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EXPERIMENTAL INVESTIGATION OF PARTIAL SAND REPLACEMENT BY COFFEE WASTE IN CONCRETE PRODUCTION

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Abstract: Recently, an increment of espresso drinks utilization has been seen from one side of the planet to the other; and its utilization expands the waste coffee beans which will turn into ecological issues. Recycling of this waste to produce new materials like sand concrete (Bio-char + Fine Aggregate + Cement) appears as one of the best solutions for reducing the problem of pollution. Study. where carried out Coffee Biochar-Cube (CBC) produced specifically from used coffee grounds through the process of pyrolysis. For this: sand substantial blends were ready with replacement of sand with the spent coffee beans squander at various rate (0.6% 0.9% and 1.8%) by volume of the sand in order to study the influence of this wastes on physical (Workability, bulk density and porosity), mechanical (compressive strength) properties of dune sand concrete. The results showed that the use of spent coffee grounds waste as partial replacement of natural sand contributes to reduce workability, bulk density and mechanical strength of sand concrete mixes with an increase in its porosity. However, the thermal characteristics are improved and especially for a level of 15% and 20% of substitution. So, it is possible to obtain an insulating material which can be used in the various types of structural components. This study ensures that reusing of waste coffee grounds in dune sand concrete gives a positive approach to reduce the cost of materials and solve some environmental problems.

Index Terms - Coffee spent grounds, Concrete, Workability, Porosity, Thermal conductivity.

1. INTRODUCTION

M-30 Grade Concrete

M-30 grade concrete is known for its high strength and durability, commonly used in heavy-duty structures such as bridges, high-rise buildings, and industrial floors. This type of concrete must meet rigorous standards to ensure safety and longevity. However, like all concrete, its production relies heavily on natural resources, particularly sand, which poses environmental concerns.

*The Environmental Impact of Sand Mining**

Sand mining has significant environmental repercussions. It leads to the depletion of riverbeds, loss of biodiversity, and the destruction of natural habitats. With the increasing demand for concrete, these impacts are escalating, necessitating alternative materials to alleviate the strain on natural sand resources.

Coffee Grounds: An Innovative Solution

One such alternative is used coffee grounds. Every year, millions of tons of coffee grounds are discarded as waste. These grounds, rich in organic compounds, have the potential to be repurposed in various industries, including construction. By incorporating used coffee grounds into concrete, we can reduce waste and lessen the reliance on natural sand.

Research and Development

Recent studies have explored the feasibility of using coffee grounds as a partial replacement for sand in M-30 grade concrete. The research involved processing the coffee grounds to enhance their compatibility with concrete mixtures. This includes drying, grinding, and infusing them with certain chemicals to improve their binding properties.

1 REVIEW OF LITERATURE

1.Maria Eliza Turek, Karllas Stival Freitas, Robson André Armindo: SPENT COFFEE GROUNDS AS ORGANIC AMENDMENT MODIFY HYDRAULIC PROPERTIES IN A SANDY LOAM BRAZILIAN SOIL (2022)

In this study, the application of SCG as soil conditioner was investigated together with its influence on lettuce growth. Changes on soil hydraulic properties were observed, such as water

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retention and aeration, evidencing SCG as a potential conditioner to soils with poor retention capacity. Water content at container capacity increased from 0 to 15% of SCG and decreased from 15 to 20%. Although 7% of increase on θcc from 10 to 15% of SCG, this gain was not significant suggesting. Soil physical and chemical properties can be amended by application of organic residues, such as spent coffee grounds (SCG). In this work we examined SCG effects on the modification of some soil physical-hydraulic properties, such as soil water retention and aeration, investigating beneficial uses for this waste product. Soil properties were evaluated using pots filled with a mixture of a sandy loam soil with the contents of 0, 5, 10, 15 and 20% of SCG. The most relevant soil properties to the purposes were the moisture at container capacity (θcc), readily available water capacity (RAWC) and drainable porosity (ϕD). Additionally, under the hypothesis that SCG can be used as soil conditioner, lettuce crop, cultivar “Mimosa Roxa Roxanne”, was transplanted to the pots where the leaf area index and the cumulative biomass throughout the growing cycle

2 Ana Cervera-Mata,Silvia Pastoriza,José Ángel Rufián-Henares,Jesús Párraga,Juan Manuel Martín-García &Gabriel Delgado: IMPACT OF SPENT COFFEE GROUNDS AS ORGANIC AMENDMENT ON SOIL FERTILITY AND LETTUCE GROWTH IN TWO MEDITERRANEAN AGRICULTURAL SOILS (2021)

