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Original Research Article

Pigment-Extender Effect of Umunze Clay on Screeding Paint

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SEM
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EDXRF

A B S T R A C T

The surface coating potentials of indigenous Nigerian clay from Umunze, Orumba South Local Government Area in Anambra state were assessed in screeding paints as part of the effort to provide sustainable materials for the coating industries. The clay samples were washed, sedimented, dried, grinded, and sieved to 80 µm, and analyzed using Energy Dispersive X-ray Fluorescence, X-ray diffraction spectrometry, and scanning electron microscope. The EDXRF results shows a high percentage of Nibioum (Nb), Silica Oxide (SiO_2), and Iron (III) Oxide (Fe_2O_3) with 16.80%, 15.58%, and 6.60% respectively. Other chemical components like Lead (Pb), Barium (Ba), Zinc (Zn), Nickel (Ni), and Gallium (Ga) were present in very small quantities in the clay gotten from Umunze, meaning that the presence of these metals is too insignificant to cause damages to humans and the environment. Meanwhile, XRD shows very high percentage of Aluminum (Al_2) and Silica (SiO_2) in Umunze clay. This indicated that the crystalline structure of the uncalcined clay obtained from Umunze is kaolinite, with chemical formula given as $Al_2Si_2O_9$. The surface morphology presented the clay particles to be clogged, thus showing that the umunze clay is desired for multiple clay purposes. The formulated screeding paint from the calcined clay of 750 °C gave a better paint than the 450 °C via these physical properties of parameters mentioned below. The 750 °C calcined screeding paint has its refractive index determined at 2.71 (PL= 1.5-9), viscosity was determined at 2039.8 (PL= 2000-3000), and durability was determined at 70% (PL=68- 98 %) and thereby, making it a better substitution as paint pigment-extender than that of 450 °C calcined screeding paint. The work revealed a better temperature performance of the sample, such that the produced sample can withstand temperature up to 320 °C before it will start deforming. Hence the clay can be used for ceramics.

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GRAPHICALABSTRACT

Introduction

In recent years, the pigment-extender has been noted to have a crucial effect on the rheological properties of paint and also in the general economics of paint production in the sense that it reduces the cost of pigment used for production [1-4]. Clays have been used indispensably as extenders in architectural and industrial paints, and other industries such as agriculture, in construction such as building material, in oil industry as drilling mud to protect the cutting bit while drilling, filtering, and deodorizing agents in the refining of petroleum, in clarifying water and wine, in purifying sewage as an adsorbent and so on, its sustainable and benign to the environment [5-9]. Clay has shown interesting effects when it is used as a pigment-extender in paint production [10-13]. Screeding paint is a water-based paint, just like the emulsion paint, screeding paint materials disperse in a liquid that contains mainly of water. The only difference is that screeding paint tends to cover cracks or holes on a wall, flattens, and smoothens the surface. This attributes to slower drying. It is also low cost effective and easy to apply [14-20].

Thus, the aim of this study is to examine the effects of locally sourced Umunze clay as pigment-extender in screeding paint. This study innovatively evaluates Umunze clay's coating potential for sustainable screeding paints. Through rigorous analysis, it elucidates its chemical composition, crystalline structure, and surface morphology, affirming its suitability for diverse applications. Furthermore, it explores optimal calcination temperatures, enhancing paint performance and contributing to sustainable coating solutions.

Geographical location: The local clay sample used as extenders for the purpose of this study work was hand dug from Ozara village, Umunze, Orumba South local government area of Anambra State with latitude 5.9621°N and longitude 7.2383°E.

Figure 1. Map of Umunze, Orumba South, Anambra State.

Materials and methods

The screeding paint production process normally involves various steps, which include raw material selection and preparation, formulation and blending, filtering, fining, packaging, and labeling. These stages are carefully measured to ensure that the desired properties and characteristics of the finished paint are obtained.

Sample collection and preparation

The clay sample was hand dug and collected from Ozara village in Umunze, Orumba South Local Government Area of Anambra State, Nigeria. The sample obtained was washed, allowed to sediment, and then dried. The dried clay sample was ground and sieved to get fine particles of mesh size 50 µm.

