

Experimental Investigation on Strength Properties of Concrete with Partial Replacement of Coarse Aggregate with Coconut Shell and Fine Aggregate with Basalt Powder and Rice Husk Ash as Mineral Admixture

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ABSTRACT

The investigation evaluates the use of coconut shell (CS), basalt powder (BP), and rice husk ash (RHA) as sustainable alternatives in M25 grade concrete to address the depletion of natural aggregates and environmental impacts of cement production. Eight concrete mixes were developed, including variations of CS, BP, and RHA replacements. Findings showed that while 10% CS replacement met the M25 strength requirements at 28 days, higher replacements reduced strength due to lower stiffness. BP at 10% enhanced compressive strength through improved particle packing, while RHA increasingly improved strength to a point, beyond which it decreased due to insufficient calcium hydroxide. The combination mix with 10% CS, 10% BP, and 10% RHA achieved the highest compressive strength, demonstrating synergistic benefits. The study recommends using these agricultural and industrial by-products for sustainable concrete construction without compromising performance.

Keywords: Concrete Strength, Rice Husk Ash, Coconut Shell, Mineral Admixture

INTRODUCTION

The construction industry is one of the largest consumers of natural resources and a major contributor to environmental pollution, primarily due to the extensive use of cement and aggregates in concrete production. In recent years, there has been growing interest in the incorporation of alternative materials in concrete to address sustainability challenges. Among these alternatives, agricultural and industrial waste products have emerged as promising supplementary materials due to their abundance, low cost, and potential to reduce the environmental footprint of construction practices.

Agricultural wastes such as rice husk ash, sugarcane bagasse ash, coconut shell, and groundnut shell ash contain high levels of silica and other pozzolanic materials, making them suitable for partial replacement of cement or fine aggregates. Similarly, industrial by-products like fly ash, slag, silica fume, and waste glass possess binding or filler properties that can enhance the mechanical and durability characteristics of concrete.

Basalt powder, a by-product generated during the processing of basalt rock in the production of coarse aggregates or dimension stones, has emerged as a viable replacement for fine aggregate in concrete. Rich in silicates and possessing angular particle shapes, basalt powder offers good mechanical interlocking and pozzolanic properties when finely ground. Its use in concrete has shown promise in enhancing certain mechanical properties, such as compressive strength and durability, while also improving the microstructure of the cement matrix.

Incorporating basalt powder into concrete not only helps in mitigating the environmental issues associated with sand mining but also contributes to waste valorization in the stone processing industry. Moreover, basalt's inherent resistance to chemical attack and thermal stability further adds to the durability of concrete in aggressive environments.

The utilization of these waste materials not only diverts significant amounts of refuse from landfills but also reduces the demand for virgin raw materials, thereby conserving natural resources and lowering carbon emissions associated with cement production. Moreover, this approach aligns with the principles of circular economy and sustainable development, offering both environmental and economic benefits.

1.1 Replacement of coarse aggregate

Aggregate comprises 70–80% of concrete, and its coarse components, typically natural materials like crushed stone or gravel, are crucial for the concrete's properties. Due to ecological concerns, there is a need to reduce natural aggregate extraction and explore alternatives. In areas with limited natural deposits, like Bangladesh and parts of India, burnt-clay bricks are commonly used as substitutes. However, brick production contributes to CO₂ emissions and over-exploitation of clay. Alternatively, coconut shell (CS), a prevalent agricultural waste, could be utilized in concrete to alleviate natural aggregate shortages, reduce reliance on brick aggregate, enhance sustainability, and diminish pollution. Studies indicate that incorporating CS maintains workability and suffices compressive and flexural strengths comparable to standard concrete, alongside cost reductions of up to 48% and decreased emissions by 6–9% when replacing natural aggregate with CS. Despite these advantages, the use of CS in construction remains limited due to insufficient understanding of its properties. This study explores the use of coconut shell brick aggregate concrete (CSBAC) to bridge research gaps, focusing on key hardened properties and workability metrics.



