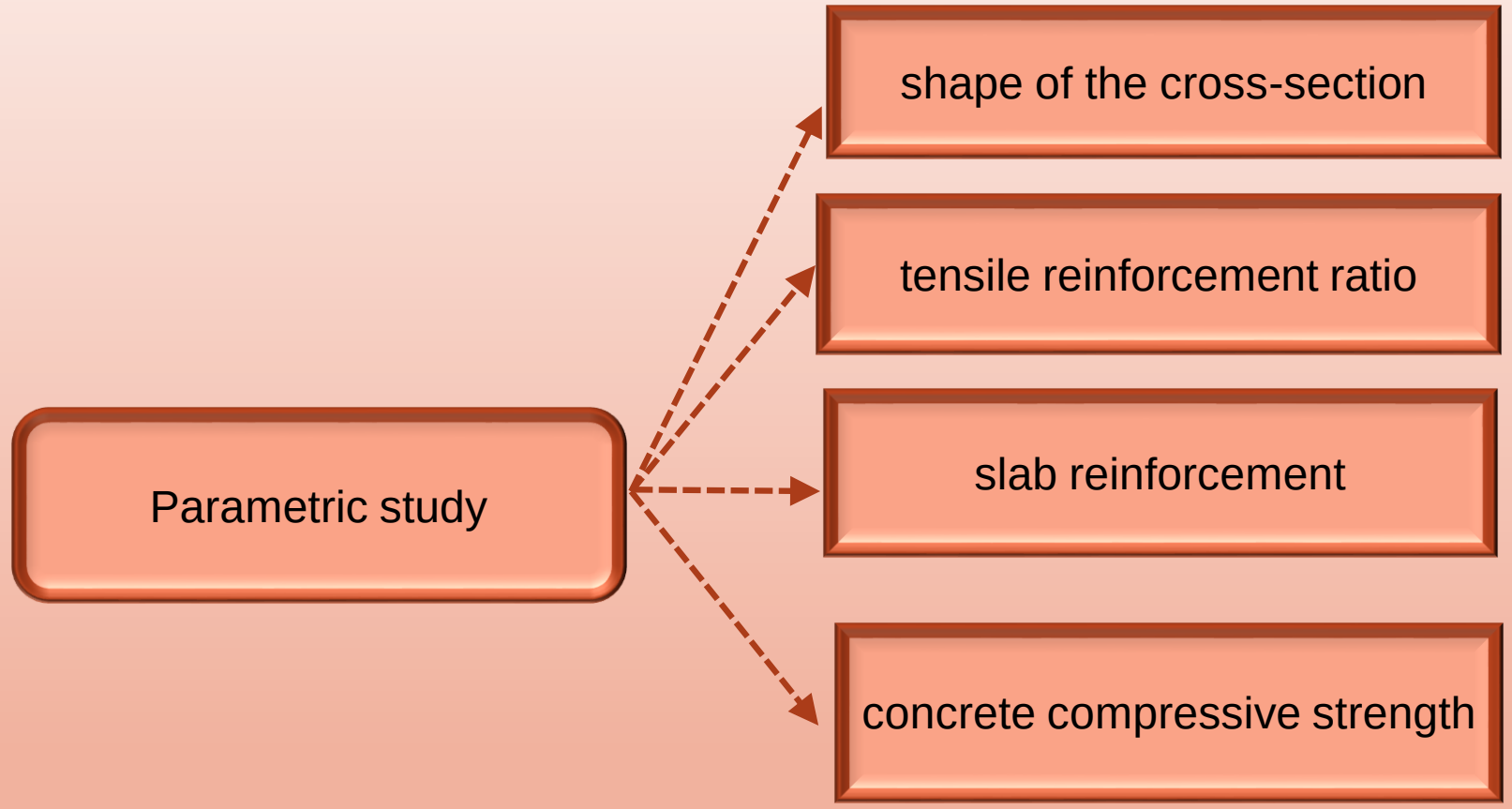
Effect of tension stiffening behaviour (GuR-18-4.5, Rahman et al. 2016)