The use of spent coffee grounds (SCG) as organic amendment is a triple solution: a reuse of this bio-residue (6 millions of tons per year), an increase in soil organic carbon (SCG contain 82% of carbohydrates and 13% of proteins) and a decrease in CO_2 emissions into the atmosphere. Thus, we investigate the effect of SCG on soil and plants in an in vitro assay. The variables considered were SCG dose (2.5 and 10%), two agricultural soils (Calcisol and Luvisol), and four cultivation times (15, 30, 45 and 60 days). The chemical and physicochemical soil properties, SEM images and growth parameters were analyzed. The highest dose of SCG increased organic carbon, total N and available K and P by 286%, 188%, 45%, and 9%, respectively, while decreasing lettuce growth by 233% compared to control. The SEM study revealed that SCG particles are incorporated into soil aggregates.

3. Antonio Forcina, Antonella Petrillo, Marta Travaglioni, Simona di Chiara, Fabio De Felice: A COMPARATIVE LIFE CYCLE ASSESSMENT OF DIFFERENT SPENT COFFEE GROUND REUSE STRATEGIES AND A SENSITIVITY ANALYSIS FOR VERIFYING THE ENVIRONMENTAL CONVENIENCE BASED ON THE LOCATION OF SITES (2021)

In the present research, the environmental performances linked to the possibility of sustainable reuse of SCG have been investigated, compared to traditional landfilling (BSC). The scenarios analyzed concern the composting process (SC1), biodiesel production (SC2), and brick-making (SC3). The impacts deriving from the analyzed scenarios were evaluated through an LCA, using

a cradle-to-gate approach, and setting a distance of 100 km, to equalize the impacts deriving from transport. Spent Coffee Ground (SGC) represents the most abundant waste generated in coffee beverage preparation and instant coffee production, with a total annual amount estimated at 60 million tons worldwide. These quantities justify the need to enhance and reuse this waste,

by implementing successful circular economy strategies. For this purpose,the production of compost, biofuels, and the incorporation of limited quantities of SCG in the bricks-making process represents a promising solution, which can avoid the impacts due to its disposal but also, result in lower greenhouse gas emissions. The present study aims to assess the environmental performance of different SCG reuse scenarios, compared to traditional landfill disposal. To evaluate environmental impacts, a comparative Life Cycle Assessment is performed among the aforementioned scenarios. The results showed that in terms of emissions to air, all the reuses investigated involve benefits compared to landfill, resulting in a decrease of 18% in composting,

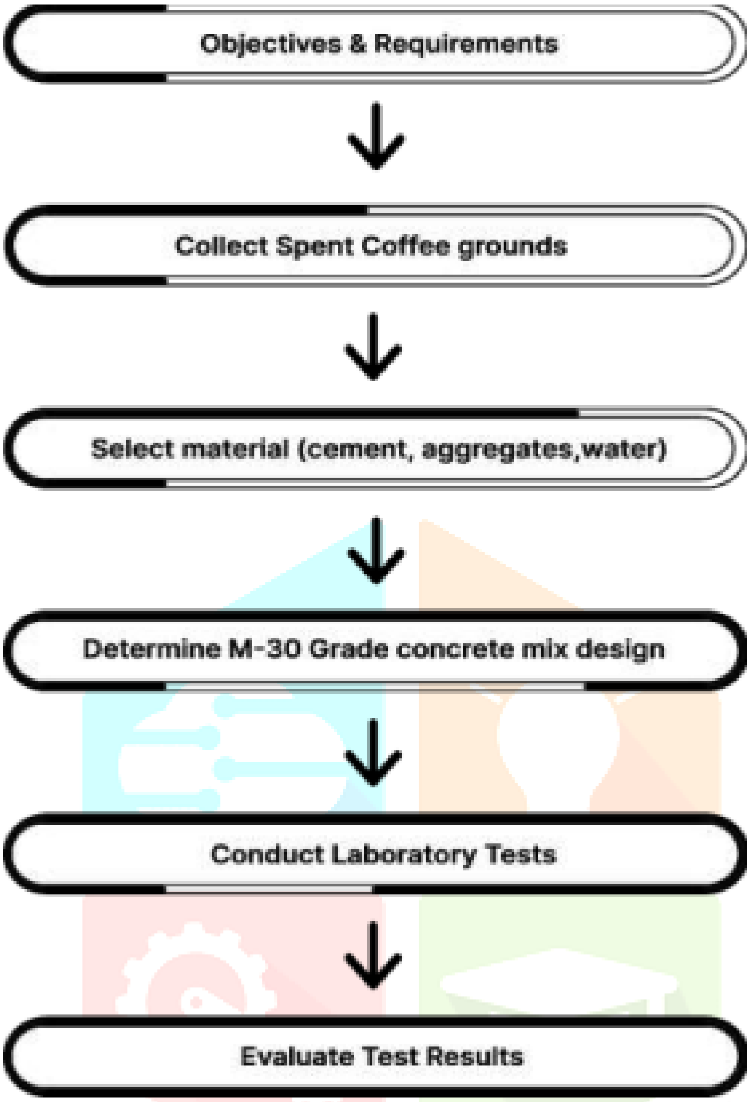
Deriving from the reuse of waste. Finally, the calculated break-even distances were compared with the average distances of the real sites in the Italian scenario, resulting in average distances for composting and brick production less than the break-even ones (40 km and 460 km respectively). On the other hand, the average distance among biodiesel production plants in Italy (500 km) is much higher than the calculated break-even one.

