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Comparative Evaluation of Pigment-Extender Effects of Calcium Carbonate and Kaolin in Emulsion Paint

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ABSTRACT

This work investigated the pigment-extender effects of calcium carbonate and kaolin (china clay) in emulsion paint by determining and comparing some important physical and performance properties of the emulsion paints produced with the two extenders. The extenders were first sieved to obtain a uniform particle size range of 32-63 microns (µm) used in the formulation of the emulsion paints. The compositional levels of the extenders in the emulsion paints were varied from 2-12% by weight. The results of the tests showed that kaolin-filled emulsion paints had higher specific gravity values, higher pigment volume concentration (PVC) values and higher viscosities than $CaCO_3$-filled at all levels. However, the calcium carbonate-filled emulsion paints had more brilliant whiteness than those produced with kaolin. The dry films of $CaCO_3$-filled emulsion paints had a noticeable gloss (sheen) while those of kaolin had a flat (non-glossy) appearance which was in conformity with their PVC values. The performance tests revealed the similarity of the two paint variants in scrub resistance, but better performance of the kaolin variants in opacity, settling resistance and brushing properties.

Keywords: *Emulsion Paint, Pigment-Extender, Calcium Carbonate, Kaolin, China Clay*

1. INTRODUCTION

In the paints industry, pigment-extenders are widely used to partially replace true pigments. 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 (Morgans,1990 ;Hughes, 1983). Some are processed minerals while others are prepared chemically. Pigment-extenders, often simply called 'extenders' or 'fillers' can be referred to as auxiliary pigments as they generally augment pigment effects by improving paint properties such as consistency, rheology, resistance to weathering, gloss, levelling, adhesion and coverage(Hughes, 1983 ;Sharma, 2011). Extenders are characterized by narrow range of refractive indices which are close to those of oils and resins and consequently contribute little or nothing to opacity (Morgans,1990). Extenders most commonly used in emulsion paints are calcium carbonate and kaolin (china clay). Combinations of these two in different ratios are also used by paint manufacturers. Calcium carbonate is the most widely used extender in paints because it is cheap, readily available and helps to reduce floating of coloured pigments (Hughes, 1983). Research investigations have reported the suitability of calcium carbonate as pigment-extender in textured paint (Igwebike-Ossi, 2012a) and as a flatting agent in red oxide primer (Igwebike-Ossi, 2012b). Kaolin grades come in different colour shades, which include off-white, milky white, cream and light brown. This colour variation often poses colour-match problems, particularly with regards to white and other light colours and this restricts its application in paints. $CaCO_3$, on the other hand, comes in white and brilliant white grades which promotes its versatility in paint application. It is generally produced from natural chalk or limestone and the different grades are known as whiting, precipitated calcium carbonate, calcite and dolomite ($CaCO_3.MgCO_3$) (Morgans, 1990). Kaolin, also known as china clay, is hydrated aluminiun silicate with the formula, $Al_2O_3.2SiO_2.2H_2O$ and is a useful flatting and thickening agent for low-sheen paints such as undercoats, eggshell and matt finishes (Morgans, 1990).Calcium carbonate particles are nodular (round and irregular) in shape while kaolin particles are generally lamellar (plate-like) in shape(Hughes, 1983). Nodular particles can pack together easily while lamellar particles generally tend to overlap. The shape of the extender particles imparts certain specific and identifiable properties to the paint as was evident in this study.

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 (Sharma, 2011; Austen, 1984). It is defined and calculated using the expression: (Austen, 1984; Sharma, 2002)

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

The volume of pigment in the paint is determined from the expression: weight of pigment + extender / S.G of pigment+ extender. The value for non-volatile constituents in the paint is obtained from the product of weight % of resin used in the paint and its total solids content. The PVC values for various coatings are as follows: flat paints, 50-70%; semi-gloss paints, 35-45% and gloss paints, 25-35% (Sharma, 2002). 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 (Sharma, 2002). 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 and was also determined in this study.

Calcium carbonate and kaolin are known to be used as pigment-extenders in paints and other surface coatings. However, an extensive literature review revealed no published work on their effects on emulsion paint properties. This is probably because such specialized investigations are usually carried out by Paint development teams of large-scale paint manufacturing companies and the findings thereof confined to the investigating paint industry. The main objective of this study is to determine and compare the effects of calcium carbonate and kaolin (china clay) as pigment-extenders on the physical and performance properties of emulsion paint. The findings from this work will provide important basic information to researchers in related areas, paint technologists, existing and prospective paint manufacturers and workers interested in exploring this area of research.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 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), standard stainless steel sieves (BS410)

2.1.2 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.

