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ANALYSIS OF TIMBERCRETE: SAWDUST-INFUSED CONCRETE MIXTURES

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ABSTRACT

This investigation aims to advance sustainable construction practices by investigating the feasibility and environmental benefits of incorporating sawdust instead of sand in concrete mixtures. By using sawdust, a byproduct of the forestry industry, in the process of making concrete, the investigation addresses the pressing need for resource conservation and waste reduction, since the construction sector is a significant user of raw materials. According to British European Norm Standard BS 8500-2:2023 for C35 grade concrete, the experimental programme examines how different percentages of sawdust (0%, 5%, 10%, 15%, 20%, and 25%) substituted for sand affect the physical characteristics of concrete, including its compressive strength, dry density, and water absorption. The workability, consistency, and strength of the sawdust-incorporated concrete mixes were assessed by a combination of techniques including sieve analysis, slump testing, casting and curing procedures, and compression tests. The results indicate a potential reduction in material costs and environmental impact with the ideal sawdust content by showing a negative association between the amount of sawdust and the concrete's density and compressive strength. A larger sawdust content was associated with higher rates of water absorption, highlighting the hygroscopic nature of sawdust and its implications for the durability of concrete. According to the investigation's results, it is possible to substitute concrete with up to 5% sawdust, providing an environmentally friendly alternative to conventional concrete while still having sufficient mechanical properties for use in construction. It is recommended that further research be conducted to improve sawdust's compatibility with cementitious materials, increase the durability of sawdust-incorporated concrete, and create industry guidelines for its use. This investigation contributes to the body of knowledge on environmentally friendly building materials by promoting the use of sawdust and other eco-friendly substitutes in the building sector to reduce negative effects on the environment and increase resource efficiency.

Keywords: *Aggregates, Concrete, Materials, Sawdust, Timbercrete.*

INTRODUCTION

In this era, sustainable development is a significant concept. Thus, to solve environmental pollution and address economic issues, the world must strike a balance between the use of energy and resources. This can be achieved by reducing the use of expensive conventional building materials while also eliminating environmental pollution through the beneficial reuse of waste (Safa *et al.*, 2014). It is commonly recognised that a large number of materials are used throughout the construction and operation stages of a building as well as during the building's service life cycle. Furthermore, building materials are a very important part of the construction process. After the food and beverage processing sector, the construction sector is the second-largest user of raw materials (Charis *et al.,* 2019), in construction projects, which require the use of materials.

According to Safa *et al.* (2014), 50–60% of the project's total cost is incurred by purchasing building materials. The cost of construction has been greatly impacted by the usage of a variety of building materials in the sector, including blocks, stone, gravel, granite, lumber, reinforced steel, bricks, blocks, gravel, lumber, stone, and granite. To preserve energy, and resources, and address environmental issues, global society needs to strike a balance at this point. For instance, sand is becoming increasingly scarce since it is used in the manufacturing of concrete, glass, and electronics. Gabbatiss (2017) and Torres *et al.* (2017) note that the scarcity of sand has disrupted the ecosystem and hiked the price of sand from a locally produced good.

Thus, in this research, sawdust was applied to partially replace sand in the making of concrete. By using sawdust instead of sand, concrete can be made more affordably and sustainably than using traditional methods. Typically, sawdust is disposed of by burning it outside, which releases toxic smoke that is dangerous to human health. Using it in cement composites is a more environmentally friendly approach to dispose of it. To lessen the strain on the limited natural resources, sawdust, which the forest industry produces in large quantities, could partially substitute fine aggregates in concrete production. According to Lei *et al*. (2006), poor compatibility, poor durability, and low mechanical performance are the characteristics of sawdust composites. Meanwhile, utilising sustainable construction materials like timbercrete, wood, bamboo, and crushed stone is one method of building sustainably. Compared to conventional blocks, timbercrete is an eco-friendly material that has several advantages.

