Supplementary Materials

Performance Constraints on Recycling Waste Tyre Carbon Black as a Cement Replacement in Masonry Mortars

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Data definitions and analysis

Tables S1–S6 report 180 specimens. Mortar compression, direct tension and flexure each comprise 36 specimens. Prism compression, diagonal shear and unit–mortar bond each comprise 24. The 0.0% group is the control mortar, made with cement, sand and water. The 2.5%, 5.0% and 7.5% groups replace those percentages of cement by mass with WTCB. The specimen numbers run consecutively within each test and replacement level.

The 2024 LEMS W&C laboratory sheets provide the specimen measurements, failure loads and reported stresses. For compression, direct tension, prism compression, diagonal shear and bond, the analysis converts the recorded kgf cm^{-2} values to MPa using 1 kgf cm^{-2} = 0.0980665 MPa. Flexural analysis uses the central three-point bending expression and the measured dimensions in Table S13. Group summaries use the arithmetic mean and sample standard deviation.

The six tests and four replacement levels used 24 mixing batches, one per test and replacement level. The ANOVA in Table S7 and Welch intervals in Table S9 describe specimen variation within the tested batches. Prism results are pooled by dosage across two test dates. Table S16 gives the results for each date separately.

Page references identify sheets in the 2024 laboratory report. In each four-sheet mechanical series, the dosage order is 0%, 2.5%, 5.0% and 7.5%. Tables S4 and S5 cite the 2025 thesis of D. A. Pacheco Torres and A. M. Torres Vásquez. Tables S10 and S11 identify the WTCB metals report and the sand grading record. We also measured WTCB particle-size distribution, specific surface area, ash content and residual organics, examined its mineral phases by X-ray diffraction, and performed scanning electron microscopy, thermogravimetric and derivative thermogravimetric analysis, and hardened-mortar porosity testing. The individual values, micrographs, diffractograms and thermal curves from these eight tests are not included in this supplement. Tables S1–S16 and Figures S1–S15 present the data used for the comparisons reported here.

Supporting content

Tables S1–S3. Individual mortar compression, direct tensile and flexural strength records.

Tables S4–S6. Individual masonry prism, diagonal shear and bond records.

Table S7. Analysis of variance for the six mechanical outcomes.

Tables S8–S16. Compression verification, differences from the control, WTCB metals, sand grading, mortar flow, flexural geometry, material densities, WTCB absorption and prism results by test date.

Figures S1–S15. Supplementary distributions, associations and observed-mean grids.

Table S1. Individual mortar compressive strength records.

WTCB (%)	Specimen ID	Age (days)	Failure load (N)	Loaded area (mm²)	Reported stress (MPa)	Reported stress (kgf cm⁻²)
0.0	01	7	24350	2495	9.76	99.50
0.0	02	7	23360	2475	9.44	96.25
0.0	03	7	24210	2466	9.82	100.10
0.0	04	14	28220	2478	11.39	116.15
0.0	05	14	26080	2636	9.89	100.90
0.0	06	14	24830	2497	9.94	101.40
0.0	07	28	29860	2458	12.15	123.86
0.0	08	28	36460	2564	14.22	145.00
0.0	09	28	28460	2488	11.44	116.63
2.5	01	7	20830	2533	8.22	83.85
2.5	02	7	22280	2572	8.66	88.33
2.5	03	7	22320	2479	9.00	91.80
2.5	04	14	27540	2474	11.13	113.51
2.5	05	14	27170	2537	10.71	109.20
2.5	06	14	27610	2493	11.08	112.96
2.5	07	28	28210	2499	11.29	115.11
2.5	08	28	32230	2465	13.08	133.34
2.5	09	28	32960	2549	12.93	131.86
5.0	01	7	20960	2455	8.54	87.07
5.0	02	7	19250	2518	7.65	77.96
5.0	03	7	20440	2440	8.38	85.42
5.0	04	14	23100	2521	9.16	93.45
5.0	05	14	21640	2419	8.95	91.22
5.0	06	14	24000	2498	9.61	97.99
5.0	07	28	24050	1829	13.15	134.12
5.0	08	28	24820	1807	13.74	140.10
5.0	09	28	24090	1825	13.20	134.60
7.5	01	7	22970	2514	9.14	93.19
7.5	02	7	21010	2503	8.39	85.58
7.5	03	7	20470	2503	8.18	83.41
7.5	04	14	23070	2525	9.14	93.18
7.5	05	14	27080	2478	10.93	111.43
7.5	06	14	26110	2500	10.44	106.50
7.5	07	28	30590	2474	12.37	126.09
7.5	08	28	32670	2448	13.35	136.11
7.5	09	28	27620	2473	11.17	113.91

Laboratory sheets 12–15. The loaded area is the individual value entered on the compression sheet. For the 5.0% WTCB specimens 07–09, loads divided by the corresponding areas reproduce the recorded MPa values to two decimal places (Table S8).

Table S2. Individual mortar direct tensile strength records.

WTCB (%)	Specimen ID	Age (days)	Failure load (N)	Loaded area (mm²)	Reported stress (MPa)	Reported stress (kgf cm⁻²)
0.0	01	7	469	641	0.73	7.46
0.0	02	7	585	641	0.91	9.30
0.0	03	7	589	641	0.92	9.36
0.0	04	14	761	641	1.19	12.11
0.0	05	14	718	641	1.12	11.42
0.0	06	14	736	641	1.15	11.70
0.0	07	28	1005	641	1.57	15.97
0.0	08	28	905	641	1.41	14.38
0.0	09	28	1156	641	1.80	18.39
2.5	01	7	599	645	0.93	9.46
2.5	02	7	613	645	0.95	9.70
2.5	03	7	700	645	1.08	11.06
2.5	04	14	968	645	1.50	15.30
2.5	05	14	912	645	1.41	14.42
2.5	06	14	913	645	1.42	14.44
2.5	07	28	1075	645	1.67	16.99
2.5	08	28	1016	645	1.58	16.06
2.5	09	28	1041	645	1.61	16.45
5.0	01	7	600	645	0.93	9.48
5.0	02	7	617	645	0.96	9.76
5.0	03	7	654	645	1.01	10.33
5.0	04	14	771	645	1.20	12.19
5.0	05	14	707	645	1.10	11.17
5.0	06	14	802	645	1.24	12.67
5.0	07	28	941	645	1.46	14.87
5.0	08	28	935	645	1.45	14.78
5.0	09	28	939	645	1.46	14.84
7.5	01	7	577	645	0.89	9.12
7.5	02	7	614	645	0.95	9.71
7.5	03	7	643	645	1.00	10.16
7.5	04	14	1052	645	1.63	16.62
7.5	05	14	1036	645	1.61	16.37
7.5	06	14	1149	645	1.78	18.15
7.5	07	28	1272	645	1.97	20.11
7.5	08	28	1384	645	2.14	21.87
7.5	09	28	1289	645	2.00	20.38

Laboratory sheets 6–9. The briquettes were tested in direct tension under NTP 334.060:2019. The recorded loaded area was 641 mm² for the control and 645 mm² for the WTCB mixtures.

Table S3. Individual mortar flexural strength records.

WTCB (%)	Specimen ID	Age (days)	Failure load (N)	Reported stress (MPa)	Reported stress (kgf cm^{-2})	Central-load strength (MPa)
0.0	01	7	1028.72	1.80	18.36	2.70057
0.0	02	7	1134.63	2.14	21.77	3.20305
0.0	03	7	1243.48	2.36	24.04	3.53629
0.0	04	14	2094.70	4.44	45.28	6.66070
0.0	05	14	2095.68	4.71	48.01	7.06063
0.0	06	14	1915.24	4.09	41.71	6.13506
0.0	07	28	2257.49	4.41	44.96	6.61068
0.0	08	28	2503.64	5.11	52.07	7.65895
0.0	09	28	2338.89	4.75	48.46	7.12647
2.5	01	7	1158.17	2.29	23.34	3.43288
2.5	02	7	1298.40	2.29	23.40	3.44245
2.5	03	7	1388.62	2.72	27.78	4.08646
2.5	04	14	1460.21	3.06	31.25	4.59673
2.5	05	14	1402.35	3.16	32.24	4.74254
2.5	06	14	1444.52	3.45	35.17	5.17348
2.5	07	28	2321.23	4.65	47.41	6.97121
2.5	08	28	2257.49	4.40	44.86	6.59794
2.5	09	28	2120.20	4.15	42.36	6.23133
5.0	01	7	990.47	1.85	18.87	2.77628
5.0	02	7	1057.16	1.91	19.47	2.86369
5.0	03	7	1167.97	2.12	21.61	3.17899
5.0	04	14	1850.02	4.12	42.05	6.18509
5.0	05	14	1486.69	3.59	36.64	5.38995
5.0	06	14	1439.62	3.52	35.93	5.28473
5.0	07	28	2462.45	4.83	49.20	7.23787
5.0	08	28	2236.90	4.47	45.61	6.70892
5.0	09	28	2242.78	4.59	46.76	6.87780
7.5	01	7	1625.94	2.93	29.87	4.39376
7.5	02	7	1507.28	2.71	27.62	4.06318
7.5	03	7	1620.06	2.95	30.05	4.42007
7.5	04	14	1700.47	3.80	38.79	5.70453
7.5	05	14	1794.62	3.87	39.44	5.80008
7.5	06	14	1935.83	4.15	42.27	6.21662
7.5	07	28	2122.16	4.19	42.77	6.29036
7.5	08	28	2144.71	4.38	44.70	6.57371
7.5	09	28	2557.57	4.88	49.74	7.31673

Laboratory sheets 16–19 identify NTP 334.120 and a 130 mm support span. The final column gives the central three-point bending strength used in the analysis. Table S13 lists each measured section and the calculation.

