Experiments and Design Method of Reinforced Concrete Beams Rehablitated by Impressed Current Cathodic Protection and Structural Strengthening (ICCP-SS) with graphene

Xiaoming Zhu | Supervised by Dr. Meini Su, Prof. Yong Wang, Department of Civil Engineering and Management, University of Manchester

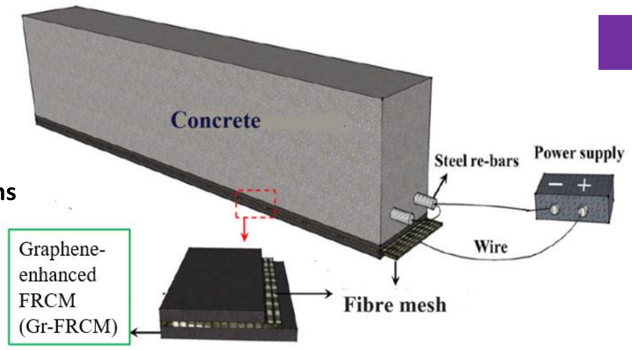
MANCHESTER 1824 The University of Manchester

The Institution of StructuralEngineers Young Researchers Conference 2025

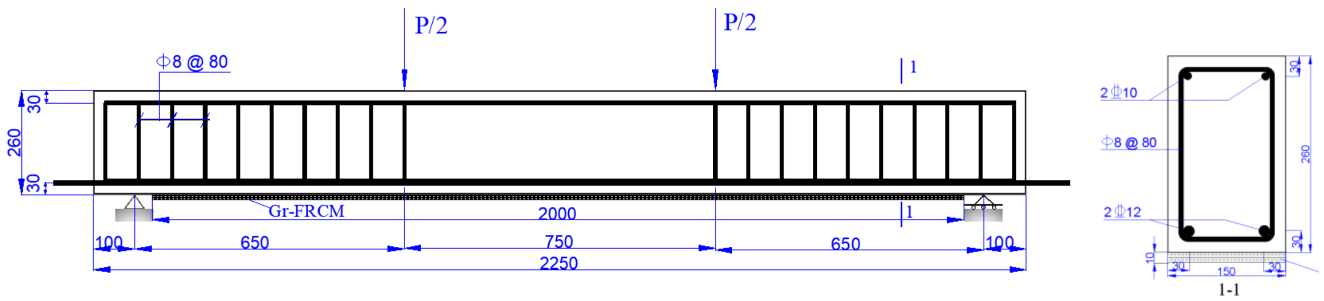
Background and Objectives

ICCP-SS system is a proved effective concrete rehabilitation technique. However, durability issue involving interface degradation needs to be addressed.

- **To understand how graphene affects the flexural behaviour of repaired RC beams**
- **To develop design method for RC beams repaired by ICCP-SS with graphene**

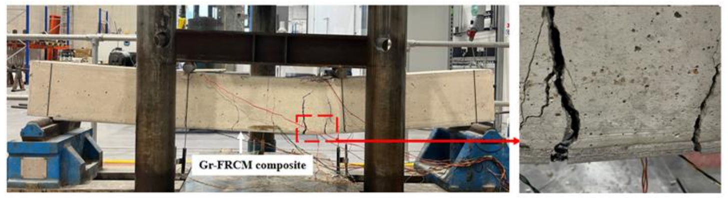


Four-point Bending Experiments

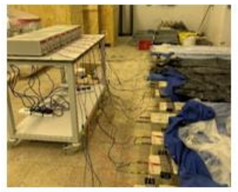


Group	Specimens	NaCl (%)	Graphene Dosage (%)	ICCP Current Density (mA/m²)	ICCP duration (Days)
I	B-RF	0	0	0	0
	C-RF	3	0	0	0
II	C-G0	3	0	0	0
	C-G35	3	0.035	0	0
	C-G70	3	0.07	0	0
III	C-G0-I20	3	0	20	640
	C-G35-I20	3	0.035	20	640
	C-G70-I20	3	0.07	20	640
IV	C-G0-I50	3	0	50	590
	C-G35-I50	3	0.035	50	590
	C-G70-I50	3	0.07	50	590
V	C-G0-I100	3	0	100	450
	C-G35-I100	3	0.035	100	450
	C-G70-I100	3	0.07	100	450