A mixture of carefully sourced cement, sand, water, and cellulose materials like sawdust from sawmills is called timbercrete. It offers many benefits, including affordability, aesthetic appeal, ease of use, thermal efficiency, reduced carbon emissions, minimal capital equipment expenses, and fire resistance (Timbercrete Pty. Ltd., 2022). Timbercrete is one of the materials that is certain to grow more and more common in the future because it is a sustainable resource. It indicates that it has excellent quality, is not harmful to the environment, and may be utilised successfully for a variety of goals (Smith *et al.,* 2012). Furthermore, it can be incorporated into a wide range of architectural materials, including blocks, panels, and bricks. Furthermore, the information consistently demonstrates that it is methodical and advantageous to both the environment and its end-users. Timbercrete distinguishes itself from other building materials with some unique qualities (Brostow *et al.,* 2010). Its embodied energy is substantially lower. It is also the only material on the market that traps carbon, which would otherwise be released into the atmosphere. Timbercrete offers a less heavy substitute (Jonathan & Charles, 2017), uses sawdust to help minimise pollution (Safa *et al.*, 2014), and can be applied to make up for the absence of fine aggregates like sand. In this research, it is discovered that density decreases as sawdust proportion increases. Sawdust waste is reduced and repurposed for use in building projects. Gopinath *et al.* (2016) state that sawdust can be used in place of some fine aggregate. In this research, the impact of sawdust is examined by preparing a matured fine aggregate by incorporating 5%, 10%, 15%, 20%, and 25% of sawdust with the fine aggregate. Suji (2016) states that a field experiment was conducted to examine the characteristics of sawdust utilised as a partial substitute in block (Khan *et al.*, 2020) in fine aggregates.

This investigation explores the feasibility and environmental advantages of substituting sawdust for sand in concrete mixtures. The investigation aims to provide insights into the feasibility of sawdust-enhanced concrete, or timbercrete, as a material for environmentally conscious construction practices by assessing the effects of different sawdust proportions on the physical properties of concrete, such as water absorption, compressive strength, and density. By conducting this investigation, the research aims to make a positive impact on the construction industry's transition to sustainable development by aiding in the creation of construction materials that are not only economical and efficient but also ecologically friendly.

This research aims to examine the practicality and environmental benefits of incorporating sawdust instead of sand in concrete mixtures, contributing to eco-friendly construction practices and promoting resource conservation. To reduce waste while simultaneously taking benefit of sawdust's availability as a by-product of the forestry industry for more environmentally friendly construction solutions, this research will evaluate the effects of various sawdust proportions on concrete's physical properties, such as density, water absorption, and compressive strength.

MATERIALS AND METHODS

The design mix for C35 grade concrete has been adopted using the British European Norm Standard (BS 8500-2:2023). Five distinct percentages of marble dust particles (MDP) by weight have been used to replace sand, with the percentages being 0%, 5%, 10%, 15%, 20%, and 25% of sawdust. The study employed ordinary Portland cement (OPC) with a 28-day compressive strength of 42.5 N/mm^2. As a fine aggregate, sharp sand with an acceptable aggregate size of 2 mm and a specific gravity of 2.65 was utilised. Additionally, sawdust from a genuine source was utilised to partially substitute the fine aggregates. For the experiment, standard concrete was made with a water-to-cement ratio of 0.51 and a mix design ratio of 1:2:4 (cement: gravel: sand). Seven cubes (to be tested on the 7th and 14th day of curing) and two cubes (to be tested on the 28th day of curing) were undertaken with each (%) replacement.

SIEVE ANALYSIS

Sieve analysis is the preferred method in particle size analysis for a variety of factors. Sieve analysis is currently an extensively utilised quality-control approach in the fine aggregate process control industry due to its low cost, efficiency, and simplicity.

