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Effects of Silica Morphology on Emulsion Paint Properties Using Rice Husk Ash and Silica Flour as Pigment Extenders

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ABSTRACT: This study investigated the effects of silica (SiO_2) morphology on emulsion paint properties by comparing the physical properties of emulsion paints produced with amorphous silica (rice husk ash) with those of crystalline silica (silica flour) used as pigment extenders in the paint. Calcium carbonate was used as the reference standard in the study. Rice husk ash (RHA) was obtained by heating rice husks on a gas stove to obtain rice husk char which was subjected to controlled incineration in a muffle furnace at a temperature of 650^0C and duration of 4hrs. The granular RHA obtained was ground to obtain powdery RHA of smaller particle size. The RHA powder, silica flour (SF) and $CaCO_3$ were then sieved to obtain the same particle size range of 32-63microns (µm) used in the formulation of the emulsion paints. The extender levels in the formulations were varied from 2-12% by weight and the physical properties of the emulsion paint variants were determined. The results revealed that RHA-filled white emulsion paints (RHAWEP) had higher viscosities than those of silica flour due to the amorphous nature of silica in RHA which conferred on it, a thickening effect superior to that of crystalline silica. RHAWEPs had higher pigment volume concentration (PVC) values than those of silica flour and $CaCO_3$ due to its lower specific gravity and this resulted in the flat (non-glossy) appearance of the RHAWEP dry films but semi-gloss appearance of those of SF and $CaCO_3$.

KEYWORDS: emulsion paint, rice husk ash (RHA), silica flour (SF), pigment extender, amorphous and crystalline silica, morphology

I. INTRODUCTION

The paints industry is constantly in search of alternative raw materials with improved properties through research and development efforts. The gradual global transition from the use of non-renewable to renewable resources triggered by environmental concerns has also come into play in the surface coatings industry, consequently, the use of rice husk ash as pigment extender in paints and other surface coatings has been the focus of many research investigations[1][2][3][4]. Emulsion (water-based) paints are classified as architectural or trade sales coatings and constitute the largest segment of the surface coatings industry in terms of production volume and value [5].It is estimated that more than 70% of the architectural paints are water-based [5]. Pigment extenders are widely used in emulsion paints to partially replace true pigments and are often simply called 'extenders' or 'fillers'. Pigment extenders are chemically inert, inorganic compounds that are added to surface coatings in order to increase bulk, reduce cost and confer some special properties to the paint[6][7]. Extenders can be called 'auxiliary pigments' as they generally supplement the pigments by improving paint properties such as consistency ,rheology, resistance to weathering, gloss, levelling, adhesion and coverage [7][8]. Extenders generally used in paints include calcium carbonate kaolin (china clay), barytes, talc and silica flour [6]. Research investigations have established that rice husk ash (in the form of amorphous silica) is a good pigment extender for emulsion paint [4]. Silica flour (quartz) is 100% crystalline silica and is obtained by grinding pure silica sand to a fine powder [9]. Silica sand deposits are normally exploited by quarrying and the material undergoes considerable processing to remove impurities and to obtain the optimum particle size distribution. The processing of quartz sand to obtain silica flour is energy intensive and this makes it a relatively expensive material. Silica flour is mostly used as extender in fillers and stoppers [6] which are materials of high solid contents used to fill holes, deep indentations or irregularities and to provide a level surface for the application of paint coat on a substrate. Fillers and stoppers are used as undercoat which is applied before the top coat. Calcium carbonate, which is available in different paint grades, is a widely used extender both in emulsion paint and other surface coatings [7].

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Studies [10][11][12] have shown that RHA obtained at a combustion temperature of 500-800^{0}C is amorphous silica while RHA obtained above 800^{0}C is predominantly crystalline silica. Thus, RHA used in this study is predominantly amorphous silica. Crystalline and amorphous forms of silica have different properties hence the need to control the temperature and duration of combustion of rice husks so as to produce RHA ash with the required properties for the desired end use. Amorphous silica has a disordered structural arrangement and is consequently porous, more reactive, has greater flexibility and larger surface area than crystalline silica which has an ordered, silica network structure, thus has structural rigidity and is also far less reactive due to its electrical neutrality [13][14].