4. S Hechmi, M Guizani, A Kallel, RI Zoghlami: Impact of raw and pre-treated spent coffee grounds on soil properties and plant growth: A mini-review (2020)

Spent coffee ground (SCG) consists of the remainder left after brewing the coffee grounds. Due to its valuable composition, SCG can provide sufficient nutrients and support plant growth, particularly in arid agricultural lands where soil fertility needs to be improved. However, the effects of SCG are highly dependent on their nature (raw or treated) and the application rate. SCG treatments namely composting and vermi-composting or pyrolysis could result in a more useful product for agricultural use, making it easy to overcome the SCG phytotoxic effect. In this paper a critical review of the research on SCG was presented.

3 MATERIALS AND METHODS

METHODOLOGY :



Procedure:

1. Concrete Mix Design

- Determine the desired concrete mix design, including the amount of cement, aggregate, and water for each mix.

- Define the percentage of coffee grounds (SCG) you want to incorporate into the mix. Common proportions range from 5% to 20%.

2. Material Preparation:

- Weigh and proportion the concrete ingredients according to your mix design, including the specified dosage of coffee grounds.

- Ensure the coffee grounds are properly prepared and screened for consistency.

3. Mixing

- Use a concrete mixer to blend the materials thoroughly. Mix for a sufficient duration to achieve a uniform and consistent mixture.

4. Assessment of Workability:

- Perform workability tests on the fresh concrete mixtures. The choice of test method (e.g., slump, flow, or others) depends on your specific application and standards. - For each dosage of coffee grounds, assess how the workability changes compared to the control mix without coffee grounds.

5. Observations and Adjustments:

- Observe how the addition of coffee grounds affects the ease of mixing, consistency, and workability of the concrete.

- Depending on the results, you may need to make adjustments to the mix design, such as the water content or the use of superplasticizers, to maintain the desired workability. **6. Data Collection:**

- Document your observations and measurements for each dosage of coffee grounds.

7. Analysis and Interpretation:

- Analyze the data to understand how different dosages of coffee grounds impact the fresh properties of the concrete.

- Identify trends, challenges, and opportunities related to workability and handling characteristics.

8. Report:

- Summarize your findings in a report, including information on the mix designs, workability tests, and observations. This report can be useful for project planning and quality control. By systematically assessing the fresh properties of concrete with varying dosages of coffee grounds, you can make informed decisions about the use of SCG in your concrete mixes for specific applications. Adjustments may be necessary to maintain the desired workability and handling characteristics.

3.1 MATERIALS USED :

The material used in the research includes:

1. Cement

2. Fine aggregate

3. Coarse Aggregate

4. Water

3.1.1 CEMENT :

Cement is a fine powder that is used to bind other materials together. It is madefrom limestone, clay, and other minerals that are heated to form a clinker. The clinker is then ground into a powder and mixed with water to form a paste.

Figure 6: Cement

3.1.2 FINE AGGREGATES :

· Fine aggregate is sand that is used in concrete to fill the voids between the coarseaggregate particles. It also helps to improve the workability of concrete.

· Fine aggregate, which may be granular material or crushed stone, is a fundamental component of concrete. The quality of the fine aggregate and the density of the fine aggregate both have a significant impact on the hardened qualities of the concrete.