Test procedure

A collection of size-specific BS410 sieves, including 0.075, 0.150, 0.300, 0.425, 0.600, 1.180, 2.360, and 4.750. Accurately balance to within 0.1g of the test sample's weight. The test sample is first dried at approximately 100°C (±5°C) to a constant weight, and then it is weighed. After that, the sample is run through a series of standardised sieves. Weighing is done on the material that is retained on each sieve after sieving. The percentage of the entire sample weight that represents the cumulative weight of the aggregates that pass through each sieve is computed. These cumulative percentages can be added up and divided by 100 to get the fineness modulus, a crucial metric in sieve analysis. A graph with a semi-logarithmic curve shows the sieve analysis results graphically. The percentage of particles smaller than a specific diameter is shown against the size of particles on a logarithmic scale in this graph. This graphical representation aids in comprehending the sample's particle size distribution, which is important for determining if aggregates are appropriate for a given type of construction.

SLUMP TEST

The concrete slump test aims to investigate the consistency and workability of the concrete mix prepared in the laboratory. During the experiment, the uniform quality of the concrete is checked by performing a concrete slump test on each batch. The slump test is the most affordable and simplest way to determine concrete's workability and It provides immediate results. The slump is completed following the steps outlined in BS EN 12350-2.

Test procedure

According to the BS EN 12350-2 standard, the concrete slump test necessitates a slump cone, a base plate for stability, a tamping rod for compaction, and a measuring scale for slump assessment. To conduct the slump test following BS EN 12350-2, it was ensured that the base plate and slump cone were dry, clean, and free of surplus water. Three layers of freshly mixed concrete, each filling up about one-third of the cone's capacity, were poured into the cone while it was resting on the base plate. Twenty-five strokes of the tamping rod were used to compact each layer of concrete, ensuring good penetration and even distribution into the layer below. Using a trowel, the concrete was levelled to the top of the cone after the last layer. After the cone was filled and the surface was levelled, it took five to ten seconds for the cone to be lifted vertically off the concrete without moving laterally.

CASTING AND CURING

Usually, the liquid material is poured into a mould that contains a hollow chamber in the desired shape during the casting process, and the mould is then allowed to harden. The process is completed when the hardened part, was ejected from the mould. Metal materials that have been cured after combining two or more ingredients are commonly used as casting materials. Most frequently, this is utilised to generate complex dimensions that would be difficult or costly to generate utilising other methods. A mechanically vibrating machine was used to accomplish the compaction.

The following percentages (0%, 5%, 10%, 15%, 20%, and 25%) were recorded for the 150 mm x 150 mm x 150 mm moulds. After 24 hours, remoulding was carried out, and seven cubes of each mix were cast. The cubes were taken out of the moulds and allowed to cure in the curing tank for 24 hours. Twelve cubes were cured for seven days, following which their dry density and water content were assessed. For the compression test, nine samples total for each mix were created, of which three were cured in three different sessions: three for seven days, three for fourteen days, and three for twenty-eight days, following which testing was completed. In this research, curing was carried out by submerging the samples in water.

COMPRESSION TEST

According to BS EN 12390-3:2019, the concrete cube compression test was utilised to determine the specimens' compressive strength. The maximum load that a timbercrete cube with standardised dimensions can withstand before failing under axial compression is determined by this test. When the timbercrete cube reaches its mature age, which occurs after 28 days of curing, it is allowed to dry before undergoing a compressive strength test to establish the validity of the sawdust-containing concrete (refer to Figure 1). At 7 and 14 days, all specimens underwent testing at the early hardening stage.

Figure 1: Crack pattern of the failed cube.

Test procedure

The following tools were used to conduct the timbercrete cube compression test following BS EN 12390-3:2019: a curing tank and conditions for keeping the specimens in a controlled environment; a balance with an accuracy of at least 0.1% of the test specimen's weight; a calibrated master gauge; steel cube moulds; vibrating machine, and a tamping rod. Following the guidelines outlined in BS EN 12390-3:2019, test specimens measuring (150 x 150 x 150 mm) are prepared, and then concrete cubes with the appropriate mix design and dimensions are cast using the (MDP) % of sawdust. To ensure correct hydration, these cubes were subsequently put through a curing procedure in a curing tank under predetermined guidelines. The cubes were then submerged in a machine designed for testing compression, where a steady, gradual load was delivered at a predetermined rate until the cube failed to compress (refer to Figure 1). By dividing the maximum load by the cube's cross-sectional area, the compressive strength is determined. In compliance with the standard.

