Assessment of Influence and Threshold Ratios of Titanium Dioxide and Calcium Carbonate as Pigments on the Physico-Mechanical Properties of Emulsion Paint

¹Raheem A. A., ^{2*}Olowu, O. A., ³Aladeloba, A. E., ⁴Hungbo, A. A., ⁵Akinsanya, A. Y.

¹Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

^{2,3,4} Building Technology Department, School of Environmental Studies, Yaba College of Technology, Lagos, Nigeria.

⁵ Building Technology Department, School of Environmental Studies, Lagos State Polytechnic, Ikorodu, Lagos, Nigeria.

*Corresponding Author Email: oluwoluwaleke2006@yahoo.com; +2348038198032

Abstract

Titanium dioxide (TiO₂) also known as Titanium White, is an inorganic, synthetic pigment used in paint to protect the substrate from harmful effects of ultraviolet light when lead pigments are regarded as toxic. However, its use is being limited since it causes flu-like symptoms, respiratory problem and skin irritation. Calcium carbonate (CaCO₃) is a chemical commonly used as an extender pigment in cement to provide bulkiness at relatively low cost. Because of the problem associated with TiO₂, it is of importance to regulate and optimize the use of TiO₂ relative to CaCO₃ and their influence on the physico-mechanical properties of emulsion paints.

Nine paint specimens were formulated using 0 - 80 grams per litre of TiO₂ and 120 - 200 grams of CaCO₃, respectively at 10gram interval. The following tests were performed on them: specific gravity, viscosity, pH, surface drying time, hard drying time, wash-ability/adhesion and opacity tests, in accordance to Nigerian Industrial Standard (NIS) 278: 1990.

The result shows that all samples met specifications of 10 poise maximum, 5%, 7.5-9.0, 20 minutes, 2 hours, and 201 minimum, for viscosity, specific gravity, pH, surface drying time, hard drying time and wash-ability/adhesion properties, respectively. However, six sample specimens only met the requirement of NIS 278:1990 of 2coats for good opacity. In conclusion, TiO₂ has no negative effect on the other physio-mechanical properties except the opacity of the paint and so specimens 7, 8 and 9, and ratio 30:170 is considered the threshold values for the paint production.

Keywords: Threshold ratio, Physio-Mechanical Properties, Pigment, Emulsion Paint.

Introduction

Paint refers to substances that consist of pigments suspended in liquid or paste called vehicle such as oil or water. Paint provides economic protection, preservation, and decoration, aesthetics and adds functionality to structures (Olowu and Raheem, 2013). Paint's composition largely determines its characteristics, usage and classification. Paints can be made dry, glossy or flat as desired by varying its constituents (Abidalla, 2011). Alessia *et al.* (2006) describe paint to primarily compose of pigments, binder, solvent and additives. Additives are added to influence both the physical and chemical properties of paint as desired. The main purpose of solvent is to adjust the curing properties and viscosity of the paint. Solvents are volatile in nature and control the flow and application properties of paint. Solvents also affect the stability of the paint while in liquid state and serves as carrier of non-volatile components of the paints (Ivor, 2005).

The binder otherwise known as the vehicle in paint is the actual film forming component of the paint. Binders held the pigments particles together and assist to adhere the paint to the surfaces of the substrate; binders' influences gloss potential property, exterior durability, flexibility and toughness properties of the paint (Ivor, 2005). Frodsham (2008) defined pigments as finely grounded particles or powdered dispersed in paint to provide colour, toughness, texture and bulkiness of the paint.

There are three types of pigments as identify by Olowu and Raheem (2013) to include hiding pigment, filler pigment and extender pigment. Hiding pigments makes the paint opaque and protect the substrate

from harmful effects of ultraviolet light; hiding pigments includes: titanium dioxide, iron oxide and lead oxide. Crowley *et al.* (2008) describe Lead oxides as toxic in nature and are responsible for lung cancer ailment; hence, attention is being shifted to the use of titanium dioxide as hiding pigment in paint. Frodsham (2008) describe titanium dioxide as the source of flu like symptom, respiratory tract cancer and skin irritation, Hence, it is of importance to regulate and optimize its usage which this study is poised to assess by determine the threshold ratio of titanium dioxide and calcium carbonate to achieve a better paint with reduce health implication.

