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Partial Replacement of Plastic Waste and Coconut Fibre in Concrete

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Abstract: The increasing demand for concrete in the construction industry, coupled with the overuse of natural resources and rising environmentalconcerns, has necessitated the development of sustainable alternatives. This research project focuses on the partial replacement of cement with coconut fiber powder and fine aggregate withHDPE plastic waste (10 mm flakes) in M25 grade concrete. The primary aim is to reduce the environmental burden associated with cement production and plastic pollution while maintaining the required mechanical properties of concrete.

The experimental program involved preparing concrete mixes with varying proportions ofcoconutfiberpowder (0%,0.5%,0.8%,1.0%,

and 1.5%) and HDPE plastic waste (0%, 5%, 10%, and 15%). A total of 36 cube specimens were cast and tested for compressive strength at 7, 14, and 28 days of curing. The optimal results were observed for the mix containing 1% coconut fiber and 10% plastic waste, which achieved a compressive strength of 26.8 N/mm² at 28 days—exceeding the minimum requirement for M25 concrete. Additionally, the use of a superplasticizer of Polycarboxylate ether further enhanced the strength to 28.5 N/mm².

The findings confirm that coconut fiber and plastic waste can be effectively used as partial replacements for cement and sand without compromising the strength or performance of concrete. This study demonstrates the potential of converting agricultural and industrial waste into valuable resources for eco-friendly, cost-effective, and sustainable construction.

Keywords: Coconut fiber powder, HDPE plastic waste, M25 concrete, compressive strength, sustainable construction, partial replacement, superplasticizer..

I. INTRODUCTION

Concrete is the most commonly used construction material in the world, known for its versatility, durability, and strength. However, its production relies heavily on non-renewable natural resources such as limestone for cement and river sand for fine aggregate. The manufacturing of cement is energy- intensive and contributes significantly to global carbon dioxide emissions. With the construction sectorexpandingrapidlyinIndia,theenvironmental impact of traditional concrete has become agrowing concern. At the same time, the improper disposal of plastic waste and agricultural by- products like coconut husk has emerged as a major issue, leading to pollution and land degradation.

To address these challenges, this studyfocuses on the sustainable development of concrete by partially replacing cement with coconut fiber powder and fine aggregate with High-Density Polyethylene (HDPE) plastic waste in shredded 10 mm form. Coconut fiber powder is a natural, lignocellulosic material derived from coconut husk, rich in binding characteristics and crack resistance. HDPE plastic waste, being lightweight, water- resistant, and non-biodegradable, offers potential as a sand replacement material in concrete mixes. The objective of this project is to evaluate the mechanicalperformance—specifically,compressive strength—of M25 grade concrete containingvarying proportions of coconut fiber powder and HDPE plastic waste. Concrete cubes were cast and testedat7,14,and28days.Thestudyalsoexplores the effect of using a superplasticizer to enhance workability and strength. The outcome aims to support eco-friendly, cost-effective concretesuitableforpracticalconstructionapplicationswhile promoting waste reuse and sustainable construction practices.

II. OBJECTIVES

The primary objectives of this project are asfollows:

1) To investigate the mechanical properties of M25 concrete when cement is partially replaced with coconut fibre powder.
2) To examine the performance of concrete with partial replacement of fine aggregate using HDPE plastic waste (10 mm size particles).
3) To evaluate the compressive strength of modified concrete at 7, 14, and 28 days of curing.

4) Todeterminetheoptimalreplacementpercentage of coconut fibre powder and HDPE plastic for strength and workability.
5) To promote the concept of sustainable constructionbyutilisingwastematerialseffectively.

III. LITERATURE REVIEW

Santhoshkumar et al. (2019)[1], coconut shell was used as a partial replacement for coarse aggregates and coir fibre as a replacement for fine aggregatesin concrete mixes. The percentages of replacement varied from 5% to 20%, and their effects were studied on compressive strength, split tensile strength,andflexuralstrengthfor7,14,and28days of curing

Sudha et al. (2020)[2], who examined the effect of coconut fibre alone on paver blocks. By replacing cement partially with coconut fibre (0.1% to 0.4%), they found that compressive strength increased progressively with fibre content, achieving a peak strength of 32.48 N/mm² at 0.4% fibre. This confirms that natural fibres improve interlocking in the cement matrix and contribute to tensile strength enhancement. Such results indicate that coconut shell and coir fibre are viable, cost-effective, and sustainablealternativestotraditionalmaterials.They reduce construction cost, utilise agricultural waste, and promote green construction practices.