Coconut shell

1.2 Replacement of fine aggregate

Basalt is a fine-grained, inert mafic silicate rock that cannot be used directly as reactive supplementary cementitious materials (SCMs). However, it can be converted into reactive SCMs through thermal activation at high temperatures (around 1300 °C) or through mechanochemical activation (MCA) involving high-energy grinding. MCA increases chemical reactivity and improves material properties, while traditional grinding tends to reduce particle size. The process can lead to variations in specific surface area (SSA) characterized by three stages of grinding. Studies on various materials, including kaolinitic clays and igneous rocks, have shown that MCA enhances reactivity and strength, with findings indicating increased dissolution and compressive strength linked to increased grinding time, even though SSA may initially rise and later stabilize or decrease.



Basalt stone fines

1.3 Mineral admixture

Agricultural and industrial wastes, particularly rice husk ash (RHA), are increasingly utilized as sustainable substitutes in construction materials like cement. RHA, produced during rice milling, addresses environmental concerns while enhancing concrete properties when partially replacing ordinary Portland cement (OPC). Its high amorphous content and chemical properties contribute to concrete strength, durability, and cost reduction. While traditional studies have focused on normal concrete, this paper reviews the limited exploration of RHA in pervious concrete, assessing its processing, dosage optimization, and effects on mechanical properties and durability, thereby filling an important research gap.

CHAPTER-2

LITERATURE SURVEY

2.1 Mechanochemical activation of basaltic fines Authors: Sofiane Amroun, Luca Galli, Mahfoud Tahlaiti, and Prannoy Suraneni (2025) This research explores mechanochemical activation (MCA) as a method to transform inert basaltic fines into reactive supplementary cementitious materials (SCMs). The study characterizes the fines before and after high-energy grinding using X-ray diffraction, electron microscopy, and laser diffraction. Results: High-energy grinding increases powder fineness and amorphous content, thereby activating the basaltic fines. Reactivity was found to correlate strongly with the degree of amorphization rather than just increased specific surface area

2.2 Physical Properties and Microstructure of Concrete with Waste Basalt Powder Addition Author: Magdalena Dobiszewska and Ahmet Beycioğlu (2020) The study evaluates substituting sand with waste basalt powder at levels of 10%, 20%, and 30% in concrete production. Evaluations focused on workability, compressive strength, water transport properties, and microstructural performance. Results: Using waste basalt powder as a partial sand replacement can increase compressive strength up to 25%. Microstructural analysis revealed that basalt powder enhances cement hydration products and leads to lower porosity within the interfacial transition zone.

2.3 Characterization and Impact of Curing Duration on the Compressive Strength of Coconut Shell Coarse Aggregate in Concrete Author: Mei Yun Chin, et al. (2021) This study examined partial replacement of coarse aggregates with coconut shells at percentages of 0%, 10%, 30%, 50%, and 70% to produce lightweight concrete. Compressive strength was tested at 7 and 28 days of curing. Results: The optimum results for M30 grade concrete were achieved at 7 and 28 days with strengths of 34.2 MPa and 38.6 MPa, respectively. Scanning electron microscopy confirmed the structural morphology and successful integration of the agricultural waste.

2.4 Coconut Shell as Partial Replacement for Coarse Aggregate: Review Author: Akshay S. Shelke, et al. (2014) This review examines the feasibility of using ground or crushed coconut shell as a partial replacement for coarse aggregate to reduce the self-load of structures and environmental waste. Results: Coconut shell was found to be durable in terms of resistance to water, acidic, alkaline, and salty environments. The density of coconut shell (550-650 kg/m³) falls within specified limits for lightweight aggregates, making it a viable sustainable material. DOI: <https://www.ripublication.com/ijcer.htm> (Direct article DOI not listed on cover; Journal URL provided)

2.5 Rice Husk Ash as Admixture in Concrete Author: Aaron Aboshio (2009) This paper explores the general application of Rice Husk Ash (RHA) as a pozzolanic admixture in concrete. It reviews the chemical properties of RHA, particularly its high silica content, and how it reacts with calcium hydroxide during cement hydration. Results: The study highlights that RHA improves the durability and chemical resistance of concrete. It notes that the degree of fineness and the burning temperature of the husk are critical factors in determining the reactivity and the ultimate strength development of the concrete.