Table S4. Individual masonry prism compressive strength records.

WTCB (%)	ID	Test date (2024)	L × t × h (mm)	Area (mm²)	Failure load (N)	Uncorr. (MPa)	Corr. (MPa)	Corr. stress (kgf cm⁻²)
0.0	01	5 Oct	240 × 120 × 306	28740	131350	4.57	4.75	48.47
0.0	02	5 Oct	239 × 120 × 304	28680	148010	5.16	5.37	54.73
0.0	03	5 Oct	239 × 120 × 305	28740	137000	4.77	4.96	50.55
0.0	04	19 Oct	240 × 120 × 306	28800	179690	6.24	6.49	66.17
0.0	05	19 Oct	239 × 120 × 304	28680	164720	5.74	5.97	60.91
0.0	06	19 Oct	239 × 120 × 305	28740	167205	5.82	6.05	61.70
2.5	01	5 Oct	240 × 120 × 303	28800	150120	5.21	5.42	55.28
2.5	02	5 Oct	239 × 120 × 304	28740	187170	6.51	6.77	69.07
2.5	03	5 Oct	240 × 120 × 303	28800	163645	5.68	5.91	60.26
2.5	04	19 Oct	239 × 120 × 306	28680	223650	7.80	8.11	82.70
2.5	05	19 Oct	240 × 120 × 301	28800	233890	8.12	8.45	86.13
2.5	06	19 Oct	239 × 120 × 303	28770	223770	7.78	8.09	82.49
5.0	01	5 Oct	240 × 121 × 302	28920	157710	5.45	5.67	57.83
5.0	02	5 Oct	244 × 121 × 293	29463	128580	4.36	4.54	46.28
5.0	03	5 Oct	244 × 121 × 297	29493	148145	5.02	5.22	53.27
5.0	04	19 Oct	245 × 121 × 301	29462	190580	6.47	6.73	68.60
5.0	05	19 Oct	240 × 121 × 301	28980	167870	5.79	6.02	61.43
5.0	06	19 Oct	242 × 121 × 301	29252	184225	6.30	6.55	66.79
7.5	01	5 Oct	240 × 121 × 302	28920	128780	4.45	4.63	47.22
7.5	02	5 Oct	239 × 121 × 302	28889	110050	3.81	3.96	40.40
7.5	03	5 Oct	240 × 121 × 302	28950	115415	3.99	4.15	42.28
7.5	04	19 Oct	244 × 121 × 307	29342	152080	5.18	5.39	54.97
7.5	05	19 Oct	238 × 121 × 305	28678	155350	5.42	5.63	57.45
7.5	06	19 Oct	242 × 121 × 306	29191	150715	5.16	5.37	54.75

Laboratory sheets 24–27 give the test dates, length (L), thickness (t), height (h), loaded area and strengths. The correction factor is 1.04 for the nominal height-to-thickness ratio of 2.5. Measured ratios range from 2.42 to 2.55. The 2025 thesis describes a nominal 28-day series (pp. 37 and 51, Table 10). The sheets give two test dates and omit construction dates. Individual curing ages are therefore undetermined. Table S16 summarises each date separately.

Table S5. Individual diagonal shear strength records under diagonal loading.

WTCB (%)	ID	Age (days)	L × h × t (mm)	Gross area (mm²)	Failure load (N)	Shear stress (MPa)	Shear stress (kgf cm⁻²)
0.0	01	14	605 × 634 × 122	75579	91174	0.85	8.70
0.0	02	14	639 × 632 × 120	76230	95049	0.88	8.99
0.0	03	14	621 × 617 × 122	75518	80746	0.76	7.71
0.0	04	28	628 × 640 × 121	76684	98326	0.91	9.24
0.0	05	28	639 × 632 × 120	76230	98394	0.91	9.31
0.0	06	28	621 × 637 × 125	78468	98502	0.89	9.05
2.5	01	14	632 × 635 × 122	77287	79991	0.73	7.46
2.5	02	14	640 × 638 × 121	77289	89163	0.82	8.32
2.5	03	14	621 × 617 × 122	75518	81864	0.77	7.82
2.5	04	28	628 × 640 × 121	76684	103368	0.95	9.72
2.5	05	28	634 × 635 × 120	75793	100602	0.94	9.57
2.5	06	28	621 × 637 × 125	78468	101887	0.92	9.36
5.0	01	14	626 × 638 × 122	77043	64775	0.59	6.06
5.0	02	14	625 × 638 × 121	76412	72535	0.67	6.84
5.0	03	14	624 × 628 × 122	76357	72604	0.67	6.85
5.0	04	28	636 × 622 × 121	76079	93058	0.86	8.82
5.0	05	28	635 × 628 × 120	75479	88506	0.83	8.45
5.0	06	28	628 × 633 × 125	78639	90419	0.81	8.29
7.5	01	14	634 × 629 × 122	77013	68621	0.63	6.42
7.5	02	14	629 × 638 × 121	76593	64471	0.60	6.07
7.5	03	14	627 × 638 × 121	76675	65565	0.60	6.16
7.5	04	28	625 × 637 × 122	76636	84994	0.78	8.00
7.5	05	28	637 × 625 × 120	75878	79785	0.74	7.58
7.5	06	28	633 × 629 × 124	78340	81408	0.73	7.49

Laboratory sheets 20–23 give the length (L), height (h), thickness (t), individual gross cross-sectional area (A) and diagonal failure load (P). Nominal diagonal shear stress v = 0.707P/A. Sheet 23 repeats the 5.0% heading from sheet 22. Table 11 of the 2025 thesis (p. 53) identifies all six matching specimen numbers, ages, loads and strengths as the 7.5% series.

Table S6. Individual unit–mortar bond strength records.

WTCB (%)	Specimen ID	Age (days)	Failure load (N)	Contact area (m^2)	Bond stress ($N\ m^{-2}$)	Bond stress ($kgf\ cm^{-2}$)
0.0	01	14	2625	0.015	177838	1.81
0.0	02	14	2156	0.014	149688	1.53
0.0	03	14	2273	0.016	146083	1.49
0.0	04	28	3551	0.015	240549	2.45
0.0	05	28	2856	0.014	198312	2.02
0.0	06	28	3105	0.016	199600	2.04
2.5	01	14	1147	0.015	76149	0.78
2.5	02	14	1182	0.016	75352	0.77
2.5	03	14	1121	0.015	74102	0.76
2.5	04	28	1847	0.015	122555	1.25
2.5	05	28	1692	0.016	107868	1.10
2.5	06	28	1709	0.015	112995	1.15
5.0	01	14	1639	0.016	104903	1.07
5.0	02	14	1536	0.016	97926	1.00
5.0	03	14	1613	0.015	104495	1.07
5.0	04	28	2180	0.015	144683	1.48
5.0	05	28	2310	0.015	152716	1.56
5.0	06	28	1994	0.015	131779	1.34
7.5	01	14	1440	0.015	95544	0.97
7.5	02	14	1379	0.015	91137	0.93
7.5	03	14	1366	0.015	90320	0.92
7.5	04	28	2718	0.015	181151	1.85
7.5	05	28	2551	0.015	167238	1.71
7.5	06	28	2733	0.015	177055	1.81

Laboratory sheets 28–31 give the failure load, contact area and bond stress. The sheets print contact areas to 0.001 m^2. The reported stresses retain the original precision. For control specimen 01, 177838 $N\ m^{-2}$ equals 0.177838 MPa or 1.81 $kgf\ cm^{-2}$ after rounding.

Table S7. Specimen-level analysis of variance for mechanical outcomes.