The pigment volume concentration (PVC) of paint, which is the volume of the paint film occupied by the pigment and pigment extenders, is a very important concept, as it controls several paint properties, such as gloss, washability, durability, reflectance and rheological properties[5][8]. It is defined and calculated by the expression [15]

$$\% \text{ PVC} = \frac{vol\ of\ pigment\ in\ the\ paint}{vol\ of\ pigment\ in\ the\ paint + vol\ of\ non-volatile\ constituents\ in\ paint} \times 100$$

The PVC values for various coatings are as follows: flat paints, 50-70%; semi-gloss paints, 35-45% and gloss paints, 25-35% [5]. Generally, the paint gloss decreases as the PVC increases. This is due to the fact that when the volume of pigment increases relative to the non-volatile vehicle, gloss decreases until the gloss of the paint becomes flat [15]. The viscosity of paint, which is also controlled by the PVC, is an important quality parameter as it affects the flow, and application properties of the paint.

In this study the effects of amorphous silica (rice husk ash) as pigment extender on emulsion paint properties were compared with those of crystalline silica(silica flour). The objective of the study was to determine the effect of morphological differences of silica on critical physical properties of emulsion paint, such as PVC and viscosity and ultimately, the suitability or unsuitability of silica flour as pigment extender in emulsion paint.

II. MATERIALS AND METHODS

MATERIALS

Equipment for Production and Testing of Paint Samples

Mini stirrer (Diaf A/S Copenhagen NV. Denmark) ; I.C.I Digital Rotothinner Viscometer (Sheen 455N); pH meter (Mettler Toledo MP 220); Washability Tester: (Elcometer 1720); K – bar (Sheen) ; Digital Weighing scale (Sauter); Wt per litre (specific gravity) cup (Sheen)

Paint Raw Materials

The raw materials used to formulate the emulsion paints were grades designed for paint production and were all obtained from assured suppliers/ importers of paint raw-materials. They all met the required specifications when subjected to standard Quality Control tests.

METHODS

Washing and Drying of Rice Husks

Milled rice husks obtained from a rice mill located in Abakaliki, in Ebonyi State of Nigeria were washed several times to remove sand and stone contaminants. The washed rice husks were then spread on plastic trays and other extraneous materials like broken rice grains were removed by handpicking. The wet rice husks were dried at 100^{0}C to a constant weight in an electric oven.

Production of Rice Husk Ash

A two-stage method, similar to that used by Sugita [16] was adopted for the production of RHA. The clean rice husks were put in a stainless steel pot, which was then placed on a gas stove and the rice husks incinerated until there was no further emission of fumes. The black, carbonized rice husk char obtained was put in medium-size crucibles which were

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placed in a muffle furnace. The muffle furnace was then switched on and left to attain the desired combustion temperature of 650^{0}C, which was maintained until the required duration of 4 hours, was exhausted. The crucibles were withdrawn from the furnace and the milky-white, granular ash samples obtained, allowed to cool, then stored in a dessicator.

Preparation of Extenders for Paint Production

The granular RHA produced after incineration in the muffle furnace was ground with a ceramic mortar and pestle until the ash was reduced to fine particle size with a powdery texture (RHA powder). The RHA powder and calcium carbonate were passed through a standard sieve of aperture 63 microns (µm) to ensure a uniform particle size range of 32-63µm in the extenders as is required in the production of emulsion paints[17].

Formulae for Production of White Emulsion Paints [17]

The formulae for the white emulsion paints produced using RHA (RHAWEP), silica flour (SFWEP) and calcium carbonate (CCWEP) extenders are presented in Table 1.The Table shows the different components of the white emulsion paints, their functions and weight percentages of extenders used in formulating the paints.