Preparation of clay as an extender for screeding paint production

The sieved clay sample was divided into two parts respectively. One part of each of the clay sample were calcined at 750 °C and its surface morphology were determined using scanning electron microscope (cc Tenex, Made in China). Likewise, the elemental composition was determined via Energy Dispersive X-Ray fluorescence (cc Tenex, Made in China) and X-ray diffractometry.

The samples were used to formulate screeding paint, the control had calcium trioxocarbonate (iv) incorporated into it. Sample A had the calcined clay at 450 °C and sample B calcined clay 750 °C incorporated into screeding paint mixture [21,22].

Table 1. Formulation of screeding paints with Umunze clay calcined at 450 °C and 750 °C

Components	Functions	Calcined clay at 450 °C. Sample A	Calcined clay at 750 °C. Sample B
Water	Solvent	60	60
Polyvinylacrylate	Binder	7	7
Milocel	Thickener	3	3
Ammonia	pH adjuster and preservative	2	2
Formalin	Fungal growth retardant	2	2
Clay (450 °C)	Extender and pigment	40	-
Clay (750 °C)	Extender and pigment	-	40

Procedure for production of screeding paint

The materials were properly weighed in grams and the weight of the crucible and beakers were noted. The same procedure was carried out on the two samples of calcined clays [23-25]. Small quantity of water was added to an empty clean bowl. 1.75 g calcined clays at 450 °C and 750 °C each were added subsequently, with continuous stirring for about 2-5 minutes to get a desired consistency. Polyvinylacrylate was added and stirring continued. 0.1 g milocel was dissolved with water in a separate bowl for few minutes before being added with vigorous continuous stirring.

Lastly, both 0.075 g of ammonia and 0.1 g formalin were added, respectively, to the mixture and the mixture was stirred thoroughly for another 10-15 minutes to obtain a homogenous mixture. The paints produced were kept in a covered container; set for analysis and testing [25].

The following figures indicate the produced screeding paint and the surfaces of application.

Results and Discussion

The properties of the screeding paint varied with the various extender pigment used in the production; from the calcium carbonate used as the control, calcined Umunze clay at 450 °C and calcined Umunze clay at 750 °C. The variation in their properties forms the basic framework of this discussion.

Compositional analysis

Energy dispersive X-ray fluorescence (EDXRF)

The EDX determinations on the uncalcined Umunze clay are presented in Table 2. These data are illustrated in Figure 3.

The result indicates the presence of Silica (SiO_2), Niobium (Nb), and Zirconium dioxide (ZrO_2) in high proportions while the other constituents are present in smaller proportions, as shown in Figure 1.

The uncalcined Umunze clay was found to contain 16.80% of Nb, 15.58% of SiO_2, and 6.60% of Fe_2O_3; this explains its reddish-brown appearance and less than 5% of other constituents. The presence of unreacted oxides in the clay is indicative that paint formulated with the clays will function as anti-corrosive paints since the unreactive oxides will slow down the diffusion of corrosive species thereby delaying the phenomenon of corrosion in painted surface [25].

X-ray diffraction (XRD) of the uncalcined Umunze clay sample

X-ray diffraction pattern of Umunze local clay sample is depicted in Figure 4. This Figure shows

Figure 2. (a) Produced screeding paint, (b) screeding paint at 450 °C, (c) screeding paint at 750 °C.