Validation

Table 1: Sample of validation

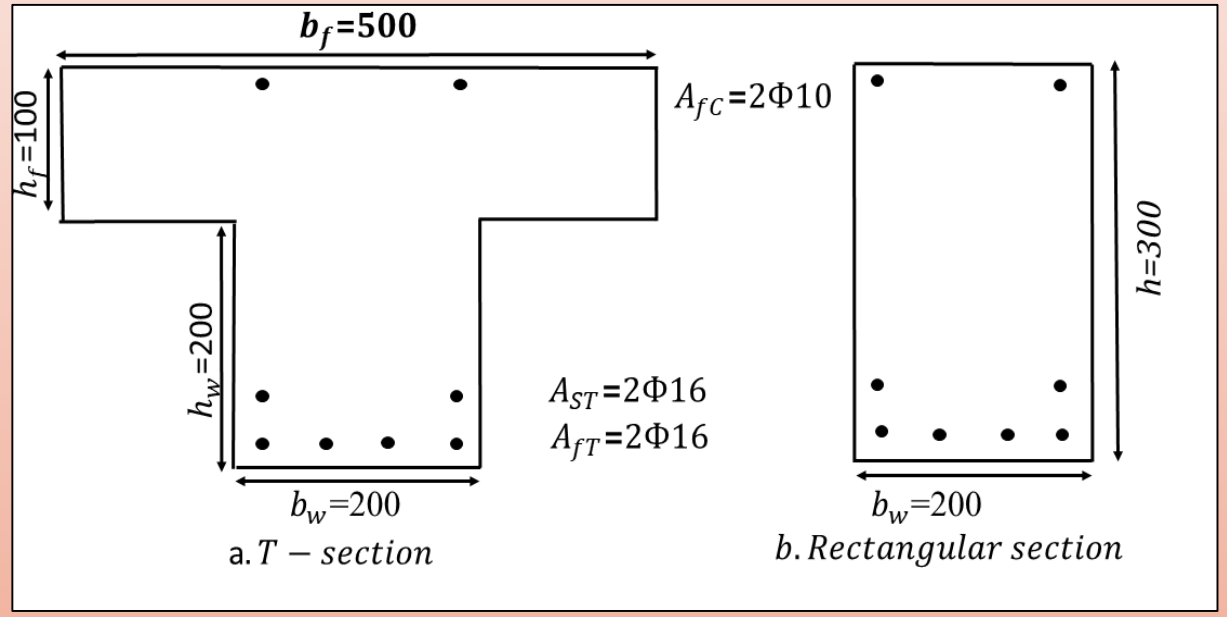
Ref	Beam	FRP type	E_f GPa	Dimensions $b \times h$ (mm ^{2})	Type of loading	Span mm	$f'c$ MPa	A_{fbot} mm^2	A_{sbot} mm^2	A_{ftop} mm^2	A_{stop} mm^2	M_{exp} kN.m	M_{tho} kN.m	$\frac{M_{th}}{M_{ep}}$	Exp. Mode of failure	Thea. Mode of failure
(Aiello and Ombres, 2002)	A1	AFRP	49	150×200	Two point	2700	45.7	88.31	100.48	_	100.48	25.14	21.59	0.85	SY-CC	SY-CC
	A2	AFRP	50.1	150×200	Two point	2700	45.7	157	100.48	_	100.48	28.41	25.8	0.90	SY-CC	SY-CC
	A3	AFRP	50.1	150×200	Two point	2700	45.7	235.5	226.08	_	100.48	35.55	32.17	0.90	SY-CC	SY-CC
	B2	AFRP	49	150×200	Two points	2700	45.7	88.31	_	_	100.48	20.21	18.12	0.75	CC	CC
	C1	AFRP	49	150×200	Two points	2700	45.7	88.31	100.48	_	100.48	25.14	22.76	0.89	SY-CC	SY-CC
(Leung and Balendran, 2003)	L0	GFRP	40.8	150×200	Two point	2200	28.5	_	157.08	_	_	13.76	10.32	0.75	SY-CC	SY-CC
	L2	GFRP	40.8	150×200	Two point	2200	28.5	142.67	157.08	_	_	22.23	18.31	0.82	SY-CC	SY-CC
	L5	GFRP	40.8	150×200	Two point	2200	28.5	214	157.08	_	_	22.07	20.77	0.94	SY-CC	SY-CC
	H2	GFRP	40.8	150×200	Two point	2200	48.8	142.67	157.08	_	_	21.11	24.21	1.15	SY-CC	SY-CC
(Qu et al., 2009)	B1	GFRP	-	180×250	Two point	1800	24.76	_	452.16	_	157.08	32.37	32.21	1.00	SY-CC	SY-CC
	B2	GFRP	45	180×250	Two point	1800	24.76	506.45	_	_	157.08	43.89	34.98	0.80	CC	CC
	B3	GFRP	45	180×250	Two point	1800	28.14	253.23	226.08	_	157.08	38.28	37.24	0.97	SY-CC	SY-CC
	B4	GFRP	41	180×250	Two point	1800	28.14	396.91	200	_	157.08	39.66	40.21	1.01	SY-CC	SY-CC
	B5	GFRP	37.7	180×250	Two point	1800	29.2	141.69	401.92	_	157.08	36.36	37.46	1.03	SY-CC	SY-CC
	B6	GFRP	45	180×250	Two point	1800	29.2	253.23	401.92	_	157.08	42.57	43.43	1.02	SY-CC	SY-CC
	B7	GFRP	37.7	180×250	Two point	1800	34.6	141.69	113.04	_	157.08	23.55	31.22	1.33	SY-CC	SY-FRPR
	B8	GFRP	41	180×250	Two point	1800	34.6	369	1205.76	_	157.08	63.3	68.87	1.09	SY-CC	SY-CC