Table 1: Formulae for Production of White Emulsion Paints using 2 to 12% by weight of RHA and $CaCO_3$

		Components (in weight %) of RHA, SF and $CaCO_3$ White Emulsion Paints					
Component	**Function**	2	4	6	8	10	12
Water	Solvent/diluent	43.15	41.15	39.15	37.15	35.15	33.15
Calgon PT	Wetting agent	0.15	0.15	0.15	0.15	0.15	0.15
Acticide Bx	Preservative	0.50	0.50	0.50	0.50	0.50	0.50
Berol 09	Emulsifier/surfactant	0.20	0.20	0.20	0.20	0.20	0.20
Antifoam	Defoamer	0.20	0.20	0.20	0.20	0.20	0.20
Coatex	Dispersant	0.20	0.20	0.20	0.20	0.20	0.20
*RHA/SF/$CaCO_3$	Extender, thickener	2.00	4.00	6.00	8.00	10.00	12.00
Titanium dioxide	White pigment	19.00	19.00	19.00	19.00	19.00	19.00
Styrene-acrylic resin	Binder	33.00	33.00	33.00	33.00	33.00	33.00
Natrosol	Cellulosic thickener	0.50	0.50	0.50	0.50	0.50	0.50
Ammonia	pH adjuster	0.10	0.10	0.10	0.10	0.10	0.10
Texanol	Coalescing agent	1.00	1.00	1.00	1.00	1.00	1.00
	Total	100%	100%	100%	100%	100%	100%

Procedure for Production of Emulsion Paints

The production method described is the same for all levels of extender but the quantities specified in the procedure are for the production of 300g of the emulsion paint which is obtained by multiplying the % by weight of each component by 3.

(i)The following components (weights in g) were loaded into a plastic vessel: Water (part), (15.15) ,Calgon PT (0.45) Acticide Bx (1.50), Berol 09 (0.60), Antifoam (0.30) and Coatex (0.60) (ii) They were stirred at low speed by means of a mini stirrer until Calgon PT dissolved. (approx 5 mins) (iii) The following ingredients were added into the same pot with low-speed stirring: RHA (24.00) Titanium dioxide (57.00) (iv) The mixture was then stirred at high speed (pigment dispersion stage) for about 20mins while intermittently scraping the sides of the vessel. When the dispersion was satisfactory, the stirring speed was reduced and the following components were added with slow stirring: Styrene - acrylic resin (99.00), Water (26.00) (vi) Slurry of the following was prepared in a separate container and added with stirring to the main pot: Water (70.35), natrosol (1.5). (vii)The following components were finally added and the mixture stirred until natrosol dissolved (approx 25mins): Antifoam (part) (0.30), Ammonia (0.30),Texanol (3.00).(iii)

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The paint was finally checked for satisfactory dispersion of the pigment with the aid of a small piece of a 100-mesh sieve and stored in sample cans.

PHYSICAL TESTS

Different colours of emulsion paints were produced with the extenders, however physical tests were carried out on white emulsion paints produced with RHA (RHAWEP), SF (SFWEP) and $CaCO_3$ (CCWEP). The tests were carried out using standard testing methods [18][19] with some modifications where necessary and include in-can assessment, pH, wt per litre (specific gravity) and viscosity.

a**. In-Can Appearance**

The finished emulsion paint samples were put in plastic sample cans, gently and thoroughly stirred, then visually observed for colour, homogeneity/consistency and smoothness.

b**. pH Determination**

. The pH meter was switched on and the pH electrode was standardized with a buffer solution of pH 7.0. The glass electrode was rinsed with distilled water and dried with tissue paper. It was then dipped into the emulsion paint and the pH reading taken.

c. **Determination of specific gravity of RHA, Silica Flour and $CaCO_3$** [20]

The weight of a 100cc measuring cylinder was obtained. 10g of the extender was put into the cylinder and kerosene poured into the cylinder until the 100cc mark was reached. The weight of the empty cylinder was subtracted to obtain the weight of known volume of extender and kerosene (W2).The weight of the extender (10g) was subtracted to give the weight of kerosene used (W1). The volume of kerosene (V1) was obtained by dividing its specific gravity by its mass (W1) and the volume of extender (V2) was calculated by subtracting V1 from 100cc. The S.G of extender was then calculated by expressing the mass (10g) over the volume (V2).