Outcome	Source of variation	df	Sum of squares (MPa^2)	Mean square (MPa^2)	F	p
Compression	WTCB level	3	2.328434	0.776145	1.371	0.275405
Compression	Curing age	2	93.827552	46.913776	82.891	1.673×10^{-11}
Compression	Level × age	6	8.048282	1.341380	2.370	0.061119
Compression	Residual	24	13.583238	0.565968		
Direct tension	WTCB level	3	0.754986	0.251662	33.212	1.045×10^{-8}
Direct tension	Curing age	2	3.282496	1.641248	216.596	4.379×10^{-16}
Direct tension	Level × age	6	0.390904	0.065151	8.598	4.779×10^{-5}
Direct tension	Residual	24	0.181859	0.007577		
Flexure	WTCB level	3	2.694118	0.898039	6.023	0.003292
Flexure	Curing age	2	69.583965	34.791982	233.346	1.874×10^{-16}
Flexure	Level × age	6	5.959094	0.993182	6.661	0.000303
Flexure	Residual	24	3.578417	0.149101		
Prism compression (pooled)	WTCB level	3	16.089341	5.363114	6.545	0.002911
Prism compression (pooled)	Residual	20	16.388248	0.819412		
Diagonal shear	WTCB level	3	0.143803	0.047934	37.119	1.953×10^{-7}
Diagonal shear	Curing age	1	0.122437	0.122437	94.812	3.974×10^{-8}
Diagonal shear	Level × age	3	0.011616	0.003872	2.998	0.061627
Diagonal shear	Residual	16	0.020662	0.001291		
Unit–mortar bond	WTCB level	3	0.025699	0.008566	61.875	5.061×10^{-9}
Unit–mortar bond	Curing age	1	0.017774	0.017774	128.381	4.705×10^{-9}
Unit–mortar bond	Level × age	3	0.001907	0.000636	4.591	0.016760
Unit–mortar bond	Residual	16	0.002215	0.000138		

The mortar tests used four dosages and three ages. Diagonal shear and bond used four dosages and two ages. Each dosage–age cell contained three specimens. The one-way prism model pools six specimens per dosage across both test dates. F and p use within-batch specimen variation. df denotes degrees of freedom.

Table S8. Verification of 5.0% WTCB compressive strengths at 28 days using recorded loads and measured loaded areas.

Original specimen	Load (N)	Measured area (mm^2)	Load/area (MPa)	Recorded stress (MPa)
07	24050	1829	13.14926	13.15
08	24820	1807	13.73547	13.74
09	24090	1825	13.20000	13.20

Laboratory sheet 14, specimens 07–09 (Table S1). The strength equals the failure load divided by the individual recorded area. The sheet does not give separate side lengths for these specimens. Statistical summaries use individual recorded kgf cm^{-2} values converted to MPa.

Table S9. Differences from the control for 28-day tests and the pooled prism series, with conditional 95% confidence intervals.

Outcome	WTCB (%)	n per group	Mean difference (MPa)	95% confidence interval (MPa)	Change (%)
Compression	2.5	3	-0.169	-3.130 to +2.791	-1.34
Compression	5.0	3	+0.763	-2.613 to +4.138	+6.05
Compression	7.5	3	-0.307	-3.298 to +2.685	-2.43
Direct tension	2.5	3	+0.025	-0.436 to +0.486	+1.56
Direct tension	5.0	3	-0.139	-0.630 to +0.353	-8.72
Direct tension	7.5	3	+0.445	+0.030 to +0.860	+27.94
Flexure	2.5	3	-0.532	-1.607 to +0.544	-7.46
Flexure	5.0	3	-0.191	-1.275 to +0.894	-2.67
Flexure	7.5	3	-0.405	-1.600 to +0.790	-5.68
Prism compression (pooled)	2.5	6	+1.527	+0.153 to +2.900	+27.27
Prism compression (pooled)	5.0	6	+0.191	-0.788 to +1.169	+3.41
Prism compression (pooled)	7.5	6	-0.743	-1.637 to +0.151	-13.27
Diagonal shear	2.5	3	+0.034	-0.002 to +0.071	+3.80
Diagonal shear	5.0	3	-0.067	-0.122 to -0.011	-7.39
Diagonal shear	7.5	3	-0.148	-0.204 to -0.093	-16.41
Unit–mortar bond	2.5	3	-0.098	-0.152 to -0.045	-46.24
Unit–mortar bond	5.0	3	-0.070	-0.120 to -0.020	-32.72
Unit–mortar bond	7.5	3	-0.037	-0.091 to +0.016	-17.51

Mean difference equals the WTCB group mean minus the control mean. Welch–Satterthwaite intervals use the two group variances without adjustment for multiple comparisons. For prisms, each group pools six specimens across both test dates. The other five outcomes compare three specimens per group at 28 days. All intervals describe variation within the tested batches.

Table S10. Complete WTCB ICP-OES screening results and method quantification limits.

Analyte	Concentration (mg kg^{-1})	Method quantification limit (mg kg^{-1})
Silver (Ag)	<0.67	0.67
Aluminium (Al)	626.77	6.67
Arsenic (As)	<2.67	2.67
Boron (B)	12.52	10.00
Barium (Ba)	16.53	0.33
Beryllium (Be)	<0.10	0.10
Bismuth (Bi)	<0.10	0.10
Calcium (Ca)	17849.94	3.33
Cadmium (Cd)	<0.33	0.33
Cerium (Ce)	<6.67	6.67
Cobalt (Co)	110.84	0.67
Chromium (Cr)	2.33	1.33
Copper (Cu)	230.45	1.00
Iron (Fe)	3246.03	10.00
Mercury (Hg)	<0.50	0.50
Potassium (K)	857.01	100.00
Lithium (Li)	1.60	0.33
Magnesium (Mg)	722.49	6.67
Manganese (Mn)	28.10	0.33
Molybdenum (Mo)	<1.33	1.33
Sodium (Na)	870.52	10.00
Nickel (Ni)	<1.67	1.67
Phosphorus (P)	1074.66	20.00
Lead (Pb)	72.38	3.33
Antimony (Sb)	13.44	2.67
Selenium (Se)	<6.67	6.67
Silica (SiO_2)	1045.67	0.50
Tin (Sn)	3.35	2.33
Strontium (Sr)	15.61	0.10
Titanium (Ti)	10.19	6.67
Thallium (Tl)	<0.33	0.33
Uranium (U)	<0.33	0.33
Vanadium (V)	1.54	1.00
Zinc (Zn)	25788.97	0.67
Sulphur (S)	20447.43	0.10

Source: SLab, Sistema de Servicios y Análisis Químicos S.A.C., report IE-2024-1198-02, sample S-2340, issued 18 June 2024. Analyte names, concentrations and method quantification limits retain the laboratory reporting basis. The less-than sign denotes a result below the method quantification limit. Silica is reported as SiO_2. Elemental composition appears separately in Table 7 of the manuscript.

Table S11. Fine-aggregate particle-size distribution.

Sieve opening (mm)	Passing (%)
9.520	100.0
4.750	100.0
2.360	99.6
1.180	84.3
0.600	47.2
0.300	11.8
0.150	9.7

Source: original fine-aggregate test sheet, NTP 400.012. Aggregate source: Pátapo–La Victoria quarry. Fineness modulus: 2.47.

Table S12. Four directional flow readings and recalculated spread and flow.

WTCB (%)	D_1 (mm)	D_2 (mm)	D_3 (mm)	D_4 (mm)	Mean D (mm)	Flow (%)
0.0	208	210	209	210	209.250	113.06
2.5	210	201	215	203	207.250	111.03
5.0	200	202	210	202.1	203.525	107.23
7.5	200	204	205	200	202.250	105.94

Laboratory sheet 11, NTP 334.057, 7 October 2024. D_0 = 98.21 mm is the initial mould diameter. Each spread has four readings in different directions. Flow (%) = $100 \times (D - D_0)/D_0$. At 5.0% WTCB the four readings give a mean of 203.525 mm and a flow of 107.23%.

Table S13. Original flexural-test geometry and recalculated central three-point bending strengths.

WTCB (%)	Age (days)	Specimen ID	P (N)	L (mm)	b (mm)	h (mm)	Central-load strength (MPa)
0.0	7	01	1028.72	130	42.82	41.65	2.70057
0.0	7	02	1134.63	130	41.70	40.70	3.20305
0.0	7	03	1243.48	130	40.20	41.30	3.53629
0.0	14	04	2094.70	130	37.48	40.45	6.66070
0.0	14	05	2095.68	130	35.94	40.13	7.06063
0.0	14	06	1915.24	130	36.48	40.85	6.13506
0.0	28	07	2257.49	130	39.73	40.94	6.61068
0.0	28	08	2503.64	130	39.80	40.02	7.65895
0.0	28	09	2338.89	130	39.78	40.11	7.12647
2.5	7	01	1158.17	130	41.20	39.96	3.43288
2.5	7	02	1298.40	130	42.50	41.60	3.44245
2.5	7	03	1388.62	130	40.80	40.30	4.08646
2.5	14	04	1460.21	130	38.89	39.91	4.59673
2.5	14	05	1402.35	130	38.46	38.72	4.74254
2.5	14	06	1444.52	130	33.86	40.10	5.17348
2.5	28	07	2321.23	130	39.90	40.34	6.97121
2.5	28	08	2257.49	130	40.10	40.79	6.59794
2.5	28	09	2120.20	130	39.76	40.85	6.23133
5.0	7	01	990.47	130	40.20	41.60	2.77628
5.0	7	02	1057.16	130	41.20	41.80	2.86369
5.0	7	03	1167.97	130	41.80	41.40	3.17899
5.0	14	04	1850.02	130	37.63	39.37	6.18509
5.0	14	05	1486.69	130	34.86	39.28	5.38995
5.0	14	06	1439.62	130	33.84	39.62	5.28473
5.0	28	07	2462.45	130	40.05	40.70	7.23787
5.0	28	08	2236.90	130	39.25	40.70	6.70892
5.0	28	09	2242.78	130	39.25	40.25	6.87780
7.5	7	01	1625.94	130	41.30	41.80	4.39376
7.5	7	02	1507.28	130	41.80	41.60	4.06318
7.5	7	03	1620.06	130	41.30	41.60	4.42007
7.5	14	04	1700.47	130	37.77	39.23	5.70453
7.5	14	05	1794.62	130	38.69	39.49	5.80008
7.5	14	06	1935.83	130	39.80	39.06	6.21662
7.5	28	07	2122.16	130	39.52	40.80	6.29036
7.5	28	08	2144.71	130	39.27	40.25	6.57371
7.5	28	09	2557.57	130	41.25	40.65	7.31673

Laboratory sheets 16–19. The central three-point bending strength is $3PL/(2bh^2)$, where P is the failure load, L the support span, b the measured width and h the measured height. Group means use the unrounded strengths. Table S3 also lists the stresses printed on the sheets.