RaviKiran etal. (2021)[3],wasteplasticflakeswere used to partially replace fine aggregate in concrete brick production. They varied the plastic content up to 20% by weight and found that a cement-to- aggregate ratio of 1:3, with 20% of the sand replaced by plastic flakes, yielded optimum compressive strength. The watercement ratio of 0.5 gave the best performance in terms of strength and workability. Notably, the plastic-modified bricks exhibited excellent thermal insulation properties, lighterweight,andminimalwaterabsorption.These bricks were ideal for low-cost housing and partition wall construction.

RajarapuBhushaiah et al. (2019)[4]highlightedthatplasticsandbricksusing wasteLDPEshoweda compressive strength of 5.6 N/mm² and zero water absorption. These bricks are eco-friendly, durable, and cost-effective, offering a sustainable alternative to traditional fired clay bricks and fly ash bricks. Moreover, the review of multiple studies in this report suggests that different types of plastic (PET, HDPE, LDPE) can be integrated into concrete and brick production. While compressive strength slightly reduces beyond a 30% replacement level, the benefits of thermal performance, ductility, and waste reduction outweigh the marginal strength losses.

G. Navya et al (2014)[5]have carried out experimental investigation on properties concrete paver block with inclusion of natural fibers. In their experimental investigation the compressivestrength, water absorption and flexural strength of paver blocks were determined by adding coconut fibers in the top 20mm thickness. Coconut fibers were added in proportions of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in volume of concrete. The compressive strength, flexural strength and water absorption were determined at the end of 7 and 28 days. They have been concluded that indicate the addition of coconut fiber by 0.3% paver block attainsmaximumcompressivestrength,i.e.addition of coconut fiber gradually increases flexural strengths and water absorption at 7 and 28 days. They investigated at 0.3% of coconut fiber content effect of top layer thickness on compressive

IV. MATERIALS USED

1) CEMENT: The manufacturing of Cement was conductedbyheatinglimestone(calciumcarbonate) with small quantities of other materials (such as clay. Tests were carried out on various physical properties of cement and the results are shown in test data of materials. cement will act as a binding material.
2) SAND :Natural river sand was used as the fine aggregateinthisstudy.Itwascollectedfromalocal riverbed and passed through a 4.75 mm IS sieve to conform with the grading requirements as per IS 383:2016. River sand is one of the most commonly used fine aggregates in concrete due to its smooth texture, natural availability, and good workability characteristics.
3) WATER: Water is an important ingredient of bricks as it actively participates in the chemical reaction with cement. Since it help to form the strength giving cement gel reinforcement and concrete inside the centre hole of this brick and act as load bearing of column.
4) GRAVEL: Gravel is classified by particle size range and includes size classes from granule to boulder-sized fragments. The gravel is categorized intogranulargravel(2to4mmor0.079to0.157in) and pebble gravel (4 to 64 mm or 0.2 to 2.5 in). ISO 14688 grades gravels as fine, medium, and coarsewithranges2mmto6.3mmto20mmto63mm. One cubic metre of gravel typically weighs about 1,800 kg.
5) PET PLASTIC: Polyethylene terephthalate, commonly abbreviated PET, PETE, or the obsolete PETP or PET-P, is the most common thermoplastic polymer resin of the polyester family and is used in fibres for clothing, containers for liquids and foods, thermoforming for manufacturing, and in combination with glass fibre for engineering resins.