d. **Determination of weight per litre (specific gravity) Values of Emulsion Paint**

The weight per litre cup was first weighed empty on a digital weighing scale. The value obtained was 'tared'. The paint sample was poured into the cup and any excess paint cleaned off from the hole in the lid. The cup with the paint was weighed to obtain the wt per litre value of the paint.

e. **Pigment Volume Concentration (PVC) Values of Emulsion Paints**

The PVC values of the emulsion paints were calculated from their specific gravity values using the expression:

$$\% \text{ PVC} = \frac{vol\ of\ pigment\ in\ the\ paint}{vol\ of\ pigment\ in\ the\ paint + vol\ of\ non-volatile\ constituents\ in\ paint} \times 100$$

The volume of pigment in the paint is determined from the expression, weight of pigment + extender/ S.G of pigment+ extender. The value of non-volatile constituents in the paint is obtained from the product of weight % of resin used in the paint and its total solids content.

f. **Determination of Viscosity of Emulsion Paints at ±27^{0}C** [18]

The paint sample was poured into a sample can to a level of about 2.5cm from the top of the can. The can was then placed on the turntable of the rotothinner after it had been switched on. The disc was immersed into the emulsion paint inside the sample can. The disc was allowed to rotate inside the paint sample until the peak viscosity value was obtained. The viscosity reading was taken from the graduated scale around the turntable. The disc was raised and the sample can removed, following which the disc was thoroughly cleaned with a brush and water.

g. **Determination of Dry Film Appearance of Emulsion Paints**

The paint was first thinned with water then applied by means of a brush on brush- out cards (6"x 4"). The first coat was allowed to dry for 1hr after which the second coat was applied and allowed to dry. The dry paint films were observed for degree of gloss/sheen.

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III. RESULTS AND DISCUSSION

a. In-can Appearance

The three emulsion paints were all homogeneous, viscous liquids with a smooth consistency. However, RHAWEPs and SFWEPs were off-white in colour while CCWEPs had a more brilliant whiteness. This difference in degree of whiteness can be attributed to the colours of the extenders; RHA and SF both have an off-white colour while the $CaCO_3$ grade used was brilliant white in colour. This difference was observed only in white emulsion paints while for other colours there was no noticeable difference between the extenders. This suggests that on the basis of appearance, there was no noticeable morphological difference between SF and RHA, therefore SF can be used to produce all other colours of paint except brilliant white provided it satisfies other requirements for the production of paint of good quality.

b. pH Values of Formulated Emulsion Paints

The pH values (at ±27^{0}C) obtained for the emulsion paints at 2-12% levels of RHA, SF and $CaCO_3$ are presented in Table 2. The pH values of SFWEPs ranged from 9.10-9.24 ; those of CCWEPs were in the range of 9.05- 9.50 thus, both were slightly more alkaline than RHAWEP with pH values of 8.00-9.00 at all extender levels. The pH values of RHAWEPs are therefore within the pH specification of 7.00-9.00 for emulsion paints [19]

Table 2: pH Value of RHAWEPs, SFWEPs and CCWEPs at 2-12% Levels of Extender

Emulsion Paint	pH Values of RHAWEP, SFWEP and CCWEP at 2-12 weight% of RHA , SF and $CaCO_3$					
	2	4	6	8	10	12
RHAWEP	8.99	9.08	8.98	8.93	8.88	8.88
SFWEP	9.10	9.10	9.16	9.16	9.24	9.22
CCWEP	9.51	9.49	9.05	9.45	9.39	9.25

Plots of pH values against extender level shown in Fig. 1 reveal that increased levels of extenders had little or no effect on the pH of the emulsion paint as no particular trend was observed for all three extenders.