Table S14. Sand bulk density and moisture, and WTCB and blended-powder densities.

Material	Property or condition	Measured value	Unit	Lab sheet
Sand	Bulk density, loose, moist	1503.35	kg m^{-3}	1
Sand	Bulk density, loose, dry	1495.83	kg m^{-3}	1
Sand	Bulk density, compacted, moist	1665.62	kg m^{-3}	1
Sand	Bulk density, compacted, dry	1657.28	kg m^{-3}	1
Sand	Moisture content	0.50	%	1
WTCB powder	Powder density	2.088	g cm^{-3}	2
Cement + 2.5% WTCB	Powder density	2.053	g cm^{-3}	3
Cement + 5.0% WTCB	Powder density	2.035	g cm^{-3}	4
Cement + 7.5% WTCB	Powder density	2.022	g cm^{-3}	5

Sand from the Pátapo–La Victoria quarry. The investigators determined bulk density under NTP 400.017:2011 (reviewed in 2016) and moisture under NTP 339.185:2013. Powder densities were measured by kerosene displacement in a Le Chatelier flask at 20 °C under NTP 334.005:2011. Each powder sheet presents one result for the identified sample.

Table S15. WTCB water absorption from replicate mass measurements.

Specimen	Saturated surface-dry mass (g)	Oven-dry mass (g)	Absorption (%)
F-1	20.50	19.06	7.56
F-2	20.10	18.70	7.49

Laboratory sheet 10, 21–23 October 2024. The investigators adapted NTP 400.022 to the WTCB powder. Absorption (%) = 100 × (saturated surface-dry mass − oven-dry mass)/oven-dry mass. The mean of the two unrounded results is 7.52%.

Table S16. Masonry prism compressive strength by test date and WTCB replacement.

WTCB (%)	Test date (2024)	Specimen IDs	n	Mean corrected strength (MPa)	Sample SD (MPa)
0.0	5 Oct	01–03	3	5.026	0.313
0.0	19 Oct	04–06	3	6.171	0.278
2.5	5 Oct	01–03	3	6.035	0.685
2.5	19 Oct	04–06	3	8.215	0.200
5.0	5 Oct	01–03	3	5.145	0.570
5.0	19 Oct	04–06	3	6.434	0.366
7.5	5 Oct	01–03	3	4.246	0.345
7.5	19 Oct	04–06	3	5.465	0.147

Individual values come from Table S4. Each mean and sample standard deviation (SD) uses the three corrected strengths in kgf cm^{-2} multiplied by 0.0980665. The 2.5% group had the highest mean on each test date.

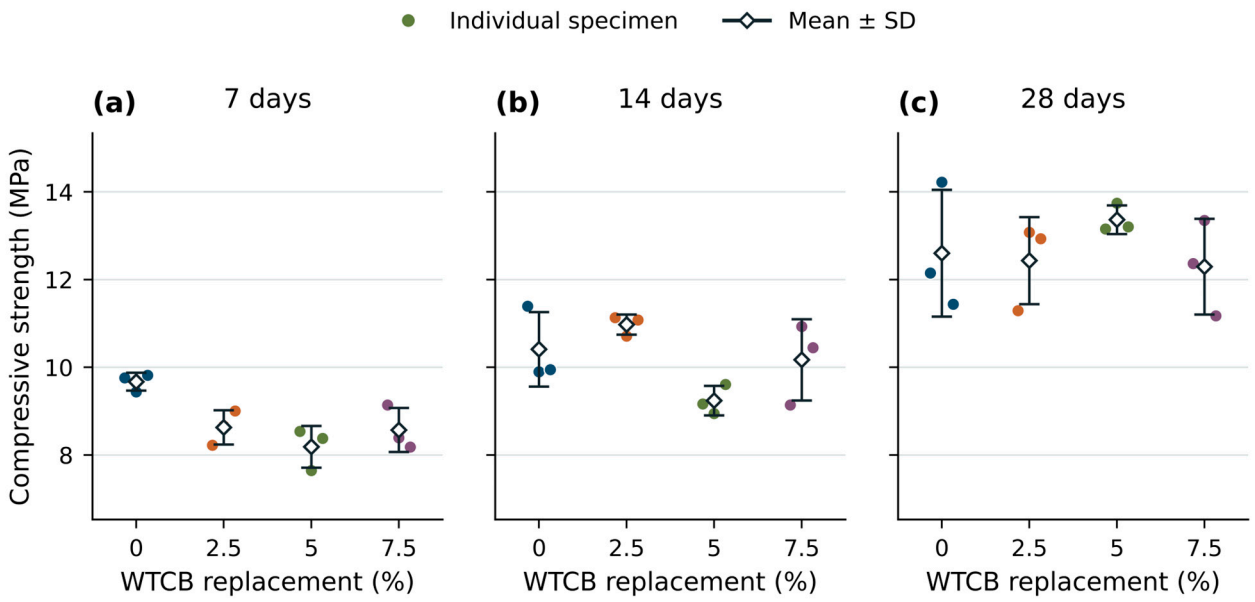


Figure S1. Distribution of mortar compressive strength by WTCB replacement level and curing age: (a) 7 days, (b) 14 days, (c) 28 days. Filled circles represent individual specimens. Open diamonds and error bars indicate the arithmetic mean and sample standard deviation, respectively (n = 3 per group).

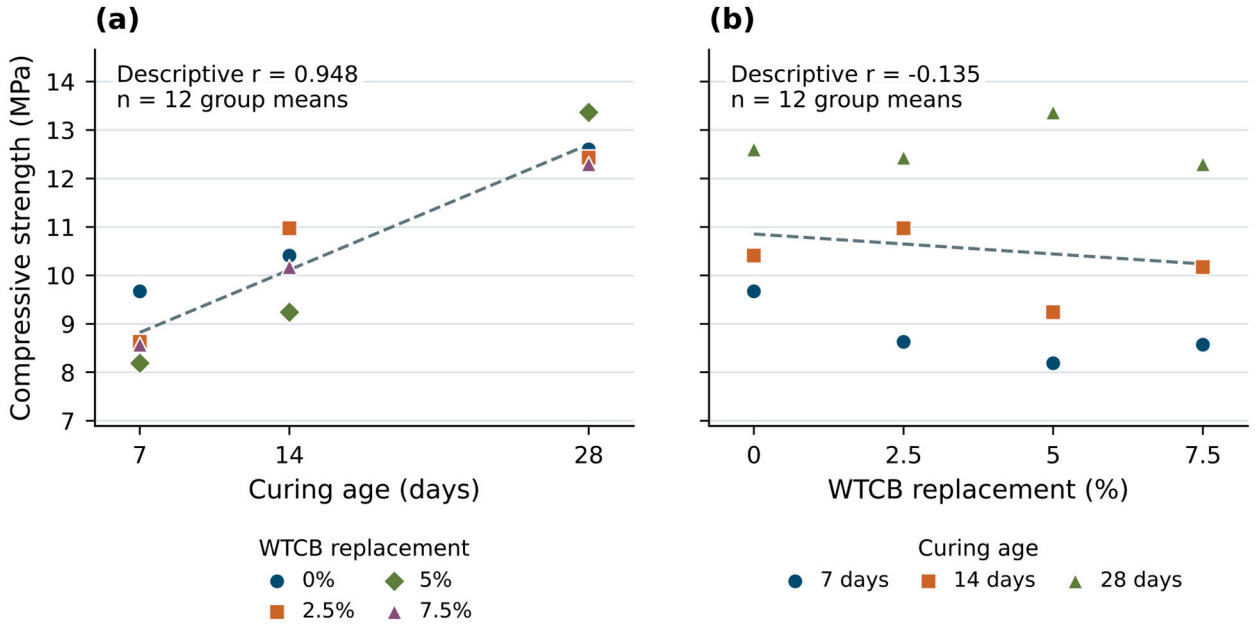


Figure S2. Descriptive associations of mortar compressive strength with (a) curing age and (b) WTCB cement replacement. Each point represents the mean of three specimens for one dosage–age combination (n = 12 group means). Dashed lines are pooled least-squares linear summaries. Pearson r is calculated from the plotted group means.

