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Combined Effects of Recycled Coarse Aggregate and GGBS Contents on Concrete Workability and Compressive Strength

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Abstract

This study evaluates workability and compressive strength using experimental records for concrete containing recycled coarse aggregates (RCA) and ground granulated blast furnace slag (GGBS). The dataset contains 36 cube observations labelled 28 days and 27 observations labelled 56 days. A primary comparison uses nine series assigned nominal RCA levels of 0%, 50% and 90% and nominal GGBS treatments of 0%, 25% and 50%. Three additional 37% GGBS series are reported separately because their RCA assignments are inconsistent. Cube strengths were recalculated from recorded failure loads using the nominal 150 mm cube area, and means, sample standard deviations and coefficients of variation were determined without imputing missing results. At 28 days, the control mean was 40.14 MPa. The nominal 90% RCA series without GGBS attained 31.16 MPa, whereas the corresponding 50% GGBS treatment attained 39.93 MPa, a descriptive increase of 28.15% and 99.49% retention relative to the control. Slump ranged from 50.0 to 58.0 mm across the primary series. Recorded 56-day means did not increase uniformly, and one series exhibited 22.03% within-series variation. The findings identify a potentially useful high-RCA treatment but do not establish an optimum or an isolated causal GGBS effect. Interpretation remains conditional on verification of binder proportioning, water control, batch identity and age records. The analysis provides a transparent experimental baseline and preserves discrepancies rather than replacing them with assumed trends.

Keywords: recycled coarse aggregate; ground granulated blast furnace slag; concrete; compressive strength; slump; experimental data; variability.

1 Introduction

Reusing concrete as aggregate creates a material whose properties depend on both the original concrete and the production of the new mixture. Water demand, moisture condition and processing can change the comparison with natural aggregate concrete. Poon et al. [1] demonstrated the relevance of aggregate moisture state to slump and compressive strength. Etxeberria et al. [2] compared mixtures containing different recycled aggregate proportions while targeting comparable strengths. These studies show why aggregate percentage should be interpreted together with the mixture design and production controls.

GGBS introduces a further variable through the binder. Its contribution depends on reaction conditions and curing, rather than replacement percentage alone [3], [4]. In recycled aggregate concrete, a beneficial response relative to an RCA mixture without slag may still leave the mixture below a conventional natural aggregate reference. Kou et al. [5] reported that their high-GGBS mixture improved durability-related performance while reducing compressive strength. Consequently, strength retention, strength gain and other performance outcomes should be distinguished.

Experimental work has already established that RCA and GGBS can be incorporated together. Majhi et al. [6] investigated a matrix of aggregate and slag contents, and Majhi and Nayak [7] extended evaluation to bond and microstructural properties. Lin and Wu [8] examined high-volume slag in natural and recycled aggregate concrete and emphasised later-age development. The present

study therefore does not claim novelty in combining these materials. Its contribution is an explicit reconstruction of specimen-level strength and variability for the available experimental programme, with separate treatment of unresolved records.

The objectives are to determine load-derived strength statistics for the recorded series, compare nominal RCA and GGBS treatments against appropriate references, examine the available age-labelled observations, and identify the limits imposed by source-record inconsistencies. Slump is considered as a recorded consistency measure. No durability, structural member, environmental inventory or cost test is introduced. The study focuses on what the available experiments can establish descriptively and what must be verified before a reproducible material recommendation can be made.

2 Experimental records and analytical methods

2.1 Data provenance and scope

The analysis uses the experimental observations in Chapters 3–7 of the supplied unpublished thesis record [9]. Chapter 4 contains series A1–L1 under 28-day test observations and A2–L2 under 56-day observations. The numerical reconstruction retains the original A–L series identifiers. Thirty-six numerical observations are available at the first age, and 27 at the second age. The nine entries for J2–L2 are marked pending and are not treated as zero-strength observations. Recorded casting dates range from 17 to 27 January 2023; actual testing dates are not supplied in the observation tables.