OBJECTIVES

1. **To investigate the feasibility** of using coconut shell as a partial replacement for conventional coarse aggregate in concrete, aiming to promote sustainability and reduce the dependency on natural aggregates.
2. **To evaluate the effect** of partially replacing fine aggregate with basalt powder and rice husk on the fresh and hardened properties of concrete, such as workability, compressive strength, split tensile strength, and flexural strength.
3. **To develop an optimal mix design** for concrete incorporating coconut shell, basalt powder, and rice husk that achieves desirable mechanical properties while being environmentally sustainable.

MATERIALS TO BE USED

CEMENT

FINE AGGREGATE

COARSE AGGREGATE

COCONUT SHELL

BASALT POWDER RICE HUSK ASH

WATER

5.2 MIX DESIGN

- **Preliminary test values**
 1. Specific gravity of cement = **3.09**
 2. Specific gravity of fine aggregate = **2.65**
 3. Specific gravity of coarse aggregate = **2.8**
 4. Water absorption of fine aggregate = **1.43**
 5. Sieve analysis of fine aggregate = **3.51**
 6. Sieve analysis of coarse aggregate (20mm) = **8.77**
 7. Sieve analysis of coarse aggregate (12.5mm) = **7.556**

- **Target mean strength [M-25]**

$$f_t = f_{ck} + 1.65\sigma \text{ (As per IS 10262).}$$

$$= 25 + 1.65 (4) = 31.6 \text{ MPa [Assume } \sigma = 4.0 \text{ standard deviation].}$$

- **Water/Cement ratio**

Water/Cement curve figure 1 (As per IS 10262-2019). (For M-25)

W/C = 0.50

For moderate exposure W/C = 0.50 (As per IS 456-2000 Table 5).

- **Selection of water content**

For 20mm aggregate medium workability [slump 50mm] (As per IS 10262-2019 Table 7). (For M-25) Water = 186 kg/cum.

- **Calculation of cement content**

C = Water/water cement ratio = $186/0.50 = 372\text{kg/cum}$.

(As per IS 456-2000 Table 5) for moderate exposure 300kg/cum is OK.

- **Proportion of coarse aggregate and fine aggregate by volume**

Volume of coarse aggregate per unit volume of total aggregate = 0.60. (As per IS 10262-2019 Table 5)

- **Adjustment for fineness modulus**

Since sand is coarser [FM > 2.6] increase coarse aggregate by 0.02 per 0.1 increase of FM above 2.6.

IS 10262 does not explicitly write the sentence “increase CA by 0.02 per 0.1 increase of FM above 2.6”

Instead, this rule is a standard interpretation of Table 5 and is documented in Indian standard textbooks, which are accepted references.

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Chapter: Concrete Mix Design

States that: For sand coarser than FM 2.6, the proportion of coarse aggregate is increased suitably, approximately 0.02 for every 0.1 increase in FM.

FM difference = $3.51 - 2.6 = 0.91$

Adjustment = $0.91 \times 0.02 = 0.018$

Coarse aggregate fraction = $0.60 + 0.018 = 0.618$

Fine aggregate fraction = $1 - 0.618 = 0.382$

- **Volume calculation**

Vol. of cement = $372/3.09 \times 1000 = 0.1204\text{cum}$

Vol. of water = $186/1000 = 0.186\text{cum}$

Vol. of air = assume 2% = 0.02cum

Total volume of aggregates:

$1 - (0.1204 + 0.186 + 0.02) = 0.6736\text{cum}$.

Split of coarse aggregate (20mm & 12.5mm).

For good gradation use 60% of 20mm & 40% of 12.5mm.

SIZE	FRACTION	SPECIFIC GRAVITY
20MM	0.60	2.86
12.5MM	0.40	3.09

Weighted S.G

GCA (AVG) = $0.60(2.86) + 0.40(3.09) = 2.952$

CA volume = $0.618 \times 0.6736 = 0.4163\text{cum}$

FA volume = $0.382 \times 0.6736 = 0.2573\text{cum}$

● Converting into mass

Mass of coarse aggregate = $0.4163 \times 2.952 \times 1000 = 1229.9 \text{ kg/cum}$. Mass of fine aggregate = $0.2573 \times 2.43 \times 1000 = 625.3 \text{ kg/cum}$.