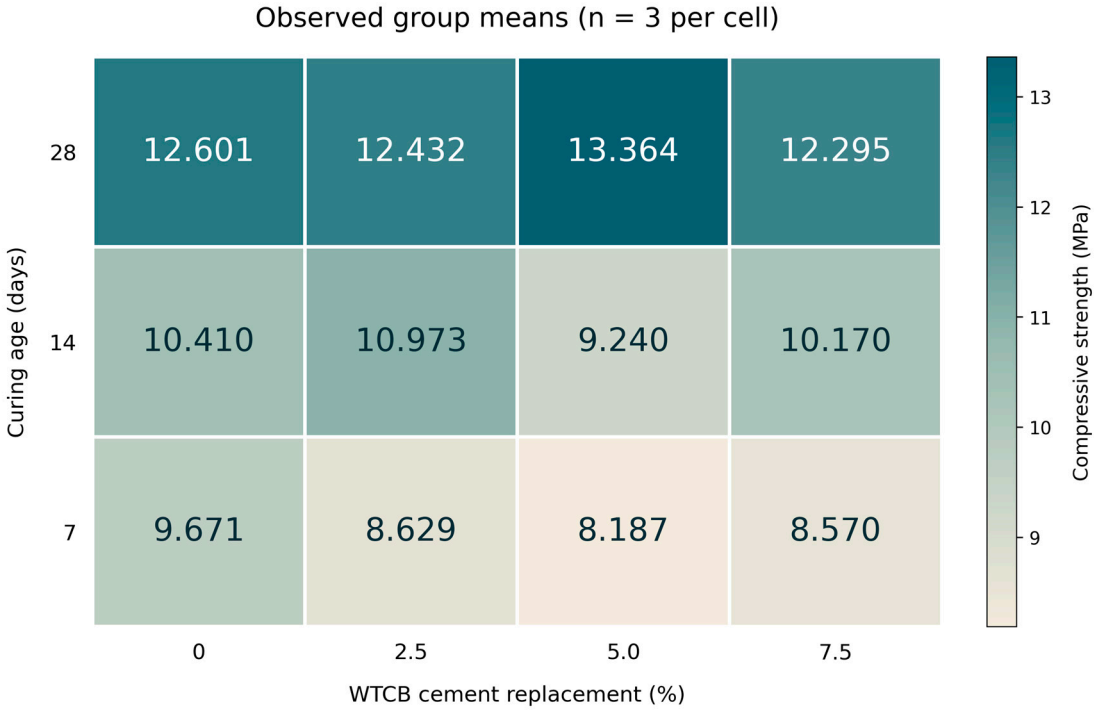


Figure S3. Observed mean mortar compressive strength at each tested WTCB replacement level and curing age. Cell colours and numeric labels show the arithmetic mean in MPa (n = 3 specimens per dosage–age cell).

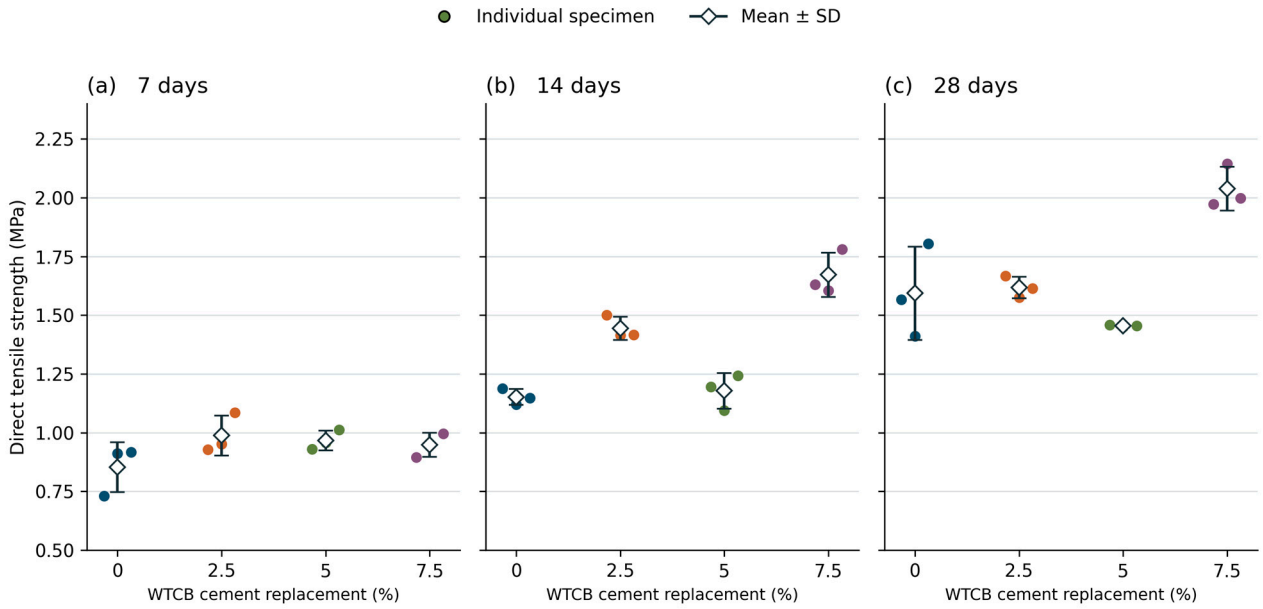


Figure S4. Distribution of mortar direct tensile strength by WTCB replacement level and curing age: (a) 7 days, (b) 14 days, (c) 28 days. Filled circles represent individual specimens. Open diamonds and error bars indicate the arithmetic mean and sample standard deviation, respectively (n = 3 per group).

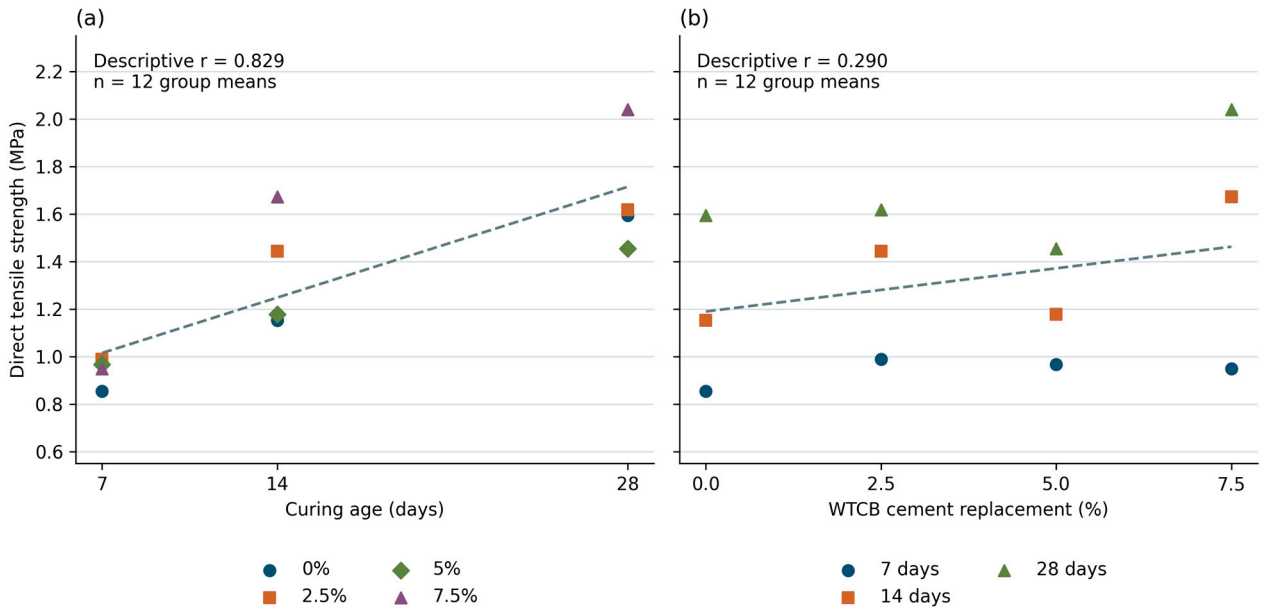


Figure S5. Descriptive associations of mortar direct tensile strength with (a) curing age and (b) WTCB cement replacement. Each point represents the mean of three specimens for one dosage–age combination (n = 12 group means). Dashed lines are pooled least-squares linear summaries. Pearson r is calculated from the plotted group means.