Accelearted corrosion



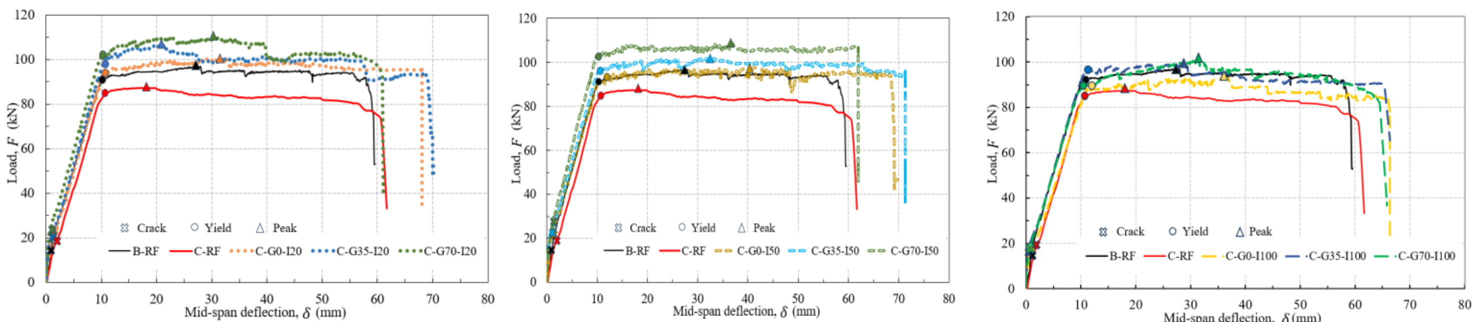
Fibre rupture and slippage failure of a representative beam specimen C-G70-I20