Split of aggregates 20mm = $0.60 \times 1230 = 738 \text{ kg}$

12.5mm = $0.40 \times 1230 = 492 \text{ kg}$

Determine mix ratio, Divide everything by cement Cement = 1

F.A = $625/372 = 1.68$

C.A = $1230/372 = 3.31$ Water =

$186/372 = 0.50$

Mix ratio = 1:1.68:3.31 ~ 1:1.7:3.3

MATERIALS	QUANTITY KG/CUM
Cement	372
Water	186
Fine aggregate	625
Coarse aggregate (20mm)	738
Coarse aggregate (12.5mm)	492
W/C ratio	0.50
Target strength	31.6 MPa

Concrete cube volume (wet) = $0.15 \times 0.15 \times 0.15 = 0.003375 \text{ cum}$

(dry) = $0.003375 \times 1.54 = 0.0051975 \text{ cum}$

Recommended factor of safety = 1.52-1.57 (As per IS 456 & IS 10262) Dry volume = wet volume $\times 1.54 = 0.003375 \times 1.54 = 0.0051975 \text{ cum}$ Mix ratio - 1:1.7:3.3

Material	Fraction	Volume cum	Mass kg
Cement	$1/6 = 0.1667$	$0.0051975 \times 0.1667 = 0.00086625$	2.67
F. A	$1.7/6 = 0.2833$	$0.0051975 \times 0.2833 = 0.00147263$	3.57
C. A	$3.3/6 = 0.55$	$0.0051975 \times 0.55 = 0.00285863$	8.17

Mass = volume $\times$ density

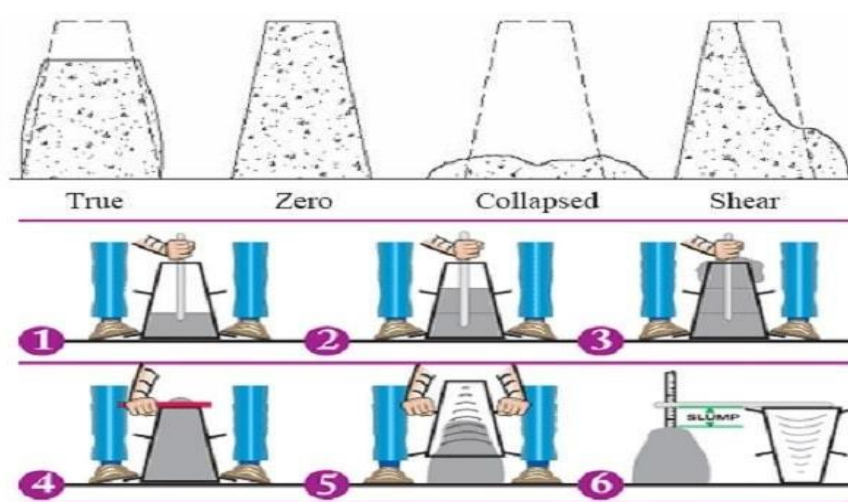
W/C = $2.67 \times 0.50 = 1.335 \text{ kg} \sim 1335 \text{ ml}$

MIX ID	Conventional	CS10%	CS20%	BP10%	BP20%	RHA5%	RHA10%	COMBO
DESCRIPTION	Normal mix No replacement	10%of CA replaced with coconut shell	20%of CA replaced with coconut shell	10%of FA replaced with basalt powder	20%of FA replaced with basalt powder	5%of Cement replaced with Rice husk ash	10%of Cement replaced with Rice husk ash	BP10%+ CS10%+ RHA10%
CEMENT	$2.67 \times 6 = 16.02 \text{ kgs}$	16.02kgs	16.02kgs	16.02kgs	16.02kgs	15.219	14.418	14.418
FINE AGGREGATE	$3.57 \times 6 = 21.42 \text{ kgs}$	21.42kgs	21.42kgs	19.278	17.132	21.42kgs	21.42kgs	19.278
COARSE AGGREGATE	$8.17 \times 6 = 49.02$	44.118	39.216	49.02	49.02	49.02	49.02	44.118