WATER ABSORPTION

The results show that sawdust has a significant hygroscopicity in the experimental test. The BS (1881-122:2011+A1:2020) draws attention to the propensity of organic, porous materials like sawdust to absorb moisture rapidly. This characteristic is highlighted by the experiment's day 28 results, which show a direct correlation between sawdust concentration and higher water absorption. These results highlight the significance of such materials' stability and durability and are essential for assessing material appropriateness in construction, particularly in areas with changing humidity.

DRY DENSITY

Concrete density may drop if sawdust, which is often lighter than other aggregates, is added in greater proportion. The impact of different aggregate quantities on concrete qualities and the fundamentals of concrete testing are consistent with this relationship.

RESULTS AND DISCUSSION

An experimental analysis was conducted to introduce the use of sawdust in timbercrete. Tables and graphs have been used to present all of the results and analyses. Table 1 illustrates the percentage of material that passes through each size sieve. If the curve is smooth, the material is well-graded; if there are steep parts, there is a specific particle size dominance.

Table 1: Particle size distribution result

Sieve Number	Sieve Size (mm)	Sieve Mass (M1)	Sieve Mass + Soil Retained (M2)	Mass of Soil (M2-M1)	Percentages Retained on each Sieve (M2-M1)/M1 X 100	Cumulative Percentage Retain (%)	Percentage CumulativePassing (%)
4	4.75	770.5	791.5	21.00	4.20	4.20	95.80
10	2.36	774.25	770.25	26.00	5.20	9.40	90.60
16	1.18	721	765.5	44.50	8.90	18.30	81.70
30	0.60	654	700.5	46.50	9.30	27.60	72.40
40	0.43	577	689.0	112.00	22.40	50.00	50.00
60	0.30	560.5	707.5	147.00	29.40	79.40	26.60
100	0.15	525.5	587.0	62.00	12.40	91.80	8.20
200	0.075	512.5	533.5	21.00	4.20	96.00	4.00
Receiving Pan		480	500	20.00	4.00	100.00	0.00
Total				500	100		

Figure 2 illustrates the graphical representation of the particle size distribution results, enhancing clarity and ease of understanding.

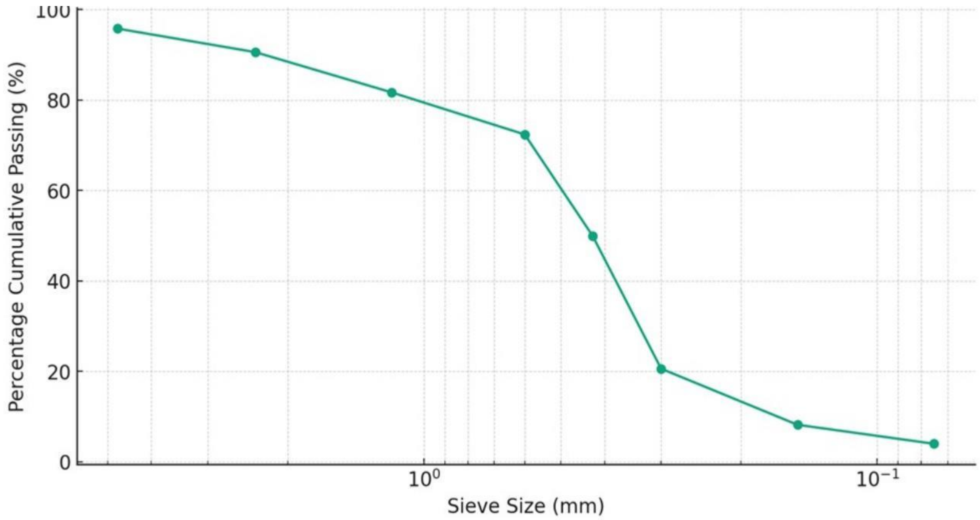

Figure 2: Particle size distribution graph representation.