The principal comparison is restricted to A–I, for which Table 5.1 assigns a consistent nominal 3 × 3 treatment grid. These series provide 27 observations at each age. Series J–L contain nine additional 28-day observations and no numerical 56-day observations. They are retained as supplementary series because their RCA assignments conflict between the summary table, listed aggregate masses and results narrative. All 63 numerical load observations are preserved in Appendix A. No specimen has been discarded as an outlier.

2.2 Materials as recorded

The materials chapter identifies the cement as ordinary Portland cement of 43 grade. It reports natural coarse aggregate, recycled coarse aggregate, fine aggregate and GGBS. The recycled material is described as originating from old concrete, but detailed parent-concrete strength, processing history and independent quality certification are unavailable. Selected physical properties are reproduced in Table 1 as reported values; they have not been independently remeasured. The aggregate fineness entries are omitted because the source labels the fineness modulus as a percentage.

Table 1 Selected material properties reported in the experimental record

Material	Specific gravity	Water absorption (%)	Other recorded property
OPC	3.150	Not stated	Standard consistency 28.0%; initial setting 35 min.
Natural coarse aggregate	2.510	0.140	Moisture content 0.050%.
Recycled coarse aggregate	2.630	2.180	Moisture content 0.320%.
Fine aggregate	2.830	0.400	Free surface moisture 0.280%.
GGBS	3.150	Not stated	Reported glass content 92%; fineness entry 2.0%.

The recycled aggregate specific gravity is reported as higher than that of the natural aggregate. This ordering is retained rather than corrected from expectation. The corresponding density basis and test sheets would be required to interpret it. Reported slag oxide values are not used to calculate a chemical reactivity index, and the study does not infer compliance from the material tables.

2.3 Treatment definitions and mixture uncertainty

Table 2 presents the nominal treatment labels. G denotes the source GGBS treatment percentage and R denotes the source recycled aggregate percentage. The labels identify reported groups; they do not certify an independently verified replacement fraction. The summary header states B = C + Ad, C = 300 kg, and Ad as a percentage of cement, while the surrounding narrative describes GGBS as cement replacement. Those descriptions are not mathematically equivalent. For example, adding GGBS at 50% of a fixed cement mass would give a slag fraction of 33.33% of the resulting binary binder; replacing 50% of total binder would give a 50% fraction.

The source also reports W/B = 0.40 in Table 5.1 but describes a water/cement ratio of 0.50 in the compression-test narrative. It does not provide a complete reconciled batch recipe with aggregate moisture corrections. The aggregate quantities vary between GGBS groups, so constant paste volume or constant aggregate volume cannot be assumed. Accordingly, treatment comparisons below are descriptive associations between recorded series, not controlled estimates of the independent chemical effect of GGBS. Absolute mixture quantities are not reconstructed by inventing unreported water or recycled aggregate masses.

Table 2 Nominal series assignments and available cube observations

Series	Nominal G (%)	Nominal R (%)	28-day n	56-day n	Slump (mm)
A	0	0	3	3	50.0
B	0	50	3	3	52.2
C	0	90	3	3	53.4
D	25	0	3	3	55.8
E	25	50	3	3	55.6
F	25	90	3	3	55.2
G	50	0	3	3	58.0
H	50	50	3	3	57.8
I	50	90	3	3	57.2
J	37	Unresolved	3	0	57.0
K	37	Unresolved	3	0	56.8

Series	Nominal G (%)	Nominal R (%)	28-day n	56-day n	Slump (mm)
L	37	Unresolved	3	0	56.2

A–I form the primary comparison. For J–L, the summary lists R = 0%, 50% and 90%, whereas the results text refers to 50%, 70% and 90%; the listed natural aggregate masses also suggest a different allocation. No assignment is selected without batch records. The G = 37% label is retained for these supplementary series, subject to the same binder-basis uncertainty as the primary series.

2.4 Specimen preparation and testing

The experimental record describes 150 × 150 × 150 mm compression cubes. Ingredients were weighed, dry-mixed and mixed with water before placement in lubricated moulds. The cube-casting procedure describes three layers with 25 tamping blows per layer and subsequent demoulding. Generic passages on cylinders and steel-fibre concrete are also present, but no fibre treatment is identified in the analysed A–L dataset. Therefore, neither cylinders nor fibre addition are included as experimental factors in this paper.