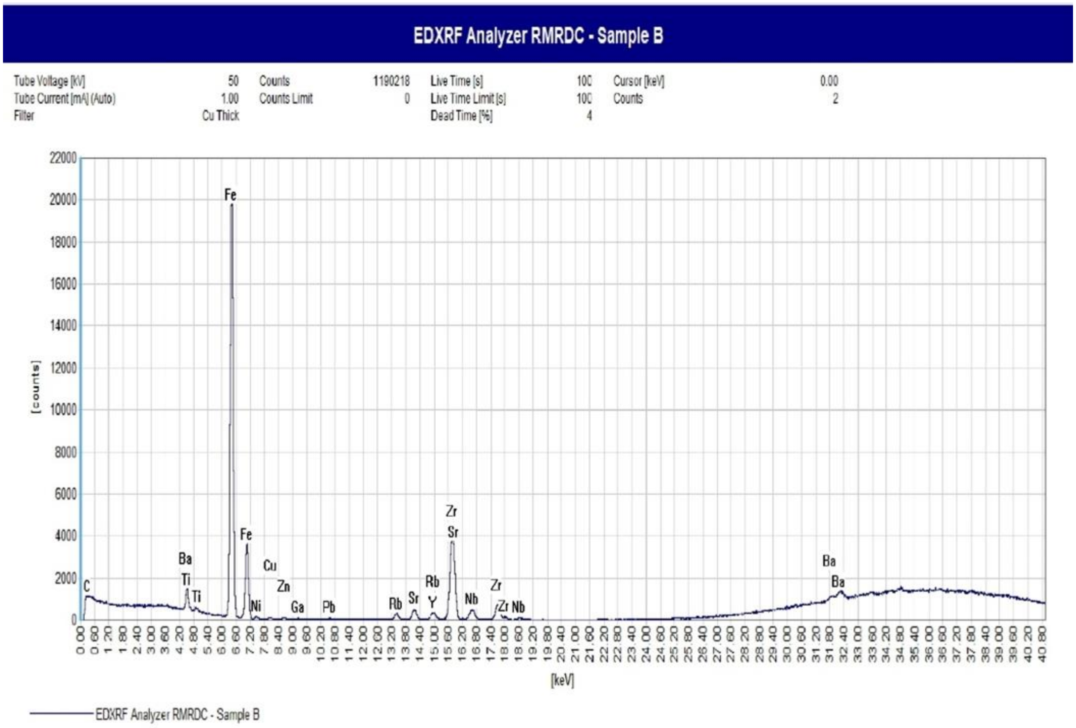

Figure 3. EDX spectra of Umunze clay.

Table 2. EDX result of uncalcined Umunze clay sample (UUC)

S/No.	Chemical Composition	UUC Wt%
1	Fe_2O_3	6.60
2	C	0.01
3	Cu	7.80
4	SiO_2	15.58
5	ZrO_2	15.60
6	Ni	-
7	Rb_2O	13.70
8	Nb	16.80
9	Pb	-
10	TiO_2	4.80

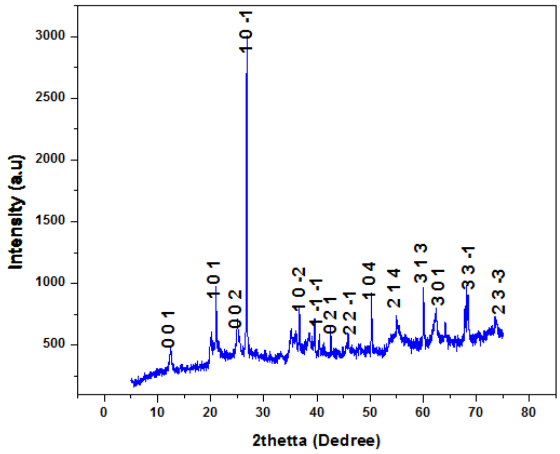

Figure 4. X-ray diffractogram of the uncalcined Umunze clay.

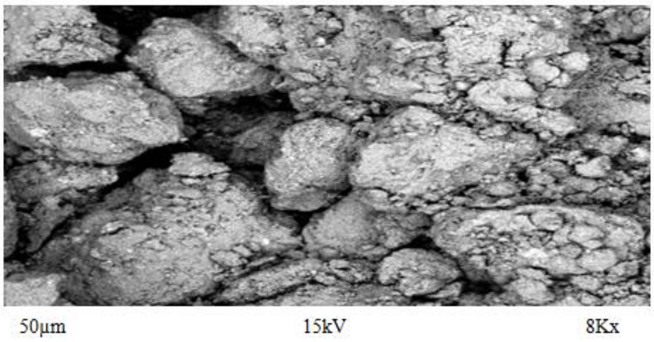

Figure 5. SEM image of the uncalcined Umunze clay.

that clay is majorly composed of kaolinite. The raw clay shows that the highest peak presence includes Aluminum, Silica, and Oxygen. The kaolinite group consists of polymorphs of formula $Al_2Si_2O_5(OH)_4$ and intensities to reference patterns in the ICDD PDF-2 database, with kaolinite peaks corresponding to PDF #96-900-9231, while the crystallographic parameter shows the clay to be Anorthic.