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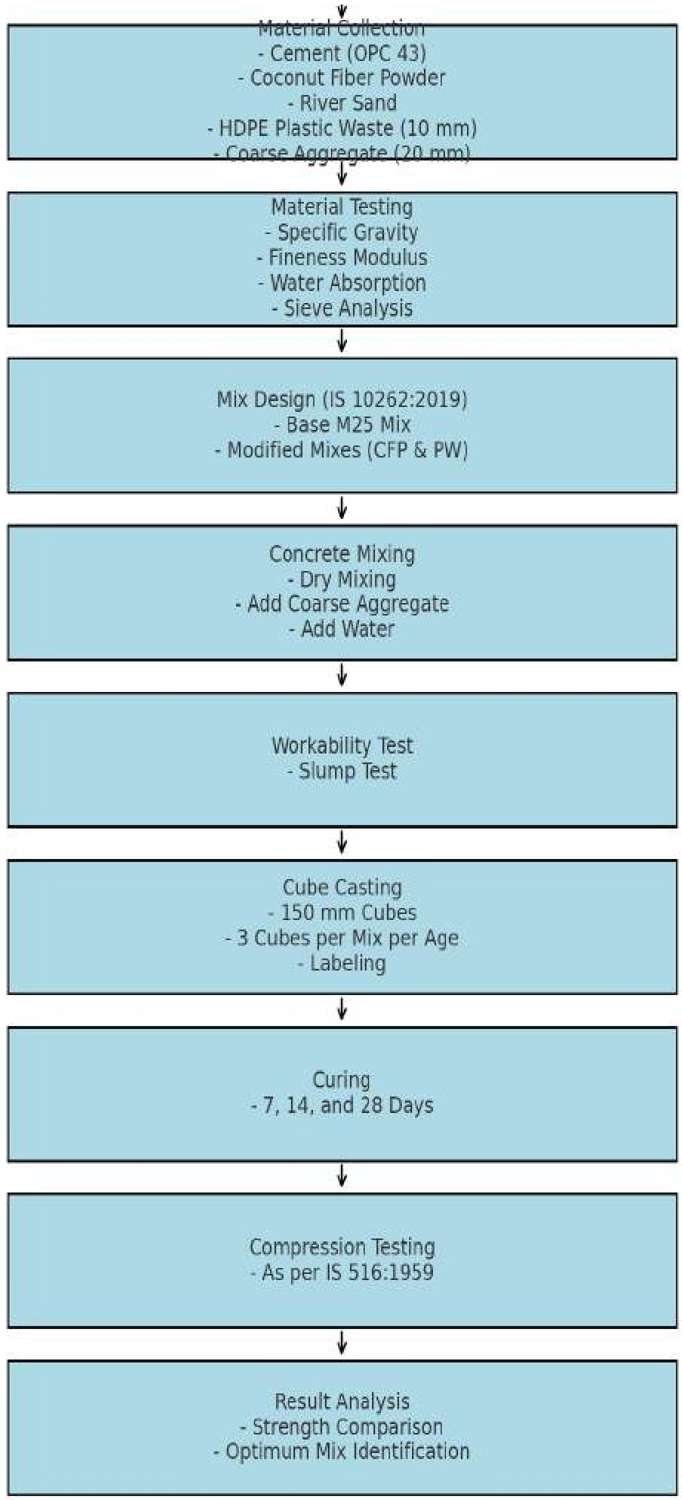
It can be used in construction industry in bricks or other building components.

6) COCONUT FIBER POWDER: Coconut fibre powder was produced by grinding dried coir husk, which was collected from a local coir processing unit. The powder was sieved to achieve a uniform finetextureandstoredindryconditions.Itservesas a partial replacement for cement in the mix.

V. METHODOLOGY



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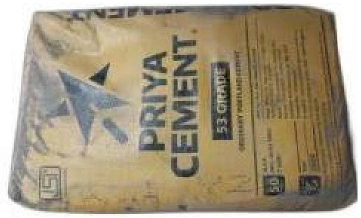
VI. MATERIAL TESTS AND THEIR RESULTS

1) *Cement*



- SpecificGravity :3.15
- StandardConsistency:31%
- InitialSettingTime : 35 minutes
- Fineness(bysieving) : 9%

2) *FineAggregate(River Sand)*

- SpecificGravity :2.62
- WaterAbsorption:1.2%
- FinenessModulus:2.85
- SieveAnalysisZone:ZoneII

