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Experimental Investigation on Partial Replacement of Coarse Aggregate with Coconut Shell in Concrete Blocks

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Abstract: *This study examines the partial replacement of conventional coarse aggregate with processed coconut shell in concrete intended for block applications. Four mixtures are considered: a control mixture with 0% coconut shell and replacement mixtures containing 10%, 20%, and 30% coconut shell by weight of coarse aggregate. The project report specifies a nominal M20 mix proportion of 1:1.5:3 and a 150 mm × 150 mm × 150 mm cube as the calculation specimen. The supplied strength dataset identifies the control values of 13.38, 17.34, and 22.06 MPa at 7, 14, and 28 days, respectively, as actual values. In contrast, the corresponding values for the 10%, 20%, and 30% replacement mixtures are explicitly presented as projected values and are treated as estimates in this manuscript. The projections indicate a reduction in compressive strength as coconut-shell replacement increases, while all mixtures show increasing strength with curing age. The 10% replacement projection reaches 20.10 MPa at 28 days, but this estimate alone cannot establish M20 grade compliance or identify an optimum replacement level. The paper therefore presents a preliminary comparison and identifies the additional mix-design verification and laboratory testing required before the results can support a final engineering recommendation.*

Keywords: Coconut-shell aggregate, coarse aggregate replacement, concrete blocks, compressive strength, sustainable construction.

I. INTRODUCTION

Concrete depends on natural coarse aggregate for a substantial part of its volume. Continued extraction of natural stone creates pressure on quarry resources, while agricultural processing generates solid residues that require productive end uses. Coconut shell is one such residue. Its use as a partial substitute for conventional coarse aggregate offers a potential route for reducing natural aggregate demand and diverting an agricultural by-product into construction materials [1], [2].

Coconut shell differs from mineral aggregate in density, shape, surface texture, stiffness, and water absorption. These differences can influence workability, particle packing, interfacial bonding, and the strength of hardened concrete. Consequently, the suitability of coconut shell cannot be inferred from its availability alone; it must be assessed through controlled mixture proportioning and standardized testing [1], [4].

The present project investigates nominal M20 concrete with a stated cement:fine aggregate:coarse aggregate ratio of 1:1.5:3. A control mixture is compared with mixtures in which 10%, 20%, and 30% of the coarse aggregate is replaced by coconut shell by weight. The objective is to examine the projected compressive-strength trend and establish the laboratory evidence needed to assess the material for concrete-block applications.

A key distinction is maintained throughout this paper: the supplied dataset labels the 0% control strengths as actual, whereas the 10%, 20%, and 30% replacement values are labelled as projected. The latter are therefore not treated as measured experimental observations.

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II. REVIEW OF LITERATURE

A. Coconut-Shell Aggregate in Concrete

Gunasekaran, Kumar, and Lakshmipathy investigated the mechanical and bond behaviour of concrete incorporating coconut shell as coarse aggregate. Their study considered compressive, flexural, split-tensile, impact, and bond properties and discussed coconut-shell concrete as a lightweight concrete material [1]. Kanojia and Jain later examined coconut shell as a partial replacement for conventional coarse aggregate in M20 concrete and evaluated compressive strength and density using cube specimens [2]. These studies establish the relevance of testing both strength and density when coconut shell is introduced into the coarse-aggregate fraction.

B. Application in Paving and Block Products

Pennarasi, Soumya, and Gunasekaran studied coconut-shell aggregate concrete paver blocks and reported evaluations that included workability, density, dimensions, compressive strength, water absorption, and abrasion resistance [3]. Their work is directly relevant to block products because it considers the manufactured paving unit rather than relying only on conventional concrete cubes. The distinction is important because specimen geometry, compaction, and product requirements affect the interpretation of test results.

C. Recent Experimental Evidence

Natarajan and co-authors examined lightweight concrete incorporating waste coconut shell together with other constituents, including sisal fibre, and reported changes in mechanical properties [4]. Since multiple modified constituents were involved, the effects cannot be attributed to coconut shell alone. Boakye and co-authors investigated 5%, 10%, and 15% coconut-shell replacement and reported that strength was not significantly compromised up to the highest replacement level used in their particular mixture; they also noted workability considerations [5]. Suraya Hani and co-authors examined 5%, 10%, and 15% replacement and reported their highest 28-day compressive strength at 5% replacement [6].

