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Research Paper

Effect of Oil Bean Husk Ash (OBHA) and Breadfruit Husk Ash (BHA) on the Compressive strength. and Heat of Hydration of concreate: A review

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Abstract
This review investigates the use of Oil Bean Husk Ash (OBHA) and Breadfruit Husk Ash (BHA) as partial substitutes for Ordinary Portland Cement (OPC) in concrete. The primary focus is to assess how these agricultural waste materials influence the compressive strength and heat of hydration of concrete. The study analyzes various research findings on concrete mixes incorporating OBHA and BHA, with different proportions (0%, 5%, 10%, 15%, 20%, and 25% by weight) of these ashes. Techniques such as X-ray fluorescence (XRF) have been employed for raw material characterization, ensuring adherence to established standards. Key properties examined include compressive strength and heat of hydration after standard curing periods. The review highlights that the inclusion of 15-20 wt.% OBHA or BHA generally enhances the compressive strength of concrete, with OBHA often showing superior performance compared to BHA. The impact on heat of hydration is also discussed, revealing insights into the thermal behavior of concrete with these waste materials. The findings suggest that both OBHA and BHA can significantly improve the performance of OPC-based concrete, offering potential benefits for sustainable construction practices.
Keywords*: Oil Bean Husk Ash; Breadfruit Husk Ash; Ordinary Portland Cement; Compressive Strength; Heat of Hydration; Sustainable Construction.*

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I. Introduction

Cement is a vital component in the construction industry, acting as an inorganic hydraulic binder that forms a paste when mixed with water. This paste undergoes hydration reactions, setting and hardening into a solid material that maintains its strength and stability even when fully submerged in water [1]. With global cement production reaching approximately 4.3 billion tonnes annually and projected to increase to around 5 billion tonnes by 2023, the environmental impact of cement manufacturing is a growing concern [2]. The production of one tonne of Portland cement clinker is associated with significant CO2 emissions, highlighting the urgent need for more sustainable practices [3-4].

To address these environmental challenges, there is a rising interest in the use of supplementary cementing materials (SCMs). SCMs, including pozzolanic and other supplementary materials, are used to replace a portion of the clinker in Portland cement, improving the performance of the hydrated cement while reducing energy consumption and CO2 emissions [5]. These materials help reduce the lime content in the final product and introduce pore-filling cement hydrates, which enhance the strength, impermeability, and resistance to chemical degradation of cement [6-7].

The pozzolanic activity of SCMs is crucial for their effectiveness. Pozzolans, such as natural pozzolans, fly ash, and silica fume, contain amorphous or vitreous structures that contribute to their hydraulic properties [8-10]. The level of pozzolanic activity in husk ashes is largely influenced by the amount of amorphous phase present [11]. For instance, research has shown that heating rice husks at 600°C produces ash with ideal pozzolanic characteristics [12-13]. The performance of cement is influenced by the proportions of its fundamental components, such as calcium silicates and aluminates, with specific compounds like tri-calcium silicate being critical for long-term strength development [14].

Ordinary Portland Cement (OPC), the most widely used type of cement globally, comprises over 90% Portland cement clinker, with minor additions of calcium sulfate and other components to regulate its setting time [15-16]. The chemical composition of OPC primarily includes lime (CaO), silica (SiO2), alumina (Al2O3), iron oxide (Fe2O3), and sulfur trioxide (SO3). The production process involves grinding raw materials, blending them in precise ratios, and heating them in a kiln to form clinker through solid-state reactions [17-20].

In recent years, there has been growing interest in incorporating bio-based materials into cement formulations. Barley husk ash (BHA) and breadfruit husk ash (BHA) are of particular interest due to their potential as sustainable substitutes for OPC. Barley, a major global crop, and breadfruit, often found in tropical regions, produce ashes rich in silicon, which can be advantageous for their pozzolanic properties. These ashes offer a promising avenue for reducing CO2 emissions and enhancing the quality of OPC [21-23].

This review aims to explore the effects of incorporating OBHA and BHA into OPC. By analyzing their impact on compressive strength and heat of hydration, the study seeks to provide insights into how these agricultural waste materials can contribute to more sustainable cement practices. The addition of OBHA and BHA not only offers a potential reduction in the ecological footprint of cement production but also holds the promise of improving the performance characteristics of concrete, including its strength and thermal properties.

