FRPRCS 16
New Orleans, Louisiana, USA
March 23-24, 2024
www.frprcs16.com

Proposed Design Method for EB-FRP Ties Debond Strain Encompassing Short/Long and Thin/Thick Ties

Junrui Zhang[1], Enrique del Rey Castillo[1], Ravi Kanitkar[2], Aniket D Borwankar[3], and Ramprasath R[4]

[1]The University of Auckland, New Zealand

[2]KL Structure, United States

[3]Simpson Strong-Tie, United States

[4]Virginia Tech, United States

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Unexpected strength

Fig. 1 Bench-press by RC ***(Powered by DALL·E 3)***

Case study *(A heritage building in Auckland)*

- **Weak tension capacity of concrete diaphragms**

(a) Before strengthening

(b) Concrete diaphragms strengthened by FRP

Fig. 2 State of the floor from the Project ***(del Rey Castillo et al., 2019)***

Potential variables *(1627/3162 direct tension tests from 88/117 works)*

- **Parametric analysis for published data**

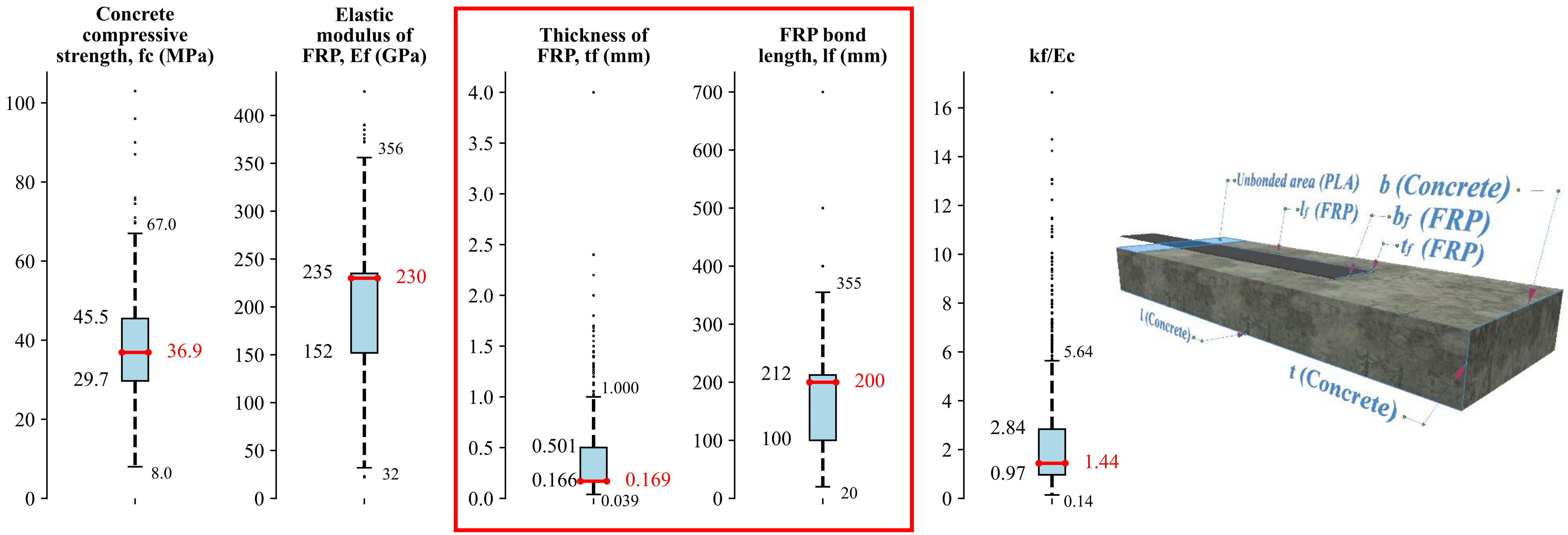
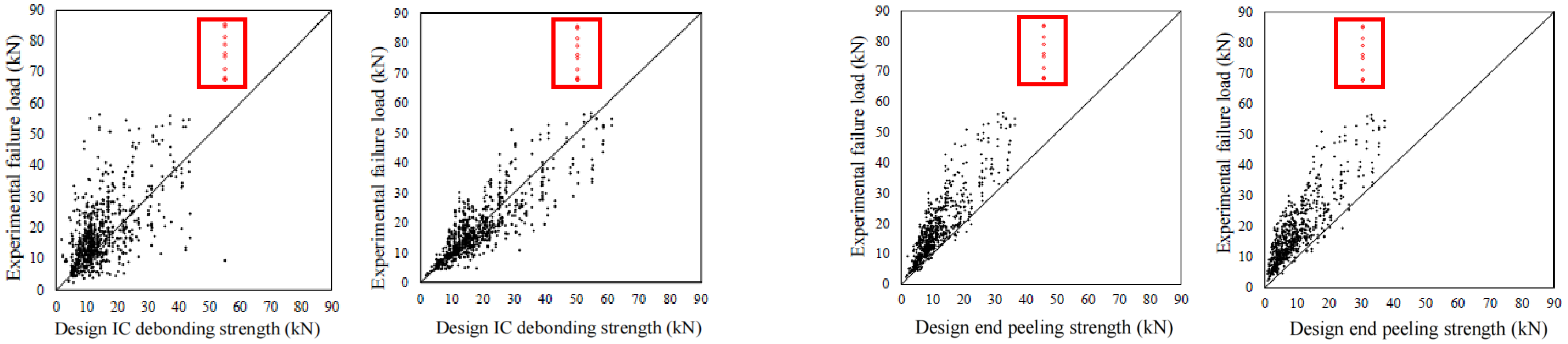