The source describes water or curing-chamber storage, but the methods refer to 7-, 14- and 28-day schedules and do not reconcile the 56-day observations. The present analysis uses the table age labels without claiming independent chronological verification. Slump values are recorded for each series, repeated beside individual cube entries. They are treated as one reported fresh-consistency value per series, not as three independent slump replicates. Test timing, slump retention, concrete temperature and admixture dosage cannot be recovered reliably from these observations.

2.5 Strength reconstruction and descriptive statistics

Strength was recalculated from failure load rather than copied from the summary. For nominal cube side a = 150 mm and recorded failure load P in kN, the nominal loaded area is 22,500 mm². The calculation is:

$$f = 1000P / a^2 = P / 22.5 \quad \text{MPa} \tag{1}$$

This convention assumes the nominal cube dimensions; measured dimensions are not available. It provides one consistent reconstruction of the recorded load data. Individual source stresses differ from these calculations by up to 0.199 MPa. Recalculation standardises the arithmetic but cannot verify machine calibration, the accuracy of a typed load or the actual specimen size.

$$\text{Mean strength} = \Sigma f_i / n \tag{2}$$

$$\text{Sample SD} = \sqrt{[\Sigma(f_i - \text{mean strength})^2 / (n - 1)]} \tag{3}$$

$$\text{CV} = 100 \times \text{sample SD} / \text{mean strength} \tag{4}$$

The standard deviation and coefficient of variation describe the three cubes within each series and age. Independent repeat batches are not documented, so no ANOVA, treatment p-value, characteristic-strength estimate or population confidence interval is reported. Cubes are not treated as independent production batches. The arithmetic mean of separate destructive tests at two ages is compared descriptively; specimens are not paired across ages.

$$\text{Change (\%)} = 100 \times (\text{comparison mean} / \text{reference mean} - 1) \tag{5}$$

Calculations use unrounded load-derived strengths, with presentation rounded to two decimals. At 28 days, comparisons are made both against A, the nominal G0R0 control, and against the series having the same nominal RCA content without GGBS. This separates retention relative to the conventional reference from change within an

RCA category. Missing results remain missing. No fitted curve is used to create a result at an untested proportion.

3 Results

3.1 Slump response

Slump ranged from 50.0 to 58.0 mm across A–I (Table 2 and Figure 1). At nominal G0, slump increased from 50.0 mm at R0 to 53.4 mm at R90. At G25, the recorded values decreased slightly from 55.8 to 55.2 mm as R increased. At G50, they decreased from 58.0 to 57.2 mm. Thus, the direction of the RCA-associated trend differed between the G0 group and the two slag-treated groups. At matched nominal RCA labels, higher G labels were accompanied by higher recorded slump.

These observations establish the recorded consistency pattern, not the cause of that pattern. With no independent slump repeats, the differences cannot be assigned a statistical uncertainty. No inference is made that differences as small as 0.2 mm would be resolved reliably by the test procedure. The reported decimal values are retained for traceability, while interpretation is restricted to the overall pattern. Available-water control, mixture yield and measurement time remain possible confounders.