2.2 Methods

2.2.1 Preparation of Extenders for Paint Production

The calcium carbonate and kaolin samples 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 (CAP Plc,2010)

2.2.2 Determination of specific gravity of $CaCO_3$ and Kaolin Powders (Hickling, 2008)

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).

2.2.3 Formulae for Production of White Emulsion Paints (CAP Plc,2010)

The formulae for the white emulsion paints produced using calcium carbonate (CCWEP) and kaolin extenders (KWEP) 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 $CaCO_3$ and kaolin

Component	Function	Components (in weight %) of $CaCO_3$ and kaolin White Emulsion Paints					
		2	4	6	8	10	12
Water	Solvent/diluent	43.15	41.15	39.15	37.15	35.15	33.15
Calgon PT	Wetting/water-softening 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
$CaCO_3$/kaolin	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%

2.2.4 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) 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.

2.2.5. PHYSICAL TESTS

Physical tests were carried out on white emulsion paints produced with kaolin (KWEP) and $CaCO_3$ (CCWEP). The tests were carried out using standard testing methods (NIS, 1990; NIS, 2008) with some modifications where necessary. The tests include in-can assessment, pH, wt per litre (specific gravity) and viscosity.

2.2.5.1. In-Can Appearance

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

2.2.5.2. 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.

2.2.5.3. 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.

2.2.5.4. Determination of Viscosity of Emulsion Paints at ±27^{0}C (NIS, 1990)

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.

2.2.5.5. 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.

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

The PVC values of the emulsion paints were calculated from their specific gravity values using the mathematical expression provided in Section 1
.

2.2.6 Performance Tests

The white emulsion paints were subjected to opacity, scrub resistance, settling resistance and brushing tests.

2.2.6.1. Determination of Opacity of Emulsion Paints

The paint sample was scooped with a palate knife and spread evenly across the width of a Morest chart (black and white striped paper) about 4cm from the edge of the paper. The paint was then evenly applied down the length of the paper by means of the K-bar (stainless steel bar) and left to dry. A second coat was applied using the same application technique but with a space of 5cm left from the edge of the first coat. The opacity was assessed by the extent to which the black and white stripes were covered by the paint.

2.2.6.2. Determination of Scrub resistance (Washability)

This test is used to determine the number of wet brushing cycles that the emulsion paint film can withstand before any scratch is observed on the film. Two coats of the emulsion paint were applied to an asbestos panel of dimension 6"x 12" using a brush. The paint was allowed to dry under ambient conditions and allowed to age for seven days. The test panels were mounted on the washability (scrub resistance) testing machine fitted with nylon brushes. The machine was set at 5,000 cycles to determine if the paint would be washed off the asbestos panel after brushing the surface 5,000 times.

2.2.6.3. Determination of Settling Resistance

The emulsion paint samples were thoroughly stirred then poured into 500ml plastic jars which were tightly covered. The samples were left to stand for a period of four weeks at the end of which they were stirred to check the presence of hard settlement.

2.2.6.4. Brushing Properties

The ease of application of the paint (after thinning) was determined using a brush. The brush was first wetted and excess water squeezed from it. It was then used to apply the paint on asbestos cement panels (300x100mm size) and the brushing/application properties observed.

3. RESULTS AND DISCUSSION

The levels of $CaCO_3$ and kaolin were varied from 2-12%, in the paint formulations, but the higher levels (8-12%) had more pronounced effects on paint quality and form the basic framework for this discussion.

3.1. Particle Size of Extenders

The particle size of the extender affects the properties of paint, thus the particle size range of the extender is usually specified for paints and other surface coatings. An extender particle size not exceeding 75µm is usually required for emulsion paint formulation (CAP,Plc, 2010). It was necessary to maintain the same particle size range of 32-63 microns (µm) in calcium carbonate and kaolin for the purpose of effective comparison of their pigment-extender properties.

3.2. Specific gravity of $CaCO_3$ and Kaolin Powders

The specific gravity (S.G) of pigments and extenders used affect the pigment volume concentration (PVC) of paint, which controls several paint properties. Consequently, it was necessary to determine the S.G of the sieved extenders at various particle sizes in order to determine the effect of particle size on the S.G of the extender, which was used in calculating the PVC values. Table 2 shows the experimentally determined S.G values of the extenders at different particle size ranges. The values show that the S.G increases with increase in particle size of the extenders.