Fig. 3 Selected variables for published testing ***(Zhang et al., 2024)***

Potential variables *(1627/3162 direct tension tests)*

- **Available Design Code/Guidelines**



(a) fib Bulletin 90 design for IC debonding

(b) CNR DT-200 design for IC debonding

(c) fib Bulletin 90 design for end-peeling debonding

(d) CNR DT-200 design for end-peeling debonding

Fig. 4 Comparison between experimental results and guide-prescribed equations ***(del Rey Castillo et al., 2022)***

Unanchored tests

Tab. 1 Critical parameters

	Published research *1627*	Our tests *51*
1 **Concrete strength (f_c)**	1500-10000 psi (10-90 MPa)	2500-6000 psi (17.2 to 41.4 MPa)
2 **Bonded length (l_f)**	From 0.8" to 27" Around *7.8"* (20-700 mm, 200 mm)	***12" to 60"*** (300 to 1500 mm)
3 **Thickness of FRP (t_f) ($k_f = nE_f t_f$)**	Around 1 or 2 layers of 11 oz, ***0.0067"*** (0.166-4 mm, 0.169 mm)	1 layer of 11 oz to 3 layers of 44 oz, ***0.02 to 0.24 inches*** (0.5-6 mm)
4 **Number of tests**	3162 tests (After cleaning 1627)	51 tests (After cleaning 48)