Parametric study



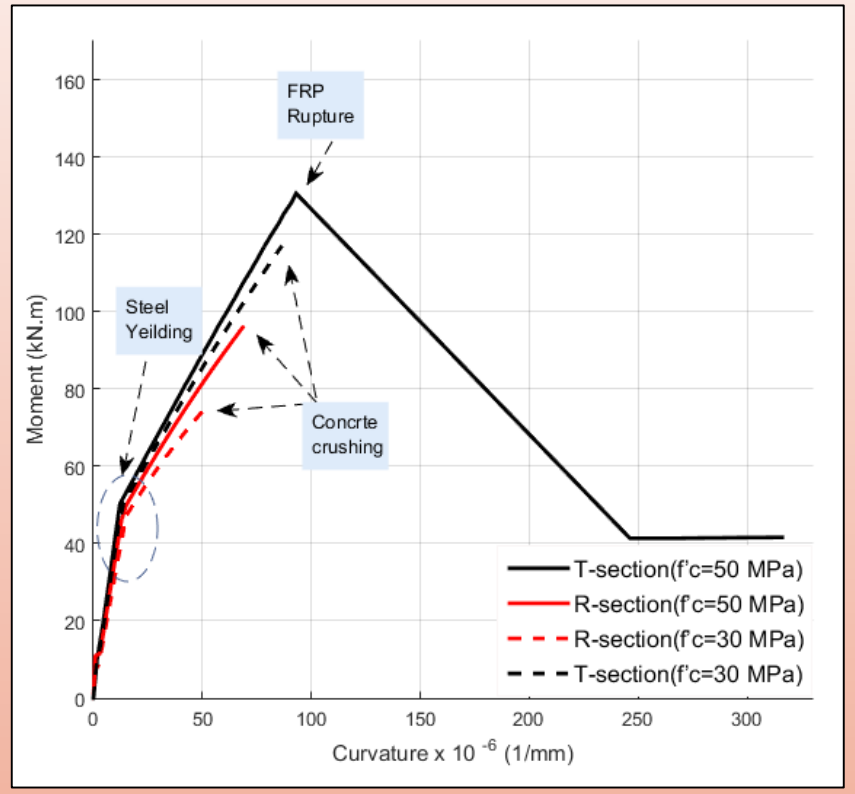
Effect of the Flange

(T section vs Rectangular section)