The reported replacement bases and mixture conditions vary across the literature. Some investigations use volume replacement, while the present project report specifies replacement by weight. Results from different replacement bases should therefore not be directly compared without converting the quantities and accounting for aggregate density. The present 0–30% replacement series provides a wider percentage range than several of the cited studies, but the modified-mixture values available for this manuscript remain projections rather than measured results.

III. MATERIALS AND METHODOLOGY

A. Materials

The constituent materials identified in the project report are cement, fine aggregate, conventional coarse aggregate, processed coconut shell, and water. Coconut shells were described as being cleaned, crushed into suitable particles, and screened before use. The actual sieve range, moisture condition, water absorption, and specific gravity of the prepared coconut-shell particles were not supplied and should be recorded from the laboratory sheets. The project report lists a conventional coarse-aggregate size range of approximately 4.75–10 mm.

The cement type requires confirmation. Different parts of the supplied project report refer to Portland Pozzolana Cement and Ordinary Portland Cement. The report also lists fine aggregate in the mixture schedule but contains a statement that fine aggregate was excluded. These details are not reconciled in the available source material; the cement type and actual presence of fine aggregate must be confirmed from the batch records before the manuscript is submitted.

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Fig. 1. Coconut-shell aggregate and conventional coarse aggregate used as project materials.

B. Mixture Designations and Proportions

Four mixtures are identified in the project report. S1 is the control mixture containing no coconut shell. S2, S3, and S4 contain 10%, 20%, and 30% coconut-shell replacement, respectively. The replacement percentage is stated as a percentage by weight of the conventional coarse aggregate. The nominal proportion is reported as 1:1.5:3, and the water–cement ratio is reported as 0.50.

The calculation example in the project report is based on a 150 mm × 150 mm × 150 mm cube. The wet volume is 0.003375 m³. Applying the stated dry-volume factor of 1.54 gives a dry volume of 0.0051975 m³. The per-cube mass entries in the source report do not reconcile with the stated 1:1.5:3 ratio; those individual batch quantities are therefore not reproduced as verified mix proportions in this paper. The original batching sheet should be checked before final publication.

C. Preparation, Mixing, Casting, and Curing

The project report describes cleaning and processing the coconut shells before they are weighed for the selected replacement levels. Cement and aggregates are measured according to the chosen mixture proportions. The dry constituents are mixed until a reasonably uniform blend is obtained, after which the measured water is added gradually. The report describes mechanical mixing and casting into cube moulds, with compaction applied to reduce entrapped air. The calculation specimen is a 150 mm cube; the final paper should confirm whether all tested specimens used this geometry or whether separate block specimens were also cast.

The source report identifies 7-, 14-, and 28-day curing ages. It describes demoulding after initial setting and subsequent water curing. The actual curing log, number of specimens per mixture, and any deviations from the stated ages were not supplied. These details should be confirmed and reported so that the strength comparison is reproducible.

D. Compressive-Strength Evaluation

Compressive strength is determined from the maximum load recorded by a Compression Testing Machine (CTM) and the loaded cross-sectional area of the specimen. The calculation is expressed as:

$$f_c = P / A$$

where f_c is compressive strength in MPa (N/mm²), P is the maximum failure load in newtons, and A is the loaded area in mm². For a 150 mm × 150 mm cube, the nominal loaded area is 22,500 mm². The available report does not include the individual failure loads, the number of replicate specimens, or the variability of the measurements. The reported data are therefore presented with their original actual/projected status rather than being reconstructed from unavailable load records.

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IV. RESULTS AND DISCUSSION

A. Compressive-Strength Dataset

Table I reproduces the strength values shown in the supplied screenshot. The 0% control series is identified as actual, while every value for the 10%, 20%, and 30% replacement mixtures is identified as projected. This distinction is retained in the table and in the discussion.

TABLE I: ACTUAL CONTROL AND PROJECTED COMPRESSIVE-STRENGTH VALUES

CS replacement	Data status	7 days (MPa)	14 days (MPa)	28 days (MPa)
0% (S1)	Actual	13.38	17.34	22.06
10% (S2)	Projected	12.15	16.22	20.10
20% (S3)	Projected	10.85	14.30	17.85
30% (S4)	Projected	9.25	12.10	15.20

The control values increase from 13.38 MPa at 7 days to 22.06 MPa at 28 days. The projected values for all three coconut-shell mixtures also increase with curing age. At each reported age, the projected strength decreases as the replacement percentage increases. This is a trend in the supplied projection table; it should not be described as an experimentally observed response until CTM results for S2, S3, and S4 are available.

