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A Calcined Aluminum Silicate Micro-based Pigment as Titanium Dioxide Replacement in Waterborne Coatings

M. Amir¹, S. Qamar¹, A. Saeed¹, U. Saeed¹, W. Aleem², M. A. Zafar¹, S. Ejaz¹, A. Shahid³, M.S. Durrani⁴

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Abstract

Effect of calcined aluminum silicate (CAS), micro-based pigment, in place of titanium dioxide (TiO₂) in waterborne paints has been studied. Five samples were prepared with TiO₂ replacement with the percentages (0%, 5%, 10%, 15% and 20%) of CAS in waterborne coatings. Additives, binder and fillers were added according to paint basic formulation. Different tests were performed to evaluate the properties in term of gloss, appearance, opacity, density, viscosity, and whiteness. It has been found that the opacity of all samples (S₁ to S₅) have been found in the range (94.96 – 95.87) %. The density of all samples has been changed very slightly from 1.493 kg/liter to 1.476 kg/liter with the replacement of CAS. The value of gloss revealed in the range of 1.9 to 2.2 for all samples (S₁ to S₅). The viscosity of the fabricated samples was increased from 12.5 poise to 16.04 poise by the replacement of titanium dioxides into calcium aluminum silicate. Almost no change in the whiteness in the samples have been found. All the results revealed that calcium aluminum silicate has the potential to replace TiO₂ in waterborne paints. Replacement of titanium dioxide give better quality and economically favorable.

Keywords: Waterborne Paints; Calcined Aluminum Silicate; Titanium dioxide; Coatings; Opacity;

1. Introduction:

Growing urban populations and increased construction activity worldwide are the main factors driving the expansion of the paint and coatings manufacturing industry [1]. Buildings are shielded from weather-related damages, corrosion, and other hazards by these protective layers. Regarding this, the available data on the genotoxic consequences of paint exposure describes both bad and good outcomes [2]. Furthermore, a significant

quantity of dioxin-contaminated wastes are produced during the chloride method of producing TiO₂ that is used in paint goods [3]. However, the use of mineral fillers in place of TiO₂ throughout the paint production process can significantly reduce environmental consequences and enhance paint surface consistency in order to offset these disadvantages of TiO₂ use [4-5].

TiO₂ is the primary white pigment that is used in waterborne coatings because it has high refractive

¹ Department of Chemical Engineering, Muhammad Nawaz Sharif University of Engineering and Technology, MNSUET 60000, Multan Pakistan

² DTU Offshore–Danish Offshore Technology Centre, Technical University of Denmark, Building 375, 2800 Kongens Lyngby, Denmark

³ Department of Mechanical Engineering and Technology, Muhammad Nawaz Sharif University of Engineering and Technology, MNSUET 60000, Multan Pakistan

⁴ Institute of Chemical Engineering and Technology, University of the Punjab, Lahore, Pakistan

*Corresponding Authors: aleem.waqas@gmail.com

index and hiding power. Inorganic like zinc oxide and titanium dioxide are known due to their photolytic properties [6]. Extenders are also used for optimum dispersion of titanium dioxide and maximum dispersion prevents from agglomeration and flocculation and also improve film efficiency [7-9]. Moreover, proper filler and extender can increase gloss of dry film of paint [10]. TiO_2 is the best white pigment that may be utilised in the paint and coatings industry out of all the chemical-based pigments. The two crystal forms of TiO_2 pigment are rutile and anatase. The best pigments are rutile TiO_2 , as they scatter light more than anatase pigments and are more stable and long-lasting [11]. It is prepared artificial, nontoxic and its main properties is that it is insoluble in acids, base and many other products. Titanium dioxide is manufactured by two methods sulfate and chloride process main function of titanium oxide in paint is brightness, whiteness, hiding power and sheen. In paints, a piece of the color is replaced with filler so that costs of shades can be diminished. Filler influences sparkle, surface, suspension, shading strength and consistency of a paint. Ordinarily fillers utilized are kaolin, calcium carbonate, chalk, deodorant powder, silica and silicates. [12-13].

Substitution of TiO_2 , perhaps the most costly elements of paint, with somewhat modest extenders like calcined kaolin or calcite with no decrease in help properties of paint is consistently a significant research topic. [14-15]. There are numerous benefits of replacing chemical-based or TiO_2 -based pigments with renewable resources like kaolin. These include a major drop in the environmental impact of paints, a reduction in abrasion, improved mechanical qualities, and increased operational durability [16-18].