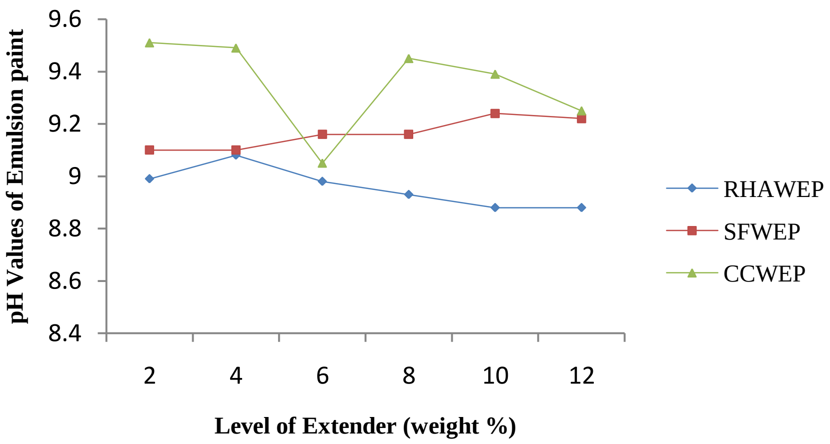

Fig. 1 Plots of pH Values of emulsion paint against Extender Level

The absence of any general trend in the plots of pH values versus extender level is probably due to the fact that pH values of emulsion paints are affected by several factors such as the pH of the resin, additives and other components of the paint as well as amount of ammonia used. Thus, the slight variation in pH values of RHAWEP and SFWEP cannot be attributed to morphological differences**,** but to a combination of the said factors.

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c. Specific Gravity Values of the Extenders

The specific gravity (S.G) values obtained for RHA, silica flour and calcium carbonate were 1.54, 2.18 and 2.24 respectively at a particle size range of 32-63microns (µm). Fig. 2 shows pictorially the S.G values of the three extenders.

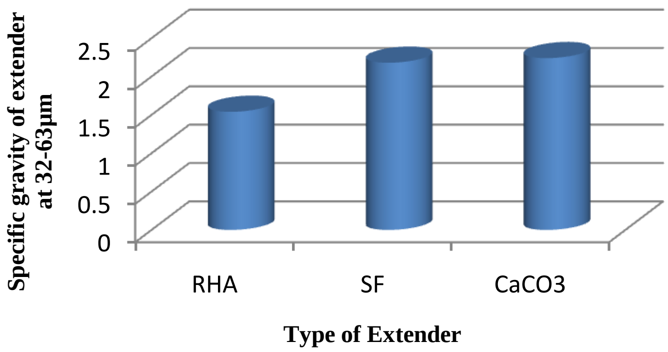

Fig. 2 .Plots of Specific gravity of extenders versus type of extender

Fig. 2 reveals the relative closeness in value between SF and $CaCO_3$ as well as the disparity between the two and RHA. The S.G of the extenders is an important physical parameter as it affects the pigment volume concentration (PVC) values of the emulsion paint which controls several paint properties such as viscosity, gloss, rheology, washability and durability [8]. The morphological differences between amorphous and crystalline silica evidently affected the S.G of RHA and SF. The higher S.G of silica flour is attributable to the ordered, rigid structure of crystalline silica while the unordered, flexible, porous amorphous silica of RHA resulted in a lower S.G. Crystalline materials generally have higher densities than amorphous ones. These differences in S.G are expected to manifest in the S.G of the emulsion paints as well as their PVC values, which is largely controlled by the specific gravity of pigments and pigment extenders used in the paint formulation.

d. **Weight per Litre (Specific Gravity) Values of Emulsion Paints**

The weight per litre values (specific gravity) of RHAWEP, SFWEP and CCWEP are presented in Table 3 SFWEP had the highest values in the range of 1.17-1.23 while RHAWEP was next with values ranging between 1.00 and 1.19 and CCWEP values were in the range of 0.98-1.04. It is evident that the S.G of the extenders affected the S.G of their emulsion paints despite the presence of other components in the emulsion paint. Thus, SFWEP had a high S.G due to the relatively high S.G of silica flour compared with RHAWEP which had a lower S.G values due to the low S.G of RHA at the same particle size range. The three extenders, however, did not show much variation in S.G with increasing extender levels.