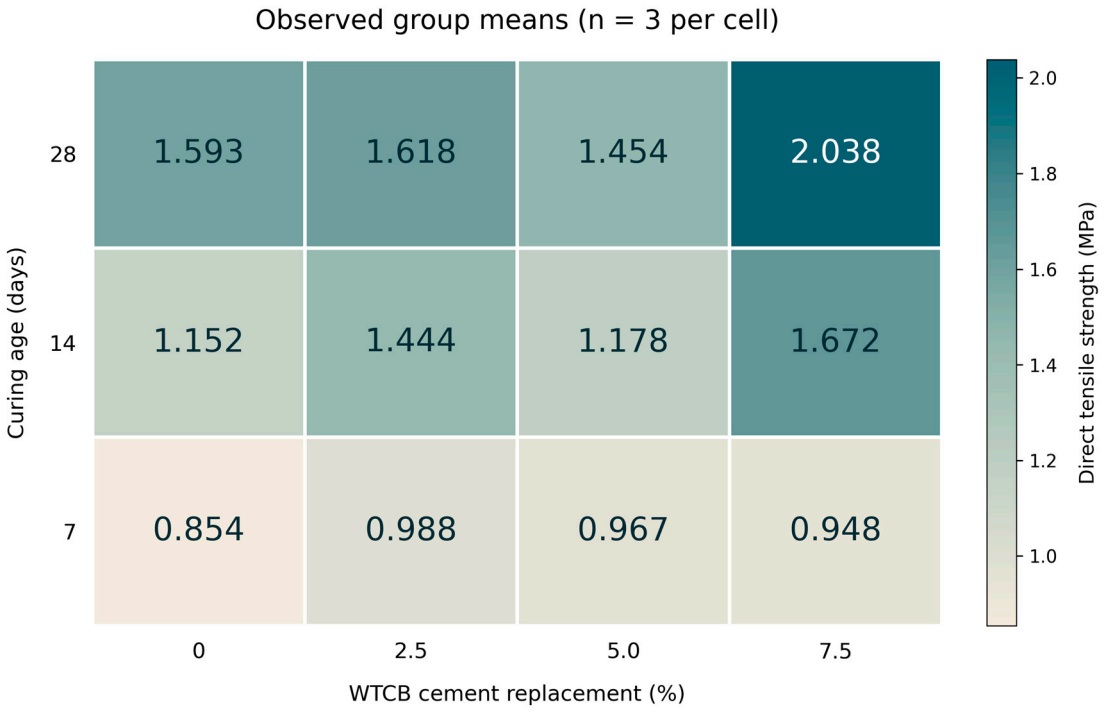


Figure S6. Observed mean mortar direct tensile strength at each tested WTCB replacement level and curing age. Cell colours and numeric labels show the arithmetic mean in MPa (n = 3 specimens per dosage–age cell).

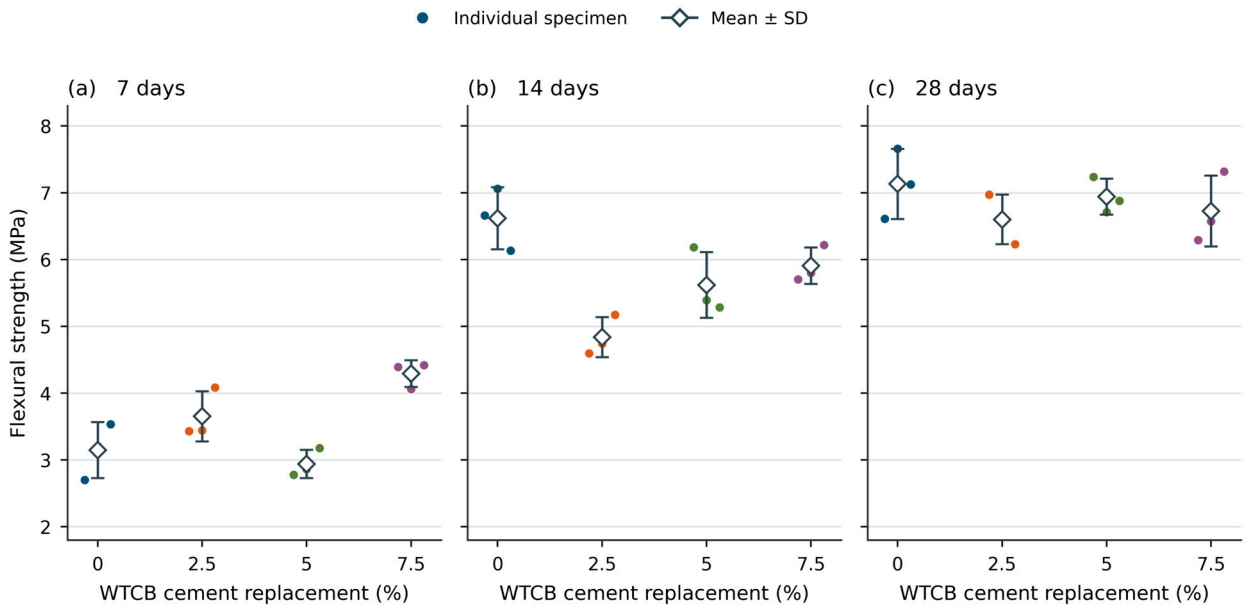


Figure S7. Distribution of recalculated mortar flexural strength by WTCB replacement level and curing age: (a) 7 days, (b) 14 days, (c) 28 days. Filled circles represent individual specimens. Open diamonds and error bars indicate the arithmetic mean and sample standard deviation, respectively (n = 3 per group). Strengths use the recorded geometry and central-load expression in Table S13.

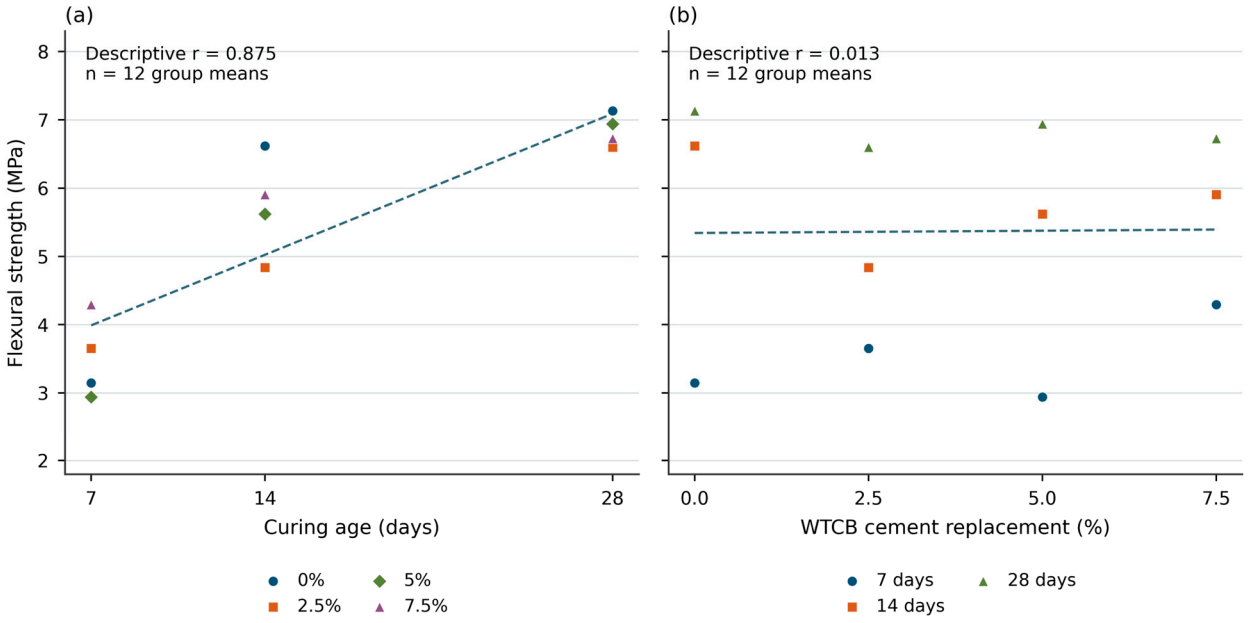


Figure S8. Descriptive associations of recalculated mortar flexural strength with (a) curing age and (b) WTCB cement replacement. Each point represents the mean of three specimens for one dosage–age combination (n = 12 group means). Dashed lines are pooled least-squares linear summaries. Pearson r is calculated from the plotted group means. Strengths use the recorded geometry and central-load expression in Table S13.

