Electronic Supplementary Materials

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Bond of rebar to crumb rubber concrete (CRC) under fiber-reinforced polymer (FRP)–stirrup dual confinement: failure mechanism and behavior modeling

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Table S1. Specimen parameters and test results

Specimen ID	r_{rv} (%)	Stirrup spacing	Layers of FRP	$\tau_{u,1}$ (MPa)	$\tau_{u,2}$ (MPa)	$\tau_{u,ave}$ (MPa)	Failure mode
0	0	-	0	8.37	10.04	9.21	S
0-S2	0	-	0	10.62	12.11	11.37	P
0-S3	0	-	0	11.69	11.00	11.35	P
0-F1	0	-	1	11.15	13.14	12.15	P
0-F2	0	-	2	17.21	15.40	16.31	P
0-S2-F1	0	80	1	14.97	14.25	14.61	P
0-S2-F2	0	80	2	16.47	17.42	16.95	P
0-S3-F1	0	40	1	15.00	16.89	15.95	P
0-S3-F2	0	40	2	16.73	17.53	17.13	P
10	10	-	0	8.09	7.74	7.92	S
20	20	-	0	7.31	5.86	6.59	S
30	30	-	0	5.68	5.12	5.40	S
30-S2	30	-	0	6.94	7.53	7.24	P
30-S3	30	-	0	7.42	7.78	7.60	P
30-F1	30	-	1	9.28	7.87	8.58	P
30-F2	30	-	2	9.85	8.12	8.99	P
30-S2-F1	30	80	1	7.06	8.47	7.77	P
30-S2-F2	30	80	2	10.55	9.89	10.22	P
30-S3-F1	30	40	1	9.10	8.50	8.80	P
30-S3-F2	30	40	2	8.86	9.32	9.09	P
40	40	-	0	5.61	5.52	5.57	SP

Note: S, P, and SP stand for splitting failure, pull-out failure and pull-out failure with splitting, respectively, $\tau_{u,1}$ and $\tau_{u,2}$ denote the bond strength of duplicate specimens, and $\tau_{u,ave}$ is their average value.

Table S2. Database

Source	Specimen ID	r_e (mm)	r_s (mm)	f_c (MPa)	l (mm)	A_{st} (mm^2)	r_{st} (mm)	A_f (mm^2)	E_f (GPa)	r_{rv}	$t_{u,exp}$ (MPa)	$t_{u,pre}$ (MPa)	Error
Present study	0(1)	55	8	30.86	80	-	-	-	-	0%	8.37	9.29	10.99%
	0(2)	55	8	30.86	80	-	-	-	-	0%	10.04	9.29	-7.47%
	10(1)	55	8	23.15	80	-	-	-	-	10%	8.09	7.74	-4.33%
	10(2)	55	8	23.15	80	-	-	-	-	10%	7.74	7.74	0.00%
	20(1)	55	8	18.67	80	-	-	-	-	20%	7.31	6.53	-10.67%
	20(2)	55	8	18.67	80	-	-	-	-	20%	5.86	6.53	11.43%
	30(1)	55	8	14.87	80	-	-	-	-	30%	5.68	5.47	-3.70%
	30(2)	55	8	14.87	80	-	-	-	-	30%	5.12	5.47	6.84%
	40(1)	55	8	10.26	80	-	-	-	-	40%	5.61	4.17	-25.67%
	40(2)	55	8	10.26	80	-	-	-	-	40%	5.52	4.17	-24.46%
	0-S2(1)	55	8	30.86	80	113.04	40	-	-	0%	10.62	10.46	-1.51%
	0-S2(2)	55	8	30.86	80	113.04	40	-	-	0%	12.11	10.46	-13.63%
	0-S3(1)	55	8	30.86	80	169.56	40	-	-	0%	11.69	11.04	-5.56%
	0-S3(2)	55	8	30.86	80	169.56	40	-	-	0%	11.00	11.04	0.36%
	0-F1(1)	55	8	30.86	80	-	-	50.1	240.0	0%	11.15	12.37	10.94%
	0-F1(2)	55	8	30.86	80	-	-	50.1	240.0	0%	13.14	12.37	-5.86%
	0-F2(1)	55	8	30.86	80	-	-	100.2	240.0	0%	17.21	15.66	-9.01%
	0-F2(2)	55	8	30.86	80	-	-	100.2	240.0	0%	15.4	15.66	1.69%
	0-S2-F1(1)	55	8	30.86	80	113.04	40	50.1	240.0	0%	14.97	13.59	-9.22%
	0-S2-F1(2)	55	8	30.86	80	113.04	40	50.1	240.0	0%	14.25	13.59	-4.63%
	0-S2-F2(1)	55	8	30.86	80	113.04	40	100.2	240.0	0%	16.47	16.93	2.79%
	0-S2-F2(2)	55	8	30.86	80	113.04	40	100.2	240.0	0%	17.42	16.93	-2.81%
	0-S3-F1(1)	55	8	30.86	80	169.56	40	50.1	240.0	0%	15.00	14.20	-5.33%
	0-S3-F1(2)	55	8	30.86	80	169.56	40	50.1	240.0	0%	16.89	14.20	-15.93%
	0-S3-F2(1)	55	8	30.86	80	169.56	40	100.2	240.0	0%	16.73	17.58	5.08%
	0-S3-F2(2)	55	8	30.86	80	169.56	40	100.2	240.0	0%	17.53	17.58	0.29%
	30-S2(1)	55	8	14.87	80	113.04	40	0	-	30%	6.84	6.85	0.15%