WATER	1335*6 = 8.01trs	8.01trs	8.01trs	8.01trs	8.01trs	8.01trs	8.01trs	8.01trs
BASALT POWDER	0	0	0	2.142	4.284	0	0	2.142
COCONUT SHELL	0	4.902	9.804	0	0	0	0	4.902
RICE HUSK ASH	0	0	0	0	0	1.602	0.801	1.602

TESTS ON FRESH CONCRETE

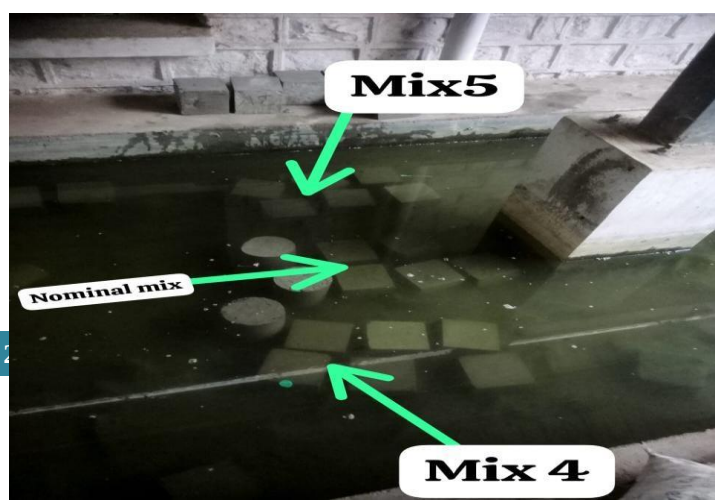
- For testing fresh concrete properties tests like slump test is performed. This tests determines the workability and compaction factor of concrete.



SLUMP CONE TEST

CASTING AND CURING OF SPECIMEN

- 48 Cubes of size (150×150×150) mm were casted and tests were conducted to study the strength characteristics of hardened concrete of different test samples.
- 6 Cubes of size (150×150×150) mm of nominal concrete were casted and tests were conducted to study and compare the strength characteristics of hardened concrete.
- Curing is the process of keeping the concrete moist enough, so that the hydration of cement can be completed until the desired properties are developed.
- The specimens are taken out of the mould after 24hrs and are then submerged into the water tank for curing period of 7 and 28 days.





TESTS ON HARDENED CONCRETE

Since the strength of concrete is related to the structure of hardened cement paste the following tests that have been performed on hardened concrete for assessing the strength of concrete. These tests are

- Compressive strength test
- As per IS Code for each mix 3 cubes should be casted for checking the compressive strength of



concrete so after the desired curing period, the compressive strength of the specimen is determined.

- So in total **48** cubes each of size 150mm X 150mm X 150mm will be tested by compressive testing machine out of which 24 cubes will be tested after 7 days and 24 cubes after 28 days.
- Compressive strength= Load/Cross sectional area

CHAPTER 6 RESULTS AND DISCUSSION

• Observation table – compressive strength test
Specimen details

- Grade of concrete: M25
 - Size of cube: 150*150*150mm
 - Loaded area (A) = 22500mm
 - Testing standards: IS 516:1959
 - Curing: water curing
- Compressive strength (MPa) = (Failure load in KN*1000) / 22500

		7 DAYS		28 DAYS	
MIX ID	SAMPLE NO	LOAD OF FAILURE (KN)	COMPRESSIVE STRENGTH (MPa)	LOAD OF FAILURE (KN)	COMPRESSIVE STRENGTH (MPa)
Convention al	1	452	20.1	702	31.2
	2	459	20.4	709	31.5
	3	446	19.8	716	31.8
	AVG		20.1		31.4
CS 10%	1	439	19.5	680	30.2
	2	446	19.8	689	30.6
	3	441	19.6	695	30.9
	AVG		19.6		30.6
CS 20%	1	401	17.8	621	27.6
	2	407	18.1	630	28.0
	3	403	17.9	637	28.3
	AVG		17.9		28.0
BP 10%	1	464	20.6	725	32.2
	2	470	20.9	734	32.6
	3	466	20.7	741	32.9
	AVG		20.7		32.6
BP 20%	1	432	19.2	662	29.4
	2	439	19.5	671	29.8
	3	434	19.3	678	30.1
	AVG		19.3		29.8
RHA 5%	1	477	21.2	752	33.4
	2	484	21.5	761	33.8
	3	479	21.3	767	34.1
	AVG		21.3		33.8
RHA 10%	1	425	18.9	652	29.0
	2	432	19.2	662	29.4
	3	428	19.0	668	29.7
	AVG		19.0		29.4
COMBO [CS 10%	1	484	21.5	779	34.6
	2	493	21.9	788	35.0