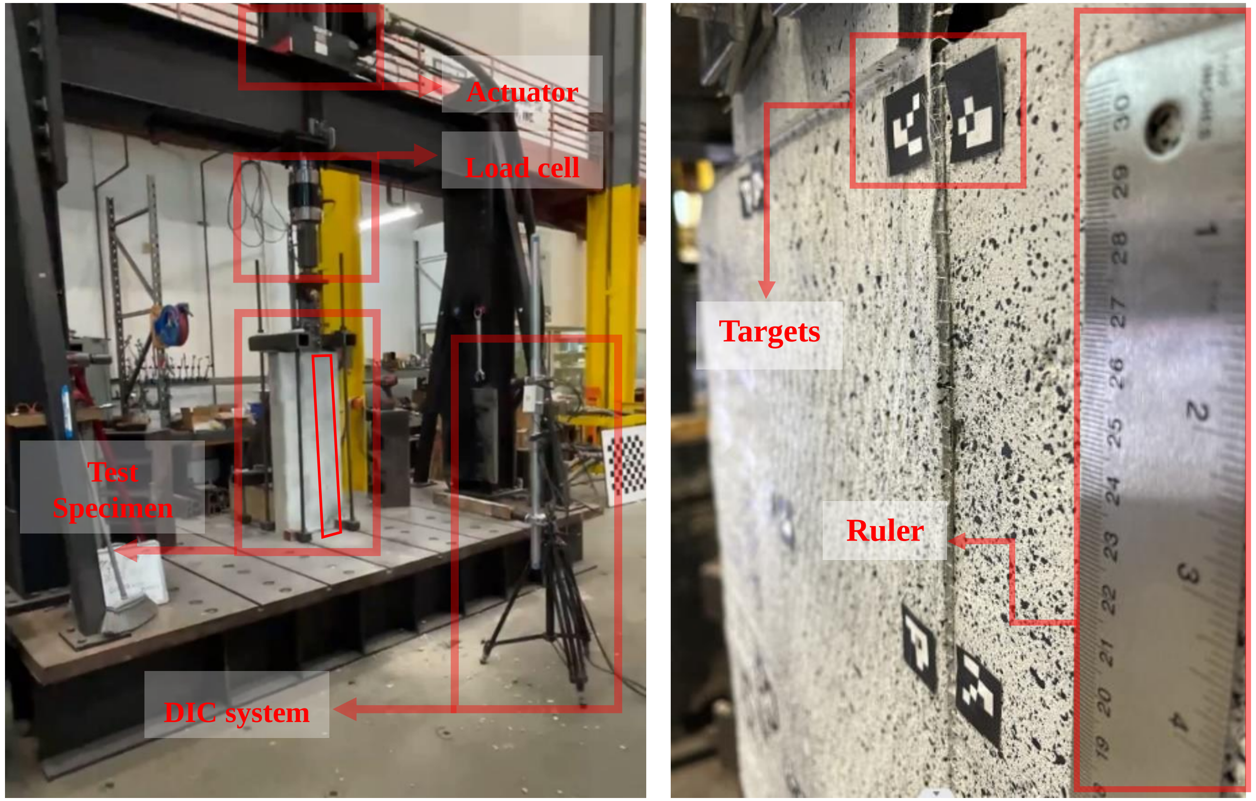


Fig. 5 Testing set-up

Debond mechanism *(2500-36-2)*

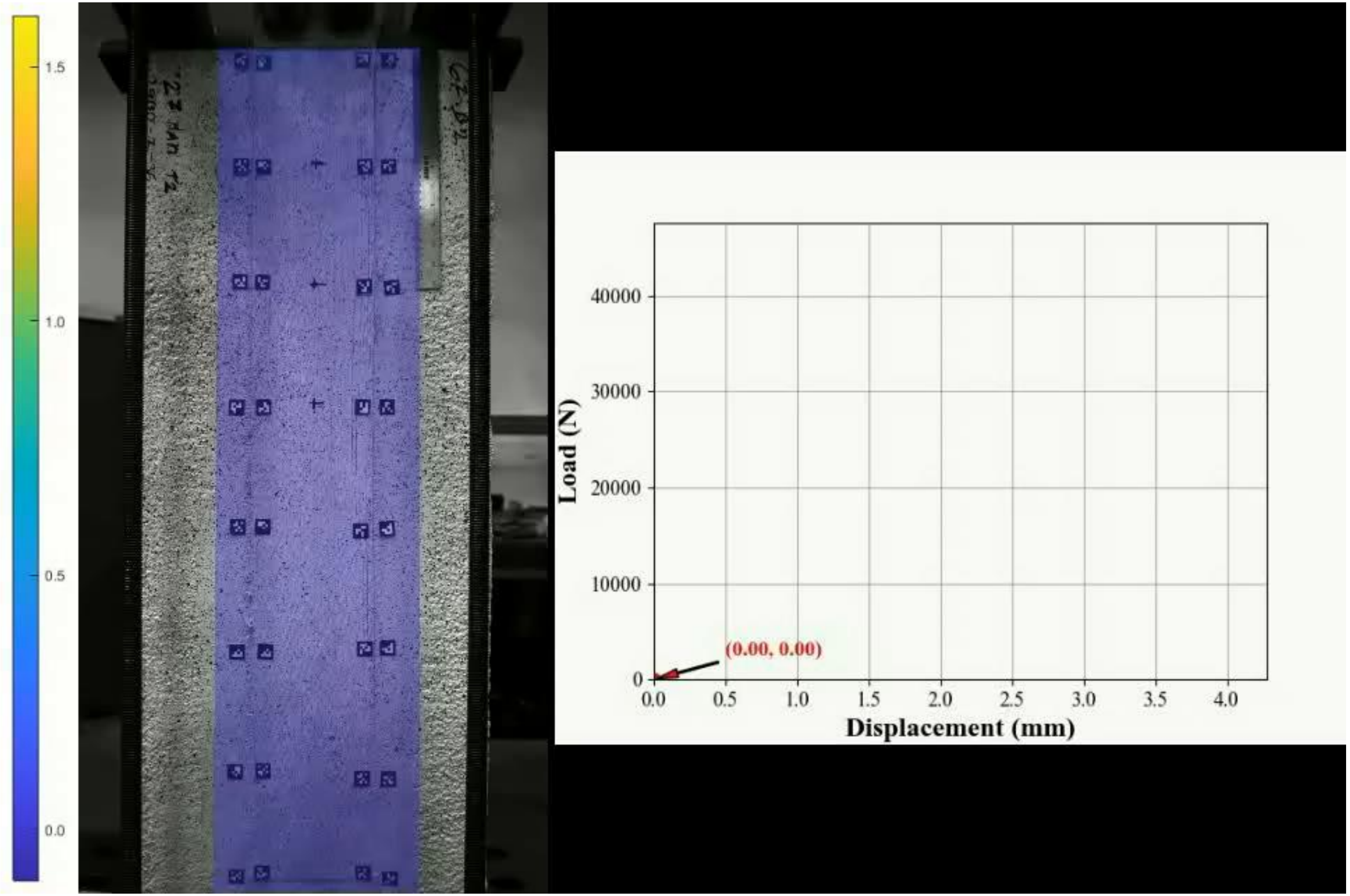
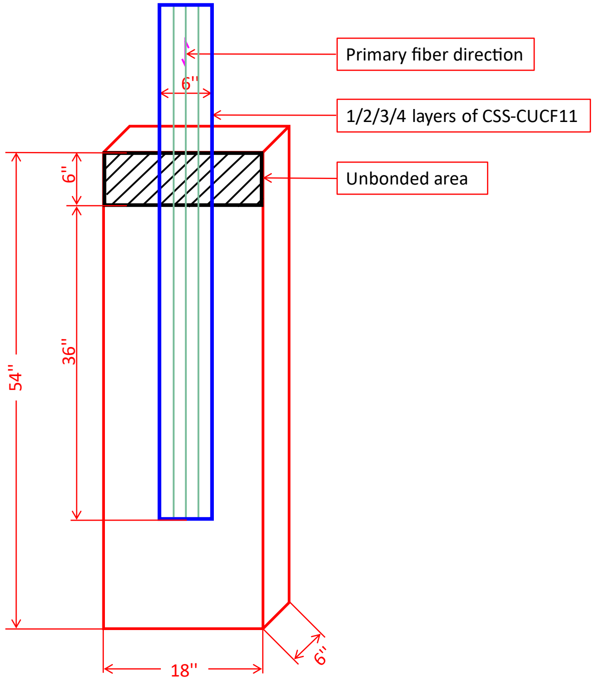
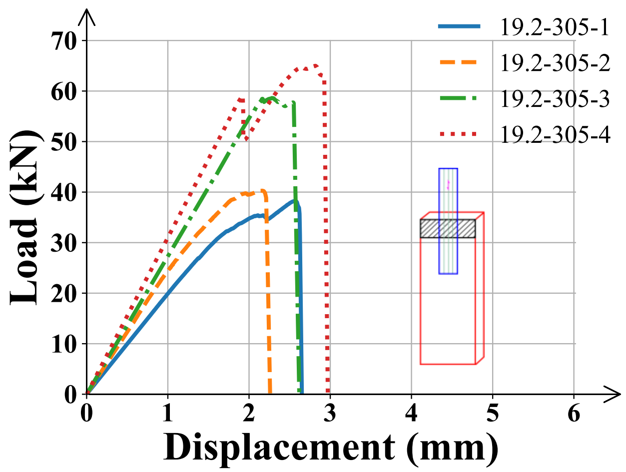


Fig. 6— Debonding

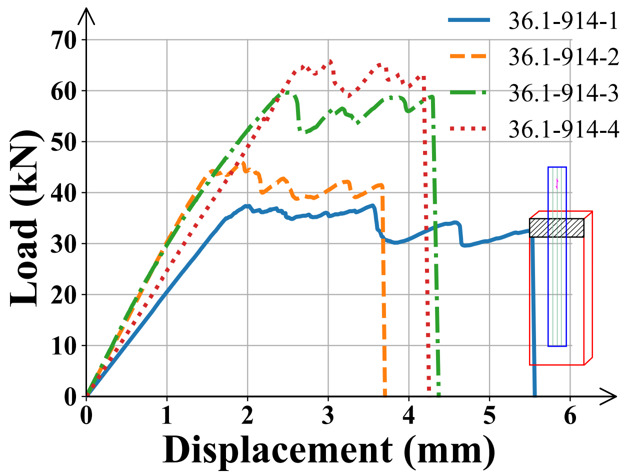


- Initial debonding happens
- Active bond zone progress from load end to free end, and plateau created (longer ties)
- Fully debonding of the ties