	30-S2(2)	55	8	14.87	80	113.04	40	0	-	30%	7.53	6.85	-9.03%
	30-S3(1)	55	8	14.87	80	169.56	40	0	-	30%	7.42	7.55	1.75%
	30-S3(2)	55	8	14.87	80	169.56	40	0	-	30%	7.78	7.55	-2.96%
	30-F1(1)	55	8	14.87	80	-	-	50.1	240.0	30%	9.28	9.23	-0.54%
	30-F1(2)	55	8	14.87	80	-	-	50.1	240.0	30%	7.87	9.23	17.28%
	30-F2(1)	55	8	14.87	80	-	-	100.2	240.0	30%	9.85	9.23	-6.29%
	30-F2(2)	55	8	14.87	80	-	-	100.2	240.0	30%	8.12	9.23	13.67%
	30-S2-F1(1)	55	8	14.87	80	113.04	40	50.1	240.0	30%	7.06	9.23	30.74%
	30-S2-F1(2)	55	8	14.87	80	113.04	40	50.1	240.0	30%	8.47	9.23	8.97%
	30-S2-F2(1)	55	8	14.87	80	113.04	40	100.2	240.0	30%	10.55	9.23	-12.51%
	30-S2-F2(2)	55	8	14.87	80	113.04	40	100.2	240.0	30%	9.89	9.23	-6.67%
	30-S3-F1(1)	55	8	14.87	80	169.56	40	50.1	240.0	30%	9.10	9.23	1.43%
	30-S3-F1(2)	55	8	14.87	80	169.56	40	50.1	240.0	30%	8.50	9.23	8.59%
	30-S3-F2(1)	55	8	14.87	80	169.56	40	100.2	240.0	30%	8.86	9.23	4.18%
	30-S3-F2(2)	55	8	14.87	80	169.56	40	100.2	240.0	30%	9.32	9.23	-0.97%
Choi et al. (2014)	25C-1L-1	50	11	31.00	150	-	-	400.0	53.3	0%	10.50	8.84	-15.81%
	25C-1L-2	50	11	31.00	150	-	-	400.0	53.3	0%	10.64	8.84	-16.92%
	25C-1L-3	50	11	31.00	150	-	-	400.0	53.3	0%	10.07	8.84	-12.21%
	25C-2L-1	50	11	31.00	150	-	-	800.0	53.3	0%	11.43	10.90	-4.64%
	25C-2L-2	50	11	31.00	150	-	-	800.0	53.3	0%	11.33	10.90	-3.80%
	25C-2L-3	50	11	31.00	150	-	-	800.0	53.3	0%	11.57	10.90	-5.79%
	25C-3L-1	50	11	31.00	150	-	-	1200.0	53.3	0%	11.80	13.06	10.68%
	25C-3L-2	50	11	31.00	150	-	-	1200.0	53.3	0%	11.98	13.06	9.02%
	25C-3L-3	50	11	31.00	150	-	-	1200.0	53.3	0%	12.51	13.06	4.40%
	35C-1L-1	50	11	40.00	150	-	-	400.0	53.3	0%	12.77	10.58	-17.15%
	35C-1L-2	50	11	40.00	150	-	-	400.0	53.3	0%	12.90	10.58	-17.98%
	35C-1L-3	50	11	40.00	150	-	-	400.0	53.3	0%	13.03	10.58	-18.80%
	35C-2L-1	50	11	40.00	150	-	-	800.0	53.3	0%	14.52	12.84	-11.57%
	35C-2L-2	50	11	40.00	150	-	-	800.0	53.3	0%	14.04	12.84	-8.55%
	35C-2L-3	50	11	40.00	150	-	-	800.0	53.3	0%	14.40	12.84	-10.83%