Scanning electron microscope (SEM) of the uncalcined Umunze clay

The image obtained from the SEM of the un-calcined clay sample is presented in Figure 5.

The use of SEM provided information about the structure and composition of the clay sample, the surface morphology (shape and texture) of the clay was also determined. From the result obtained from SEM (snapped at 15 kV energy and 50 micrometers scale with magnification range of 8 Kx), it was showed that the clay sample from Umunze is clogged, this property made the clay recommendable for the production of screeding paint used in the course of this work.

Test for refractive index

The two screeding paints produced with Umunze clay was compared with a control screeding paint produced with calcium carbonate as shown in Figure 6. The refractometer was calibrated using the standard oil after powering on the equipment. The samples were introduced into the refractometer sample chamber and allowed to complete the refractive index check. The result showed good refractive index and compared well with [25].

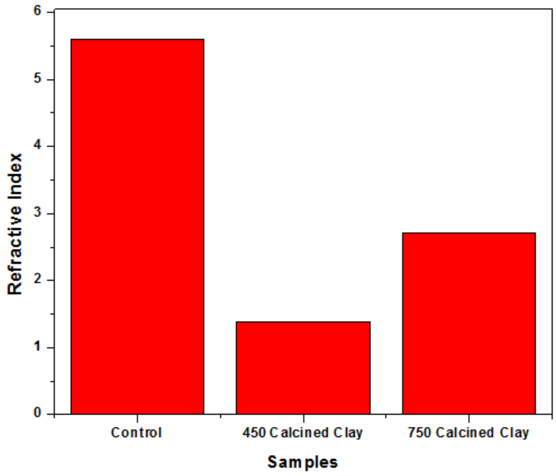

Figure 6. Graphical chart of refractive index of the produced screeding paint samples.

Color test result

The three paint samples; the control produced with calcium carbonate, Umunze calcined clays at 450 °C and 750 °C B were put to test for their color. The control and calcined clay of 750 °C showed a better result on a painted surface as there was no color variation from the production time up till the drying time. This showed that the paint recipes blended well.

Abrasion resistance test result

From Figure 7, the control screeding paint and Umunze clay calcined at 750 °C showed a better abrasion resistance than the screeding paint produced with clay calcined at 450 °C. It was quick to degradation due to mechanical wear and tear by hard objects such as nails, knives, and finger-nail scratch. This result also agrees with other authors [1,7].

Homogeneity test result

The three screeding paint samples showed no degree of separation after been subjected to high spin speed. This suggests that the binder had good interaction with the extender and the other constituents and that paint samples had high degree of compactness as seen in Figure 8. Hence, settling is less likely to occur in the paint samples and this is in line with [1,18].

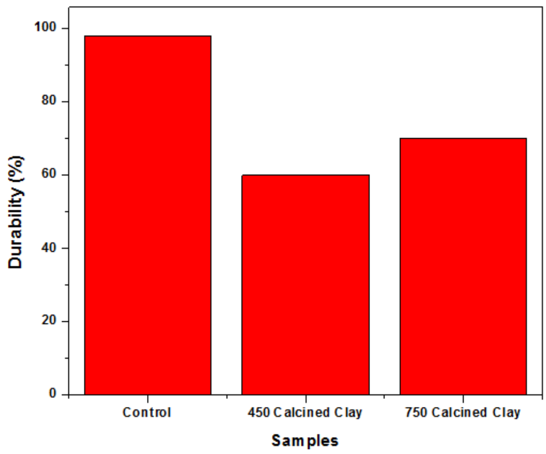

Figure 7. Graphical chart of durability of the produced screeding paint samples.