Table 2. Experimentally Determined Specific Gravity Values of $CaCO_3$ and Kaolin at Different Particle Size ranges

Extender Particle size range	Determined S.G of Extender	
	$CaCO_3$	Kaolin
32-63µm (for emulsion paint)	2.24	1.76
32-106 µm	2.26	1.80
32-212 µm	2.28	1.88

The experimentally determined specific gravity (S.G) values of 2.24 and 1.76 obtained for calcium carbonate and kaolin at a particle size range of 32-63microns (µm) are lower than the literature values of 2.7, 2.8, 2.87 and 2.6 for precipitated calcium carbonate, calcite, dolomite and kaolin respectively(Morgans, 1990) Fig. 1 shows a chart of the S.G values of kaolin and $CaCO_3$ at various particle size ranges. The disparity in S.G between $CaCO_3$ and kaolin at the different particle size ranges is evident.

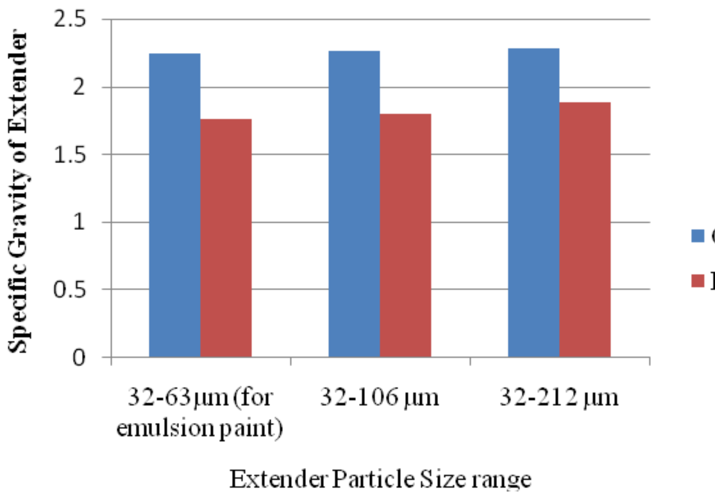

Fig.1 Plot of specific gravity of extender against emulsion type

The lower S.G values of $CaCO_3$ and kaolin obtained experimentally can be attributed to sieving of the extenders to obtain a smaller and narrow particle size range of 32-63µm before the determination of their S.G values. The literature values, however involve a wider distribution of particle sizes, including much larger particle sizes. This combination, invariably gives higher S.G values. The S.G of the extenders is an important physical parameter as it affects the pigment volume concentration (PVC) of the emulsion paint which controls several paint properties such as viscosity, gloss, rheology, washability and durability ((Sharma, 2011; Austen, 1984)

3.3. In-can Appearance

The two emulsion paint samples were homogeneous, viscous liquids with a smooth consistency. However, KWEPs 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. The kaolin grade used had 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, kaolin can be used to produce all colours of paint except brilliant white while $CaCO_3$ can be used to produce all colours.

3.4. pH Values of Formulated Emulsion Paints

The pH values (at ±27^{0}C) obtained for the emulsion paints at 2-12% levels of kaolin and $CaCO_3$ are presented in Table 3. The pH values of KWEPs ranged from 9.0-9.5 while those of CCWEPs were in the range of 9.05-9.50 thus, both extenders produced emulsion paints with pH values slightly higher than specification of 7.00-9.00 for emulsion paints (NIS,2008)

Table 3: pH Value of CCWEPs and KWEPs at 2-12% Levels of Extender

	pH Values of CCWEP and KWEP at 2-12% Extender Level					
	2	4	6	8	10	12
CCWEP	9.51	9.49	9.05	9.45	9.39	9.25
KWEP	9.21	8.96	9.15	9.13	9.44	9.47

Plots of pH values against extender level shown in Fig. 2 reveal that increased levels of extenders had little or no effect on the pH of CCWEP, as the values were quite close except for the lower value of 6%. In the case of KWEP, there was a slight increase in pH at higher extender levels (10-12%).