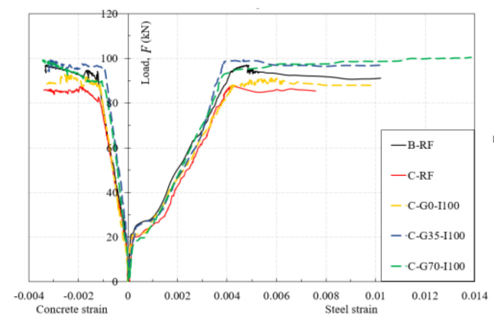
Accelearted polarization

Fibre full rupture failure of a representative beam specimen C-G0-I100

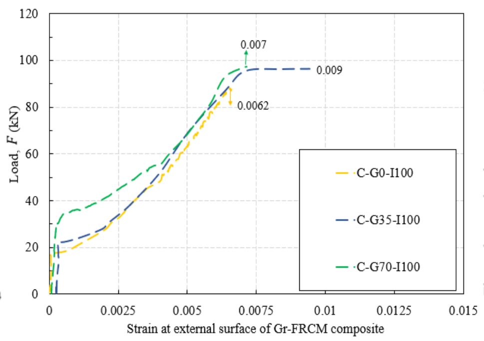
Experimental Results



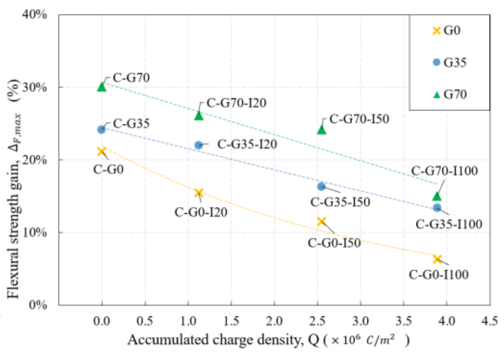
Load-midspan deflection curves



Load-concrete and steel strain curves

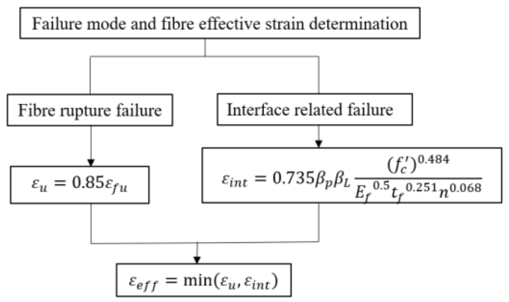


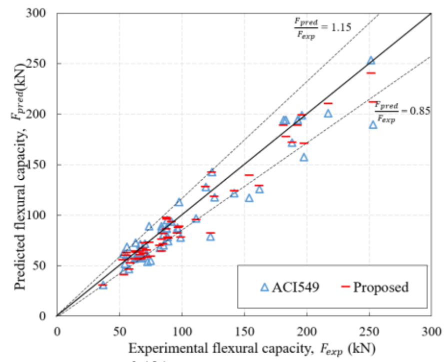
Load-fibre strain curves

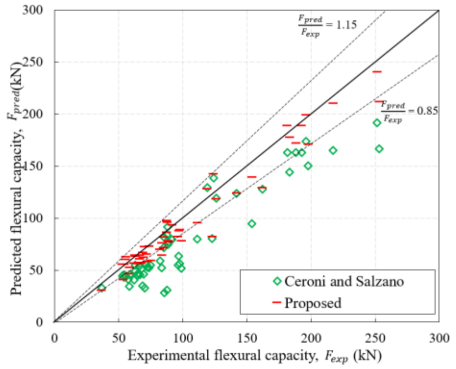


Flexural strength reduction with ICCP

Design Method

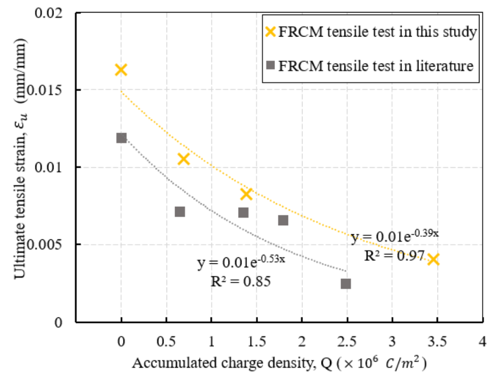


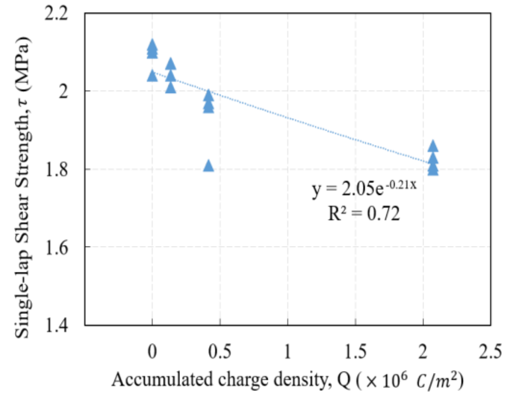


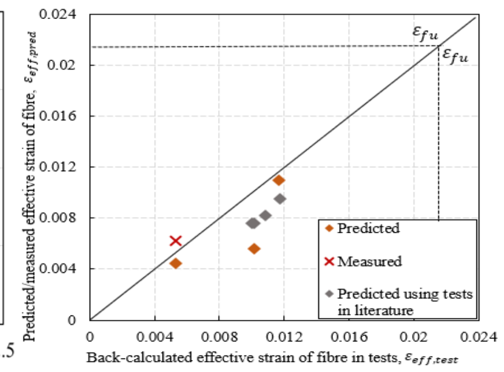


Proposed: $\varepsilon_{eff} = \min(\varepsilon_u, \varepsilon_{int}) = \min(0.85\varepsilon_{fu}, 0.735\beta_p\beta_L \frac{f_c'^{0.484}}{E_f^{0.5} t_f^{0.251} n^{0.068}})$ Validation