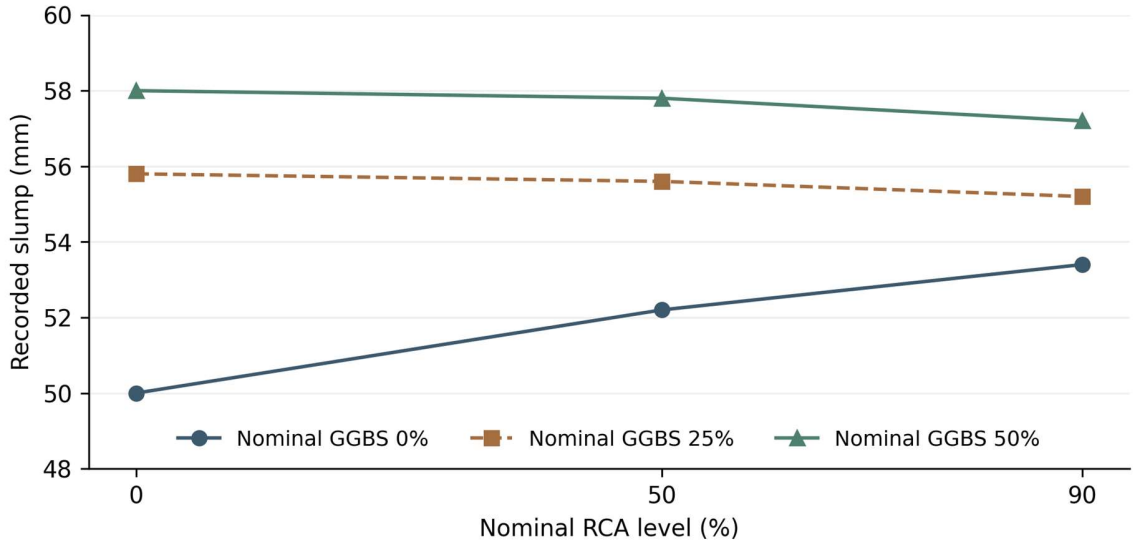


Figure 1 Recorded slump by nominal treatment in the primary A–I series. Each marker is one reported series value. Connecting lines guide comparison and do not constitute fitted models.

3.2 Strength and variability at 28 days

Table 3 Load-derived 28-day cube-strength statistics

Series	Mean (MPa)	SD (MPa)	CV (%)	Change from A (%)
A	40.14	1.65	4.11	+0.00
B	43.32	3.82	8.81	+7.94
C	31.16	3.66	11.76	-22.36
D	47.37	4.47	9.43	+18.03

Series	Mean (MPa)	SD (MPa)	CV (%)	Change from A (%)
E	38.26	5.45	14.24	-4.68
F	32.32	2.30	7.11	-19.48
G	49.28	0.89	1.80	+22.79
H	43.41	1.78	4.10	+8.16
I	39.93	3.77	9.45	-0.51

The control A had a mean of 40.14 MPa and a sample SD of 1.65 MPa. In the G0 group, B reached 43.32 MPa, 7.94% above A, whereas C reached 31.16 MPa, 22.36% below A. The results therefore do not support a monotonic decrease in strength with RCA across all recorded groups. They show an increase at the intermediate nominal RCA level followed by a reduction at the higher level in the G0 group.

Within G25, means decreased from 47.37 MPa at R0 to 38.26 MPa at R50 and 32.32 MPa at R90. Within G50, they decreased from 49.28 to 43.41 and 39.93 MPa. G had the largest 28-day mean in the primary grid, but its nominal RCA content was zero. It therefore cannot be selected as the preferred recycled aggregate mixture solely because its mean strength was highest.

At R50, G25 series E was 11.70% below the G0 series B, while G50 series H was only 0.20% above B. This latter difference is small relative to the observed specimen spread. At R90, F was 3.71% above C, and I was 28.15% above C. I retained 99.49% of A's mean at 28 days. These are differences between recorded means; they do not establish statistical equivalence, significance or a causal replacement effect.