The slump test data, shown in Table 2, illustrates the measured values for various mix samples ranging from A1 to F6. These figures represent the height variation between the concrete specimen's highest point and the cone, which serves as an instantaneous measure of slump.

Table 2: Concrete Specimens Slump Tests.

Mix Sample	Value (mm)
A1	40
B2	90
C3	100
D4	120
E5	150
F6	175

Figure 3 represents the slump values derived from the tested specimens, offering an in-depth analysis of the concrete's workability and consistency.

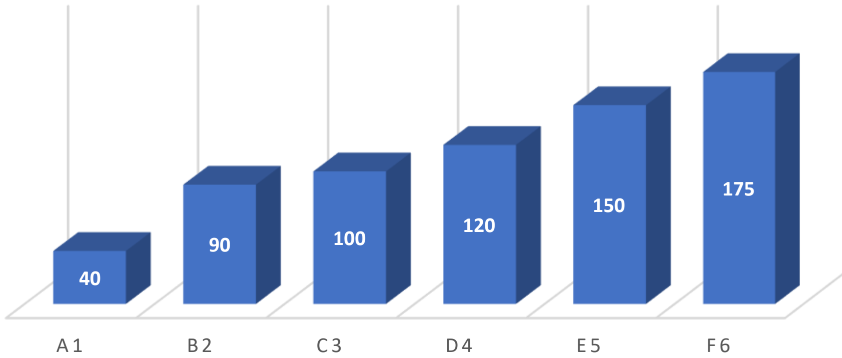

Figure 3: Concrete Specimens Slump Tests Graphical Representation

As represented by Table 3, compressive strength decreases noticeably as the percentage of sawdust used increases. As a result, the test can be used to adopt a timbercrete-based construction project to reduce dead load and costs. By properly curing to a mix of 1: 1.9:3.8 or 5% replacement, timbercrete can attain the average strength value required, which varies from 7.32 to 13.32 Mpa. Based on density analysis, it was found that density decreases as sawdust percentage increases.

Table 3: Concrete Specimen's Compressive Strength Test Results.

Composition and Proportions of Concrete Specimens Incorporating Sawdust						Compressive Strenght (N/mm2)		
Specimens	**Cement**	**Gravel**	**Sand**	**Sawdust (%)**	**W/C Ratio**	**7 (Days)**	**14 (Days)**	**28 (Days)**
A1	1	2.0	4.0	0	0.51	9.45	13.33	15.62
B2	1	1.9	3.8	5	0.56	7.23	8.75	13.32
C3	1	1.8	3.6	10	0.61	6.14	7.45	8.75
D4	1	1.7	3.4	15	0.66	4.82	6.97	7.45
E5	1	1.6	3.2	20	0.72	3.60	5.40	6.82
F6	1	1.5	3.0	25	0.77	3.10	4.20	5.43

Figure 4 demonstrates a clear relationship between the percentage of sawdust additive in concrete and its compressive strength during various curing periods (7, 14, and 28 days).