3) *CoarseAggregate*

- SpecificGravity :2.61
- WaterAbsorption:0.5%
- Fineness Modulus:6.02

4) *CoconutFiber Powder*

- Appearance:Brown,fine-texturedpowder
- Source: Agricultural waste from coconut processing

- SpecificGravity:~1.2
- Notable Characteristics :High lignin and cellulose content, thermal insulation, crack resistance

5) HDPE PlasticWaste(10 mmParticles)

- Size : 10 mm (average)
- SpecificGravity:~0.95
- Properties: Water-resistant, low density, chemically inert, non- biodegradable
- Impact: Reduces the overall weight of concrete and enhances waste reuse

VII.CUBE CASTING AND TESTING

1) Cube Specifications:

Concrete cube specimens were cast with standard dimensions as per IS 516:1959:

- CubeSize: 150 mm ×150 mm × 150 mm
- Number of Specimens: 3 cubes per mix per curing period (7, 14, and 28 days)
- Total Cubes: 27 (for 9 different mixes: M0P0, M0.5P0, M0.8P0, M1P0, M1.5P0, M1P5, M1P10, M1P15)

Each cube was labelled immediately after castingto ensure correct identification throughout the curing and testing process.

2) Casting Procedure

- Mixing: Concrete was prepared in a mechanical drum-typemixer.Themixwasprepared byfirstdry mixing coconut fibre powder with cement and HDPE plastic flakes with fine aggregate. Then, all dry ingredients were mixed with coarse aggregate and water.
- Mould Preparation: Steel cube moulds were cleaned, oiled, and properly assembled to prevent leakage.
- Placingthe Concrete:
  - ➢ Concrete was filled in three layers into the mould. various plastic contents and strip sizes.
  - ➢ Each layer was tamped 25 times using a standard steel rod to ensure compaction and minimize voids.
  - ➢ Excess concrete was removed, and the surface was levelled.

3) InitialSetting:

The moulds were covered with wet gunny bags and left undisturbed for 24 hours at room temperature for initial setting

4) Curing Procedure

After 24 hours, the cubes were demoulded and submerged in a curing tank filled with clean water atambientroomtemperature.Thefollowingcuring durations were maintained (7,14,28) days

5) Compressive Strength Test

Thecompressivestrengthtestwasconductedusing a Compression Testing Machine (CTM) with a capacity of 2000 kN. The test was carried out in accordance with IS 516:1959

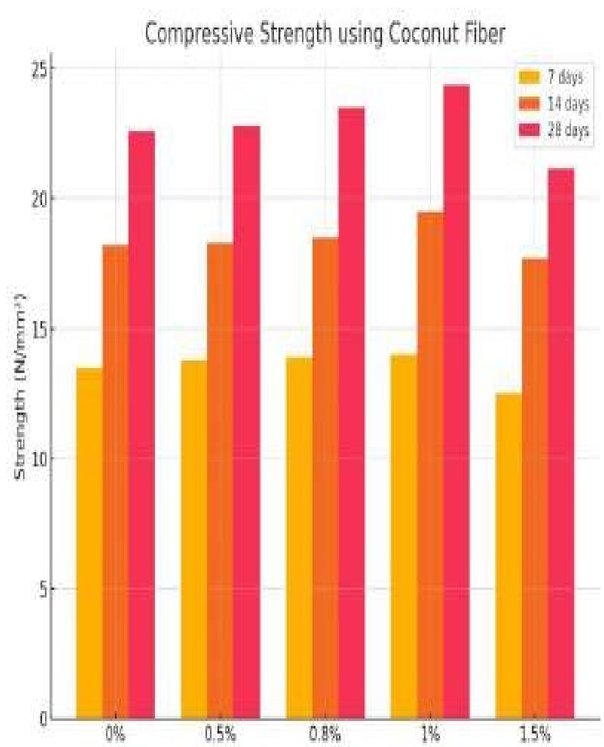
VIII. TEST RESULTS AND DISCUSSION

A. *Compressive Strength Results*

1) *UsingOnlyCoconutFiberPowder (as Cement Replacement)*

Coconut Fiber(%)	7 Days (N/mm²)	14 Days (N/mm²)	28 Days (N/mm²)
0%(Control)	13.5	18.2	22.6
0.5%	13.78	18.3	22.79
0.8%	13.9	18.5	23.5
1.0%	14.0	19.5	24.37
1.5%	12.5	17.7	21.15