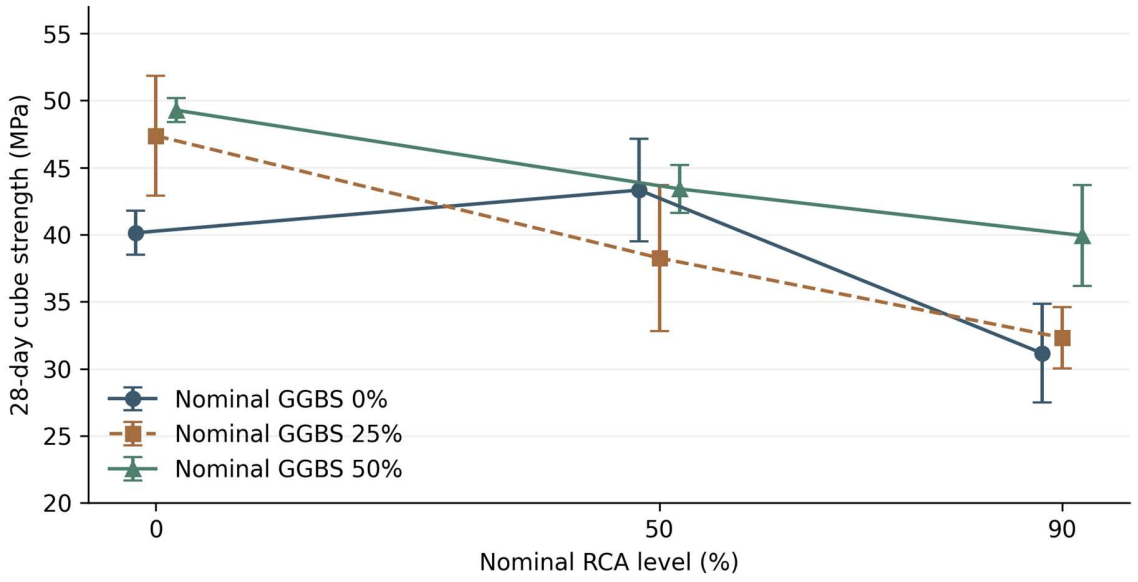


Figure 2 Mean 28-day load-derived cube strength for the primary series. Error bars show sample SD of three cubes, not confidence intervals or independent-batch variability. Nominal treatment labels are subject to the proportioning limitations in Section 2.3.

Within-series CV values at 28 days ranged from 1.80% for G to 14.24% for E. The three E loads correspond to approximately 42.84, 39.69 and 32.24 MPa. Retaining all three observations gives a lower mean and larger spread than would be obtained by removing the lowest cube. No documented basis for such removal is available. Variability is therefore part of the result rather than a reason to select a more favourable subset.

3.3 Available observations labelled 56 days

Table 4 Load-derived strength at the two recorded ages

Series	28-day mean	56-day mean	56-day SD	56-day CV (%)	Mean change (%)
A	40.14	41.96	6.38	15.21	+4.53
B	43.32	46.75	6.44	13.77	+7.91
C	31.16	34.21	2.93	8.57	+9.80
D	47.37	43.13	4.91	11.38	-8.95
E	38.26	42.01	1.37	3.27	+9.82
F	32.32	33.41	2.08	6.23	+3.36
G	49.28	38.77	3.26	8.41	-21.32
H	43.41	39.35	8.67	22.03	-9.35
I	39.93	43.65	5.84	13.38	+9.30

All strength quantities in Table 4 are in MPa except the percentage columns. Six of the nine series had higher means at the recorded later age, while D, G and H had lower means. The changes ranged from −21.32% for G to +9.82% for E. A increased from 40.14 to 41.96 MPa. I increased from 39.93 to 43.65 MPa, a change of 9.30%, and its later mean was 4.04% above the later control mean. These comparisons use different cubes and are not specimen-paired growth measurements.

G has three available later-age loads even though the source summary marks its 56-day result with a dash. Their reconstructed mean is 38.77 MPa. For H, the recorded loads 1008.4, 987.2 and 660.5 kN give 44.82, 43.88 and 29.36 MPa, with a mean of 39.35 MPa and CV of 22.03%. The summary value of 44.34 MPa is not reproduced by those loads. That discrepancy is not resolved by assuming that the lowest observation is erroneous.

The arithmetic mean of the nine series-specific age changes is +0.57%, not the approximately +6.7% stated in the source discussion. This average is reported only as a reconciliation check: it is neither a pooled hydration parameter nor a substitute for the separate series results. In particular, the decreases cannot be interpreted as verified material deterioration without checking age, curing, specimen condition and data-entry records.

