Palm Kernel Shell Ash As A Soil Stabilizing Agent And Its Optimum Calcine Temperature

Ogbodo Munachiso C

Department of Civil University of Port Harcourt Rivers State, Nigeria, PH-(+234) 803 719 3188 Munachiso.ogbodo@uniport.edu.ng

ABSTRACT: The correct assessment of agricultural by-products as soil stabilizing agents requires an in-depth knowledge of their characteristics. In thermally activated products, the calcine conditions have an important influence on the properties and later behaviours of cementitious matrices. This study was carried out to determine the effect of calcine conditions on the properties of Palm Kernel Shell Ash (PKSA). The Calcine conditions considered were: 200°C, 400°C, 600°C, 800°C and atmospheric condition. Investigations were conducted using GBC Sens AA dual double beam Atomic Absorption Spectrophotometer (AAS) with flame emission capability in order to provide a complete understanding of the chemical properties of the calcined Palm Kernel Shell, as well as the possibility of using it as a pozzolan or in blended cement. The test for pozzolanicity was also considered according to BS EN 196-5. The result showed that the material is pozzolanic, even though the chemical properties are affected by the thermal conditions. Finally, it was established that the optimum calcine temperature is 200°C on the bases of the chemical compositions of the material after calcinations.

Keywords: Calcination, Cement, Palm Kernel Shell Ash(PKSA), Pozzollan,pozzolanic,pozzolanicity

1. Introduction

Expansive soil deposits are problematic to engineering structures because of their swelling and shrinkage properties. The deformations produced as a result of swelling or shrinking are significantly greater than elastic deformations and classical elastic or plastic theory cannot predict them. Structures on these soils experience large-scale damage due to basal heaveduring water ingress and settlement arising from water expulsion. The apparent extent of swelling is observed as considerable distress in the form of ground cracks, building cracks, canal lining slides, beds of canal heave, heaving and rutting of pavements etc. The soil engineer must choose the most efficient method of mitigation considering the environment, type of structure and, most importantly, the degree of treatment needed for the structure to survive under future moisture changes. The treatment is referred to as Soil stabilization and involves processes aimed at improving the engineering properties of the soil. Many techniques are available for soil stabilization, including compaction, dewatering and the use of chemical additives. In practice, the process is generally categorized into mechanical and chemical stabilization. Mechanical stabilization improves soil properties by densification. It involves the use of physical force to bring about closer packing of the soil particles thereby improving the soil engineering properties. Chemical stabilization, on the other hand, uses the addition of cementitious or pozzolan materials to improve the soil properties. Traditionally, it has relied on Portland cement (PC) and lime as the cementitious materials used in improving the properties of soil. In recent times however, various researchers have investigated the utilization of some natural products, industrial and agricultural by-products known to be pozzolans as partial or full substitutes to the popular PC that is usually the major component of chemical stabilizers. A similar quest to identify local alternatives for OPC resulted in the work presented here targeted at investigating the utilization of natural by-product of palm oil production (Palm Kernel Shell Ash) as a pozzolan for engineering use. Palm Kernel Shell is the hard endocarp of palm kernel fruit that surrounds the palm seed. It is obtained as crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil.

1.1. Pozzolanic Materials

A pozzolan is a material which, when combined with calcium hydroxide (Lime) in the presence of water, exhibits cementitious properties. Pozzolans are commonly used as additives to Portland cement mixtures to increase the long-term strength and other material properties of the final product and in some cases, reduce the material cost. They are primarily vitreous, siliceous or aluminosilicate materials which react with calcium hydroxide to form calcium silicates. Other cementitious materials may also be formed depending on the constituents of the pozzolan. These materials independently have few cementitious properties, but in the presence of lime-rich medium, like calcium hydroxide, show better cementitious properties andappreciable later strength. Pozzolanic materials may be divided into two categories, natural pozzolans and artificial pozzolans. Natural pozzolans include volcanic ashes such as those found around Pozzouli near Mount Vesuvius, hence the name. The Romans used to add volcanic ash to lime as they found that it created a stronger matrix. In some parts of Europe naturally occurring pozzolanas are still in use. Artificial pozzolans include pulverized fuel ash, crushed burnt bricks and tiles. The most commonly used pozzolans today are fly ash, silica fume, high-reactivity metakaolin (clay), and ground granulated blast furnace slag (GGBS). It was sequel of the search for other locally available material as pozzolans that Falade used sawdust ash as a partial replacement for cement[1]. He observed that the strength of concrete reduced when sawdust ash was added. He also found out that the reducing effect is more pronounced in mixtures with high aggregate/cement ratio. Also, Rojas, M.F. et al have worked extensively on the use of clay as a pozzolan [3], [4]. They studied a product called metakaolin (MK), which is a material obtained under a carefully controlled process of thermal activation of kaolinite clay. The kaolinite is dehydrated at 600-700°C, which causes major structural disorganization and significant increase in pozzolanic activity. Though they concluded in one of their papers that MK exhibits lower pozzolanic activity than silica fume, but significantly greater pozzolanic activity than fly ash[4]. This fact is related to chemical and mineralogical
composition, pozzolanic activity, and fineness of the materials. The main objective of this research is to completely characterize Palm Kernel Shell Ash (PKSA) at different temperatures of calcination as a pozzolanic material and also determine at what range of temperature of calcination the pozzolanic properties will be considered optimum. The study covers the chemical investigation of PKSA produced at different calcination temperatures and also a study of its pozzolanicity using the Rio-Tratini method.