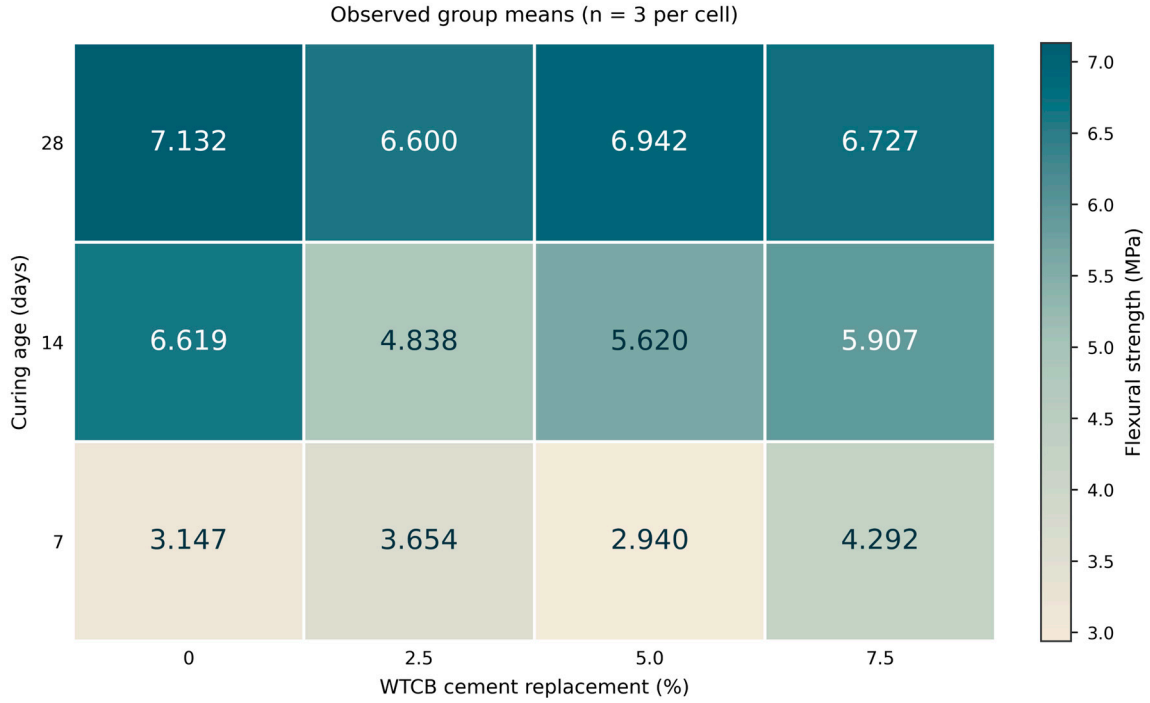


Figure S9. Observed mean recalculated mortar flexural strength at each tested WTCB replacement level and curing age. Cell colours and numeric labels show the arithmetic mean in MPa (n = 3 specimens per dosage–age cell). Strengths use the measured geometry and central-load expression in Table S13.

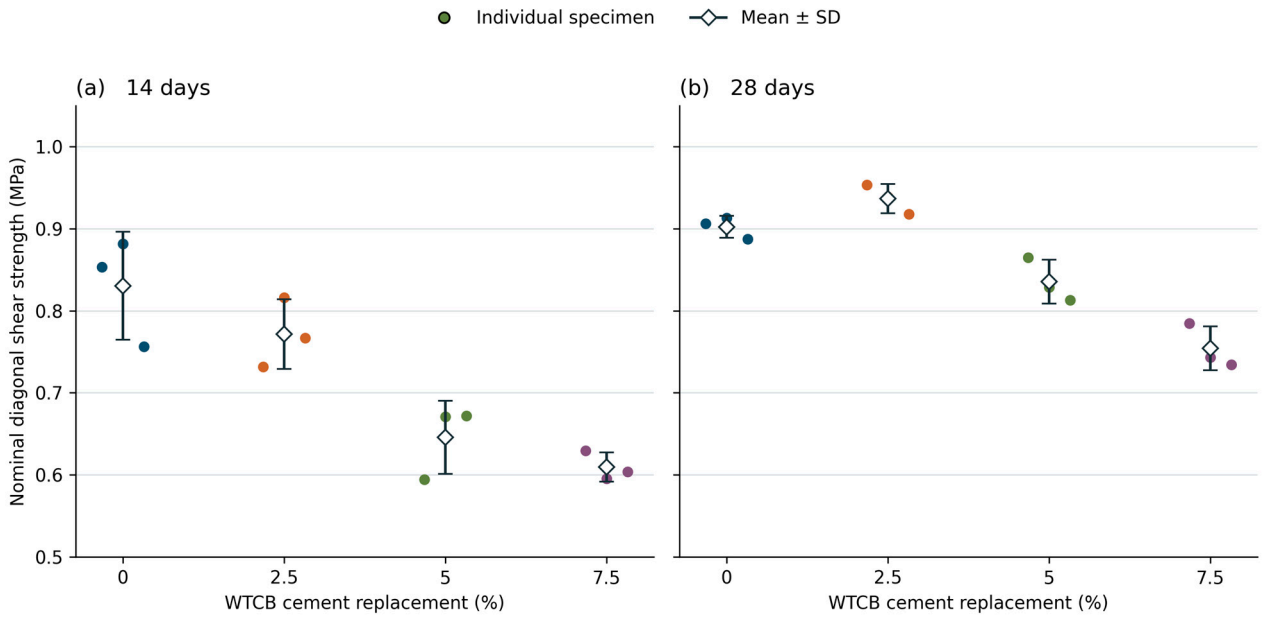


Figure S10. Distribution of masonry diagonal shear strength under diagonal loading by WTCB replacement level and curing age: (a) 14 days, (b) 28 days. Filled circles represent individual specimens. Open diamonds and error bars indicate the arithmetic mean and sample standard deviation, respectively (n = 3 per group).

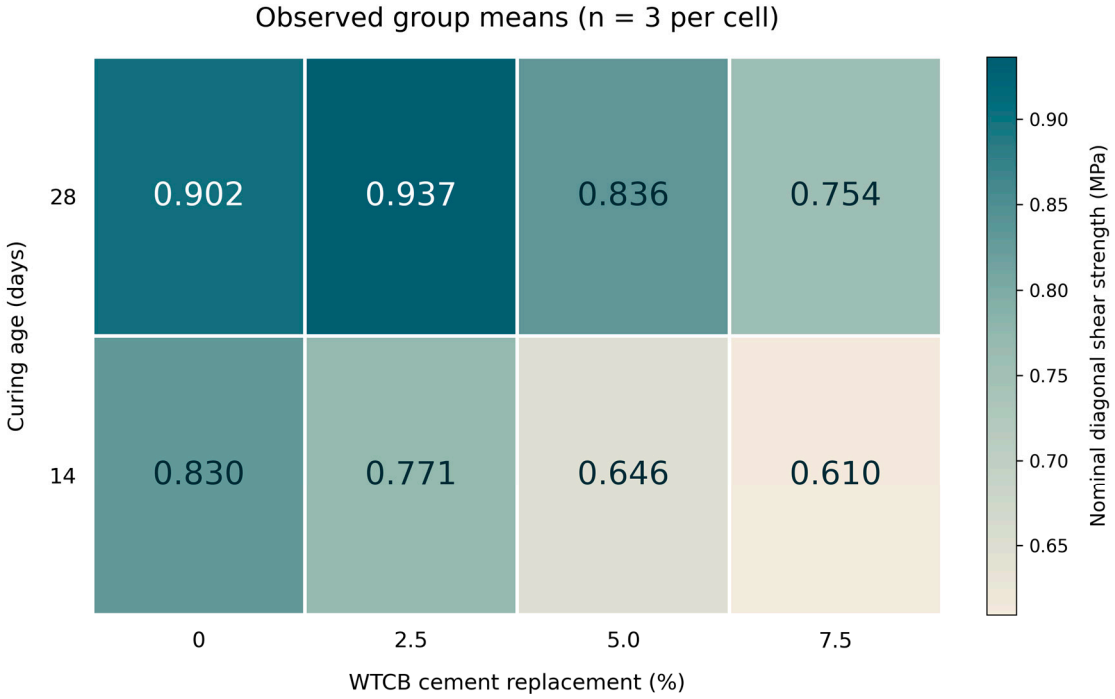


Figure S11. Observed mean nominal diagonal shear strength at each tested WTCB replacement level and curing age. Cell colours and numeric labels show the arithmetic mean in MPa (n = 3 specimens per dosage–age cell).

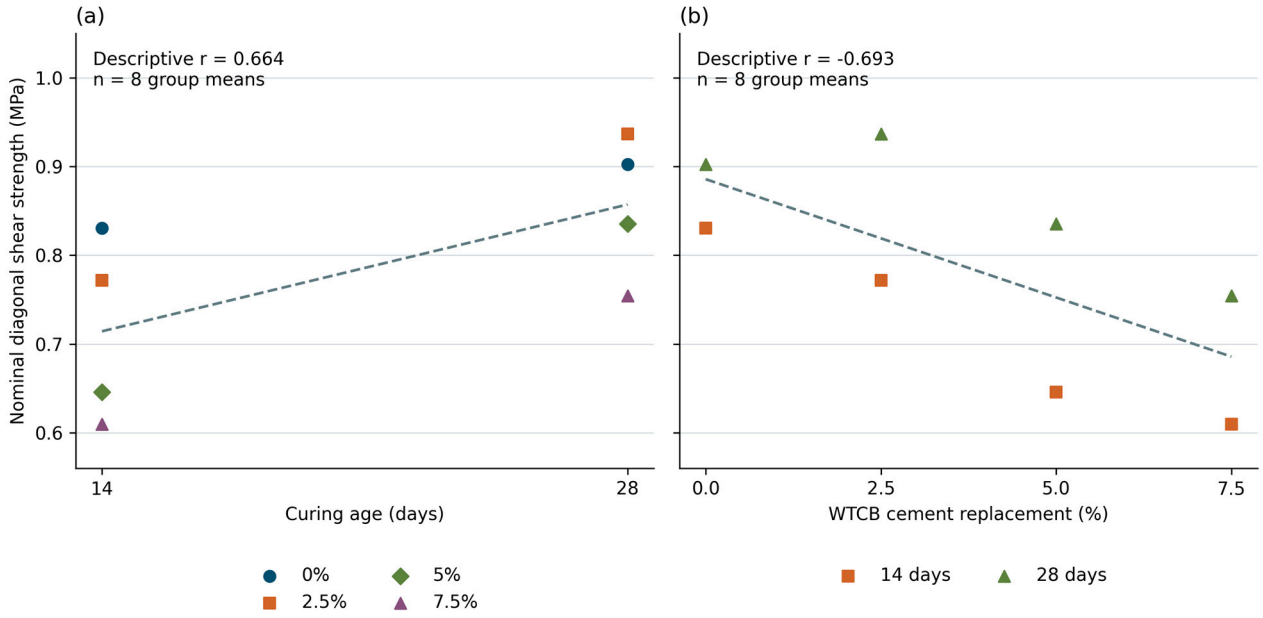


Figure S12. Descriptive associations of nominal diagonal shear strength under diagonal loading with (a) curing age and (b) WTCB cement replacement. Each point represents the mean of three specimens for one dosage–age combination (n = 8 group means). Dashed lines are pooled least-squares linear summaries. Pearson r is calculated from the plotted group means.