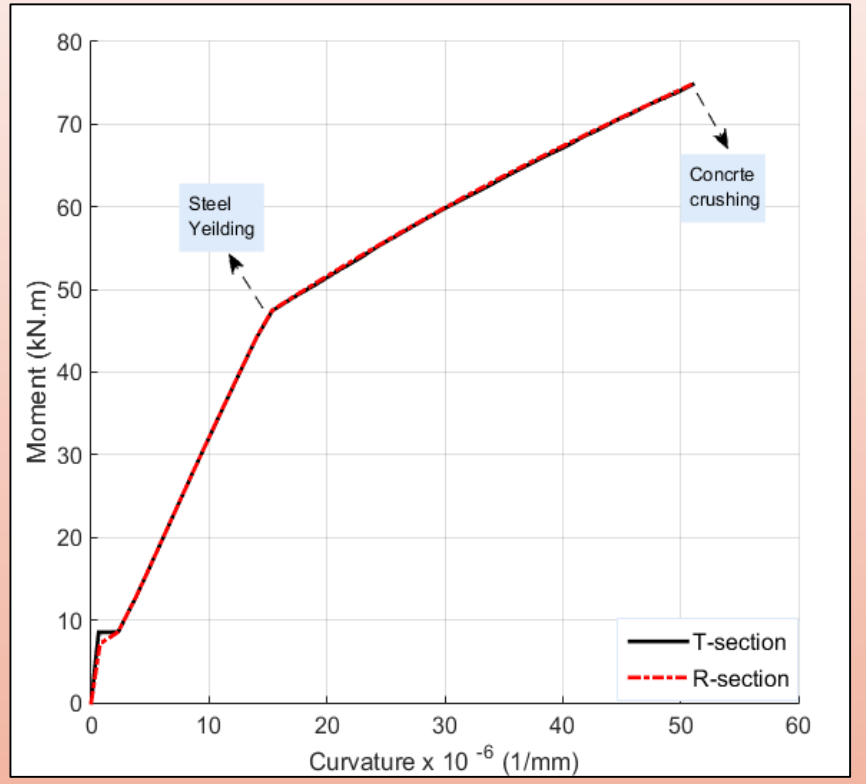


Details of the different cross-section chosen for parametric study

Effect of the Flange

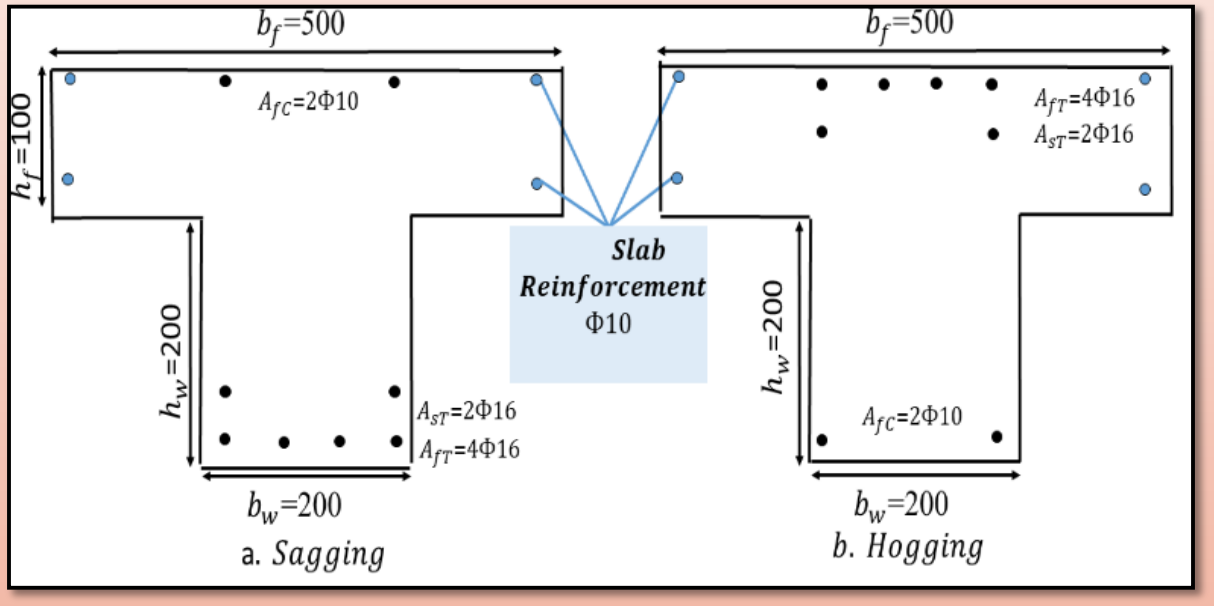


Moment-curvature relationship for different type of cross-section (sagging moment).



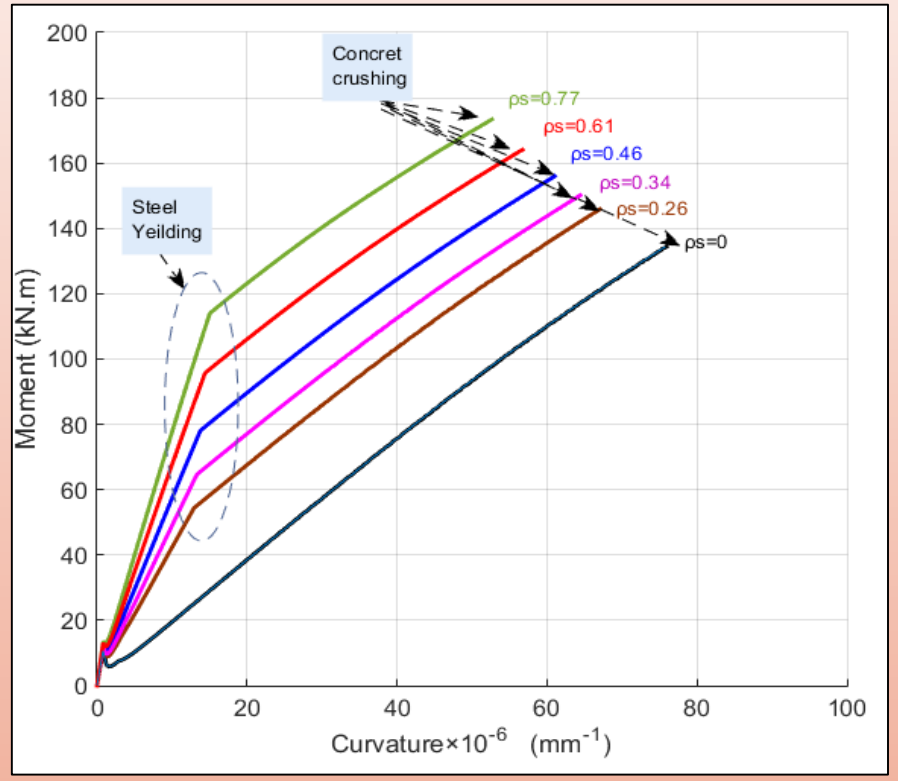
Moment-curvature relationship for different type of cross-section (hogging moment).