2. Materials

Cement: The cement used was ordinary Portland cement (OPC) type from the Eagle Cement factory in Port Harcourt, Nigeria with properties conforming to those specified in the relevant British Standard document (BS 12, 1971).

Palm Kernel Shell Ash: The Palm kernel Shell used as a starting material for this research was sourced from a mini palm oil producing factory in Umuahia, Abia State Nigeria. The Shell was machine cracked and freshly dumped. The dump site consists of red soils and the collected sample was washed and allowed to dry before proceeding to lab.

Water: Tap water and Ultrapure water obtained in the laboratory was used in the preparation of the concrete. The density of water was assumed to be 1000Kg/m³.

3. Determination of Chemical Content of PKSA

The washed palm kernel shell was divided into ten samples of seven gram (7g) each. These were taken into crucibles and subjected to the following burning temperatures and conditions; 200°C, 400°C, 600°C, 800°C and under open air without regulating the temperature. Two samples were considered for each burning condition in order to control the results. An electrical laboratory muffle furnace was used and temperature was maintained for about 30mins-1hr for every burnt sample. After the samples have been burnt into ash at these temperatures, each burnt product was allowed to cool to room temperature in a desiccator. Table 1 shows the designation of the different products and burning conditions. All palm kernel samples were ground in an agate mortar and pestle and then sieved to less than 45μm before analysis, in order to reduce the particle size and to secure homogeneity.

<table>
<thead>
<tr>
<th>Temperature(°C)</th>
<th>Retention Time (hours)</th>
<th>Designations</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKS Calcined at 200</td>
<td>1</td>
<td>PKS A1</td>
</tr>
<tr>
<td>PKS Calcined at 400</td>
<td>1</td>
<td>PKS A2</td>
</tr>
<tr>
<td>PKS Calcined at 600</td>
<td>1</td>
<td>PKS A3</td>
</tr>
<tr>
<td>PKS Calcined at 800</td>
<td>1</td>
<td>PKS A4</td>
</tr>
<tr>
<td>PKS Calcined at Atmospheric</td>
<td>-</td>
<td>PKS A5</td>
</tr>
</tbody>
</table>

GBC Sens AA dual double beam Atomic Absorption Spectrophotometer (AAS) with flame emission capability was employed for the determination of the major elements, including Al, Ca and Fe. The silica content was deduced by difference. The samples dissolution was carried out as follows: a small amount of the sample was treated with hydrofluoric acid in an open vessel and heated on a hot plate. This is followed by the addition of aqua regia and heating again until the samples get dried. The residue was dissolved with 1ml of concentrated hydrochloric acid and diluted with water to a fixed mark in a teflon volumetric flask. Care was taken to avoid contamination.

4. Test for Pozzolanicity

Rio-Tratini method was used since it is the method proposed by the British Standard documents (BS EN 196-5). The pozzolanicity is assessed by comparing the quantity of calcium hydroxide in the aqueous solution in contact with the hydrated cement, after a fixed period of time, with the quantity of calcium hydroxide capable of saturating a solution of the same alkalinity. This is considered positive if the concentration of the calcium hydroxide in the solution is lower than the saturation concentration.

5. Results and Discussion

5.1. Chemical Analysis of PKSA

The chemical analysis of the PKSA samples were conducted as mentioned above and the results are presented in table 2.