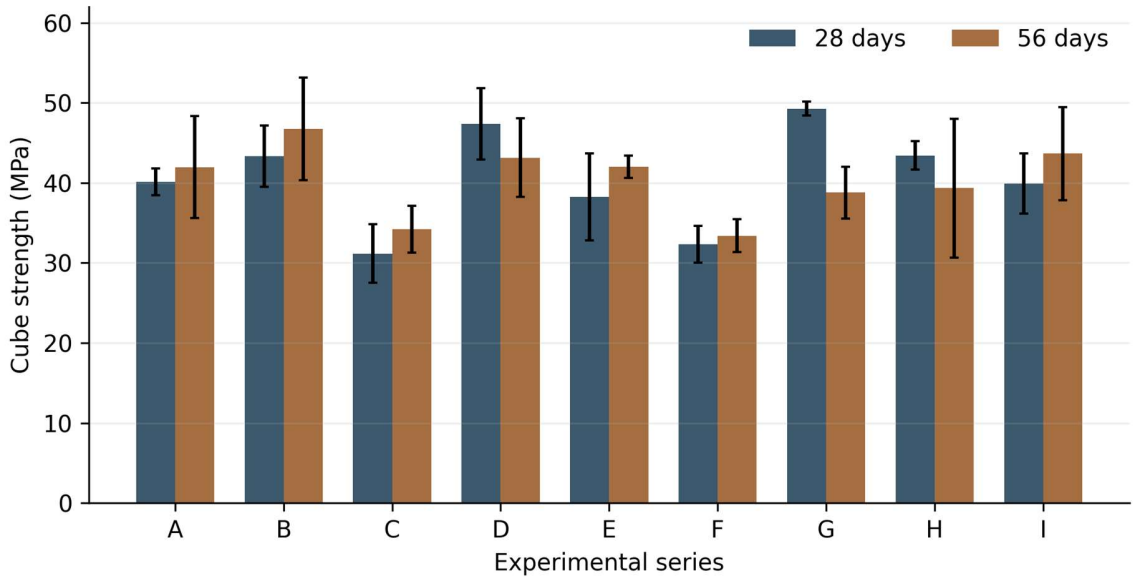


Figure 3 Strength means at the two recorded ages for A–I. Error bars indicate the sample SD of three distinct cubes at each age. Later-age decreases are retained as recorded outcomes pending laboratory-record verification.

3.4 Supplementary observations for the nominal 37% treatment

Table 5 Supplementary 28-day series with unresolved RCA assignments

Series	Nominal G (%)	Slump (mm)	Mean (MPa)	SD (MPa)	CV (%)
J	37	57.0	45.88	4.07	8.87
K	37	56.8	42.89	3.71	8.64
L	37	56.2	41.09	4.86	11.84

J, K and L had mean strengths of 45.88, 42.89 and 41.09 MPa, respectively. These outcomes can be reported by their original series identifiers. They cannot be placed confidently at 0%, 50% and 90%, or at 50%, 70% and 90% RCA without resolving the allocation conflict. There are no numerical later-age loads for these series. Consequently, the available records do not establish that a 37% GGBS treatment is optimal, and no interpolation around that percentage is presented.

4 Discussion

4.1 Practical interpretation of strength retention

The principal favourable observation is the near-control 28-day mean of I at the nominal high-RCA condition. It indicates a candidate treatment for confirmation because its mean substantially exceeds that of C. However, a candidate result and a validated formulation are different outcomes. The binder basis and available water are not resolved, so the difference cannot be attributed entirely to replacing cement with GGBS. The small difference between B and H also demonstrates why a higher nominal GGBS label does not produce the same apparent benefit at every RCA level.

The literature provides context without supplying missing experimental controls. Majhi et al. [6] found an acceptable combination within their own RCA–GGBS matrix; those proportions are not a calibration for the present dataset. Kou et al. [5]

and Lin and Wu [8] distinguish strength responses from other performance improvements and from later-age gain. Together, these studies support testing a material-specific response rather than importing a universal optimum. The present results remain a set of descriptive treatment comparisons.