L-D responses *(36/51 unanchored tests results)*



(a) 19.2 MPa, 305 mm with 1-4 layer(s)
[2500 psi, 12 in., with 1-4 layer(s)]



(b) 36.1 MPa, 914 mm with 1-4 layer(s)
[5000 psi, 36 in., with 1-4 layer(s)]

Fig. 7 Load-displacement curves (Partial)

- Thicker ties, Stiffer, Load-carrying (/)
- Longer ties, Plateau, Load (-), Post-elastic(debonding) deformation (/)
- Concrete compressive strength (-)

Contributions *(1627 + 51 unanchored tests, Tyrell Gilb Research Lab, CA)*

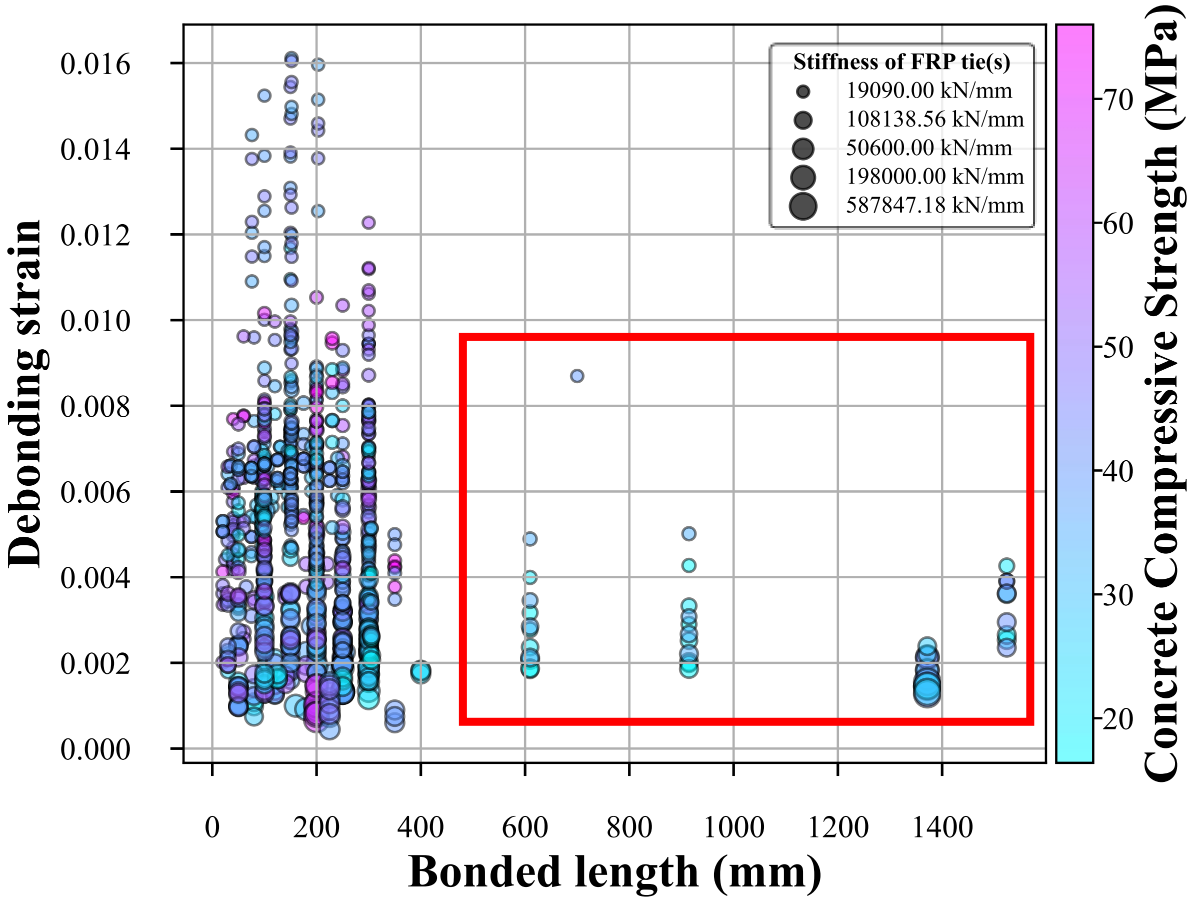


Fig. 8 Test results of 1627+51 unanchored tested

Failure patterns *(36 unanchored tests results)*

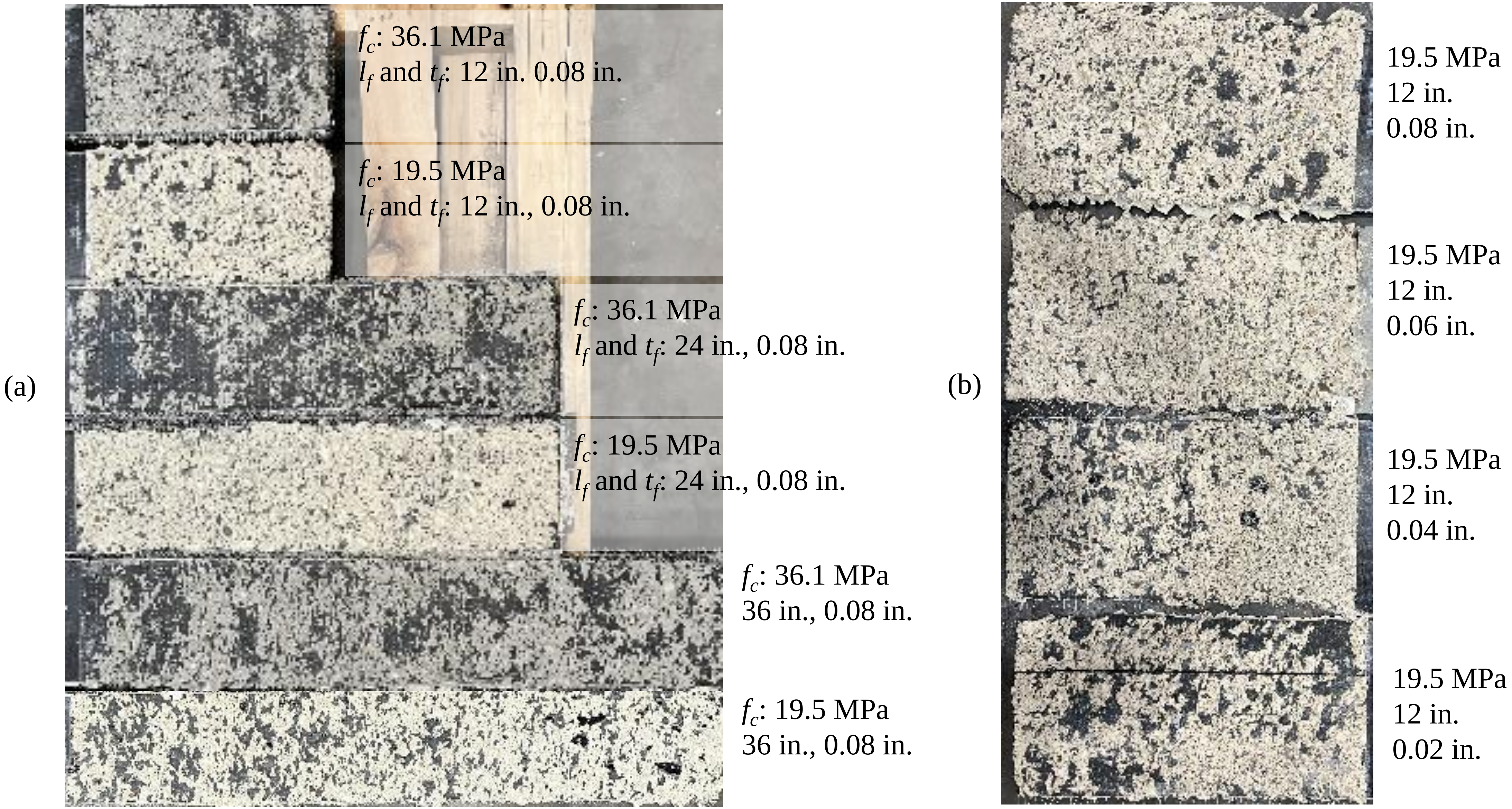
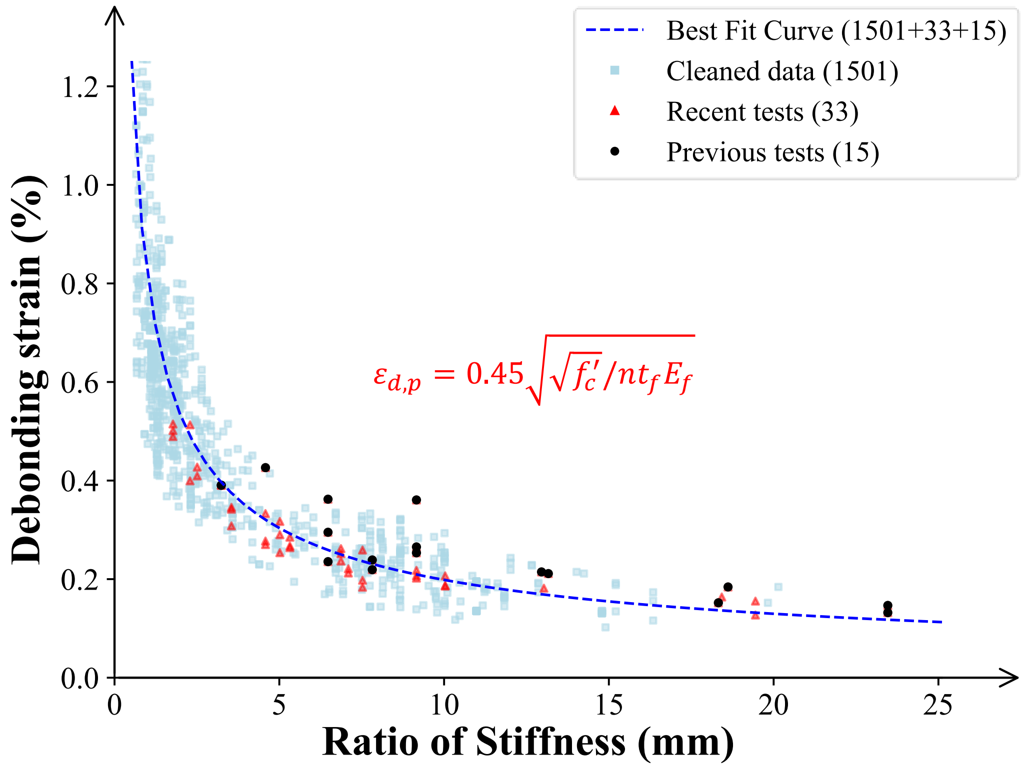
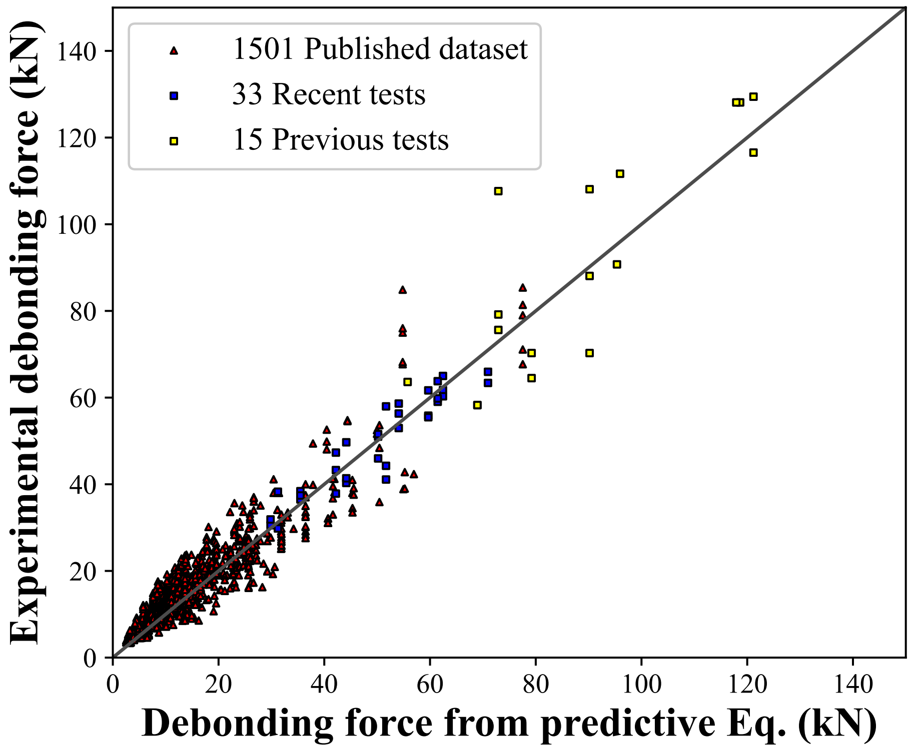