Effect of Tensile Reinforcement Ratio

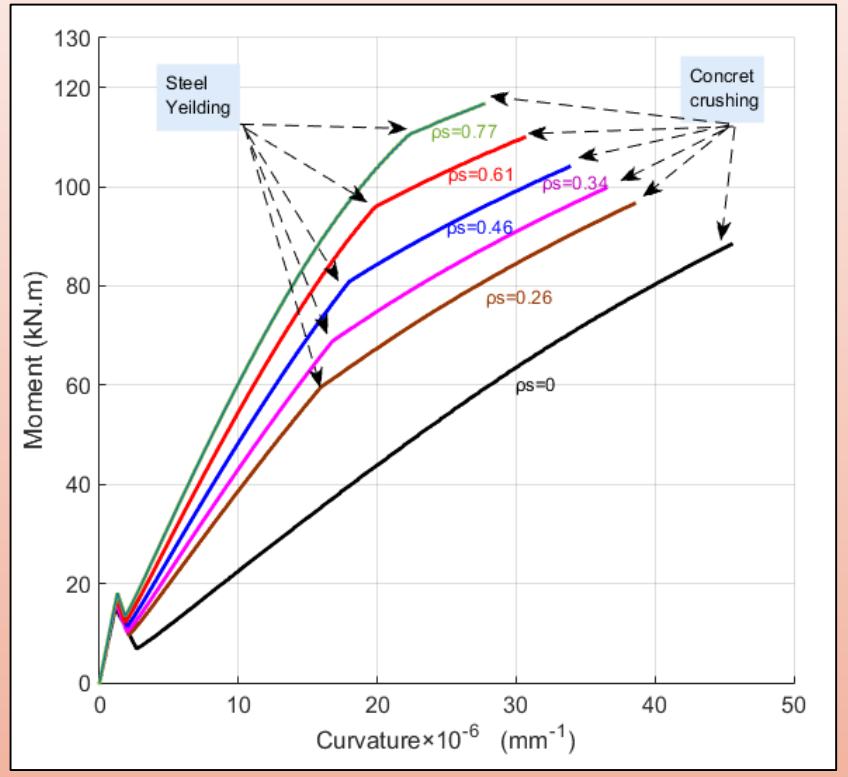


Control specimens used in the parametric study.

Effect of Tensile Reinforcement Ratio



Moment-curvature relationship for different tension steel reinforcement ratios (sagging section).



Moment-curvature relationship for different tension steel reinforcement ratios (hogging section).

