EFFECT OF WATER REPELLENT COATING ON THE PROPERTIES OF OIL PALM SHELL CONCRETE

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Abstract

One way to build structures that are sustainable and environmentally beneficial is to use industrial waste as a building material. Concrete coarse aggregate may one day be replaced with oil palm shell, which is created during the palm oil extraction process. In this work, the water absorption rate in an oil palm shell is adjusted with a water-repellent chemical, preserving the mechanical qualities of normal-weight concrete (NWC). Because of their low weight, oil palm shells (OPS) can be employed as coarse aggregate in structural applications. The chemical and physical properties of such aggregate are analyzed and refined to satisfy the specifications required to manufacture concrete of superior quality. An additional benefit for long-lasting concrete is the internal curing that happens when a treated oil palm shell is utilized as a lightweight aggregate. We measured and talked about compressive strength, aggregate impact, and water absorption. With compression strengths between 25 and 30 MPa, similar to NWC, the results show that substituting industrial waste products for ordinary aggregate is both ecologically friendly and structurally sound.

Keywords: Water repellent; Water absorption; Oil palm shell (OPS); Density; concrete; lightweight

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1. Introduction

The building industry is growing quickly and consumes a lot of natural resources. Now, policymakers are concentrating on making concrete more environmentally friendly and on improving its strength, durability, and lightweight. The purpose of the new material development is to use industrial waste. The byproduct of producing palm oil, oil palm shell, is easily obtainable in India. [1] These shells are like concrete aggregates in terms of their mechanical properties and lightweight. Certain material aspects need to be enhanced because OPS's fundamental physical and chemical properties are insufficient for direct usage in structural concrete. [2] The usual air-dry density of structural lightweight concrete (SLC) falls between 1440 and 1840 kg/m3, according to the ASTM 567-A Standard Test Method for Density of SLC. Low-density concrete can be produced using both commercial and natural waste materials, such as pumice, scoria, and oil palm shells. According to [3], the density of concrete produced using these waste materials and natural ingredients is between 1200 and 1900 kg/m3. SLC has a density that is 25% to 35% lower than normal-weight concrete (NWC).

There are four steps involved in processing palm oil from palm oil fruit: sterilization, pressing, separation, shell separation, and kernel and clarifying. [4] Shells are the waste products that are disposed of as waste throughout the processing stage. Shells are often dark grey or black. After being crushed, the concrete created with this oil palm shell has a dark appearance. [5] These shells are exposed to the outdoors without any maintenance or safeguarding. It was necessary to investigate the use of this industrial waste in the concrete. The mechanical and physical qualities of these shells, which can be used in place of aggregate in concrete, are significantly improved.

Compressive strength and durability qualities are influenced by the LWC aggregate parameters, but the constituent material matrix has a bigger impact. The cohesive nature of the concrete mixture should be preserved by the fine particles in the fine aggregates employed in the matrix. For many years, mix designs for SLC were developed to achieve the best strength and longest-lasting concrete. According to [6], Malaysia has been using SLC to construct ecologically sustainable structures among emerging nations. To make the building ecologically conscious and the concrete portable, certain farm waste and manufacturing byproducts are used. OPS is extensively utilized and accessible in tropical areas. OPS are agricultural wastes from the global oil palm industry. [7] Palm kernel shells (PKS) and oil palm shell (OPS) are their byproducts. In Malaysia, research on OPS for SLC was initiated in 1985 and was conducted. Numerous nations, including Indonesia, Nigeria, Malaysia, and others, have developed oil palm businesses. Malaysia produces and exports 57.8% of the world's total supply of palm oil to other nations.

According to[8], OPS for SLC has good physical and mechanical qualities as well as good thermal efficiency for low-cost housing. Utilizing solid agricultural wastes as building aggregates helps save building costs.[9] The greatest substitute for granite gravel, which is frequently used to make concrete, is OPS. Concrete made from such industrial trash solves the issue of how to dispose of waste products produced by various companies.

Before casting, the oil palm shell needs to be treated. Eight times more water is absorbed, or the sorptivity value, than in a typical aggregate.[10] After being separated from the fruit, the shells are crushed; they have an angular or polygonal shape, among other shapes. The smooth surface of the shells ranges in thickness from 2.3 to 10 mm. According to [11], OPS has a high porosity and a density of 350–600 kg/m3, with a specific gravity ranging from 1.13 to 1.38.OPS has a 60% lesser density than gravel, which is a typical weight aggregate. OPS is tough and resistant to deterioration.