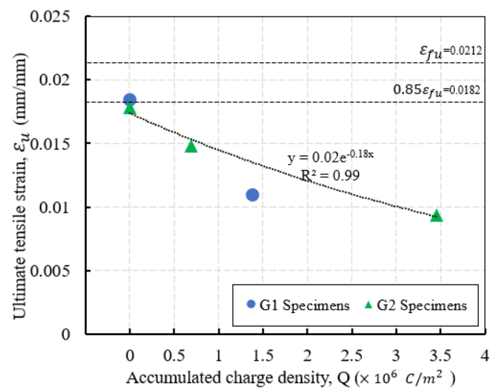
Validation

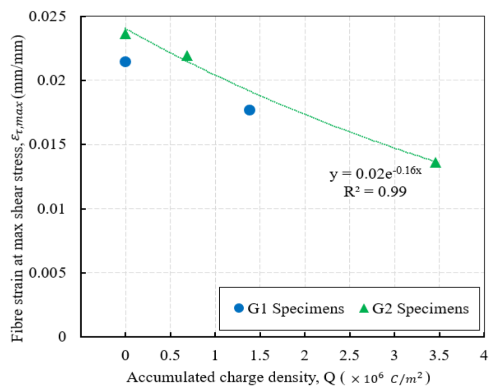


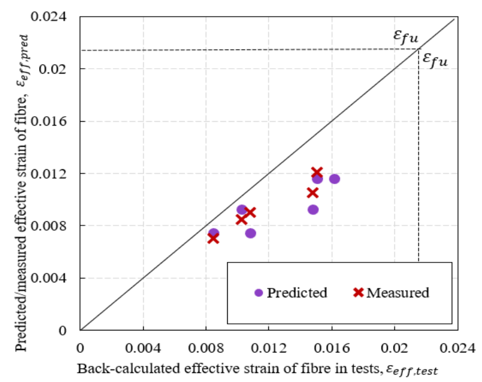




Proposed: $\varepsilon_{eff,I} = \min(\varepsilon_{u,I}, \varepsilon_{int,I}) = \min(0.85\varepsilon_{fu}(e^{-0.46Q}), 0.735\beta_p\beta_L \frac{f_c'^{0.484}}{E_f^{0.5} t_f^{0.251} n^{0.068}}(e^{-0.21Q}))$ Validation







Proposed: $\varepsilon_{eff,IG} = \min(\varepsilon_{u,IG}, \varepsilon_{int,IG}) = \min(0.85\varepsilon_{fu}(e^{-0.18Q}), 0.735\beta_p\beta_L \frac{f_c'^{0.484}}{E_f^{0.5} t_f^{0.251} n^{0.068}}(e^{-0.16Q}))$ Validation

Conclusions

- For sole structure strengthening, as the graphene dosage increased from 0% to 0.035% and 0.07%, the flexural strength gain achieved at 21.2%, 24.1%, and 30.1%, respectively.
- The incorporation of graphene helps mitigate the degradation rate caused by long-term ICCP. Without graphene, the flexural strength of beams rehabilitated by ICCP-SS increased by 15.5% with comparison to reference beam; With 0.07% graphene, the rehabilitated beam can have up to 26.2% improvement on flexural strength.
- New formulas proposed to predict the effective strain of fibres in ICCP-SS system considering graphene and ICCP are proved accurate in design of flexural bearing capacity of repaired concrete beams.

Acknowledgements

The author would like to acknowledge the financial support from the Engineering and Physical Sciences Research Council (EPSRC) Fund (EP/T021748/1) for the completion of this research work.