· If the fine aggregate is chosen for its grading zone, particle geometry and surface characteristics, wear and skid resistance, soaking and surface moisture, then the concrete mixture will last longer, become sturdier, and cost less.

Figure 7 : Fine aggregate

3.1.3 COARSE AGGREGATES :

· Coarse aggregate is gravel or crushed rock that is used in concrete to providestrength and stability. It also helps to reduce the shrinkage of concrete.

· Coarse aggregates are an essential ingredient in concrete. They provide strength, stability, durability, and workability to concrete.

Figure 8: Coarse aggregate

3.1.4 WATER :

Water is used to activate the cement and to make the concrete workable. It is important to use the correct amount of water, as too much water can weaken theconcrete. · Water is one of the most important materials used in construction. It is used in avariety of ways, including:

· Mixing concrete and mortar: Water is essential for mixing concrete and mortar. It activates the cement and helps to create a workable mix.

· Curing concrete: Concrete must be cured properly in order to reach its full strengthand durability. Curing involves keeping the concrete moist for a period of time, typically 7 to 28 days. Water is used to keep the concrete moist during the curing process.

MIX PROPORTIONING

From the mix design as per IS: 10262-2019, the mix proportions for M30 Grade of concrete are as follows:

- Cement = 2.3 kg/m^3
- Fine aggregate = 1.925 kg/m^3
- Coarse aggregate = 3.36 kg/ m^3
- Spent Coffee Grounds = 0.0634 grams
- For four cubes

PREPARATION OF SAMPLE FOR TESTING

Mixing of concrete with replacement

CASTING AND CURING

Casting and curing are essential processes in the production of high-quality concrete structures. Casting refers to the pouring and shaping of concrete into molds to achieve the desired form and dimensions. This process involves the careful mixing of cement, aggregates, water, and sometimes additives to create a workable and durable concrete mix. Once the mix is prepared, it is poured into molds that have been designed to meet the specific requirements of the project, whether it be a foundation, slab, column, or other structural elements.

After casting, the concrete undergoes a crucial phase known as curing. Curing is the process of maintaining adequate moisture, temperature, and time to allow the concrete to achieve its optimal strength and durability. Proper curing is vital for minimizing cracks, improving durability, and ensuring long-term structural integrity. It typically involves covering the freshly cast concrete with wet burlap, curing blankets, or applying curing compounds to retain moisture and regulate temperature. The duration of the curing process can vary depending on factors such as the type of cement used, ambient conditions, and the size and nature of the concrete element.

Both casting and curing are integral to the overall quality and performance of a concrete structure. A well-executed casting process ensures that the concrete takes the desired shape and form, while meticulous curing enhances the strength and durability of the material. These processes are crucial considerations in construction projects to ensure the longevity and structural integrity of concrete elements.

Certainly, let's delve a bit deeper into the processes of casting and curing of concrete: Casting, in the realm of concrete construction, is the meticulous procedure of forming and shaping concrete into predefined molds. This fundamental process involves the precise amalgamation of cement, aggregates, water, and potential additives to create a homogeneous and structurally sound mixture. The composition of the mix is crucial, as it determines the final characteristics of the concrete structure. Engineers and construction professionals carefully consider factors such as compressive strength, durability, and workability during the casting process.

Following casting, the concrete undergoes a crucial phase known as curing. Curing is the methodical preservation of adequate moisture, temperature, and time to facilitate the concrete's optimal hydration and hardening. Proper curing plays a pivotal role in preventing cracks, enhancing durability, and ensuring the long-term resilience of the structure. The duration and methods of curing can vary based on factors such asAll the sample mixes after workability tests were casted in molds of size 50X50X50mm. After casting, the molds were demoulded after 24 hours and kept in curing tank for a period of 7, 14 and 28 days respectively. Compressive strength test was carried out after 7, 14 and 28 days of curing. Water permeability test was conducted on all sample mixes after 28 days of curing.environmental conditions, the type of cement used, and the specific requirements of the project.

Curing of cubes

MIX TRAIL:

Cement mixtures with 0% to 3.0% CBC showed enough workability for molding. In the mixture with 6.0% CBCs, significantly reduced workability was noticeable, due to the high hygroscopic property of the CBCs. When water was blended in with the sand, Portland concrete, and CBCs, it was quickly retained into the CBCs. The combination then turned out to be exceptionally dry and solid, prompting troubles with embellishment. Other samples with less than 6% CBCs did not show such a rapid water absorption property and maintained sufficient workability. The current review considered concrete mortar blends with a decent concrete-to- water proportion however various proportions of totals (both sand and CBCs). Considering that CBCs can essentially impact the concrete to water proportion, a further report differing the concrete-to-water-to-sand proportion ought to be led to explore concrete to-water proportions that can oblige higher CBC proportions.