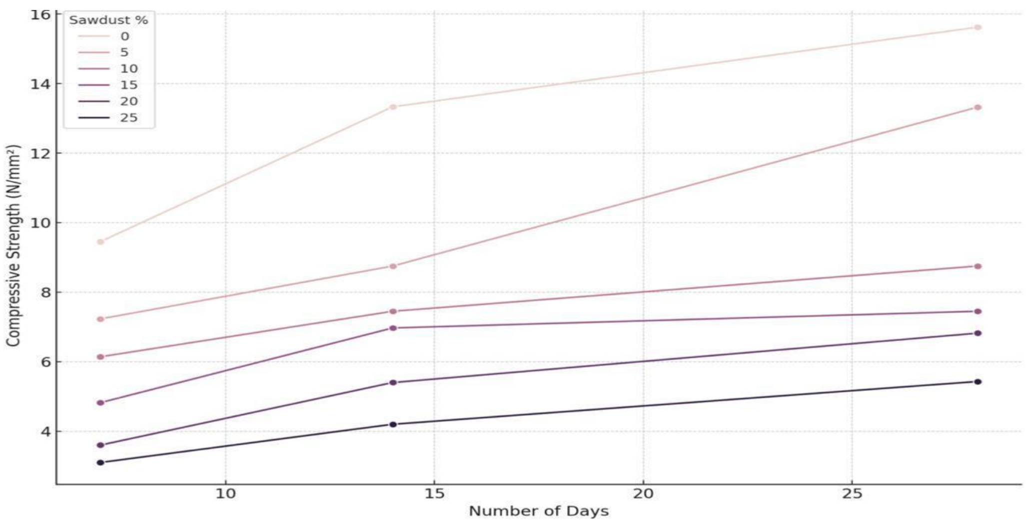

Figure 4: Graphical Representation Of Concrete Compressive Strength Test Results

Table 4 illustrates the water absorption results for the tested specimens, revealing a significant variation between the percentage of sawdust admixture and water absorption. As the percentage of sawdust increases, there is a corresponding increase in water absorption. This indicates that adding sawdust to the concrete mix increases water absorption rates, emphasising its effect on the material's properties.

Table 4: Water absorption tabulated results of the specimens

Specimens	Cement	Gravel	Sand	Sawdust (%)	Water Absorption (%)
A1	1	2.0	4	0	0.57
B2	1	1.9	3.8	5	1.40
C3	1	1.8	3.6	10	2.75
D4	1	1.7	3.4	15	3.73
E5	1	1.6	3.2	20	5.20
F6	1	1.5	3.0	25	7.40

Figure 5 presents a graphical representation of the water absorption data for the examined specimens, revealing significant differences in water absorption due to different amounts of sawdust admixture.

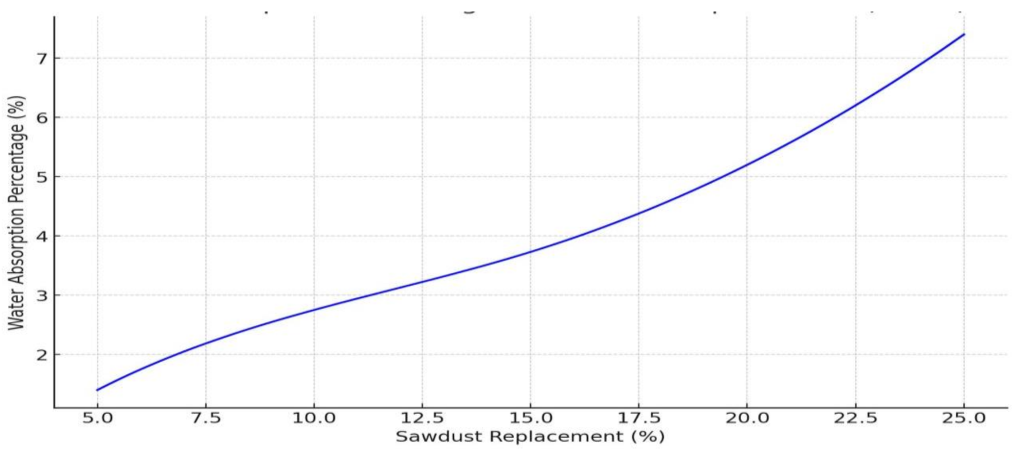

Figure 5: Water absorption curve.

Table 5 displays the results of the experiment while the undertaken test with a mix ratio of 1:1.9:3.8 and 5% replacement was found to have a density of 2450. A certain amount of water absorption is acceptable; however, excessive absorption causes water to seep into the timbercrete, which then shrinks after drying and eventually cracks. There is a noticeable rise in water absorption as the sawdust percentage increases. However, it should be emphasised that the increase in water absorption is simply due to the sawdust's proportion. The water absorption is 1.40% for a 1:1.9:3.8 mix ratio with a 5% replacement factor, which is acceptable.