Inert pigments or fillers that are low cost and have low refractive index can be used in paints as extenders. The prudent replacement of extender for the most part delivers comparable opacity, scrub, tinting, stains etc. Extender's replacement assists with lessening the expense as well as assists with working on the properties, like the flow and rheological development under pressure, shine,

mechanical resistance, brightness, hiding power, and reflectance. Titanium dioxide is expensive and low stock make fillers more important that give high opacity and reduce cost in paint. Filler or extender like calcined kaolin can replace titanium dioxide in waterborne paint without changing properties like opacity and gloss. [19]

Kaolin is widely used in paint and for decoration of architecture buildings. The most valuable term for mineral fillers made up of plate-like, coarse-to-fine-grained aluminium silicate particles is kaolin [20-21]. The Chinese word "kaolin" is derived from "Kao ling." [22]. In the cement, paint, rubber, paper and pharmaceutical industries, kaolin is widely used [22-23]. Artificially, kaolin is a hydrated aluminum silicate framed from enduring and disintegration of field's phatic rock. In the same way as other minerals, it happens as lattice rock. Calcined kaolin is prepared at high temperature about 1000°C . By this process air voids are generated between particles of kaolin. This clay gives the rheological, flow and opacity. From the results it is showed that due to high opacity and brightness kaolin can replace titanium dioxide in waterborne paints [24].

Calcined kaolin likewise displays properties like titanium dioxide and it can be used as alternative for titanium dioxide. Properties incorporate whiteness, brightness and hiding power. Calcined kaolin successfully disperses light because of its permeable design, thus when light experiences it, a portion of the light gets reflected off the planar surfaces, a piece of the light enters the construction and these beams upon reflection experience different crystals closely. This light then, at that point, goes through different inside reflections and diffractions giving superb optical disperse. As per the structure, the rutile TiO_2 structure has TiO_6 octahedrons that structure segments by sharing two edges. Titanium has six oxygen closest neighbors and oxygen has three titanium closest neighbors. Adjoining segments are connected through sharing corners of other octahedral. Moreover, the mulita structure comprises of chains of misshaped edge-sharing Al-O octahedral at the corners and focus of every unit cell. These chains are

further cross-connected by Si-O and Al-O corner-sharing tetrahedral [25].

2. Materials And Methods:

Five samples of waterborne coatings are prepared using high speed mixer (2800 RPM) at laboratory scale. After preparation these samples are applied on opacity chart and concrete wall. All samples were prepared on room temperature and with equal time. Amount of ingredients in formulation were added with pigments ratio.

Titanium dioxide was used from Chinese company

Annanda Titanium Company with product name Rutile ATR-312. Calcined Aluminum Silicate was used BASF product P90. Acrylic binder of Nimir Chemical is used. Sample are prepared and tested in R&D laboratory of Black Horse Paint Industry Lahore Pakistan. Pigments were dispersed for 30 minutes in high-speed disperser. During this time period titanium dioxide and calcined aluminum silicate were dispersed. Dispersion was checked by using particle measuring gauge of Sheen Company. Formulations of sample were made according formulation structure given in Table 1.

Table 1: Formulation of Paint

Sr. No.	Material	Quantity %				
		S1 (0%)	S2 (5%)	S3 (10%)	S4 (15%)	S5 (20%)
1	Water	30.326	30.321	30.226	30.311	30.315
2	Defoamer	0.2	0.2	0.2	0.2	0.2
3	Dispersing Agent	0.4	0.4	0.4	0.4	0.4
4	Fragrance	0.078	0.078	0.078	0.078	0.078
5	Kerosene oil	1.2	1.2	1.2	1.2	1.2
6	Antsettling agent	0.3	0.3	0.3	0.3	0.3
7	PH Adjuster	0.2	0.21	0.21	0.22	0.22
8	Antifreeze	0.9	0.9	0.9	0.9	0.9
9	Biocide	0.35	0.35	0.35	0.35	0.35
10	Thickener	0.5	0.5	0.5	0.5	0.5
11	Wetting Agent	0.2	0.2	0.2	0.2	0.2
12	Coalescing agent	0.4	0.4	0.4	0.4	0.4
13	Titanium dioxide	9.91	9.41	8.98	8.42	7.93
14	CaCO ₃	36.036	36.036	36.036	36.036	36.036
15	Calcined Aluminum Silicate	0	0.495	0.990	1.486	1.981
16	Binder	19.0	19.0	19.0	19.0	19.0

There are five samples of this work; sample (S1) is standard that contains titanium dioxide with no aluminum silicate. S2, S3, S4 and S5 are prepared by reduction of titanium dioxide by 5%, 10%, 15% and 20%.