Fig. 9— Comparison of fractured surfaces of FRP ties considering: (a) bond lengths of FRP (Long to short), and (b) thickness of FRP (Thick to thin)

Proposed models *(1501 +51 unanchored tests, Tyrell Gilb Research Lab, CA)*



(a) Regression algorithm



(b) Quantile-q plot (Predict)

Fig. 10 Predictive model of unanchored tested

Proposed models *(1501 +51 unanchored tests, Tyrell Gilb Research Lab, CA)*

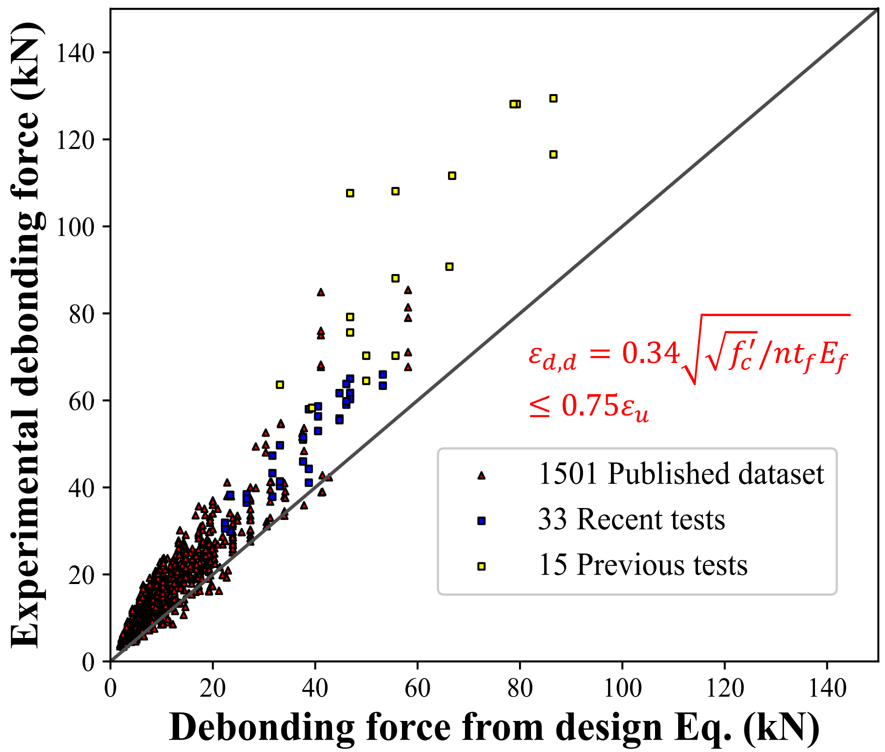


Fig. 11 Design model of unanchored tested

Conclusion

- Thicker FRP ties influencing load-bearing capacity and longer ties showing greater post-debond deformation capacity.

- The debonding load capacity showed a certain correlation with concrete strength, but limited sensitivity to changes in bond length.

- Debond strain correlates non-linearly with FRP-to-concrete stiffness ratio, following a power relationship.

Conclusion

- **Thicker** FRP ties influencing **load-bearing capacity** and **longer** ties showing greater **post-debond deformation** capacity. (↑)

- The **debonding load capacity** showed a certain correlation with **concrete strength**, but limited sensitivity to changes in **bond length**. (─)

- **Debond strain** correlates **non-linearly** with FRP-to-concrete **stiffness ratio**, following a power relationship. (x^a)

Reference

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Acknowledgements

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HĪKINA WHAKATUTUKI

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

ENGINEERING
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

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Junrui.zhang@auckland.ac.nz
ajhz740@aucklanduni.ac.nz

Thanks
Q & A

Junrui Zhang

Junrui.zhang@auckland.ac.nc
ajhz740@aucklanduni.ac.nz