Table 3. Weight per litre Values (Specific Graavity) of Emulsion Paints produced with RHA, SF and $CaCO_3$

Type of Emulsion	**Specific gravity Values of of RHAWEP, SFWEP and CCWEP at 0-12 weight% of RHA , SF and $CaCO_3$**						
	0	2	4	6	8	10	12
RHAWEP		1.16	1.13	1.00	1.13	1.19	1.16
SFWEP		1.17	1.20	1.23	1.23	1.19	1.19
CCWEP		0.98	0.99	1.03	0.93	1.03	1.04
Control(0%extender)	1.17						

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Plots of weight per litre values of the emulsion paints versus the level of extender are shown in Fig.3 which clearly reveals that SFWEP had the highest S.G values followed by RHAWEP and then CCWEP. Although, the S.G values of the emulsion paints seemed to correspond to the S.G values of the extenders used in producing them, there was a slight deviation in the case of $CaCO_3$ which had a slightly higher S.G (2.24) than SF (2.18) but the S.G values of CCWEP were slightly lower than those of SFWEP. This shows that the slight difference in their S.G did not have much impact on the S.G of their emulsion paints.

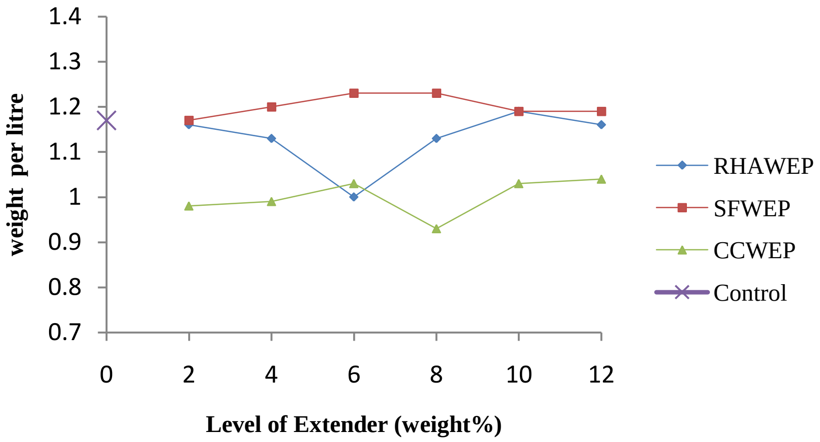

Fig. 3.Plots of weight per litre values of emulsion paint versus level of extender

However, the S.G of paint can also be affected by a number of factors such as the specific gravity of pigment and extender used, level of pigment dispersion, presence and amount of air bubbles, amount of foam produced thus it varies but the variation usually falls within the range of ±0.2.

e. Pigment Volume Concentration (PVC) Values of Emulsion Paints

The calculated PVC values of RHAWEPs, SFWEPs and CCWEP obtained at 2-12% extender levels are presented in Table 4. Plots of calculated PVC values versus extender levels for RHAWEP, SFWEP and CCWEP are shown in Fig.4.

Table 4: Pigment Volume Concentration (PVC) Values of RHAWEP, SFWEP and CCWEP

Emulsion Paint	PVC Values of Emulsion Paints at 2-12 weight% of RHA , SF and $CaCO_3$					
	2	4	6	8	10	12
RHAWEP	26.83	30.82	34.39	37.59	40.52	43.18
SFWEP	25.58	28.51	31.25	33.79	36.86	38.32
CCWEP	25.49	28.39	31.05	33.52	35.77	37.99

The plots show that the PVC values increased with increase in the levels of extender with RHAWEP having the highest values.