	35C-3L-1	50	11	40.00	150	-	-	1200.0	53.3	0%	14.75	15.20	3.05%
	35C-3L-2	50	11	40.00	150	-	-	1200.0	53.3	0%	14.96	15.20	1.60%
	35C-3L-3	50	11	40.00	150	-	-	1200.0	53.3	0%	15.20	15.20	0.00%
	45C-1L-1	50	11	51.00	150	-	-	400.0	53.3	0%	15.08	12.78	-15.25%
	45C-1L-2	50	11	51.00	150	-	-	400.0	53.3	0%	15.25	12.78	-16.20%
	45C-1L-3	50	11	51.00	150	-	-	400.0	53.3	0%	14.99	12.78	-14.74%
	45C-2L-1	50	11	51.00	150	-	-	800.0	53.3	0%	17.27	15.29	-11.46%
	45C-2L-2	50	11	51.00	150	-	-	800.0	53.3	0%	16.93	15.29	-9.69%
	45C-2L-3	50	11	51.00	150	-	-	800.0	53.3	0%	16.96	15.29	-9.85%
	45C-3L-1	50	11	51.00	150	-	-	1200.0	53.3	0%	17.86	17.91	0.28%
	45C-3L-2	50	11	51.00	150	-	-	1200.0	53.3	0%	17.67	17.91	1.36%
	45C-3L-3	50	11	51.00	150	-	-	1200.0	53.3	0%	17.24	17.91	3.89%
Gao et al. (2019)	R4C1-12N-1	75	6	22.56	60	-	-	-	-	0%	18.20	16.84	-7.47%
	R4C1-12N-2	75	6	22.56	60	-	-	-	-	0%	16.80	16.84	0.24%
	R4C1-16N-1	75	8	22.56	80	-	-	-	-	0%	10.98	11.83	7.74%
	R4C1-16N-2	75	8	22.56	80	-	-	-	-	0%	11.62	11.83	1.81%
	R4C1-20N-1	75	10	22.56	100	-	-	-	-	0%	6.96	8.84	27.01%
	R4C1-20N-2	75	10	22.56	100	-	-	-	-	0%	7.32	8.84	20.77%
	R4C1-12Y-1	75	6	22.56	60	301.44	55	-	-	0%	18.50	22.56	21.95%
	R4C1-12Y-2	75	6	22.56	60	301.44	55	-	-	0%	17.80	22.56	26.74%
	R4C1-12Y-3	75	6	22.56	60	301.44	55	-	-	0%	17.70	22.56	27.46%
	R4C1-16Y-1	75	8	22.56	80	301.44	55	-	-	0%	15.91	14.92	-6.22%
	R4C1-16Y-2	75	8	22.56	80	301.44	55	-	-	0%	15.17	14.92	-1.65%
	R4C1-16Y-3	75	8	22.56	80	301.44	55	-	-	0%	16.38	14.92	-8.91%
	R4C1-20Y-1	75	10	22.56	100	301.44	55	-	-	0%	11.98	10.75	-10.27%
	R4C1-20Y-2	75	10	22.56	100	301.44	55	-	-	0%	10.36	10.75	3.76%
	R4C1-20Y-3	75	10	22.56	100	301.44	55	-	-	0%	10.00	10.75	7.50%
Bai et al. (2023)	R0-F16-A80	75	8	28.08	80	-	-	-	-	0%	13.74	11.93	-13.17%
	R10-F16-A80	75	8	24.96	80	-	-	-	-	10%	12.73	11.20	-12.02%
	R20-F16-A80	75	8	22.64	80	-	-	-	-	20%	11.25	10.19	-9.42%