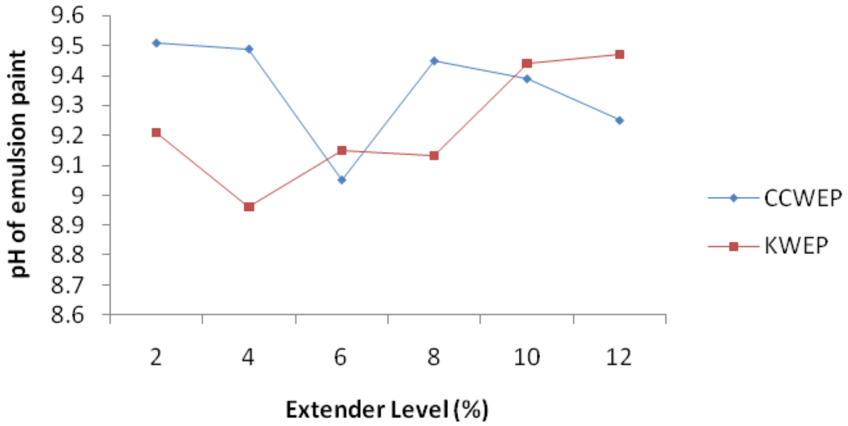

Fig.2 Plots of pH values of Emulsion paints versus extender level

This trend 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 CCWEPs and KWEPs is attributable to a combination of the said factors.

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

The weight per litre values (equivalent to specific gravity) of CCWEP and KWEP are presented in Table 4. KWEP had the highest values in the range of 1.01-1.15 while CCWEP values were in the range of 0.98-1.04. It is evident that the S.G of the extenders had little or no effect on the S.G of the emulsion paints otherwise CCWEPs would have had higher S.G values than KWEPs since $CaCO_3$ has a higher S.G than kaolin.

Table 4: Weight per litre (Specific Gravity) Values of Emulsion Paints

	Weight per Litre Values of CCWEP and KWEP at 2-12% Level						
	0	2	4	6	8	10	12
CCWEP		0.98	0.99	1.03	0.93	1.03	1.04
KWEP		1.04	1.08	1.10	1.15	0.99	1.01
Control	1.17						

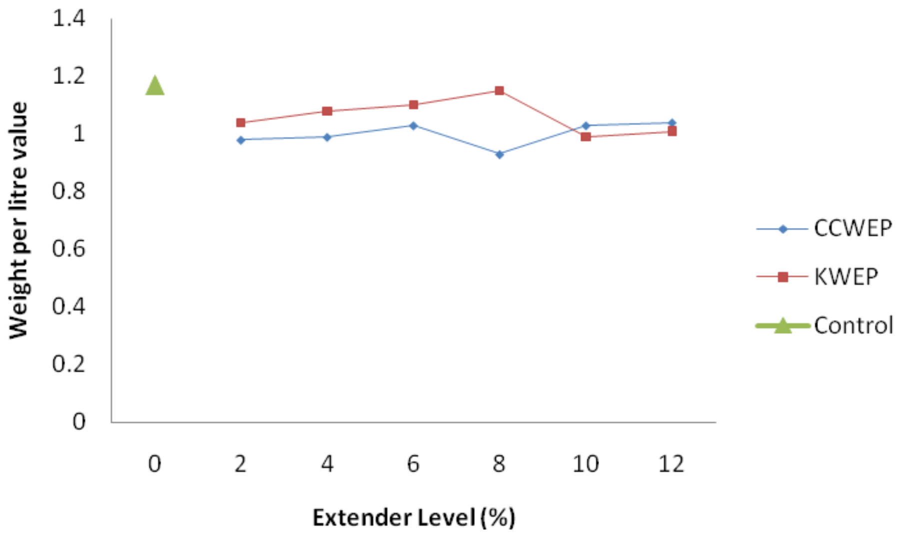

Fig .3. Plots of Weight per litre values of Emulsion paint versus Extender level

The little or no impact of the S.G of extender on emulsion paints S.G can be attributed to the presence of other components in the emulsion paint as well as other factors. Such factors that can affect the S.G of the emulsion paint include specific gravity of pigment, level of pigment dispersion, presence and amount of air bubbles and amount of foam generated during blending of the paint. Thus the S.G of the emulsion paint varies but the variation usually falls within the range of ±0.2. The S.G of the Control (1.17) which had no extender also substantiates this observation as it is higher than the values of the emulsion paints containing extender. The high S.G of the Control can be attributed to the high S.G of 4.6 of titanium dioxide (www.espimetals.com) used as pigment in the paint. The addition of an extender of lower S.G evidently reduced the impact of the high S.G of TiO_2. The two extenders, however, did not show much variation in S.G with increasing extender levels.