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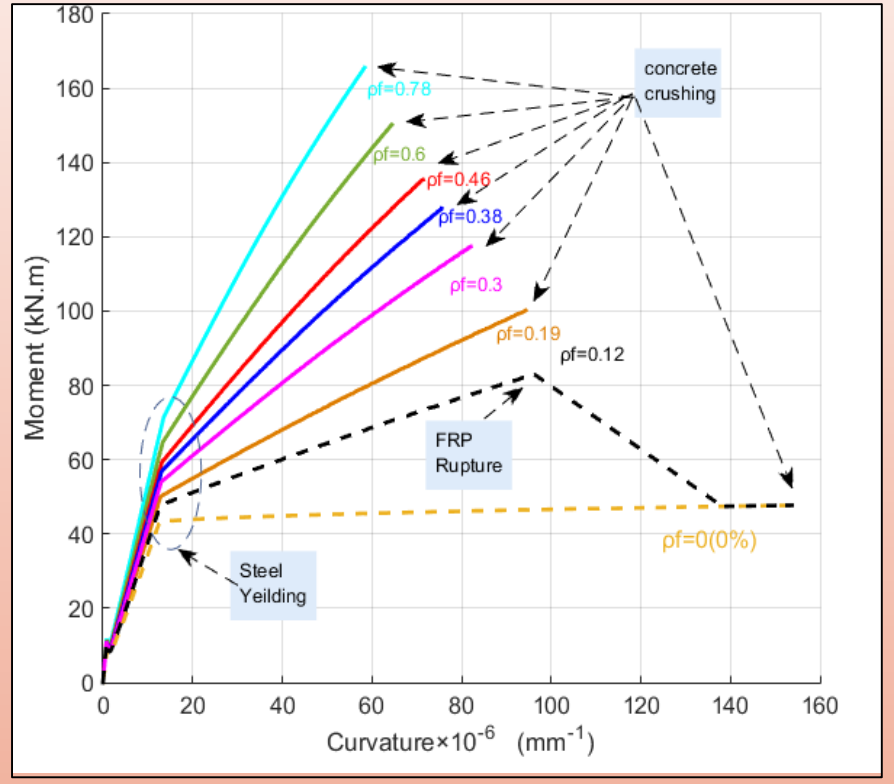
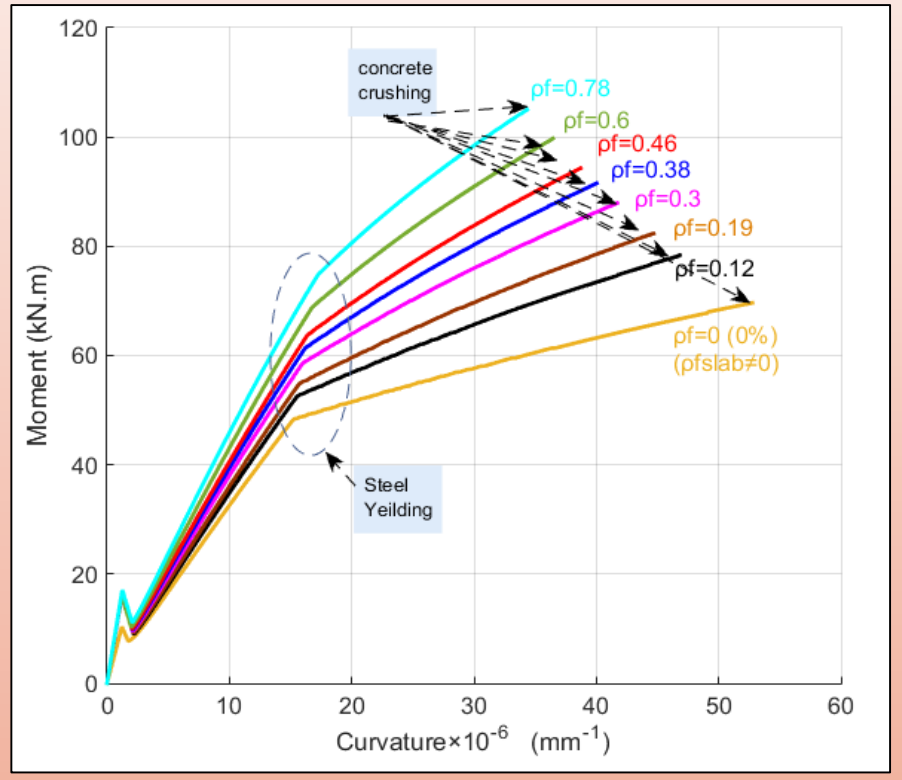
Effect of Tensile Reinforcement Ratio