Table : Trial concrete mix design in the case of used coffee waste

Concrete Mix(m^3)	**Cement (kg)**	**CBC (kg)**	**Water(L)**	**FA(kg)**	**CA(kg)**
Conventional Concrete	1	0	0.6	0.75	1.52
CBC-0.6%	1	0.0045	0.6	0.7455	1.52
CBC-0.9%	1	0.00675	0.6	0.7432	1.52
CBC-1.8%	1	0.0135	0.6	0.7365	1.52

Trial concrete mix design in the case of biochar used coffee waste

Concrete Mix(m^3)	**Cement (kg)**	**CBC (kg)**	**Water(L)**	**FA(kg)**	**CA(kg)**
Conventional Concrete	1	0	0.6	0.75	1.52
CBC-0.6%	1	0.0021	0.6	0.7479	1.52
CBC-0.9%	1	0.00315	0.6	0.7468	1.52
CBC-1.8%	1	0.0063	0.6	0.7437	1.52

RESULTS AND DISCUSSION

PROPERTIES OF SPENT COFFEE GROUNDS

Engineering properties of Spent coffee grounds (SCGs).

Engineering parameters	S1	S2	S3
Specific Gravity, GS	1.36	1.37	1.36
Natural Moisture Content (%)	107	156	149
Organic Content (%)	86	89	88
pH	5.15	5.15	5.12
Maximum Dry Unit Weight (kN/m^3)	4.4	4.2	4.02
Optimum Moisture Content (%)	130	134	147

RESULTS ON PROPERTIES OF COARSE AGGREGATE

In order to check whether the coarse aggregate procured is compatible to be used in high strength concrete, certain physical property tests were conducted and results were compared to that mentioned in Indian standards. The results of physical properties of natural coarse aggregate are tabulated .

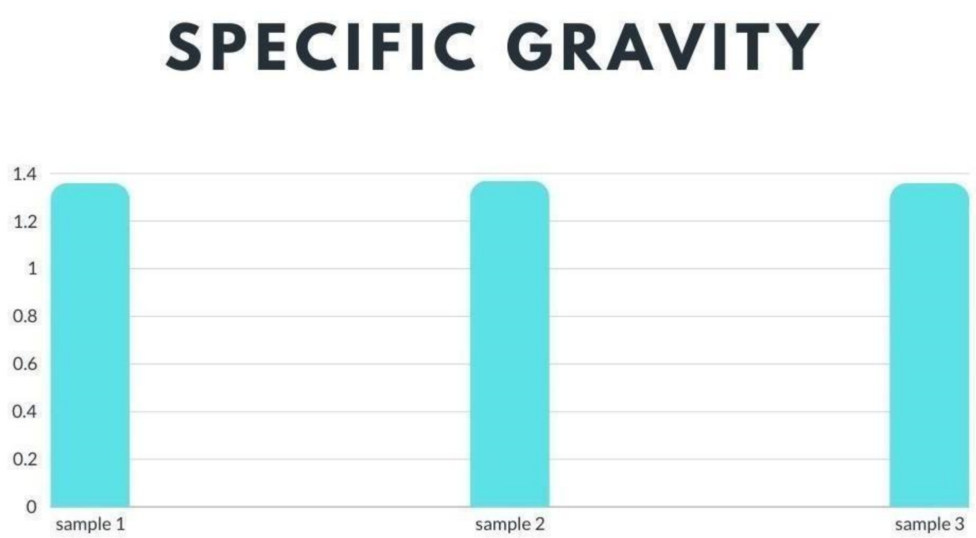
Table 5: Physical Properties of Natural Coarse Aggregate.

Property	As per the Test	As per I.S. Code	I.S. Code referred
Bulk Density	1478.46 Kg/m^3	1500-1600 Kg/m^3	IS 2386 Part 3-1963
Specific Gravity	2.74	----	
Water Absorption	1%	----	
Abrasion Value	18.60	< 35	IS 2386 Part 4-1963
Impact Value	12.00	< 30	
Crushing Value	16.50	< 30	
Elongation Index	13.10	< 30	IS 2386 Part 1-1963
Flakiness Index	19.08	< 30	

Specific gravity

The specific gravity test involves weighing a known volume of spent coffee grounds and comparing it to the weight of an equal volume of water. The specific gravity value is calculated as the ratio of the weight of the coffee grounds to the weight of water.