3. Results & Discussions:

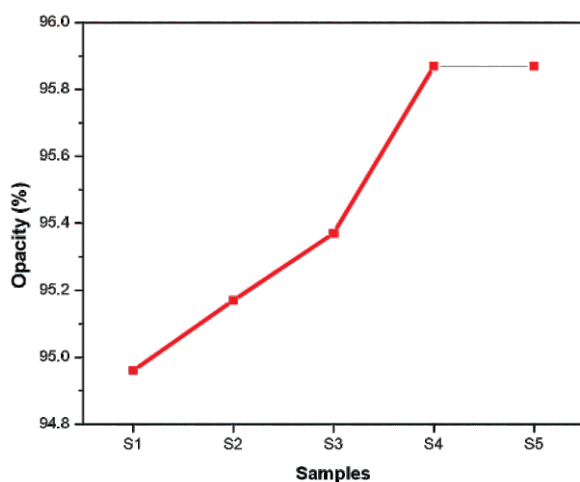
Hiding power or opacity depends upon refractive index of fillers if refractive index is higher than binder then hiding power will be high [26]. As we see in graphs opacity of paint slightly increases then remains constant. Our main purpose is that partial

replacement of titanium dioxide by calcined aluminum silicate. Opacity is main factor that is needed in paint and our focus is to reduce titanium dioxide in paint but opacity remains same. Replacement of titanium dioxide is partially, first sample is standard and it is compared with four other samples S2, S3, S4 and S5. Titanium dioxide is replaced in each sample by 5%, 10%, 15% and 20%. Table 2 represents the opacity and other factors such as density, gloss, whiteness and viscosity.

Table 2. Comparison of different parameters of paint samples

Sr. No.	Parameters	Samples				
		S1	S2	S3	S4	S5
1	Opacity (%)	94.96	95.17	95.37	95.87	95.87
2	Density (Kg/L)	1.493	1.486	1.481	1.476	1.476
3	Gloss	1.9	2	2	2.1	2.2
4	Viscosity (Poise)	12.5	15.5	15.9	16.01	16.04
5	Whiteness (%)	99.4	99.5	99.5	99.3	98.7
6	P ^H	8.50	8.51	8.51	8.52	8.52

Figure 1 shows that with replacement of titanium dioxide opacity of emulsion paint slightly increase and become constant. Opacity or hiding power depends upon particles size of pigments and their dispersion in emulsion. Results shows that maximum dispersion of pigments calcined aluminum silicate with calcium carbonate and titanium dioxide.

**Figure 1.** Opacity of samples ($S_1 - S_5$)

Gloss can be observed as sensation when light is reflected from paint surface at specific angle. Gloss is very important factor in many coatings and it is affected by particle size and concentration of titanium dioxide in paint [27]. Figure 2 shows gloss values of paint formulated with titanium dioxide, calcium carbonate and calcined aluminum silicate. Introduction of calcined aluminum silicate in paint have positive impact on paint. Gloss of paint increase as we replace titanium dioxide with calcined aluminum silicate. Similarly, calcium coronate has positive combination with calcined aluminum silicate that increase opacity and gloss of the paint.

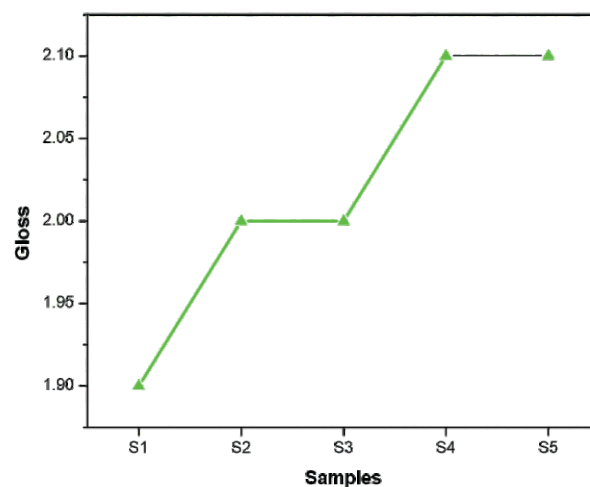
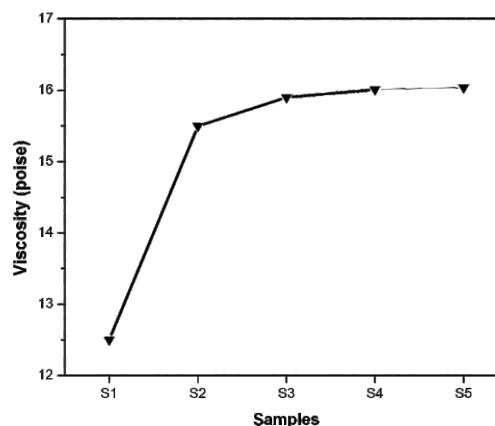
**Figure 2.** Gloss of samples ($S_1 - S_5$)