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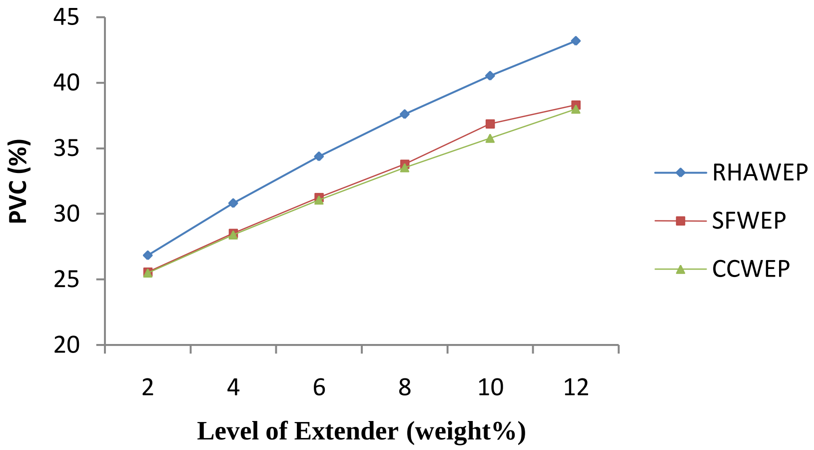

Fig.4. Plots of PVC values of the emulsion paint versus extender level

RHAWEP had the highest PVC values (26-43%) at all the extender levels due to its having the lowest specific gravity of 1.54 at 32-63 microns (µm). SFWEPs and CCWEP had lower PVC values that ranged from 25-38 %. The closeness in PVC values of SF and $CaCO_3$ is due to the closeness in their S.G. This trend is due to the fact that specific gravity has an inverse relationship with PVC; the lower the S.G of the extender, the greater its volume and the higher the PVC value of the paint thus, RHA flour with lowest S.G produced emulsion paints with higher PVC values than silica flour and $CaCO_3$. The PVC values of RHAWEP correspond to those of exterior house paints which have a low-gloss or flat appearance while the PVC values of SFWEP fall within the category of semi-gloss paints [5][15].

f. **Effect of RHA and Silica Flour on Viscosity of Emulsion Paints**

The viscosity of emulsion paint is an important paint parameter as it affects the consistency, flow and application properties of the paint.

This viscosity values (in poises) of the white emulsion paints produced with RHA (RHAWEPs), silica flour (SFWEP) and $CaCO_3$ (CCWEPs) are presented in Table 5.

Table 5: Viscosity values(poises) of White Emulsion Paints Produced with RHA (RHAWEP), SF (SFWEP) and $CaCO_3$ (CCWEP) at 2-12% Levels

Emulsion Paint	Viscosity (poises) of white Emulsion Paint at 0-12 Extender Level at $\pm 27^0$C						
	0	2	4	6	8	10	12
RHAWEP		2.8	3.5	3.8	4.3	4.9	6.4
SFWEP		2.2	2.5	3.0	3.8	5.0	6.5
CCWEP		2.6	3.2	3.5	3.6	4.0	5.0
Control	2.8						

Plots of viscosity values of the emulsion paints against extender levels are shown in Fig.5. The emulsion paints showed a gradual increase in viscosity at lower extender levels (2-6%) but sharp increases at higher levels (8-12%), which implies that higher levels of extenders are required in the paint formulation for a pronounced increase in the viscosity of the emulsion paints. SFWEP had the lowest viscosity at 2-6% (lower than the Control), but displayed a sharp rise from 8-12 % extender level and slightly surpassed that of RHAWEP at 10-12% levels.