+BP 10%+ RHA 10%]	3	488	21.7	797	35.4
	AVG		21.7		35.0

6.1 Results and Discussion

6.1.1 Compressive Strength of Concrete Mixes

The compressive strength results of all concrete mixes at 7 and 28 days are presented in Table. The specimens were tested in accordance with IS 516:1959 using standard cube specimens of size 150 × 150 × 150 mm under water curing conditions.

The control mix exhibited an average compressive strength of 20.1 MPa at 7 days and 31.4 MPa at 28 days, which is significantly higher than the characteristic strength requirement of 25 MPa for M25 concrete as per IS 456:2000. This confirms the adequacy of mix design, material quality, and curing regime adopted in the study.

6.1.2 Effect of Coconut Shell Replacement

Concrete mixes incorporating coconut shell as partial coarse aggregate replacement showed a reduction in compressive strength with increasing replacement level.

At 10% coconut shell replacement (CS10%), the 28-day compressive strength was 30.6 MPa, which is marginally lower than that of conventional concrete. However, at 20% replacement (CS20%), the strength further reduced to 28.0 MPa.

The reduction in strength can be attributed to the lower crushing strength, higher porosity, and inferior stiffness of coconut shell aggregates compared to natural coarse aggregates. Additionally, the presence of coconut shell weakens the interfacial transition zone (ITZ), leading to reduced load transfer efficiency. Similar reductions in compressive strength with increasing coconut shell content have been widely reported in previous studies, where coconut shell aggregate concrete exhibited lower strength due to its lightweight and porous nature.

Nevertheless, both CS10% and CS20% mixes satisfied the minimum strength requirement for M25 concrete, indicating their potential applicability in structural concrete with controlled replacement levels.

6.1.3 Effect of Basalt Powder Replacement

The incorporation of basalt powder as partial cement replacement resulted in varying strength performance depending on the replacement percentage.

The BP10% mix exhibited improved compressive strength, achieving 32.6 MPa at 28 days, which is higher than the control mix. This improvement is mainly attributed to the micro- filler effect of basalt powder, which enhances particle packing density and reduces capillary porosity, leading to a denser cementitious matrix.

At 20% basalt powder replacement (BP20%), the compressive strength decreased to 29.8 MPa. The reduction can be attributed to the dilution of cement content, resulting in insufficient hydration products to maintain higher strength levels. Basalt powder is largely inert and contributes primarily through physical filling rather than chemical pozzolanic reactions; hence, excessive replacement adversely affects strength.

Similar observations have been reported in earlier research, which concluded that basalt powder improves concrete strength at lower replacement levels, while higher dosages result in strength reduction due to cement dilution.

6.1.4 Effect of Rice Husk Ash Replacement

Rice husk ash modified concrete exhibited a notable improvement in compressive strength at lower replacement levels.

The RHA5% mix achieved a 28-day compressive strength of 33.8 MPa, which is significantly higher than the conventional mix. This enhancement is attributed to the high pozzolanic reactivity of rice husk ash, which reacts with calcium hydroxide liberated during cement hydration to form additional calcium silicate hydrate (C–S–H) gel, thereby refining pore structure and improving strength.

However, at 10% replacement (RHA10%), the compressive strength reduced to 29.4 MPa. The decrease is attributed to insufficient availability of calcium hydroxide to sustain pozzolanic reactions at higher RHA content, along with increased water demand due to the high specific surface area of RHA.