Table.1CompressiveStrengthResultsofUsingCoconutfibrePowder

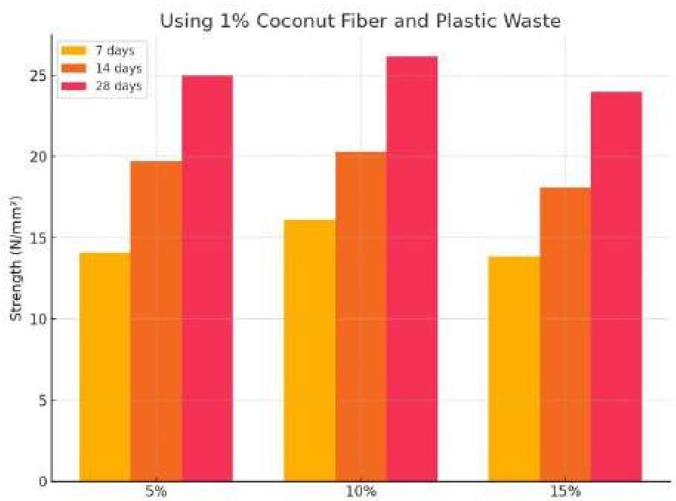


Graph.1CompressiveStrengthResultsofUsingCoconut fibre Powder

2) Using 1% Coconut Fiber + Plastic Waste (as Fine Aggregate Replacement)

Plastic Waste(%)	7 Days (N/mm²)	14 Days (N/mm²)	28 Days (N/mm²)
5%	14.1	19.7	25.0
10%	17.1	21.3	26.8
15%	13.8	18.1	24.0

Table.2CompressiveStrengthResultsbyUsingCoconut fibre Powder And Plastic Waste

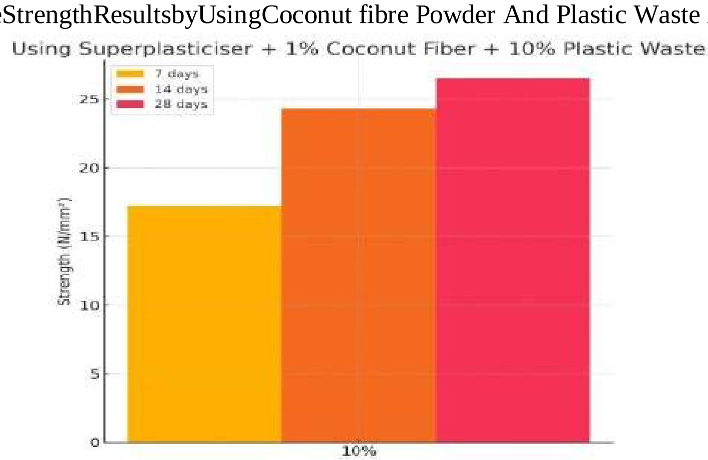


Graph.2CompressiveStrengthResultsbyUsingCoconut fibre Powder And Plastic Waste

3) UsingSuperplasticizer(Polycarboxylateether) (with 1% Coconut Fiber + 10% Plastic Waste)

MixDescription	7 Days (N/mm²)	14 Days (N/mm²)	28 Days (N/mm²)
1%CF+10% Plastic + Superplasticizer (10%)	18.2	24.3	28.5

Table.3CompressiveStrengthResultsbyUsingCoconut fibre Powder And Plastic Waste And Superplasticizer



Graph.3CompressiveStrengthResultsbyUsingCoconut fibre Powder And Plastic Waste And Superplasticizer

B. Observations

1) *CoconutFiberOnly Mixes:*

- The compressive strength improved steadily up to 1.0% replacement.
- Beyond 1.0%, the strength decreased, likely due to reduced bonding and increased internal voids from excessive fibre content.