II. Experimental Procedures

2.1. Materials

The materials utilized in this investigation include:

1. **Barley Husk Ash (BHA)**: Obtained from the ash of barley husks, which is rich in silica and is evaluated for its pozzolanic properties.
2. **Oats Husk Ash (OHA)**: Derived from the ash of oats husks, used to assess its suitability as a supplementary cementing material.
3. **Ordinary Portland Cement (OPC)**: Type 42.5 N Portland cement, produced under Libyan specifications (No. 340/2009) at Zliten Cement Factory, Libya.

2.2. Processing of Oats and Barley Husk Ashes

The husks of oats and barley were processed individually as follows:

1. **Washing and Drying**: The husks were washed thoroughly with running water and rinsed with distilled water to remove any impurities. They were then dried under sunlight to reduce moisture content.
2. **Roasting**: The dried husks were subjected to roasting at a temperature of 800°C for five hours. This high-temperature treatment was aimed at converting the husks into a fine ash with enhanced pozzolanic properties.

2.3. Preparation of Cement Pastes

The preparation of cement pastes involved the following steps:

1. **Determining Optimal Water Content**: Various blends of OPC with different weight proportions of BHA and OHA were formulated. The optimal water content for these blends was determined based on graphical representations and calculations (refer to Figure 1).
2. **Molding and Curing**: The cement pastes were mixed thoroughly for two minutes and poured into 4x4x4 inch steel molds. The molds were then placed in an environment with 100% relative humidity. After one day, the molded samples were removed from the molds to obtain cubic samples representing the matured cement paste.
3. **Sample Curing**: The samples were submerged in water for curing until the investigation commenced. Evaluation was conducted at various intervals—10, 14, 21, and 28 days—to assess the development of properties such as bulk density and apparent porosity.

2.4. Density Measurement

Density measurements were performed to compare the densities of the OPC, BHA, and OHA samples. The results are summarized in Table 1:

Material	Density (g/cm³)
Cement	2.031
Barley Husk Ash	0.753
Oat Husk Ash	0.702

The observed lower density of the ash samples compared to OPC indicates differences in material composition and structural properties, which could influence the performance of the cement blends.

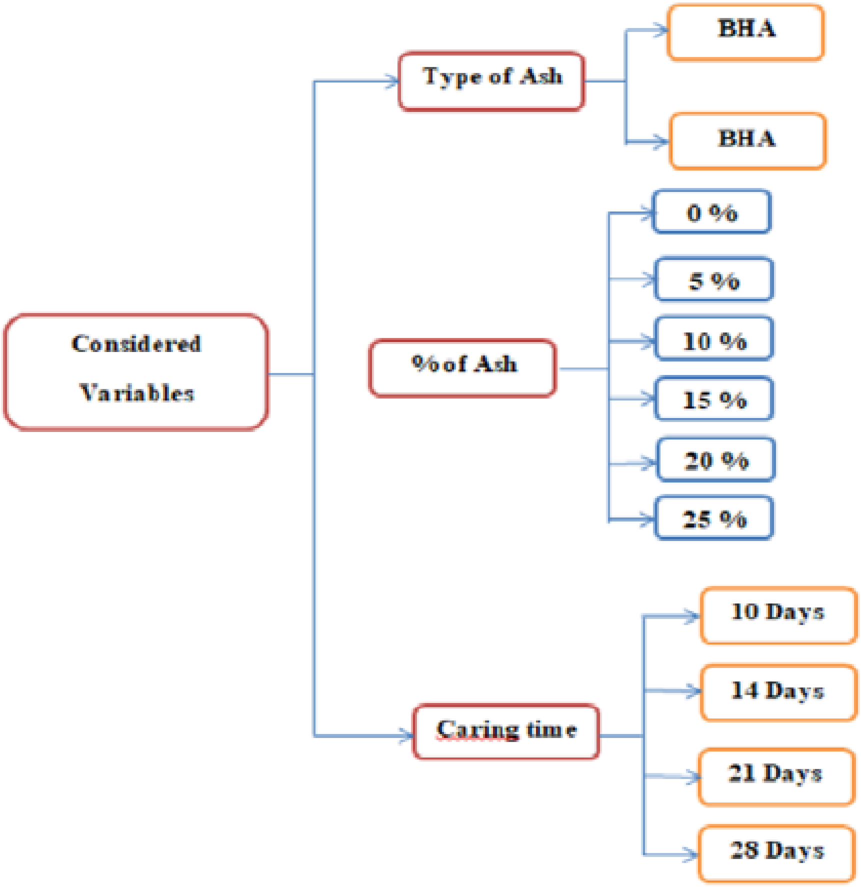

Fig. 1 - Methodology (Tested Variables) of Research Experiments

The methodology for the research experiments, including tested variables and procedural flow, is illustrated in Figure 1. This provides a visual representation of the experimental setup and the variables under investigation.