Materials and Methods

Materials

The following materials: Bermocol as the thickener, Water as the main diluents for the paint, Texanol, Sodium hydroxide as preservative, Encor Binder (Ae557 as thickener, Calgon as a dispersant, Defoamer as antifoam, Calcium Carbonate as an extender, Acticide, Titanium dioxide to provide opacity, Aluminium silicate for brightness and as anti-settling agent and Duapol as dispersant, used in the paint production were obtained from DN Meyer Plc, Mobolaji Johnson Avenue, Oregun Industrial Estate, Alausa, Ikeja, Lagos..

Methods

Production of paint specimen involved three main stages viz: milling stage, stabilization Stage, and the let-down stage. This is as shown in Figure 1 (NIS 273: 1990).

Figure 1: Stages in Paint Production

Source: Chudley and Greeno (2005)

Milling stage

150ml of water was weighed and poured into nine (9) 1 litre capacity cans each. Into the nine cans was added the following materials: Titanium dioxide (TiO_2), Calcium carbonate (CaCO_3), Aluminum silicate (AlSiO_2) and Calgon in the following proportions: (80, 120, 30 and 10) grams; (70, 130, 30 and 10) grams; (60, 140, 30 and 10) grams; (50, 150, 30 and 10) grams; (40, 160, 30 and 10) grams; (30, 170, 30 and 10) grams.

10) grams; (20, 180, 30 and 10) grams; (10, 190, 30 and 10) grams and (0, 200, 30 and 10) grams respectively. The mixtures were placed on a high-speed dissolver machine for milling one after the other until consistencies were achieved. A typical milling machine is as shown in Figure 2.

Figure 2: Typical Milling Machine
Source: DN Meyer Plc

Stabilization stage

Into the mixtures in the nine 1 litre capacity cans were added Defoamer, Duapol, Bermocol and water in the following proportion: (18ml, 2ml, 10g and 350ml) respectively. The cans were placed on the high-speed dissolver machine until consistencies were achieved.

Let-down stage

At this stage Encor Binder, Acticide, Texanol and Sodium hydroxide were added into each of the nine 1 litre capacity cans in the following proportion: (200g, 15ml, 10ml and 5ml) respectively. The cans were placed back on the high-speed dissolver machine until consistency was achieved.

Testing of specimen (Quality control tests)

The paints produced were made to undergo laboratory quality control test which includes: Opacity Test, Viscosity Test, pH Test, Drying Time Test, Specific Gravity Test and Resistance to Wet Abrasion/Washability Test. All tests conform to NIS 273:1990; BS EN 14713: 2015 and were carried out at DN Meyer Plc laboratory.

i. Opacity test

Half a handful of each nine paint specimens were dropped on the upper part of the mohris charts; mohris staffs were then placed across each nine mohris charts and dragged against the charts from the top to the bottom of the charts with even paints across the charts.

ii. Viscosity test

In succession, each nine (9) paint samples were placed into rotor cup, placed on the rotor seat meter. The Viscosity disc was lowered into the sample in the cup by pinning down the rotor handle and as the viscosity disc spins inside the paint specimen the viscosity value, is read off from the Viscometer.

iii. pH test

The pH meter detectors were deep into the paint specimens and the pH values read from the meter.

iv. Drying time test

The nine (9) paint specimens were applied on masonry wall and left to dry. Checking was done at intervals of 5 minutes.

v. *Specific gravity test*

This test is conducted in succession of the nine paint specimens. An empty Specific Gravity cup (SGC) is weighed and the weight (D_1) recorded. The cup is filled in succession with the paint specimen and cover to allow the paint to overflow through the pin hole in the cover. Specific Gravity cup was re-weighed with the paint specimen and recorded (D_2). The value of Specific Gravity was computed thus:

$$SD = \frac{D_2 - D_1}{100} \quad 1$$

vi. *Resistance to wet abrasion/washability test*

Apply each of the nine paint specimens on the black panels with film applicator; leave for seven days, after seven days place the panels into the wet abrasion tester.

Results and Discussion

Opacity analysis

Figure 3 showed the result of opacity test on paint samples. Paint specimens (1, 2, 3, 4, 5 and 6) met the requirement of Nigerian Industrial Standard (NIS 273: 1990-7.9.2) of good opacity for not more than two (2) coats; while paint specimens (7, 8 and 9) did not meet the requirement.

Figure 3: Opacity of Paint Samples

Viscosity analysis

Figure 4 showed that all the paint specimens (1, 2, 3, 4, 5, 6, 7, 8 and 9) met the NIS 279: 1990 of minimum requirement of 6 poises when tested in accordance to NIS 278:1990-7.3.