Table 2: Chemical Composition of the five samples of PKSA

<table>
<thead>
<tr>
<th>Component</th>
<th>Test Method</th>
<th>PKSA 1%</th>
<th>PKSA 2%</th>
<th>PKSA 3%</th>
<th>PKSA 4%</th>
<th>PKSA 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOI</td>
<td>ASTM D7348</td>
<td>24.67</td>
<td>56.55</td>
<td>41.45</td>
<td>48.6</td>
<td>93.15</td>
</tr>
<tr>
<td>SiO2</td>
<td>ASTM D3605</td>
<td>28.59</td>
<td>16.4</td>
<td>24.46</td>
<td>20.68</td>
<td>4.78</td>
</tr>
<tr>
<td>Al2O3</td>
<td>ASTM D3605</td>
<td>22.44</td>
<td>8.9</td>
<td>7.86</td>
<td>9.73</td>
<td>0.06</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>ASTM D3605</td>
<td>9</td>
<td>9.52</td>
<td>11.21</td>
<td>5.46</td>
<td>0.09</td>
</tr>
<tr>
<td>CaO</td>
<td>ASTM D3605</td>
<td>0.043</td>
<td>0.018</td>
<td>0.038</td>
<td>0.03</td>
<td>0.08</td>
</tr>
<tr>
<td>MgO</td>
<td>ASTM D3605</td>
<td>2.01</td>
<td>0.034</td>
<td>1.04</td>
<td>3.6</td>
<td>0.03</td>
</tr>
<tr>
<td>SO2</td>
<td>ASTM D3605</td>
<td>0.06</td>
<td>0.054</td>
<td>0.036</td>
<td>0.021</td>
<td>0.05</td>
</tr>
<tr>
<td>Na2O</td>
<td>ASTM D3605</td>
<td>8.43</td>
<td>3.4</td>
<td>8.72</td>
<td>6.49</td>
<td>0.02</td>
</tr>
<tr>
<td>K2O</td>
<td>ASTM D3605</td>
<td>0.02</td>
<td>0.23</td>
<td>0.51</td>
<td>0.22</td>
<td>0.45</td>
</tr>
</tbody>
</table>

The result from the chemical analysis of the PKSAs indicates that PKSA5 has the highest % of loss on Ignition (LOI) which indicates the presence of carbon and the level of the in-act portion of the sample when used as a pozzolan. PKSA1 has the least of LOI 24.67% which is slightly above the 20% that is the maximum specified by the ASTM C618-08. The result also indicates that the material is a good source of Silicon Oxide which is the most important component of a pozzolan. PKSA1 contains the highest % (28.58%) while Calcium Oxide needed for cement hydration and Sulphur dioxide that is the unwanted chemical were relatively absent in entire samples. The graphical representation of table 2 is shown in figure 1.
5.2. Test for Pozzolanicity
The results of the Rio-Fratini test are presented in the figure 2 for PKSA cement paste. It is known that a measured point below the solubility curve of Ca(OH)$_2$ is an indication that the examined suspension is undersaturated in Ca(OH)$_2$ due to the fact that Ca(OH)$_2$ produced during the cement hydration has been consumed by pozzolanic reaction.

![Figure 1: Chemical composition of Calcined PKSAs](image)

![Figure 2: Rio-Fratini test (X-Hydroxyl ion concentration, mmol/l.](image)

Y – Calcium ion concentration (expressed as calcium oxide), mmol/l)

6. Conclusion and Recommendation
From the results obtained in characterizing the local PKSA, the following conclusion and recommendation can be drawn.
1. Local Palm Kernel Shell Ash consists mainly of SiO$_2$, Al$_2$O$_3$ and Fe$_2$O$_3$. Traces of CaO and SO$_3$ were seen but very insignificant.
2. The chemical composition and Pozzolanicity test suggests that the material is pozzolanic.
3. Loss on Ignition was generally high in all the PKSA samples, suggesting the presence of organics.
4. Increase in calcination temperature does not give corresponding increase in Pozzolanic quality of the material. At 200$^\circ$C, the material is optimally activated as a pozzolan.
5. The presence of SiO$_2$ in large quantity and the relative absence of CaO in the material suggest that in combination with another material with high CaO will yield very good Cementitious material.

It is recommended that Palm Kernel Shell Ash calcined at 200$^\circ$C should be used as a pozzolan and further investigation should be carried out when considered as a chemical stabilizer for different soils.

7. Reference

Author Profile
Ogbodo, Munachiso. C. received B.Eng. in Civil Engineering from University of Port Harcourt, Rivers State, Nigeria in 2007 and M.Sc. degrees in Structural Engineering from University of Lagos, Nigeria in 2013. He is currently working as an Academic Staff in University of Port Harcourt, Rivers State, Nigeria.