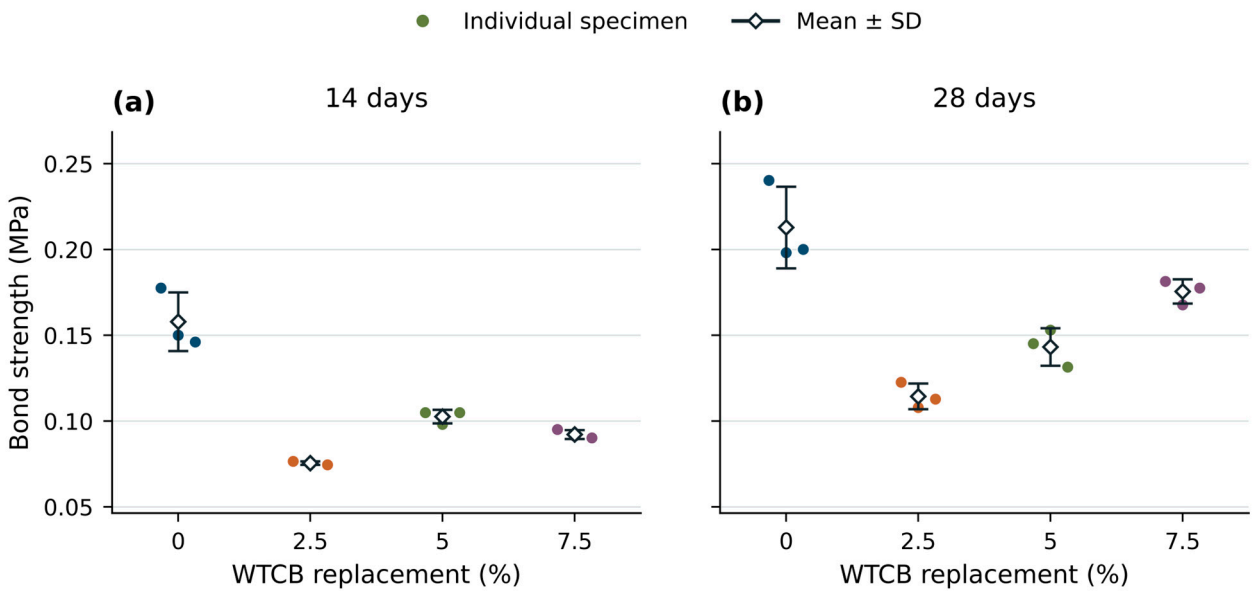


Figure S13. Distribution of mortar–unit bond strength by WTCB replacement level and curing age: (a) 14 days, (b) 28 days. Filled circles represent individual specimens. Open diamonds and error bars indicate the arithmetic mean and sample standard deviation, respectively (n = 3 per group).

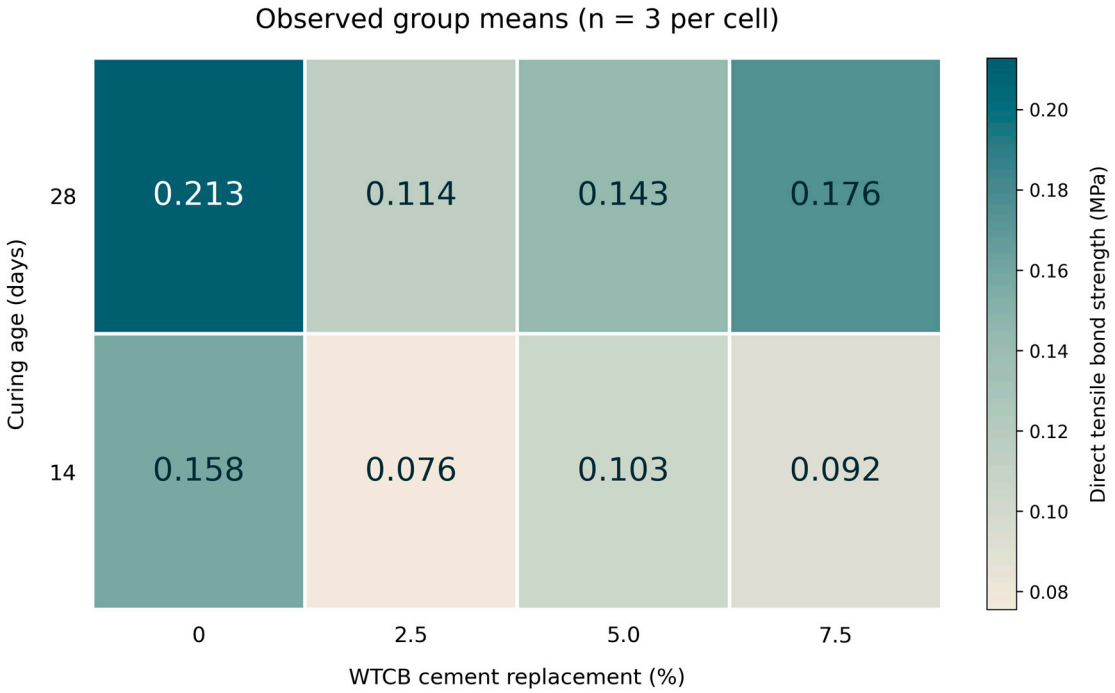


Figure S14. Observed mean mortar–unit direct tensile bond strength at each tested WTCB replacement level and curing age. Cell colours and numeric labels show the arithmetic mean in MPa (n = 3 specimens per dosage–age cell).

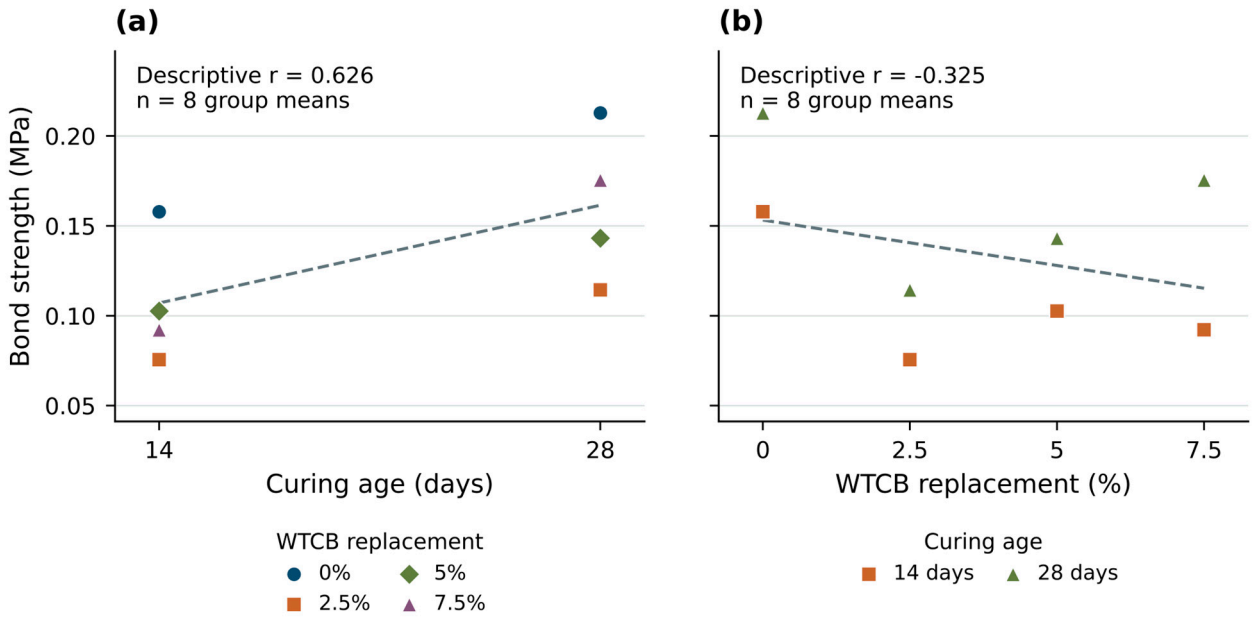


Figure S15. Descriptive associations of mortar–unit bond strength with (a) curing age and (b) WTCB cement replacement. Each point represents the mean of three specimens for one dosage–age combination (n = 8 group means). Dashed lines are pooled least-squares linear summaries. Pearson r is calculated from the plotted group means.