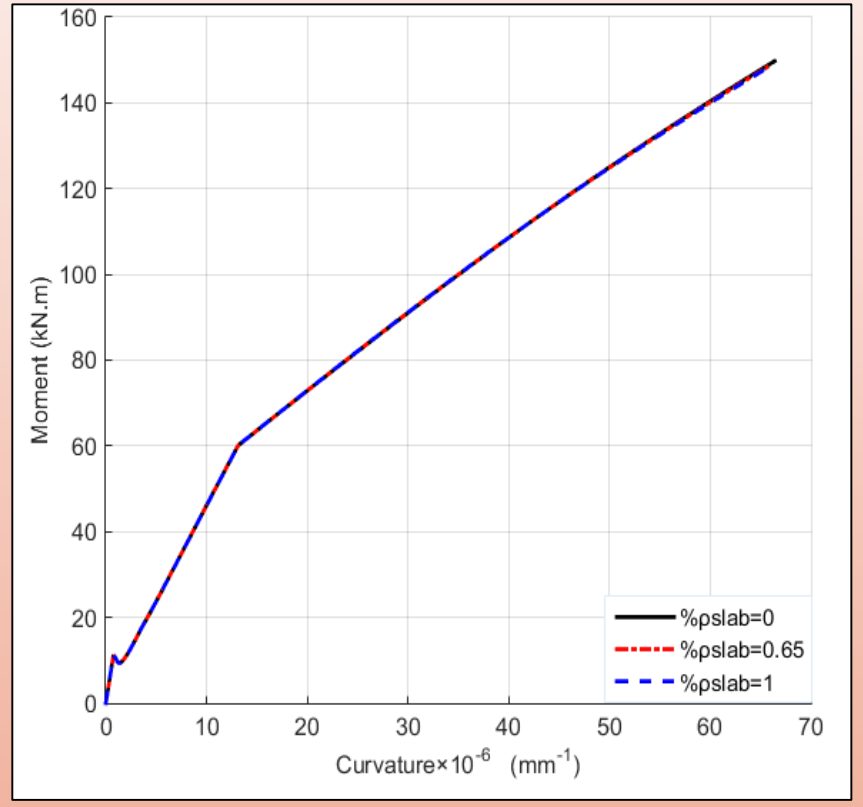


Moment-curvature relationship for different tensile FRP reinforcement ratios (sagging section).

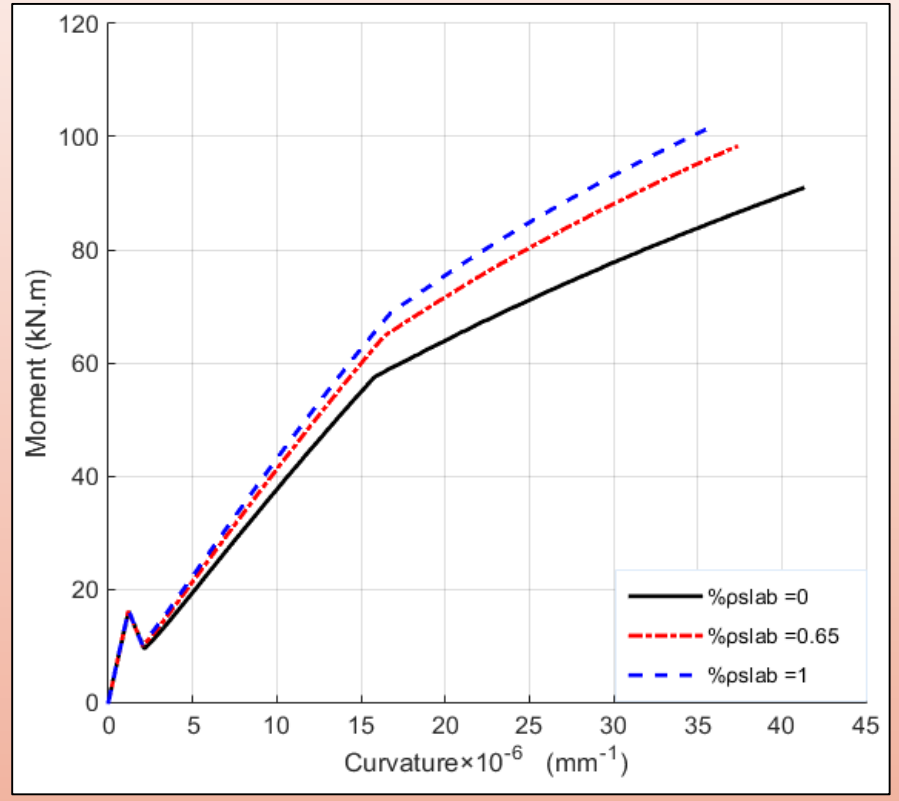


Moment-curvature relationship for different tensile FRP reinforcement ratios (hogging section).

Effect of Slab Reinforcement



Moment-curvature relationship for different slab reinforcement ratio (sagging section).



Moment-curvature relationship for different slab reinforcement ratio (Hogging section).