III. Results and Discussions

3.1. Chemical Composition of Barley Husk Ash (BAH) and Oat Husk Ash (OAH)

The chemical composition of the materials used in this study is summarized in Tables 2 and 3.

Table 2 - Chemical Analysis of the Used Cement

Compound	Formula	Content (%)
CaO	-	64.4
SiO_2	-	20.5
Al_2O_3	-	4.7
Fe_2O_3	-	4.49
SO_3	-	4.6
TeO_3	-	0.441
K_2O	-	0.493
MnO	-	0.0805
NiO	-	0.0708
CuO	-	0.0209
PbO	-	0.0045

The cement used in the experiments shows a high content of calcium oxide (CaO) at 64.4%, along with significant amounts of silicon dioxide (SiO_2) at 20.5% and iron oxide (Fe_2O_3) at 4.49%. Minor components such as aluminum oxide (Al_2O_3), sulfur trioxide (SO_3), and potassium oxide (K_2O) also contribute to its overall composition.

Table 3 - Chemical Composition of Barley Husk Ash (BAH) and Oat Husk Ash (OAH)

Compound	Formula	BAH (%)	OAH (%)
K_2O	-	26.2	24.1
P_2O_5	-	24.4	33.7
SiO_2	-	22.7	15.3
CaO	-	6.38	2.34
Fe_2O_3	-	3.81	1.66
TeO_2	-	2.48	1.45
Sb_2O_3	-	0.07	0.417
NiO	-	0.547	0.611
MnO	-	0.382	0.811
ZnO	-	0.238	0.492
CuO	-	0.213	0.313
SrO	-	0.0563	0.0159

The chemical analysis using X-ray fluorescence (XRF) reveals that both Barley Husk Ash (BAH) and Oat Husk Ash (OAH) are primarily composed of silica (SiO_2), with BAH containing 22.7% and OAH 15.3%. The proportions of iron oxide (Fe_2O_3) are 3.81% in BAH and 1.66% in OAH. Other constituents such as potassium oxide (K_2O), phosphorus pentoxide (P_2O_5), calcium oxide (CaO), and various trace elements are present in varying amounts.

These results provide a detailed understanding of the elemental makeup of the ashes, which is essential for evaluating their potential effects on cementitious materials.

3.2. Cementing Properties of Cement Pastes

3.2.1. Water Requirement (Water of Consistency)

Figure 2 illustrates the variation in water of consistency for cement pastes with increasing levels of Barley Husk Ash (BHA) or Oat Husk Ash (OHA) as substitutes for conventional cement. The graph indicates a steady increase in water requirement with higher proportions of BHA or OHA. This trend is attributed to the higher specific surface area of the ashes (11,000 to 12,000 cm²/g) compared to OPC (3,100 cm²/g), and their hygroscopic nature, which leads to greater water absorption.

These findings are consistent with previous studies [31-33], confirming that the water demand increases as the proportion of ash increases, affecting the fluidity and workability of the cement mixture. This observation provides valuable insights for developing more effective and tailored cement blends.

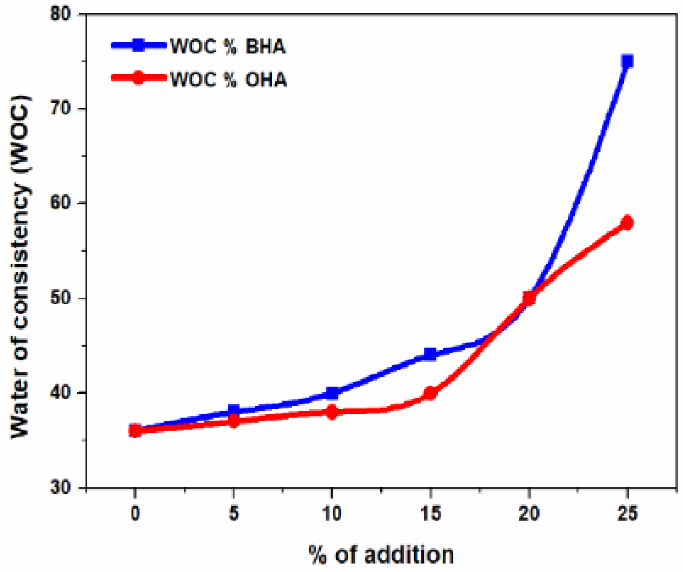

Fig.2 – Water of consistency (WOC) of different cement mixes.