This test can be valuable in assessing the extraction efficiency of the coffee brewing process. Higher specific gravity values may indicate that more soluble compounds have been extracted from the coffee grounds, contributing to the overall flavor and strength of the brewed coffee. On the other hand, lower specific gravity values may suggest that the grounds have not been fully utilized during brewing.

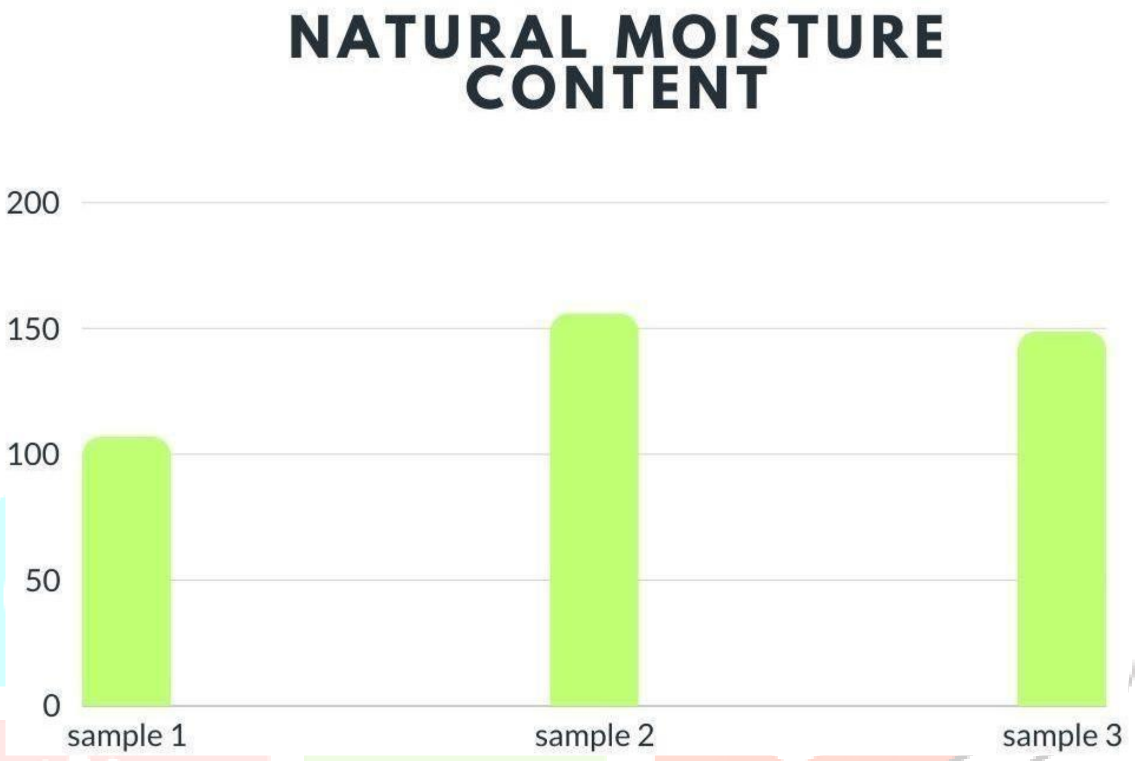


Representation of Specific gravity for S1,S2,S3

Natural moisture content

Average moisture content of sample 1 , sample 2 , sample3

=107+156+149/3 =137.3%



5.1.1 Organic Content

Organic Content (%) = {Initial Mass} - {Final Mass}/{Initial Mass}*100 . Ensure that the procedure is conducted with proper safety measures and adherence to any relevant standards or protocols for accurate and consistent results.