2.Materials and Methods

2.1 Binder

Ordinary Portland cement (OPC) is used to make structural lightweight aggregate concrete. Its specific gravity is 3.14, and its Blaine-specific surface area is 3510 cm2/g. On the other hand, silica fume, which is employed in the process, has a specific gravity of 2.05 and a specific surface area of 15,000 m2/kg. The specific surface area and specific gravity of GGBS are 4000 cm2/g and 2.85, respectively. Table 1 provides information about OPC's chemical makeup.

2.2 Aggregates

Ordinary river sand, which ranges in size from 300 microns to 5 mm, is considered fine aggregate; oil palm shells, on the other hand, have a specific gravity of 1.3. As seen in Fig. 1, these come from Andhra Pradesh, India, and range in size from 2.36 mm to 10 mm. The physical characteristics of OPS are 510 kg/m3 for compacted bulk density and 380 kg/m3 for loose bulk density, according to [12].In 24 hours, oil palm shell (OPS) absorbs 22% of its weight in water, whereas gravel only absorbs 4%. The sieve size range is 2–10 mm, and sieve analysis is done. The impact on OPS concrete's mechanical qualities is displayed on the grading curve. Mix design is completed with a compressive strength of roughly 25–30 MPa for 56 days.

Fig. 1 Oil palm shell

2.3 Water

To combine the ingredients of concrete, regular water is utilized. The water-to-cement ratio used is 0.35, or between 170 and 220 kg/m3.

2.4 Water Repellents

Penetrative waterproofing and acrylic bonding agents are the admixtures that reduce aggregate porosity and generate a water-resistant cementitious bonding coat. It works wonders as a bonding agent to increase the adherence of concrete. OPS has a water absorption of roughly 23–30%, which is 60–70% more than NWC. Utilizing a water-repellent admixture can result in the OPS aggregate absorbing less water, as demonstrated in (Fig 2). The graph shows that when the amount of water-repellent admixture increases, the rate of water absorption decreases. [13] state that this Nano-sealer should be added to the aggregate within 24 hours of creating OPS concrete, as it becomes an essential component of the mixture. Fig. 3 shows that oxygen and silicon combine to generate a hydrophobic nature. This yields good workability and slump value. Low yields are obtained with untreated OPS concrete.

Fig. 2 Comparison of Water absorption in Treated & Non-Treated OPS

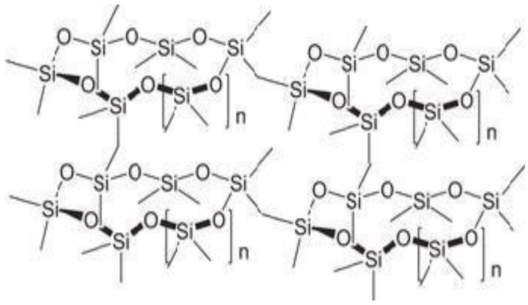

Fig. 3 Oxygen and silicon combine to generate a hydrophobic nature.

3.Tests on Aggregate (OPS) PropertiesBulk density:

Oil palm shell has a bulk density of 380–400 kg/m3, or about 27% of conventional aggregate, compared to 1440 kg/m3 for conventional aggregate (CA). Oil palm shell is classified as a lightweight aggregate by ACI 318-R. Oil palm shell concrete has a density of 1790–1890 kg/m3. Oil palm shell's specific gravity is 1.24, while conventional aggregate's is 2.61.

3.2 24 hours Water absorption:

Oil palm shell has a 25% potential to absorb water. To mix the concrete, more water is needed because the OPS has a higher absorption capacity. Concrete's durability and bond strength are lowered as a result.

3.3 Aggregate impact value:

These are the two aggregate impact values.

OPS – 29.4%
CA- 17.85%

The mechanical qualities of concrete are reduced when the impact value of OPS aggregate surpasses that of CA.

3.4 Characterization of OPS

Studying the criteria below is crucial whenever we add a new substance to the concrete.

- The chemical composition
- Morphology of the aggregate surface

3.5 Study of Elemental Composition

- XRD (X-ray diffraction Analysis) is conducted on the OPS aggregate to study its chemical composition.The following observations were made.
- XRD spectroscopy of OPS shows 40% silica peaks at almost all major peaks.
- Besides silica peaks, XRD analysis detected aluminum oxide, calcium oxide, iron oxide, and magnesiumoxide. (figure 4)
- An amorphous hump was observed in the XRD peaks due to the presence of amorphous glassy material.