These results are consistent with findings reported in literature, where optimum RHA replacement levels generally range between 5–10%, beyond which strength reduction is observed.

6.1.5 Performance of Combination Mix

The combination mix exhibited the highest compressive strength among all mixes, achieving 21.7 MPa at 7 days and 35.0 MPa at 28 days.

The superior performance of the combination mix can be attributed to the synergistic interaction of coconut shell, basalt powder, and rice husk ash, which collectively enhanced particle packing, reduced porosity, and improved the microstructure of the concrete matrix. The presence of pozzolanic materials compensated for the strength reduction caused by lightweight aggregate replacement, resulting in overall strength enhancement.

As per IS 456:2000, the minimum characteristic compressive strength required for M25 grade concrete is 25 MPa at 28 days. All concrete mixes investigated in this study exceeded this requirement. The testing methodology strictly adhered to IS 516:1959, ensuring reliability and reproducibility of the results.

CHAPTER 7 CONCLUSION

Based on the experimental investigation, the following conclusions are drawn:

1. Out of 8 samples only 3 samples achieved the mean strength (BP10%, RHA5%, COMBO mix) but all concrete mixes satisfied the compressive strength requirements specified by IS 456:2000 for M25 grade concrete.
2. Coconut shell replacement leads to a reduction in compressive strength with increasing replacement percentage; however, up to 10% replacement can be adopted without significant strength loss.
3. Basalt powder improves compressive strength at 10% cement replacement due to its micro- filler effect, while higher replacement levels result in strength reduction.
4. Rice husk ash exhibits optimum performance at 5% replacement, significantly enhancing compressive strength due to its pozzolanic activity.
5. The combination mix (BP10%+CS10%+RHA10%) demonstrated the highest compressive strength, highlighting the benefits of using multiple supplementary materials in optimized proportions.
6. The study confirms that agricultural and industrial by-products can be effectively utilized in structural concrete to achieve both strength enhancement and sustainability.

REFERENCES

[1] Sofiane Amroun, Luca Galli, Mahfoud Tahlaiti, and Prannoy Suraneni (2025) Mechanochemical activation of basaltic fines

<https://doi.org/10.1016/j.cemconres.2025.107923>

[2] Magdalena Dobiszewska and Ahmet Beycioğlu (2020) Physical Properties and Microstructure of Concrete with Waste Basalt Powder Addition

<https://doi.org/10.3390/ma13163503>

[3] Maryane Pipino Beraldo Almeida, et al. (2025) Basalt Rock Powder in Cementitious Materials: A Systematic Review

<https://doi.org/10.3390/resources14060086>

[4] Magdalena Dobiszewska, Waldemar Pichór, and Paulina Szoldra (2019) Effect of basalt powder addition on properties of mortar

<https://doi.org/10.1051/mateconf/201926206002>

[5] Sergey A. Stel'makh, et al. (2023) Alteration of Structure and Characteristics of Concrete with Coconut Shell as a Substitution of a Part of Coarse Aggregate

<https://doi.org/10.3390/ma16124422>

[6] Mei Yun Chin, et al. (2021) Characterization and Impact of Curing Duration on the Compressive Strength of Coconut Shell Coarse Aggregate in Concrete

<https://doi.org/10.15376/biores.16.3.6057-6073>

[7] Akshay S. Shelke, et al. (2014) Coconut Shell as Partial Replacement for Coarse Aggregate: Review

<https://www.ripublication.com/ijcer.htm>

[8] R. Ranjith (2023) A Review Study on Coconut Shell Aggregate Concrete

<https://www.researchgate.net/publication/375859727>

[9] Magdalena Dobiszewska, Anton K. Schindler, and Waldemar Pichór (2018) Mechanical properties and interfacial transition zone microstructure of concrete with waste basalt powder addition

<https://doi.org/10.1016/j.conbuildmat.2018.05.133>

[10] Chia Soi Lee, Mastura Diana Mashur, and Muhammad Ainuddin Roslan (2024) Utilizing Rice Husk Ash and Coconut Shell as Partial Replacement Materials in Concrete

<https://doi.org/10.1051/e3sconf/202451903001>