Table 11: Organic content of s1,s2,s3

Sample	Initial mass (g)	Final mass(g)	Organic content (%)
1.	100	14	86
2.	100	11	89
3.	100	12	88

Organic content (%) = 87%

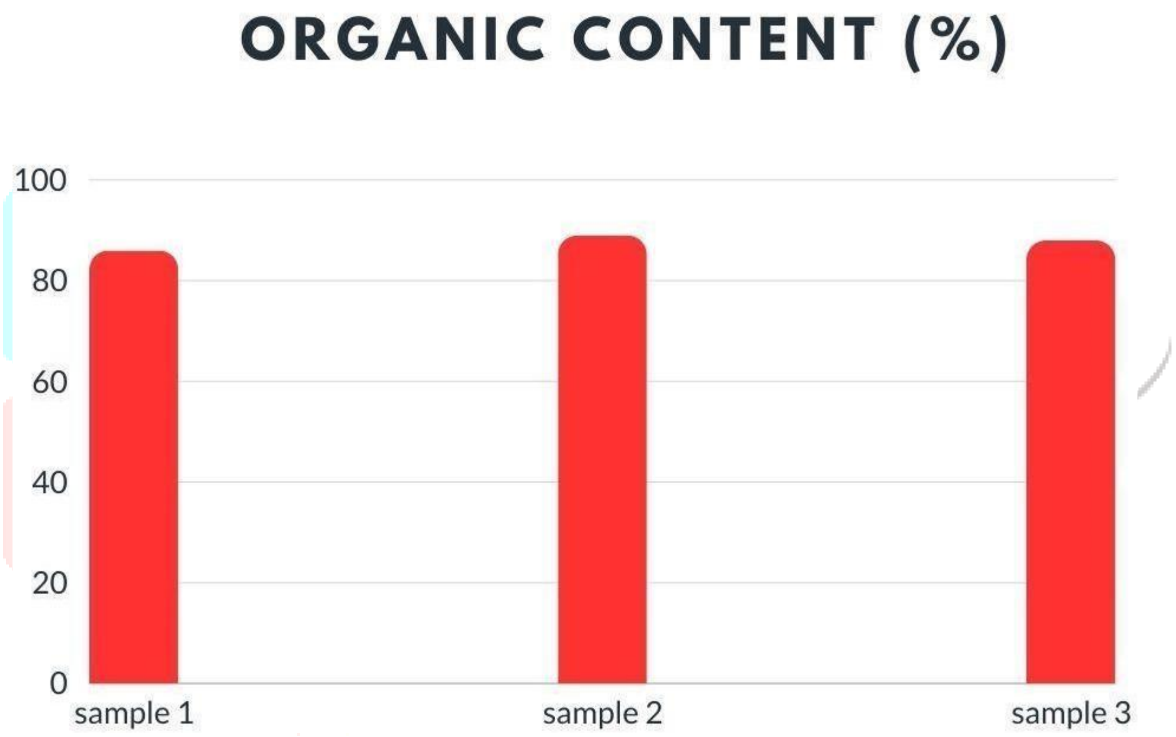


Figure 19: Representation of Organic content for S1,S2,S3

COMPRESSIVE STRENGTH

Compressive strength testing is a fundamental procedure in materials testing that plays a critical role in assessing the suitability and durability of various construction materials. The test involves applying a compressive load to a standardized specimen of the material until it fails or reaches a predetermined deformation. Concrete, a widely used construction material, is commonly subjected to compressive strength testing to ensure it meets design requirements for structures. Engineers use the data obtained from these tests to determine the material's ability to resist forces such as crushing, cracking, or deformation under compression. This information is crucial in designing structures to withstand the anticipated loads and environmental conditions they may encounter. Compressive strength testing is also applicable to other materials, including metals, ceramics, and rocks, providing insights into their mechanical properties. The results of these tests aid in material selection, quality control, and the overall safety and reliability of constructed infrastructure. Additionally, the data generated can be valuable in research and development efforts to improve and innovate new materials for diverse applications. The compressive strengths of all specimens gradually increased by aging over time. Except for a few cases, early age strength trends observed in the 3- and 7-day tests were generally consistent with the 28-day strengths, which were 0.9%,0.0 %, 1.8% and 0.6% from highest to lowest. Surprisingly, samples with 0.6% CBCs (the least) showed a significant strength deterioration compared to the control samples (i.e., 0% CBCs). For all curing days, the 0.6% CBC samples displayed the weakest compressive strengths, except for the 6% CBC samples. However, adding more CBCs resulted in certain differences. 1) Samples with 0.9% CBCs showed the highest compressive strength of all specimens, regardless of curing days. 2) The 1.8% CBC samples showed maximum stresses almost identical to those of the control samples. More than 1.8% CBCs of cement weight in the mortar samples accelerated the deterioration of the compressive strength, CBC samples showed reduced compressive strength compared to control specimens and 1.8% CBC samples.