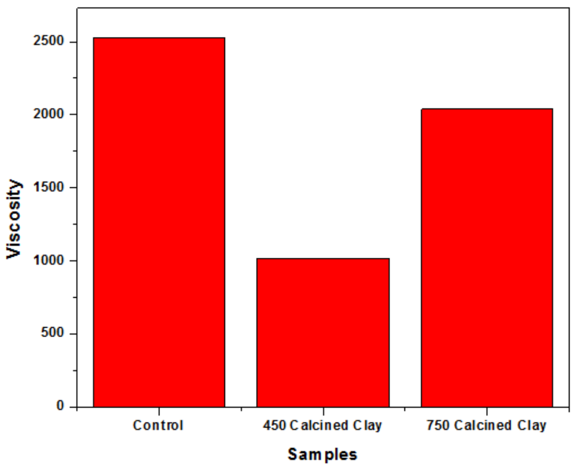

Figure 8. Graphical chart of viscosity of the produced paint samples.

Thermogravimetric analysis (TGA) results

The TGA curves for each sample heated at the rate of 20 K/min to 1000 °C are illustrated in Figure 9.

When samples are exposed to high temperature, the sample weight will be affected by loss. In this work, Figure 9 demonstrates the relationship between weight and temperature. As the temperature increases up to 320 °C, the weight remains relatively constant. After this temperature, the weight gradually decreases with the increase in temperature up to 500 °C. This showed that the produced sample can withstand temperature up to 320 °C before it will start deforming.

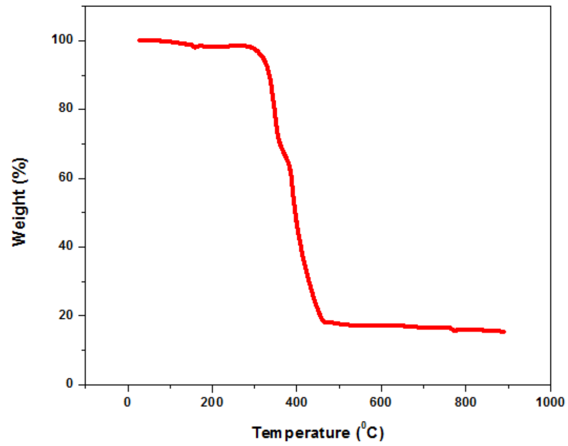

Figure 9. Thermogravimetric analysis (TGA) of the produced paint samples.

Conclusion

The aim of this study was to evaluate the suitability of indigenous Nigerian clay sourced from Umunze, Orumba South Local Government Area in Anambra state for application in screeding paints, to provide sustainable materials for the coating industries. The clay underwent a series of preparation steps including washing, sedimentation, drying, grinding, and sieving to achieve a particle size of 80 µm. Analysis of the prepared clay samples was conducted to assess their chemical compositions using Energy Dispersive X-ray Fluorescence (EDXRF) spectrometry, crystalline structure via X-ray diffraction spectrometry (XRD), and surface morphology through scanning electron microscope (SEM). Two different calcination temperatures, 450 °C and 750 °C, were applied to the clay samples. The resulting calcined clays (CC) were incorporated into screeding paint formulations. Various physical and performance properties of the produced paint were evaluated, including refractive index, viscosity, homogeneity, durability, color, and abrasion resistance. The analysis revealed high percentages of Nibioum (Nb), Silica Oxide (SiO_2), and Iron (III) Oxide (Fe_2O_3) in the Umunze clay, with 16.80%, 15.58%, and 6.60%, respectively, as indicated by XRF. Trace amounts of other chemical components such as Lead (Pb), Barium (Ba), Zinc (Zn), Nickel (Ni), and Gallium (Ga) were also detected, but their quantities were deemed insignificant in terms of potential harm to humans and the environment. XRD analysis showed a predominant presence of Aluminum (Al_2) and Silica (SiO_2) in Umunze clay, indicating a kaolinite crystalline structure with a chemical formula of $Al_2Si_2O_9$. SEM images depicted the clay particles as clogged, suggesting its suitability for various clay applications. Comparative analysis between 450 °C and 750 °C calcined screeding paints revealed superior performance of the latter based on refractive index (2.71), viscosity (2039.8), and durability (70%). Consequently, the 750 °C calcined screeding paint was deemed a more effective pigment-extender substitute compared to the 450 °C calcined screeding paint. In addition, the clay's favorable inherent properties suggest its potential utility in ceramic wares production. The work revealed a better temperature performance of the sample, such that the produced sample can withstand temperature up to 320 °C before it will start deforming, making it better for utilization in ceramic industries.

Conflict of interest

No potential conflicts of interest were disclosed.

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