	R30-F16-A80	75	8	18.84	80	-	-	-	-	30%	10.18	8.79	-13.65%
	R10-F14-A70	75	7	24.96	70	-	-	-	-	10%	14.75	12.99	-11.93%
	R10-F18-A90	75	9	24.96	90	-	-	-	-	10%	10.84	9.81	-9.50%
	R10-F20-A100	75	10	24.96	100	-	-	-	-	10%	8.89	8.70	-2.14%
	R10-F16-A64	75	8	24.96	64	-	-	-	-	10%	13.51	11.20	-17.10%
	R10-F16-A96	75	8	24.96	96	-	-	-	-	10%	12.91	11.20	-13.25%
Li et al. (2020)	R16-1-CRC	75	8	36.90	80	-	-	-	-	18%	17.80	17.27	-2.98%
	R16-2-CRC	75	8	36.90	80	-	-	-	-	18%	18.60	17.27	-7.15%
	R16-3-CRC	75	8	36.90	80	-	-	-	-	18%	19.40	17.27	-10.98%
	R12-1-CRC	75	6	36.90	60	-	-	-	-	18%	13.70	16.56	20.88%
	R12-2-CRC	75	6	36.90	60	-	-	-	-	18%	12.90	16.56	28.37%
	R12-3-CRC	75	6	36.90	60	-	-	-	-	18%	12.80	16.56	29.38%
Kammash et al. (2022)	B1-R50%	75	6	24.00	60	-	-	-	-	50%	9.09	12.10	33.11%
	B2-R25%	75	6	24.00	60	-	-	-	-	25%	9.94	13.18	32.60%
	B3-R0%	75	6	24.00	60	-	-	-	-	0%	10.81	13.26	22.66%

Table S3. Parameters of analytical model

Common
c_1= 3 (Reinhardt et al., 1986)
c_2= 7 (Reinhardt et al., 1986)
m_1= 0.52 (Zhao and Zhu, 2018)
m_2= 0.28 (Zhao and Zhu, 2018)
a= 25° (Ka et al., 2018)
s_c, s_r, s_{r+c}, h_r can be obtained as per GB1499.2 (2007)
NC
f_t= 0.3(f_c-8)$^{2/3}$ (f_c≤40MPa) (*fib* 2010)
f_t= 2.12ln(1+ f_c/10) (f_c>40MPa) (*fib* 2010)
E_c= 21500((f_c)/10)$^{1/3}$ (*fib* 2010)
w_0= 5G_f/f_t (*fib* 2010)
G_f= 0.073(f_c)$^{0.18}$ (*fib* 2010)
CRC
f_t= 0.26(f_c)$^{2/3}$ (Bompa and Elghazouli, 2017)
E_c= 12000((f_c)/10)$^{2/3}$ (Bompa and Elghazouli, 2017)

Note: f_c is the concrete cylinder compressive strength (ASTM 2018), which can be transformed from f_{cu} as per fib (2010).