Table 12: Compressive strength

Sample Mix	**Compressive Strength (N/mm^2)**
	28 Days
0%	15
0.6%	12.52
0.9%	21.02
1.8%	18.33

The improved or nearly equivalent compressive strengths of samples with 0.9% and 1.8% CBCs (despite the same cement-to-water ratio) could be due to the high water-absorption property of CBCs. A suitable measure of CBCs decreased how much water yet at the same time considered a full hydration response between the concrete and water, bringing about more diligently concrete. A chemical hydration reaction was not fully achieved, leading to significantly reduced strength. Diminished usefulness because of the water ingested during the example creation process has proactively been talked about above. This perception uncovers that the utilization of high CBC proportions more than 1.8% to solidify weight ought to be kept away from except if ways ariseto get full hydration and adequate usefulness. No promising increase in compressive strength of concrete was found after 28 days curing of the cubes of CBC.

Figure- Compressive strength test machine

On testing the cubes after 28 days of curing on an average of 25-30% of increase in compressive strength over conventional concrete was found using Biochar concrete cubes subjected to 650^0C temperature at 1.8% partial replacement of sand with Biochar. Significantly it was also found that at and above Biochar concrete cube cannot offer the same compressive strength and the same was found declining.

CONCLUSION

The investigation into the variation in compressive strengths of concrete yielded valuable insights into the influence of CBC on concrete performance. The key findings and conclusions are as follows:

- The addition of CBC has demonstrated a noticeable impact on the compressive strength of concrete up to increase in 30% of strength than conventional concrete.
- Samples with 0.9% CBCs showed the highest compressive strength of 21.02N/mm^2 for 28 days for all specimens, regardless of curing days.

Benefits of Using Coffee Grounds in Concrete**

1. **Environmental Sustainability**: By diverting coffee grounds from landfills and reducing sand mining, we significantly lessen the environmental footprint of concrete production.

2. **Waste Reduction**: Utilizing coffee grounds addresses the issue of coffee waste, contributing to a more circular economy.

3. **Economic Efficiency**: Repurposing coffee grounds can potentially lower material costs, benefiting the construction industry financially.

4. **Enhanced Properties**: Some studies suggest that the inclusion of coffee grounds can improve certain properties of concrete, such as thermal insulation and durability

.To find out variation in compressive strength of concrete using CBC.

1. Compressive Strength:

i. The inclusion of spent coffee grounds in concrete may lead to variations in compressive strength.

ii. Optimal percentages and particle sizes of spent coffee grounds need to be determined through careful mix design to minimize any negative impact on compressive strength.

iii. It's possible that with the right proportioning and curing conditions, concrete containing UCW could exhibit compressive strength comparable to or even exceeding that of traditional concrete.

iv. **Optimization and Mix Design:**

The variation in both compressive and tensile strengths is likely dependent on the optimization of mix designs.

v. Adjusting factors such as the water-cement ratio, aggregate size, and the percentage of spent coffee grounds can help achieve desired strength characteristics.

***2.* Influence of Curing Conditions:**

i. Curing conditions play a significant role in the development of concrete strength.

ii. The influence of curing on the hydration process and the overall performance of concrete with spent coffee grounds should be considered.

***3.* Long-Term Performance:**

i. Assessing the long-term performance of concrete with UCW is crucial to understanding how its mechanical properties evolve over time.

ii. Factors such as durability, resistance to environmental conditions, and aging characteristics need to be evaluated for a comprehensive conclusion.

***4.* Environmental Considerations:**

i. If the use of spent coffee grounds in concrete proves successful, it may offer environmental benefits by repurposing waste material.

ii. Life cycle assessments should consider not only the immediate mechanical properties but also the broader environmental impact.

In conclusion, the variation in compressive and tensile strengths of concrete using spent coffee grounds (CBC) is a complex interplay of factors, including mix design, curing conditions, and the inherent properties of the coffee grounds. Comprehensive experimentation, optimization, and consideration of long-term performance are essential in drawing meaningful conclusions.he partial replacement of sand with used coffee grounds in M-30 grade concrete represents a remarkable step towards sustainable construction. It aligns with global efforts to reduce waste and preserve natural resources while potentially offering economic and performance benefits. As we continue to innovate and refine this approach, we move closer to a future where construction practices contribute positively to our environment.

Let us embrace this opportunity to lead in sustainability, transforming waste into a valuable resource and paving the way for a greener, more sustainable construction industry.

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