Figure 4: Viscosity Rating of Paint Samples

pH analysis

Figure 5 showed that all the paint specimens were within the range of 7.5-9.0 as specified by NIS 278:1990-7.4 test method.

Figure 5: pH Values of Paint Samples

Drying time analysis

Figures 6 and 7 showed that all the paint specimens met the NIS 278:1990 requirement of 20 minutes surface drying time and 120 minutes hard drying time when tested in accordance to NIS 278:1990-7.14 test methods.

Figure 6: Surface Dry Time of Paint Samples

Specific gravity analysis

Figure 8 showed the result of specific gravity test for nine paint specimens. It was observed that all time the paint samples satisfied NIS 278:1990 requirement of 5 percent maximum.

Figure 7: Hard Dry Time of Paint Samples

Figure 8: Specific Gravity of Paint Samples

Adhesion/washability test analysis

Figure 9 showed that the entire nine paint specimen met the requirement of NIS 278:1990 -7.8 of 201 cycles minimum for emulsion (premium).

Figure 9: Wash-ability values of Paint Samples

Conclusion

It was observed that Titanium dioxide did not affect other physio-mechanical properties of emulsion point produced except for the opacity of the paint specimens and ratio (30:170). This is considered the threshold value for the paint specimens produced.

Recommendation

It is highly recommended that ratio (30:170) be adapted as the threshold value for emulsion paint production in larger scale for commercial purposes in order to annex and maximize the potential of titanium dioxide with reduction in health hazard implications.

References

- Abidalla, M (2011). Natural house paint, Retrieved on March 3rd 2011, from <http://www.ecologist.com>
- Alessia, A., Maria, B., Maria, P.C., Gwenaelle, G., Francesca, M., and Erika, R. (2006). Combined GC/MS Analytical Procedure for the Characterization of Glycerolipid, Waxy, Resinous, and Proteinaceous Materials in a unique Paint Micro sample, American Society of Chemistry ASC Publications, 78 (13): 4490-4500.
- British Standard Institution European Norm (2015). Code of Practice for the Protective Coating of iron and Steel Structures against Corrosion, 77th Ed. BS EN ISO 14713, British Standard Institution, London.

- Crowley, J. D., League, Jr., Jack, W and Lowe, Jr. (2008). A Three-Dimensional Approach to Solubility, Journal of Paint Technology, 38 (2): 20 - 28.
- Frodsham, C. (2008). Earthborn clay Paint, Retrieved May 6th, 2014, from <http://www.earthbornpaint.co.uk>
- Ivor, H. S. (2005). Building Technology, Palgrave Macmillan, New York, London.
- Nigerian Industrial Standard, (1990). Specification for Emulsion Paint for Decoration Purpose, Lagos, NIS, 273:1990.
- Nigerian Industrial Standard, (1990). Standard for Paints and Varnishes part 6 Test Method for Paint and Varnishes, Lagos, IMIS, 278:1990.
- Olowu, O. A. and Raheem, A. A. (2013). Production of Household Paint using Clay Materials, International Journal of Engineering Research and Applications (IJERA), 3 (2): 085-093.

APPENDIX

Table1: Specification for Emulsion Paints for Decorative Purpose (NIS)

S/N	CHARACTERISTICS	REQUIREMENTS	TEST METHODS NIS: 278: 1990
1	Viscosity	6.0 poises (min) using Viscometer method	7.3
2	pH	7.5-9.0	7.4
3	Drying Time	<ul style="list-style-type: none"> Surface dry 20min (max) Hard dry 120mins (max) 	7.14
4	Opacity	Good Opacity	
5	Resistance to Wet Abrasion	<ul style="list-style-type: none"> Interior Emulsion *51 cycles (min) Economy Emulsion** 101 cycles (min) Standard Emulsion*** 201 cycles (min) Premium Emulsion paint***** 501 cycles (min) 	7.8
6	Specific Gravity	<ul style="list-style-type: none"> Shall not differ by more than 5% from approved sample 	