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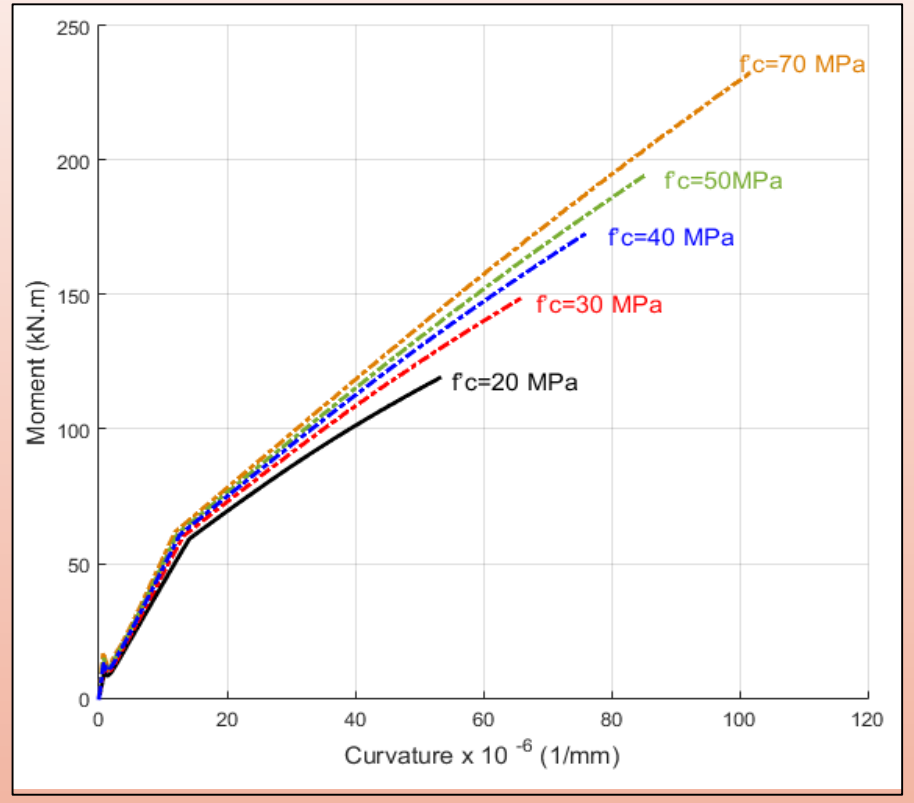
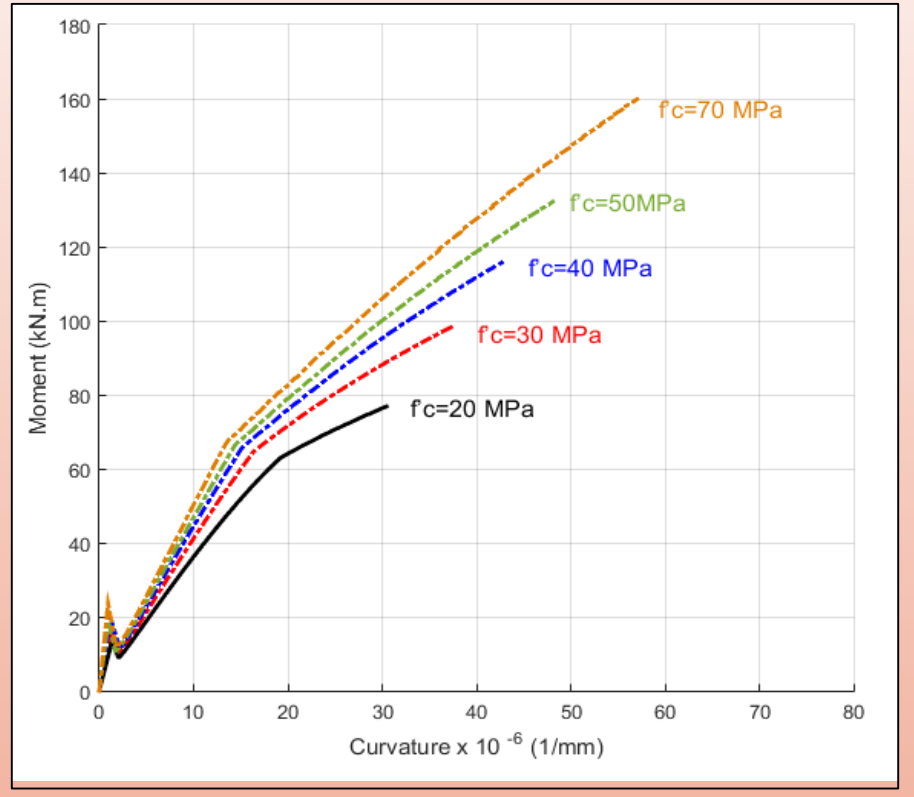
Effect of Concrete Compressive Strength



Moment-curvature relationship for different Concrete compressive strength (Sagging).



Moment-curvature relationship for different Concrete compressive strength (Hogging).

Conclusions

- The difference between rectangular and T-sections is more obvious in the sagging section, due to the effect of the flange part.

- Increasing the slab reinforcement ratio will increase the moment capacity in the hogging sections, whereas it has a slight effect on the sagging sections.

- Increasing either steel or FRP tensile reinforcement ratio will increase the moment capacity in both sagging and hogging sections.

Conclusions

- Adding steel to FRP-RC beams changes the mode of failure from brittle failure to ductile failure.

- Adding steel reinforcement to FRP beams enhance the ductility and stiffness of the beam.

- Increasing the compressive strength of concrete increases both moment capacity and curvature of the section in both sagging and hogging sections.

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Thank you for listening