Fig. 2 - Water of Consistency (WOC) of Different Cement Mixes

3.2.2. Bulk Density and Apparent Porosity

Figures 3 and 4 present the bulk density measurements of solidified cement pastes with varying ash contents, while Figures 5 and 6 show the corresponding apparent porosity ratios. The data reveal a clear trend: as the concentration of BHA or OHA increases, the bulk density decreases, and the apparent porosity increases.
This relationship can be explained by the lower density of BHA and OHA compared to OPC, which contributes to the decrease in bulk density and the increase in porosity. This trend aligns with findings from previous research [34], highlighting the impact of ash content on the physical properties of the cement matrix.

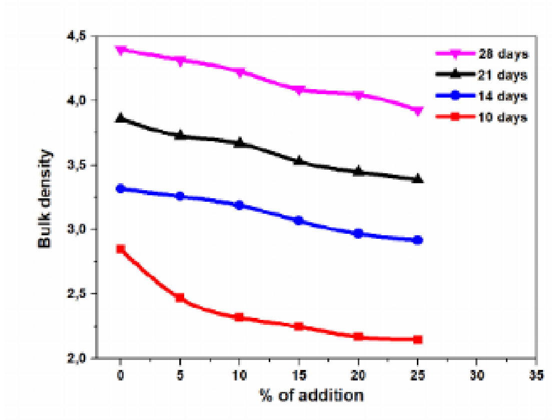

Fig.3 – Bulk density of the hardened cement pastes containing different contents of BHA at different curing times.

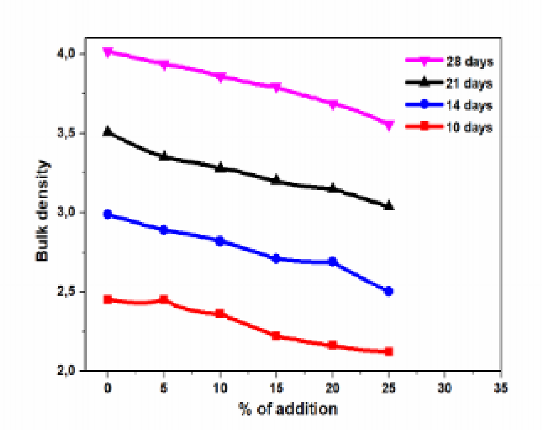

Fig.4 – Bulk density of the hardened cement pastes containing different contents of OHA at different curing times.

It is important to highlight that the addition of ash significantly influences the porosity of solidified cement pastes. Specifically, Barley Husk Ash (BHA) exerts a more pronounced effect compared to Oat Husk Ash (OHA). The order of impact on bulk density is as follows: cement with BHA shows greater bulk density enhancement than cement with OHA. Additionally, a noticeable trend emerges with increasing curing time. As the curing duration extends from 10 to 14 days, and further to 21 and 28 days, there is a clear increase in bulk density values. This is accompanied by a gradual decrease in apparent porosity percentages across various levels of BHA or OHA, as well as in the control sample without ash content. The evolution of these physical properties over time underscores the complex interplay between hydration, ash inclusion, and the resulting structural characteristics of the cementitious matrix.

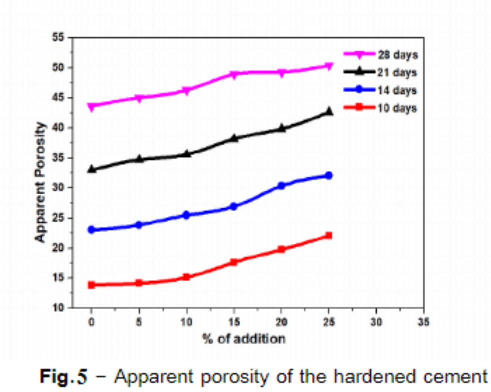

Fig.5 – Apparent porosity of the hardened cement pastes containing different contents of BHA at different curing times.

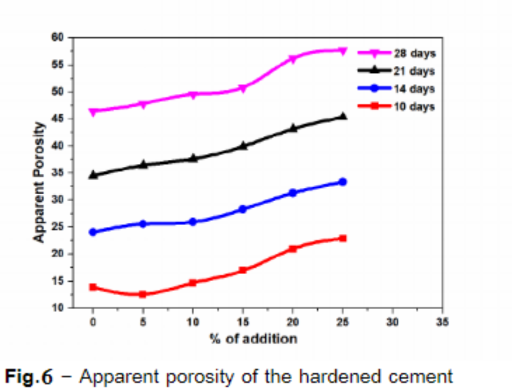

Fig.6 – Apparent porosity of the hardened cement pastes containing different contents of OHA at different curing times.