Figure 3 shows that viscosity of paint increases as titanium dioxide is replaced with calcined aluminum silicate. Viscosity of paint increases as particle size of extender decreases and vice versa. When particle size increases then it increases parking efficiency, so viscosity of paint increases [28]. The calcined aluminum silicate has small particle size as compared to titanium dioxide and it has high water absorption as compared to titanium dioxide. That's why calcined aluminum silicate makes paint thick.

**Figure 3:** Viscosity of samples ($S_1 - S_5$)

Whiteness is developed by purification process of pigment. Particle size and concentration of pigment or fillers measure whiteness or brightness of paint [29]. Figure 4 shows whiteness or brightness of paint, first whiteness of paint increase then decreases. When calcined aluminum silicate replaced titanium dioxide 5% and 10% then whiteness increases. When it is replaced by 15% and 20% then whiteness decreases. Reason is that calcined aluminum silicate has low whiteness as compared to titanium dioxide that's why whiteness of paint reduced when more titanium dioxide is replaced.

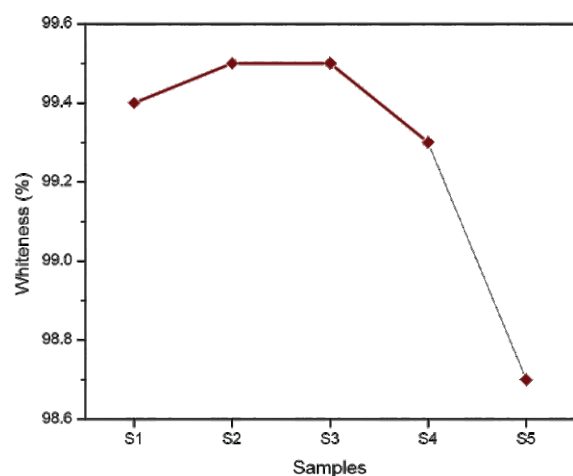


Figure 4. Whiteness of samples ($S_1 - S_5$)

Density at different concentration of calcined aluminum silicate showed graphically. Density of paint increases as particle size of fillers decrease and its decreases as particle increases [30]. Figure 5 shows density of paint samples compared with standard. Density of paint decreases from standard to sample 5. Density of standard paint is maximum and sample 5 that replace 20% titanium dioxide is minimum. Reason is that titanium dioxide has low water or oil absorption and calcined aluminum silicate has more oil or water absorption as compared to titanium dioxide. Due to high absorption volume of paint increases and density decreases.

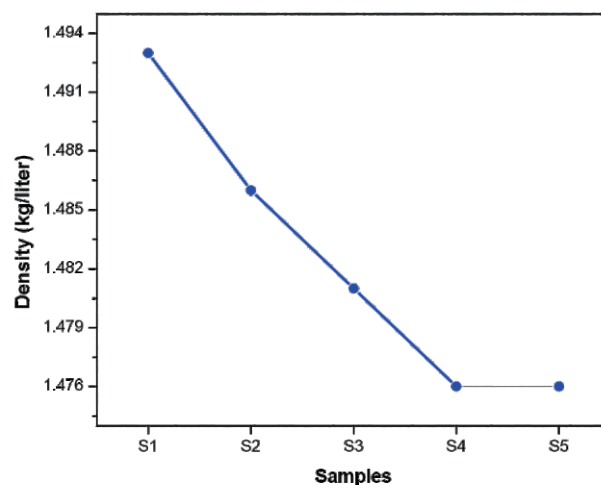


Figure 5. Density of samples ($S_1 - S_5$)

4. Conclusions:

It is concluded that calcined aluminum silicate has potential to replace titanium dioxide in water borne paint. The properties of paint like weather resistance, mechanical resistance, gloss, sheen, and rheological were studied. Other properties such as scrub resistance, brushability, brightness, reflectivity and light fastness were also in range. Quantity of replacement of titanium dioxide depends upon type of paint like gloss, semi-gloss or matt. In our study it is observed that titanium dioxide can be replaced from 5% to 20% by calcined aluminum silicate without any effect on properties for waterborne interior and exterior paint. Change in opacity or gloss depends upon substitution of calcined aluminum silicate in paint. Replacement of titanium dioxide gives better quality and economically favorable.

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