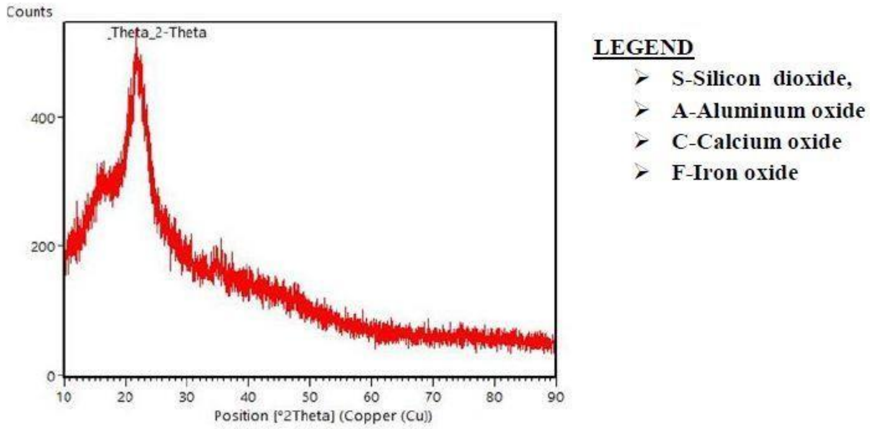

Fig.4: XRD image of Oil Palm Shell

Study of Surface Morphology

Analysis using Scanning Electron Microscopy (SEM) is done to examine the OPS aggregate's surface. (figure 5) on the surface of the OPS aggregate, micropores with a size range of 0.5 to 15 micrometers are visible.

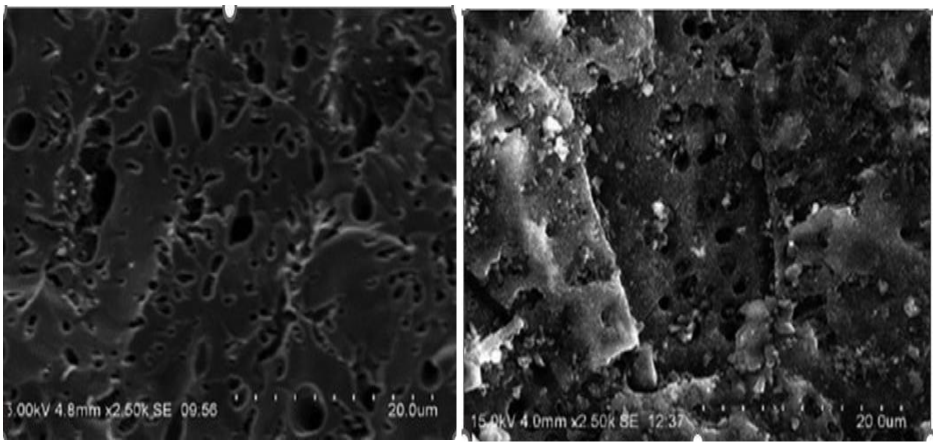

Fig.5: SEM images of Oil Palm Shell

4. Results & Discussions

After the treatment of OPS aggregate with Si-H compound chemical, there is a significant change in all the parameters of the aggregate which are as follows.

4.1. Water Absorption Test

OPS aggregates are tested for water absorption rate before and after coating. OPS are treated with surface coating with low pressures. TOPS and NTOPS are dipped in a wire basket for 24 hours. With surface dry conditions check the density of aggregates. Keep the sample in the oven for 24 hours and check the sample for every hour. As the OPS aggregates are highly porous, within the time of 8 hours the water gets evaporated.

Water absorption of OPS is decreased with the help of surface treatment. Si-H compound chemical is used as coating based on organosilane chemistry. This fills the pores in the OPS aggregate. (figure 6)

Porous silica on the surface of the aggregate reacts with organosilane compounds to give adhesion properties. The adhesion of this organosilane to the aggregate is increased by 50%. Maintaining the absorption level to 6-8%.