3.6. Effect of Calcium Carbonate and Kaolin on Viscosity of Emulsion Paints

The viscosity of emulsion paint is an important paint property as it affects the consistency, flow and application properties of the paint. The viscosity of $CaCO_3$- and kaolin-filled emulsion paints are presented in Table 5. Plots of viscosity values of the emulsion paints against extender levels are shown in Fig.4.

Table 5. Viscosity Values (poises) of CCWEPs and KWEPs at different Extender Levels

	Viscosity(poises) of CCWEP and KWEP at 2-12%						
	0	2	4	6	8	10	12
CCWEP		2.6	3.2	3.5	3.6	4.0	5.0
KWEP		2.8	3.4	4.1	4.4	5.0	5.9
Control	2.8						

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.

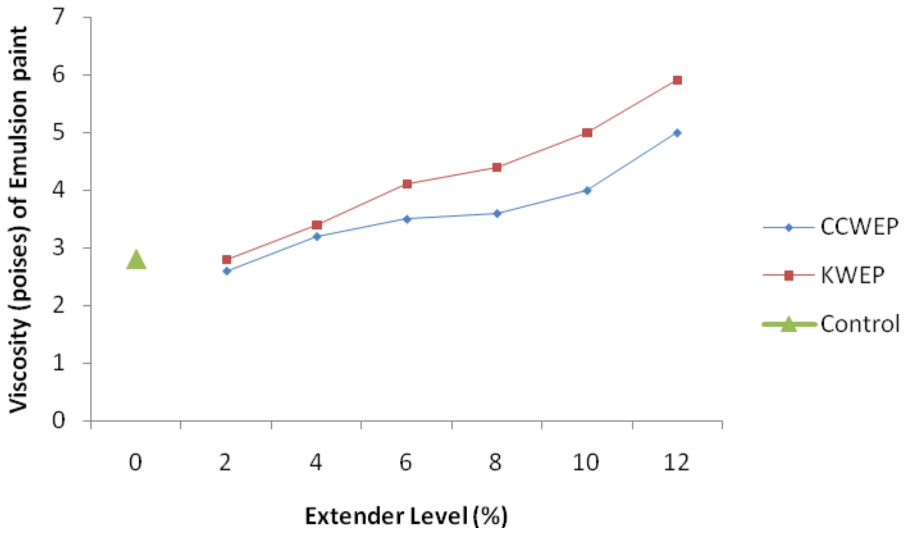

Fig. 4 Plots of Viscosity (poises) of emulsion paint versus extender Level

The superiority of kaolin to $CaCO_3$ in thickening performance can be attributed to its having a lower S.G than $CaCO_3$ of the same particle size range. The low S.G of kaolin results in a higher pigment volume concentration (PVC) of KWEPs due to the inverse relationship between S.G and PVC of paint. This increase in the volume of pigment/extender particles in the paint, implies that more kaolin 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. The Control which had 0% extender had a value of 2.8 poises which is the same as that for 2% KWEP, and slightly higher than that of 2% CCWEP. This suggests that low levels of $CaCO_3$ and kaolin have little effect on paint viscosity.

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

The calculated PVC values of CCWEP and KWEP obtained at 2-12% extender levels are presented in Table 6. Plots of calculated PVC values versus extender levels for CCWEP and KWEP are shown in Fig.5

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Table 6. Pigment Volume Concentration (PVC) values of Extenders

	PVC Values of CCWEP and KWEP at 2-12% Levels					
	2	4	6	8	10	12
CCWEP	25.49	28.39	31.05	33.52	35.77	37.99
KWEP	26.30	29.84	33.09	36.05	38.73	41.22

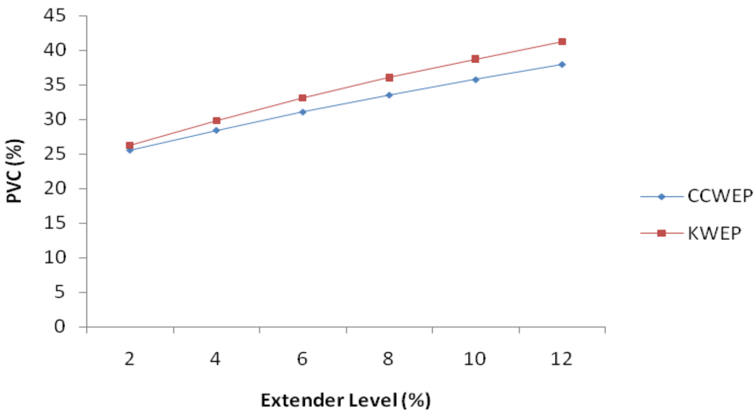

Fig. 4. Plots of PVC versus Extender Level (%)