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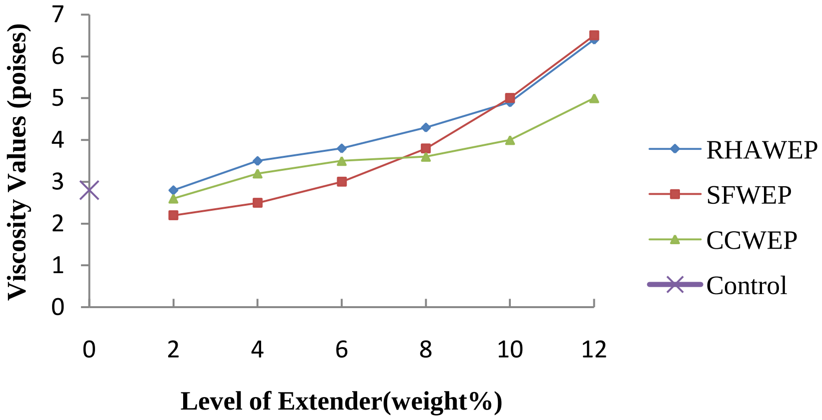

Fig.5. Plots of ViscosityValues against extender level

The observed trend in the viscosity of the emulsion paints can be explained in terms of pigment volume concentration and silica morphology.

i**. Pigment Volume Concentration (PVC)**

The superiority of RHA to SF in thickening effect can be attributed to its having a lower S.G than silica flour at the same particle size range. This low S.G of RHA results in a higher pigment volume concentration (PVC) of RHAWEPs due to the inverse relationship between S.G and PVC of paint as earlier stated. This increase in the volume of pigment/extender particles in the paint, implies that more RHA particles are dispersed in the paint which invariably results in a proportionate increase in its resistance to flow, which is described as 'viscosity' of the paint.

ii **Silica Morphology**

The amorphous and crystalline nature of silica in RHA and SF respectively also had an impact on their thickening ability which consequently affected the viscosity of the paint. This is due to the fact that amorphous and crystalline silica have different properties [13]. The high surface to volume ratio, expanded conformation, disorderliness and porosity of amorphous silica which is the major component of RHA used in the study, confers greater surface area, flexibility and reactivity to RHA [13] [14] which translates into greater thickening capacity than silica flour. On the other hand, the ordered, rigid structure of crystalline silica in SF reduces its surface area, reactivity and the volume of crystalline silica in the paint, thereby reducing the viscosity of SFWEP. The Control which had 0% extender had a value of 2.8 poises which is the same as that for 2% RHAWEP, slightly higher than that of 2% CCWEP but much higher than that of 2% SFWEP. This suggests that low levels of RHA and $CaCO_3$ have little effect on paint viscosity. Interestingly, in the case of SF, lower levels (2-6%) reduced viscosity while higher levels (8-12%) increased the viscosity substantially.

g. **Dry Film Appearance of Emulsion Paints**

The PVC values of the paint reflected in the appearance of the dry emulsion paint films when applied on a substrate. SFWEP had a noticeable gloss (sheen) while RHAWEP had a rather flat appearance. This effect has substantiated the 'semi-gloss' category of SFWEP and the 'exterior house paint' category of RHAWEPs based on PVC values.

IV. CONCLUSION

The results of the study revealed that the differences in morphology between amorphous and crystalline silica had an impact on emulsion paint properties. The disorderliness, flexibility, porosity, reactivity and large surface area of amorphous silica (in RHA) conferred on it a thickening effect superior to that of crystalline silica(in silica flour) which has an ordered, rigid, structure with reduced surface area. The resultant effect of these properties is that RHAWEPs had higher viscosities than SFWEPs. The pigment volume concentration (PVC) values of RHAWEP were higher than those of SFWEP at all extender levels due to the lower specific gravity of RHA while the PVC values of SF were comparable

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to those of $CaCO_3$ due to the closeness in their specific gravity. The PVC values affected the viscosity and dry film appearance of the emulsion paints such that the dry films of SFWEP and CCWEP had a slightly glossy appearance while those of RHAWEP were rather flat. Amorphous silica (RHA) displayed an overall superior performance when compared with crystalline silica (silica flour). Silica flour can be used as an extender in emulsion paint at 8-12% levels since it was comparable to $CaCO_3$ in PVC value but higher in viscosity at 8-10%. However, the relatively high cost of silica flour as well as the better pigment extender properties of amorphous silica makes RHA preferable to silica flour for use as pigment extender in emulsion paint.

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