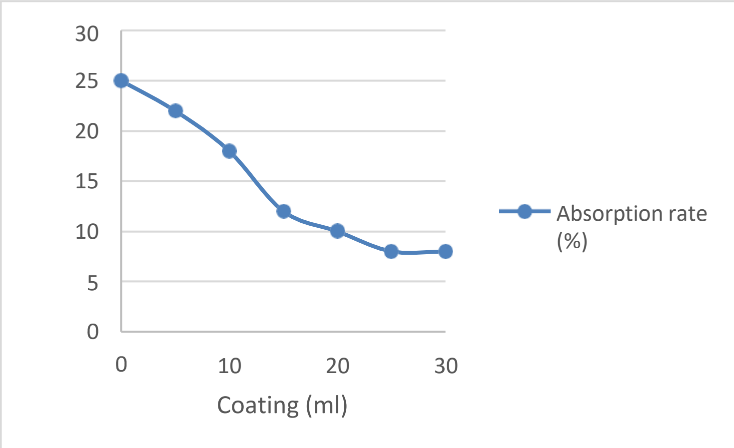

Fig.6: Coating Vs Absorption

4.2 Aggregate Impact Value Test

Non-treated ops have an aggregate impact value of 29.5%. On the other hand, the treated ops had an aggregate impact value of 21.9%. Due to the water absorption coating, the coating acts as a layer on the surface of the aggregate. (figure 7) This makes aggregate strong enough to hold the structure for more load.

Fig.7: Aggregate Impact Value Test

4.3 XRD Analysis of Treated Oil Palm Shell

OPS substrate is coated with Si-H compounds. This Si-H is combined with the Si present on the OPS aggregate. (figure 8) This interacts with the silica present on the oil palm shells. The minimal segregation of Al2O3 from the surface of the oil palm shell forms a crystalline peak as shown in the TOPS aggregate. XRD shows a crystalline peak at 2 theta 28.6 degrees.

It shows the clear improvement of Al_2O_3.

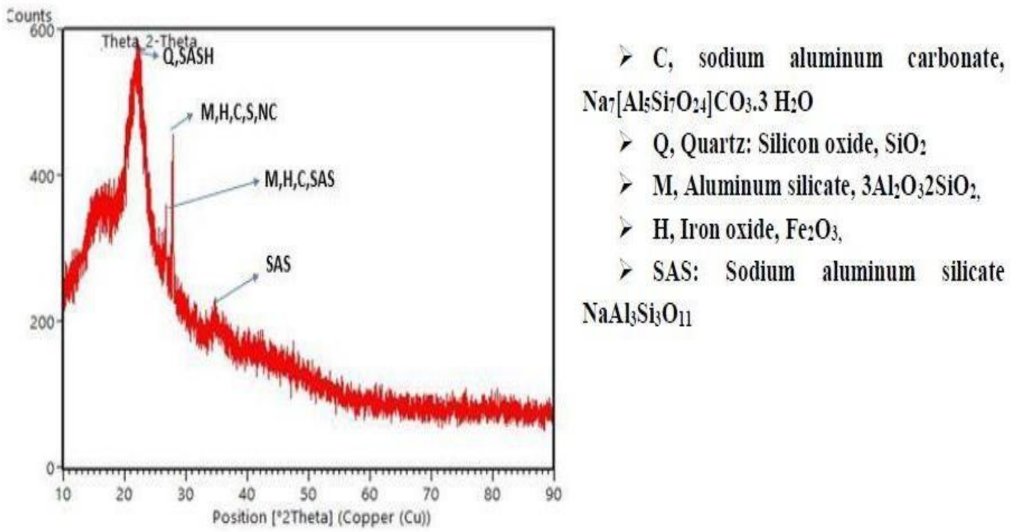

Fig.8: XRD Analysis of Treated Oil Palm Shell

4.4 SEM Analysis of Treated Oil Palm Shell

Water-repellent coating fills the OPS pores, (figure 9) this shows the strong bond between the aggregate to cement matrix which is observed during the test.