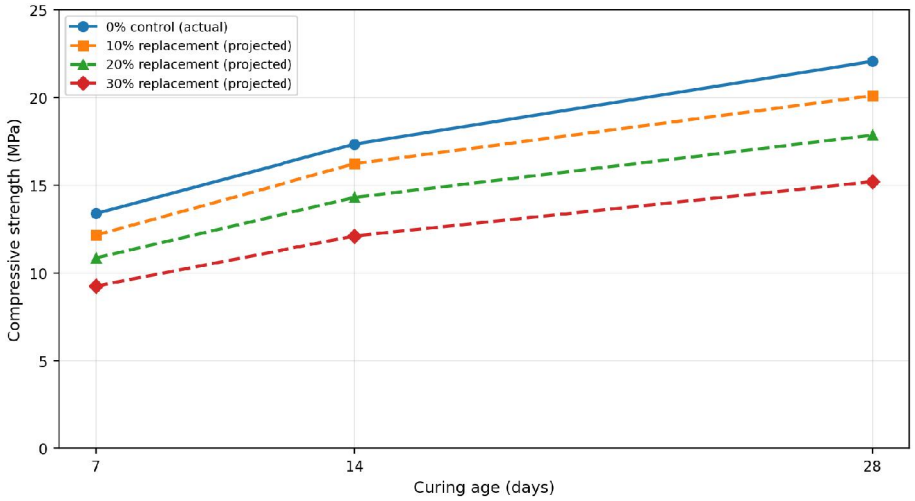


Fig. 2. Compressive strength by curing age: actual control values and projected replacement-mixture values.

B. Comparison at 28 Days

Relative to the 22.06 MPa actual control value at 28 days, the projected values correspond to reductions of approximately 8.9%, 19.1%, and 31.1% for 10%, 20%, and 30% replacement, respectively. These percentages are calculated from the supplied values and are comparisons between actual control data and projected replacement data; they are not measured strength losses.

The 10% replacement mixture has a projected 28-day value of 20.10 MPa. This is 0.10 MPa above the 20 MPa characteristic cube-strength value associated with the M20 grade designation [7]. However, a projected value cannot demonstrate that the concrete satisfies M20 acceptance requirements. The grade must be assessed using properly proportioned batches and the required measured test results, including the applicable sampling and acceptance criteria.

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C. Interpretation and Study Limitations

The supplied dataset suggests that a lower coconut-shell replacement percentage may involve a smaller projected reduction in compressive strength than higher replacement percentages. It does not establish an optimum percentage, because the replacement-mixture values are not laboratory measurements and no statistical information is available. The study also lacks verified aggregate characterization results, complete batch quantities, actual failure loads, and replicate counts in the materials supplied for this manuscript.

The report lists split-tensile and flexural tests among the intended investigations, but no numerical observations for these properties were provided. Likewise, water absorption and abrasion resistance are not supported by project-specific results in the supplied material. These properties are therefore not presented as completed findings. Future testing should include replicated compressive-strength measurements for all four mixtures, verification of the mass-replacement basis, aggregate absorption and density, and product-level tests where concrete blocks or pavers are intended.

V. CONCLUSION

The project examines the use of processed coconut shell as a partial replacement for conventional coarse aggregate in nominal M20 concrete, with replacement levels of 10%, 20%, and 30% by weight. The supplied dataset provides actual compressive-strength values for the 0% control mixture and projected values for all modified mixtures. The control strength increases from 13.38 MPa at 7 days to 22.06 MPa at 28 days. The projected results show lower strength values as the coconut-shell replacement percentage increases, with the 10% mixture giving the highest projected strength among the modified mixtures.

The projected 28-day value of 20.10 MPa at 10% replacement is close to the M20 reference value, but it cannot be used as proof of grade compliance or as a final recommendation. Before publication, the team should verify the cement type, fine-aggregate inclusion, batch quantities, specimen details, and test records, and replace all projected values with measured CTM results. Based on the evidence currently supplied, coconut shell remains a candidate partial aggregate replacement requiring further experimental validation.

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