Table 5: Dry density tabulated results of the specimens.

Specimens	Cement	Gravel	Sand	Sawdust (%)	Dry Density
A1	1	2.0	4.0	0	2560
B2	1	1.9	3.8	5	2450
C3	1	1.8	3.6	10	2390
D4	1	1.7	3.4	15	2330
E5	1	1.6	3.2	20	2330
F6	1	1.5	3	25	2150

Figure 6 illustrates the correlation between sawdust content and dry density of concrete samples. As the percentage of sawdust increases, there is a continuous fall in dry density, demonstrating that sawdust admixture reduces density in concrete.

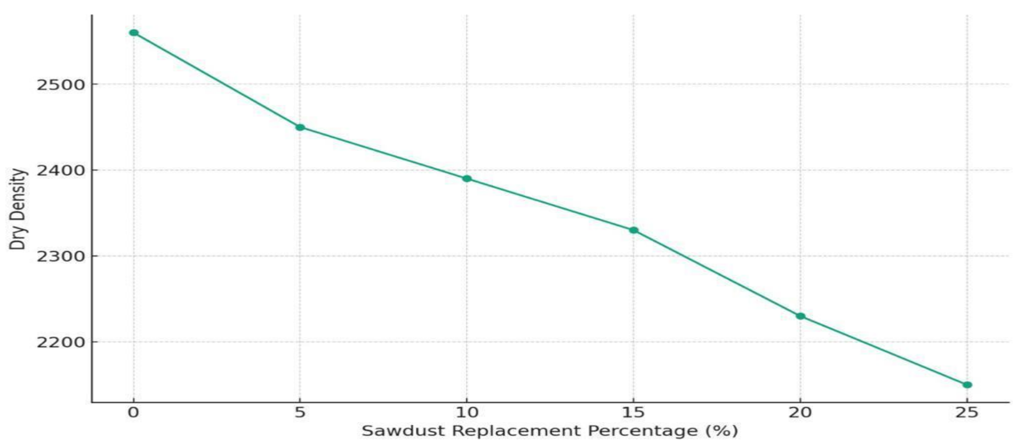

Figure 6: Dry density graphical representation

CONCLUSION AND RECOMMENDATIONS

The quantity of sawdust and cubes has a negative correlation. It was determined that the 1:1.9:3.8 ratio with 5% replacement was noteworthy for the compressive strength and density characteristics. The outcome of the experiment indicates that 5% is a suitable substitute proportion for sawdust. A percentage of more than 5%, however, presents issues as it reduces the timbercrete's strength. With 5% replacement factors and a 1:1.9:3.8 mix ratio, the hygroscopicity is 13.32%, which is permissible. The slump value of the timbercrete increases gradually as the quantity of sawdust in the timbercrete-ready concrete increases. It is essential to perform additional research and analysis on the topics of sawdust quality and its effects on compressive strength, as well as heat and fire resistance. It may be possible to incorporate hollow concrete blocks and other bricks in the research's scope.

The results of this research recommend that to improve sustainability and reduce the impact on the environment in the construction industry, sawdust be precisely added to concrete mixtures in place for certain amounts of sand. To maintain a satisfactory balance between mechanical properties and environmental benefits, up to 5% sawdust substitution is the ideal level. The performance of sawdust-incorporated mixtures may be improved by more research into how to treat and modify sawdust, which could increase its compatibility with cementitious materials. To guarantee that these timbercrete materials are suitable for a range of structural applications, the construction industry should also look into the materials' lifespan assessment and long-term durability. Furthermore, the industry would be able to accept and use sawdust in building materials more widely if guidelines and standards were developed for its use. The commercialisation of timbercrete products, pilot testing, and innovation are all dependent on cooperation between research institutes and industrial stakeholders. Lastly, encouraging experts and the general public to learn about the benefits of sustainable building materials is essential to the uptake of eco-friendly substitutes like sawdust-reinforced concrete.

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