The optimal fibre replacement wasfound at **1.0%**, yielding **24.37 N/mm²** at 28 days.

2) *CoconutFiber+ Plastic Waste Mixes:*

- 1% coconut fibre + 10% plastic yielded the best performance, reaching 26.8 N/mm² at 28 days.
- Strength dropped slightly at 15% plastic due to weaker bonding and segregation.

3) *Useof Superplasticizer:*

- Superplasticizer improved both workability and strength.
- The1%coconutfibre+10%plastic+ superplasticizer mix achieved a compressive strength of **28.5N/mm²**, marginally higher than the non-admixture counterpart.

C. ComparisonandAnalysis

- All mixes met or exceeded the minimum requirement of 25 MPa for M25 concrete, except the 1.5% coconut fiber-only mix (21.15 MPa).
- M10P10 (1% fiber + 10% plastic) proved to be the most effective in terms of strength and sustainability.
- Superplasticizers provided marginal additional improvement, especially in early strength gain and compaction.

IX. CONCLUSIONS AND RECOMMENDATIONS

This chapter summarises the key findings from the experimental investigation on the partial replacement of cement with coconut fiber powder andfineaggregatewithHDPEplasticwasteinM25 grade concrete. The study also evaluated the effect of adding a superplasticizer to the optimal mix.

A. Conclusions

Based on the results and analysis of compressive strength testing at 7, 14, and 28 days, the following conclusions can be drawn:

1) *UseofCoconutFiberPowder***:**

- Replacing cement with coconut fiberpowder up to 1.0% resulted in improved compressive strength across all curing periods.
- At 1.0%, the compressive strength at 28 days reached 24.37 N/mm², higher than the control mix (22.6 N/mm²).
- Beyond1.0%,strengthdecreased,likelydue to poor bonding and increased internal porosity caused by excess fiber.

2) *UseofHDPEPlasticWastewithCoconut Fiber:*

- Replacing fine aggregate with HDPE plastic waste at 10% in combination with 1% coconut fiber achieved the best performance: 26.8 N/mm² at 28 days.
- The mix exhibited good compaction, uniformity,andminimalvisiblesegregation.
- Strengthdeclinedslightlyat15%plasticdue to possible interference with cement paste bonding.

3) *Useof Superplasticizer:*

- Incorporating a superplasticizer (at 10% dosage) into the 1% coconut fiber + 10% HDPE mix further enhanced the concrete performance.
- The compressive strength increased to 28.5 N/mm² at 28 days, and workability also improved notably.
- Superplasticizershelped inreducinginternal voids and enhancing particle dispersion, especially beneficial in fiber and plastic-containing concrete.

4) *OverallObservations:*

- The mix with 1% coconut Fiber powder and 10% plastic waste, with or without superplasticizer, meets the strength requirements for M25 concrete.
- All modified mixes (except the one with 1.5% Fiberonly) surpassed the minimum 25 MPa requirement at 28 days.

- WastematerialslikecoconutcoirandHDPE can be effectively utilized in structural concrete up to certain limits without compromising on strength.

B. Recommendations

Based on this study, the followingrecommendations are proposed:

1) OptimalMixProportion:

- Use 1% coconut fibre powder as partial cement replacement.
- Use 10% HDPE plastic flakes (10 mm) as partial fine aggregate replacement.
- Addition of superplasticizer is advisabletoenhanceworkabilityand compressive strength.

2) Applications:

- Suitable for non-load-bearing walls, partition blocks, low-rise buildings, and paver blocks.
- Ideal for sustainable and low-cost construction in rural and semi-urban areas.

3) FurtherResearch:

- Investigate long-term durability, shrinkage, and water absorption characteristics.
- Explore the use of other admixtures or curing techniques to enhance performance.
- Extend the study to include flexural and split tensile strength tests.

4) Environmental Benefit:

- This approach provides an effective solution for managing agricultural and plastic waste.
- Promotes eco-friendly construction and aligns with sustainable development goals (SDGs) and national missions like SwachhBharat Abhiyan.

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