Table 2: Opacity test of Paint Specimens Produced

VARYING FACTORS				
PAINT SAMPLES	TiO ₂ Content (g)	CaCO ₃ Content (g)	Opacity	NIS Requirement
Specimen 9	0	200	Very Bad	2 Coats (Good)
Specimen 8	10	190	Bad	2 Coats (Good)
Specimen 7	20	180	Bad	2 Coats (Good)
Specimen 6	30	170	2 Coats (Good)	2 Coats (Good)
Specimen 5	40	160	2 Coats (Good)	2 Coats (Good)
Specimen 4	50	150	2 Coats (Good)	2 Coats (Good)
Specimen 3	60	140	2 Coats (Good)	2 Coats (Good)
Specimen 2	70	130	1 Coat (Good)	2 Coats (Good)
Specimen 1	80	120	1 Coat (Good)	2 Coats (Good)

Table 3: Viscosity test

VARYING FACTORS				
PAINT SAMPLES	TiO ₂ Content (g)	CaCO ₃ Content (g)	Viscosity rating (poises)	NIS Requirement (Poises)
Specimen 9	0	200	9.1	6 (min)
Specimen 8	10	190	7.8	6 (min)
Specimen 7	20	180	6.8	6 (min)
Specimen 6	30	170	6.3	6 (min)
Specimen 5	40	160	8.2	6 (min)
Specimen 4	50	150	9.1	6 (min)
Specimen 3	60	140	6.8	6 (min)
Specimen 2	70	130	8.2	6 (min)
Specimen 1	80	120	7.9	6 (min)

Table 4: pH test

VARYING FACTORS				
PAINT SAMPLES	TiO ₂ Content (g)	CaCO ₃ Content (g)	pH value	NIS Requirement (Poises)
Specimen 9	0	200	8.2	7.5 – 9.0
Specimen 8	10	190	8.4	7.5 – 9.0
Specimen 7	20	180	8.1	7.5 – 9.0
Specimen 6	30	170	8.2	7.5 – 9.0
Specimen 5	40	160	7.8	7.5 – 9.0
Specimen 4	50	150	8.0	7.5 – 9.0
Specimen 3	60	140	8.5	7.5 – 9.0
Specimen 2	70	130	7.9	7.5 – 9.0
Specimen 1	80	120	8.2	7.5 – 9.0

Table 5: Surface drying time test

VARYING FACTORS				
PAINT SAMPLES	TiO ₂ Content (g)	CaCO ₃ Content (g)	Time (Minutes)	NIS Requirement (Minutes)
Specimen 9	0	200	20	20
Specimen 8	10	190	20	20
Specimen 7	20	180	20	20
Specimen 6	30	170	20	20
Specimen 5	40	160	20	20
Specimen 4	50	150	20	20
Specimen 3	60	140	20	20
Specimen 2	70	130	20	20
Specimen 1	80	120	20	20

Table 6: Hard drying time test

VARYING FACTORS				
PAINT SAMPLES	TiO ₂ Content (g)	CaCO ₃ Content (g)	Time (Hours)	NIS Requirement (Hours)
Specimen 9	0	200	2	2
Specimen 8	10	190	2	2
Specimen 7	20	180	2	2
Specimen 6	30	170	2	2
Specimen 5	40	160	2	2
Specimen 4	50	150	2	2
Specimen 3	60	140	2	2
Specimen 2	70	130	2	2
Specimen 1	80	120	2	2

Table 7: Specific gravity test

VARYING FACTORS				
PAINT SAMPLES	TiO ₂ Content (g)	CaCO ₃ Content (g)	Specific Gravity (%)	NIS Requirement (%)
Specimen 9	0	200	1.13	5 Max.
Specimen 8	10	190	1.16	5 Max.
Specimen 7	20	180	1.18	5 Max.
Specimen 6	30	170	1.10	5 Max.
Specimen 5	40	160	1.13	5 Max.
Specimen 4	50	150	1.16	5 Max.
Specimen 3	60	140	1.12	5 Max.
Specimen 2	70	130	1.17	5 Max.
Specimen 1	80	120	1.18	5 Max.

Table 8: Adhesion/wash-ability test

VARYING FACTORS				
PAINT SAMPLES	TiO ₂ Content (g)	CaCO ₃ Content (g)	Wash-ability (Cycles)	NIS Requirement (Cycles)
Specimen 9	0	200	500	201 min.
Specimen 8	10	190	500	201 min.
Specimen 7	20	180	500	201 min.
Specimen 6	30	170	500	201 min.
Specimen 5	40	160	500	201 min.
Specimen 4	50	150	500	201 min.
Specimen 3	60	140	500	201 min.
Specimen 2	70	130	500	201 min.
Specimen 1	80	120	500	201 min.