4.2 Workability and water control

The higher slump in nominal slag-treated groups may be compatible with changes in the binder or paste system, but the measurements cannot isolate a mechanism. Poon et al. [1] showed that aggregate moisture condition affects consistency and its loss with time. In the current dataset, available-water corrections and slump measurement times are not established. An explanation based only on a lubricating effect of slag would therefore be incomplete. Confirmation tests should hold mixture yield and effective water ratio constant or state explicitly which adjustments are made to achieve a target consistency.

No inference about placement retention follows from the reported slump values. Similarly, the recorded 50–58 mm range does not by itself establish suitability for a structural element, reinforcement configuration or construction process. Those decisions require the intended application and its acceptance criteria. The present paper reports the laboratory consistency observations without assigning an untested use class.

4.3 Later-age behaviour and evidence limits

Slag reaction is sensitive to hydration conditions [3], [4], so later strength development is a plausible research expectation. It is not a rule that can overwrite the observed means. The G and H results require checking rather than chemical explanation by assertion. The recorded discrepancy for H is large enough to affect any conclusion about the G50 group. A traceable manuscript should retain this uncertainty until the original machine reports and specimen identifiers can determine whether the load records, age labels or summary are wrong.

Microstructural interpretation would also require independent evidence. Majhi and Nayak [7] included bond and microstructural investigation, whereas the current programme provides no matched microscopy or porosity dataset for the analysed cubes. The strength differences cannot therefore prove interfacial densification, increased hydration-product formation or a change in failure mechanism. Such mechanisms remain hypotheses for follow-up rather than measured outcomes of this experiment.

4.4 Implications for material selection and sustainability

A confirmation experiment should include conventional control, RCA-only, GGBS-only and combined treatments with a reconciled binder definition. Independent repeat batches would distinguish production variability from cube-to-cube scatter. Additional levels around a promising treatment could then support optimisation, provided the selected mixture is confirmed experimentally. No optimum is inferred here from three nominal GGBS levels or from the unresolved 37% series.

RCA utilisation offers a resource-recovery rationale, but environmental benefit is not measured in this dataset. Marinković et al. [10] showed that transport assumptions can influence comparisons of recycled and natural aggregate concrete. A local assessment would need the actual binder quantities, processing and transport, and an equal-performance reference. No carbon saving, cost reduction, durability enhancement or service-life extension is quantified here. Those outcomes cannot be obtained by relabelling a strength comparison as a sustainability assessment.

5 Limitations

The study is a secondary analysis of experimental thesis records rather than a new laboratory campaign. The original treatment assignment is incompletely documented, and the primary series are compared under nominal labels. The

replacement-versus-addition basis, full mix quantities, aggregate conditioning, chemical admixtures, independent batch identities, testing dates and exact later-age curing are unresolved. Nominal cube area is used because measured dimensions are unavailable. These gaps limit reproducibility and prevent a controlled causal estimate of either material's effect.

Three cubes per series and age provide only a small within-series sample. The study does not establish population-level equivalence, code compliance or structural suitability. Supplementary J–L observations cannot support RCA-factor comparisons. Missing 56-day entries are not imputed. The retained anomalous age comparisons and summary discrepancies should be resolved from source laboratory evidence before stronger conclusions are drawn.

6 Conclusions

For the primary nine nominal treatment series, the load-derived 28-day control mean was 40.14 MPa. At G0, the R50 mean exceeded the control, while the R90 mean was 22.36% lower. A universal monotonic RCA-related strength reduction is therefore not supported by these records.

The nominal G50R90 series attained 39.93 MPa at 28 days, 28.15% above the nominal G0R90 series and 99.49% of the control mean. This identifies a promising confirmation candidate; it does not demonstrate an isolated GGBS replacement effect or a validated optimum.

Recorded slump ranged from 50.0 to 58.0 mm in the primary grid. Slag-treated groups had higher recorded slump at matched nominal RCA labels, but measurement replication, available-water control and retention data are insufficient for causal or placement-performance claims.

The later-age observations did not improve uniformly. Three series had lower recorded means, and the H series had a CV of 22.03%. Recalculation does not support the source's blanket later-age improvement statement. These outcomes require laboratory-record verification rather than deletion or forced agreement with an expected hydration trend.