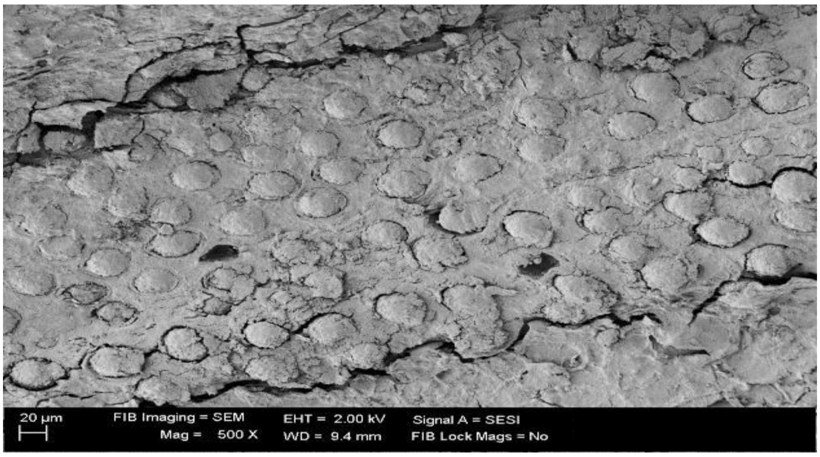

Fig.9: SEM Image of Treated Oil Palm Shell

4.5 Compressive Strength of Treated and Non-treated Oil Palm Shell concrete

Soaked OPS for 24 hours is used in the preparation of concrete. The Mix ratio used is 1:1.8:0.75 (C:S: A). The water/ cement ratio was maintained at 0.45. The finishing of concrete is not adequate as shown in figure 10. The density of OPS concrete is 1805 kg/m3, which is 28% less than conventional concrete. The resultant Compressive strength is 15.6 MPa. Table 1 shows the compressive strength value for different days (before treatment)

Table 1 compressive strength (before treatment)

7 days	14 days	28 days	56 days
6 MPa	11 MPa	15 MPa	15.6 MPa

Fig.10: Non-treated OPS Concrete cube 150*150*150 mm

4.6 After Treatment

Si-OH compound is applied to the surface of OPS. Figure 11 shows that the mix ratio is 1:1.8:0.75 and the water-to-cement ratio is 0.45. The surface of the TOPS concrete is similar to NWC. The resultant compressive strength is 28.9 MPa. The variability in compressive strength (after treatment) is displayed in Table 2.

Table 2 Compressive strength (after treatment)

7 days	14 days	28 days	56 days
15.8 MPa	23.4 MPa	28.5 MPa	28.9 MPa

Fig.11: Treated OPS Concrete cube 150*150*150 mm

4.7 Comparison of compressive strengths

This study examined the impact of partially substituting palm shell aggregate for coarse aggregate on the mechanical characteristics of concrete. The following table illustrates the increase in compressive strength that concrete experiences after 7, 14, 28, and 56 days, based on the specific grade of concrete that we employ. Concrete strengthens by 16 percent in a day, 15 percent in 7 days, 23 percent in 14 days, 29 percent in 28 days, and 30 percent in 56 days, according to the below figure 12.

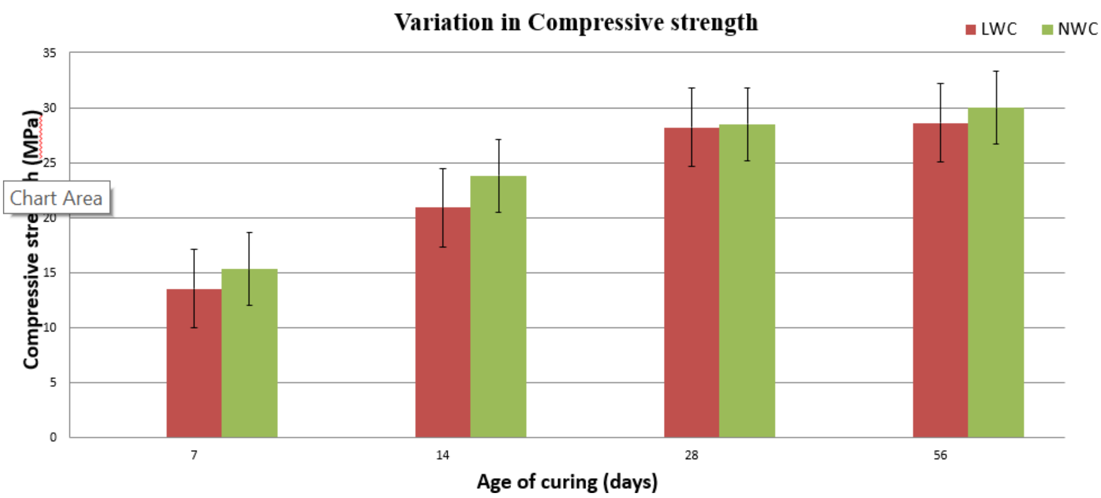

Figure 12 Variations in compressive strength

5. Conclusion

a. OPS is a material that absorbs a lot of water; thus, it is coated with a coating that reduces the rate of absorption from 25% to 8%.

b. After applying a water absorption coating on the OPS, the desired aggregate impact value is determined. The TOPS aggregate has an aggregate impact value of 21.6%.

c. Using TOPS as coarse aggregate improves compressive strength in lightweight concrete. TOPS concrete has a compressive strength of 28.6 MPa, which is almost equal to the Normal weight concrete (NWC).

d. Using TOPS improves the physical bonding between the matrix phase and the aggregate.

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