KWEPs have higher PVC values (26-41%) at all the extender levels due to its having a lower specific gravity of 1.76 at 32-63 microns (μm) than 2.24 for $CaCO_3$. CCWEPs, on the other hand, have lower PVC values that range from 25-38 %. This trend can be attributed to the inverse relationship between specific gravity and PVC; the lower the S.G of the extender, the greater its volume and the higher the PVC value of the paint. Thus, kaolin with a lower S.G produced emulsion paints with higher PVC values than $CaCO_3$. The PVC values of KWEP correspond to those of exterior house paints which have a low-gloss or flat appearance while the PVC values of CCWEP fall within the category of semi-gloss paints [6,7].

3.8. Dry Film Appearance of Emulsion Paints

The PVC values of the emulsion paints reflected in the appearance of the dry paint films when applied on a substrate. CCWEP had a noticeable gloss (sheen) while KWEP 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.

3.9. Opacity of Emulsion Paints

The opacity of the paint, which is also known as the hiding or obliterating power, is largely dependent on the nature and amount of pigment in the paint. However, KWEPs were observed to be slightly better than CCWEP in opacity at 8-10% level. Although, they both covered the Morest chart in two coats, KWEP was found to obliterate the black and white stripes on the chart slightly better than CCWEPs. This suggests that kaolin contributes to opacity which conforms with literature finding (Morgans, 1990). Since extenders have little or no effect on opacity, the hiding power of the white emulsion paints is due mostly to the presence of titanium dioxide pigment,which has excellent hiding power.

3.10. Scrub Resistance (Washability)

The CCWEPs and KWEPs showed, excellent scrub resistance of over 5000 cycles at all extender levels. This implies that the dry paint films can be washed (scrubbed) over 5000 times without loss of the paint from the substrate. This shows that the paint is of premium (high) quality. The excellent scrub resistance is attributable to the type of resin (styrene-acrylic copolymer) and level of resin (33%) used in the formulation. Styrene-acrylic has very good binding properties which was evident in the strong adherence of the paint film to the substrate and resultant high resistance to scrubbing. This factor is largely dependent on the type of resin used. The two far exceeded the specification of a minimum of 501 cycles for premium quality emulsion paint (NIS, 2008).

3.11. Settling Resistance

KWEPs showed greater resistance to settling as there was little hard settlement at the bottom of the container compared to CCWEP which had more hard settlement when the paint samples were stirred. This can be attributed to the nodular shape of the $CaCO_3$ particles which makes them capable of packing together easily resulting in hard settlement unlike the lamellar shape of kaolin particles (Hughes, 1983) which tend to aid overlap of particles. In addition, the lower density of kaolin particles makes them more likely to remain suspended in the resin while the $CaCO_3$ particles which are denser are more likely to settle.

3.12. Brushing Properties

KWEPs displayed better brushing properties than those of CCWEP, in terms of ease of application, flow and spread of the paint on the substrate when applied with both brush and roller. This is probably due to the difference in their particle shapes. The lamellar (plate-like) shape of kaolin particles promotes ease of application better than the nodular (round) shape of the $CaCO_3$ particles.

4. CONCLUSION

The results of the study revealed that KWEPs had higher viscosities than CCWEPs at all extender levels. The pigment volume concentration (PVC) values of KWEP were higher than those of CCWEP at all extender levels due to the lower specific gravity of kaolin. The PVC values were evident in the dry film appearance of the emulsion paints such that the dry films of CCWEPs had a noticeable gloss (sheen) while those of KWEP were rather flat (non-glossy). Kaolin-filled emulsion paints showed better performance in opacity, settling resistance and brushing properties than $CaCO_3$-filled. The findings suggest that for a glossy appearance as well as brilliant white colours, calcium carbonate is preferable to kaolin. However, if a glossy finish is not required, kaolin might be a better choice because of the additional benefits in viscosity, opacity and brushing properties. Further research work will explore effects of combinations of kaolin and $CaCO_3$ in different ratios on emulsion paint properties.

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