The 37% treatment series have unresolved RCA assignments and missing later-age data. They cannot establish a 37% optimum. A reproducible recommendation requires the original batch sheets, confirmed specimen identities and repeat production batches. The present contribution is the transparent numerical baseline and bounded interpretation of the available experiments.

Data availability

Recorded specimen loads and the corresponding derived values are provided in Appendix A. The experimental source is the unpublished thesis record identified in Reference [9]. No unrecorded cube result has been generated or imputed.

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Appendix A Specimen observations and reconstructed strength

Table A1 preserves all 63 numerical failure loads. Each row represents three cubes belonging to one source series and recorded age. Derived strengths use the same nominal 150 mm cube area as the main analysis. The absence of J–L at 56 days reflects missing numerical observations. Series J–L have unresolved RCA assignments.

Table A1 Recorded failure loads and recalculated cube strengths

Series	Age label (days)	Cube loads 1, 2, 3 (kN)	Derived strengths 1, 2, 3 (MPa)
A	28	925.9, 860.2, 923.1	41.15, 38.23, 41.03
A	56	821.6, 1102.0, 908.4	36.52, 48.98, 40.37
B	28	938.9, 912.7, 1072.8	41.73, 40.56, 47.68
B	56	1193.0, 1059.0, 903.6	53.02, 47.07, 40.16
C	28	655.0, 796.3, 652.1	29.11, 35.39, 28.98
C	56	799.8, 815.5, 694.2	35.55, 36.24, 30.85
D	28	1167.4, 966.3, 1063.9	51.88, 42.95, 47.28
D	56	850.8, 992.2, 1068.4	37.81, 44.10, 47.48
E	28	964.0, 893.0, 725.3	42.84, 39.69, 32.24
E	56	938.7, 979.0, 918.3	41.72, 43.51, 40.81
F	28	752.5, 667.7, 761.3	33.44, 29.68, 33.84
F	56	787.1, 698.6, 769.2	34.98, 31.05, 34.19
G	28	1128.8, 1088.9, 1108.8	50.17, 48.40, 49.28
G	56	938.1, 885.9, 793.3	41.69, 39.37, 35.26
H	28	933.9, 983.1, 1013.2	41.51, 43.69, 45.03
H	56	1008.4, 987.2, 660.5	44.82, 43.88, 29.36
I	28	982.4, 812.6, 900.5	43.66, 36.12, 40.02
I	56	1057.8, 1058.1, 830.4	47.01, 47.03, 36.91
J	28	968.7, 991.1, 1137.4	43.05, 44.05, 50.55
K	28	986.9, 872.9, 1035.4	43.86, 38.80, 46.02
L	28	799.7, 1003.7, 970.4	35.54, 44.61, 43.13

Appendix B Record reconciliation

The issues below are retained to make the numerical reconstruction auditable. None is resolved by changing a recorded observation without supporting laboratory evidence.

Table B1 Discrepancies and the evidence needed for resolution

Record issue	Effect on interpretation	Required source evidence
GGBS addition versus replacement	The percentage denominator is uncertain.	Weighed cement and slag masses for each batch.
Water ratio 0.40 versus 0.50	Effective water-to-binder control cannot be established.	Water quantities, aggregate moisture and absorption corrections.
J–L RCA assignments	The 37% series cannot support factor-level comparisons.	Mix-code key and aggregate batch masses.
G at 56 days	Summary has a dash, but three loads are recorded.	Machine reports and specimen identities.
H at 56 days	Load-derived mean 39.35 MPa differs from summary 44.34 MPa.	Machine reports for all three specimens; no automatic outlier removal.
E at 56 days	A recorded stress of 43.71 MPa for 979.0 kN is inconsistent with nominal area.	Measured dimensions or correction of the source stress entry.
Later-age decreases and pending observations	A general hydration-gain claim is unsupported.	Actual test dates, curing logs and any completed J–L results.
Independent batch replication	Cube SD cannot quantify production variability.	Batch logs and allocation of each cube to a batch.