3.2.3. Compressive Strength of the Hardened Cement Pastes

Figure 7 displays the compressive strength values observed in hardened cement pastes after a 28-day hydration period for different proportions of BHA and OHA. The results demonstrate a noticeable enhancement in compressive strength with increasing concentrations of BHA or OHA until a peak is reached at 15 wt.%. The peak compressive strength for BHA reinforcement increased by 42% (from 358 to 510 kg/cm²), and for OHA addition, the increase was 38% (from 340 to 470 kg/cm²). However, at a 20 wt.% BHA ash level, the strength slightly decreases but remains higher than the control sample, showing only an 8% increase. Reducing the ash content from 20 wt.% to 25 wt.% results in a detrimental effect on compressive strength for both BHA and OHA. Consequently, the solidified cement pastes exhibit compressive strength values closer to the control samples without any ash. This behavior is consistent with previous research [35], which observed that adding 15% wheat straw ash (WSA) led to the highest compressive strength, whereas other increments (5%, 10%, 25%) resulted in decreased strengths.

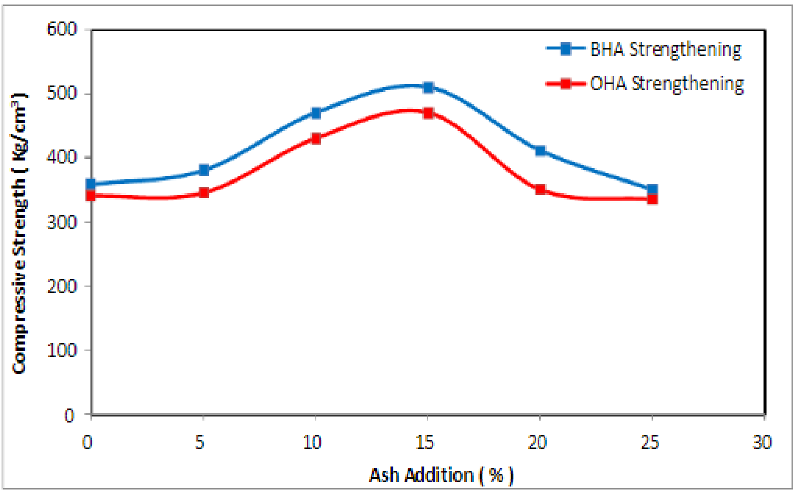

Fig.7 – 28 days compressive strength of the hardened modified cement pastes.

Fig. 7 - Compressive Strength of Hardened Cement Pastes with Various Proportions of BHA and OHA

IV. Conclusion

This study investigates the impact of Barley Husk Ash (BHA) and Oat Husk Ash (OHA) on the physical and mechanical properties of cementitious materials. The results reveal that both types of ash significantly influence the characteristics of cement pastes, but their effects vary.

1. **Porosity and Bulk Density**: The addition of BHA results in a more substantial reduction in apparent porosity and a higher bulk density compared to OHA. This can be attributed to the higher specific surface area and inherent hygroscopic nature of BHA, which affects the water demand and compaction of the cement paste.
2. **Compressive Strength**: The compressive strength of cement pastes improves with the inclusion of BHA and OHA up to a certain proportion. Specifically, a 15 wt.% inclusion of BHA leads to a notable 42% increase in compressive strength, while OHA enhances strength by 38% at the same concentration. However, excessive ash content (beyond 20 wt.%) negatively impacts the strength, likely due to over-dilution of the cementitious matrix.
3. **Hydration Effects**: The curing duration plays a critical role in the development of cement paste properties. As the curing time extends from 10 to 28 days, both bulk density increases and apparent porosity decreases. This trend reflects the progressive hydration and reaction between the cementitious materials and the ash components.

The findings align with existing literature that emphasizes the benefits of incorporating supplementary materials like rice husk ash (RHA) and other biomass residues in cement production. These materials not only contribute to reducing environmental impact by utilizing waste products but also enhance certain properties of cementitious materials.

Future research could explore the long-term durability of cement pastes with BHA and OHA, as well as their performance under various environmental conditions. Additionally, investigating the synergistic effects of combining these ashes with other supplementary materials may offer further insights into optimizing cement blends for specific applications.

In conclusion, the use of BHA and OHA as partial replacements for ordinary Portland cement holds promise for enhancing the properties of cementitious materials while contributing to sustainable construction practices. The study underscores the importance of material selection and curing conditions in achieving optimal performance in cement-based applications.

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