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Effects of Glycolic Group on Some Physical and Performance Characteristic of a Satin Paint

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Abstract:
This study investigated the effects of glycolic groups on some physical and performance characteristics of a satin paint, by comparing the properties with those of reference. Satin paints were successfully formulated using commercially obtained ethylene glycol (EG), polyethylene glycol (PEG), propylene glycol (PG), polypropylene glycol (PPG), butylene glycol (BG) and dibutylene glycol (DBG) as additives and analysed. Physical properties such as pH, viscosity, density, refractive index, and solid contents were found within the accepted standard while the paints samples show extended drying time due to the low vapour pressure of glycols. The performance properties reveal that EG and PG shows poor adhesion, gloss, flexibility, resistance to blistering, water, scratch and stain resistances. PG show poor storage stability and DBG show poor resistance to stain. However, all paints samples show good opacity, resistance to soap and salt medium. Surface defect was observed for DBG, PG, EG in alkali. This will introduce a new and cheaper satin paint for commercial purpose.

Keywords: *Glycols, physical characteristics, performance characteristics, satin paints*

1. Introduction

Paint is fluid, or semi-fluid material which may be applied to surfaces in relatively thin layers, and which changes to a solid coating with time. The change to a solid material may or may not be reversible, and may occur by evaporation of solvent, by chemical reaction or by a combination of the two. Painting is unique human activities that have helped the human race to contribute significantly in earning a better livelihood [1]. Paints are basically categories into two which include Emulsion paint (Water based) and solvent paint (Oil based). Emulsion paint is a water-based paint principally used for internal and external surface painting, mostly in buildings for protection, decoration, durability and other special purposes. Satin paints are water base paint, they are made by a process known as emulsion polymerization. It has some reflectivity, offer improved durability, frequently used for interior and exterior painting and in high–traffic environment like kitchen, bathroom and children's bedroom where easy clean-up is possible [2, 3]. It is more flexible to better give the illusion of a perfectly smooth surface than other types of water-based paint due to its components, which gives it extra sheen properties owing to the presence of glycols [2].

Paint is made up of four constituents; the binder, Pigment, Solvent and additives. The binder holds the pigment and any other additives together to form an emulsion, Pigment gives paint its colour and opacity, the solvent gives the paint its ability to be spread over a surface while the additives use in painting are added to modify certain properties of the paint [1, 5]. Satin paints basically required the use of glycols, water and a coalescent/plasticizer agent in substantial quantities, the glycols and water have plays important role as part of the solvent.

As many materials become available, the need to modify the surface continues to grow, many surfaces believed to be satisfactory without coating are been attacked by weather, chemicals, atmospheric pollution or other factors and must be protected before certain uses [3].

Glycols are hygroscopic chemicals consisting of two –OH group with high vapour pressures and are used to promote the retention of moisture in a solvent system. The glycol in paint is used as antifreeze and help to allow the water to evaporate before the paint's particles fuse into a continuous film [7]. Also, the mixture of glycol with water prevents corrosion and acid degradation, as well as inhibiting the growth of most microbes and fungi [8]. Butylene glycol is the major glycol used in paint formulation but due to its high cost and difficulties in the refinery process others glycols of low cost with higher and varying molecular weight, chemical and physical properties will be tested in order to access or evaluate their stability in the satin paint's formulation. This is hoped may bring forward a low-cost satin paint to the painting industry. This work aimed at the evaluation of some glycols as additives for the formulation of satin emulsion paint.

2. Materials and Methods

The chemicals used to formulate the satin paints are of analytical grade and are purchased from Yola market – Nigeria and were used as received.

3. Methods for Paint Formulation

The method described by Akinterinwa et al., [11] was adopted for the formulation of the satin paints. The method splits the production process into three main stages. The mixture in each step will be stirrer for 15 minutes using mechanical stirrer. Table 1 shows the varied combination ratio of the materials for the different paint's formulation

Stage	Material	Quality (grams)
First	Water	450
	Calgon	0.40
	Deformer	0.80
	Genepour	0.60
	Texanol	0.60
	Glycol	10.00
Second (mill base)	TiO_2	50.00
	Cellulose	2.00
	Ammonia	0.40
Third (letdown)	Binder	60.00
	Formaldehyde	0.80
	Water	50.00

Table 1: Satin Paint Formulation Recipe with Glycols as Additives

3.1. Characteristic of the Satin Paints Sample

- pH: The pH of paint sample was determine using phywe pH meter model 18 195.04
- Density: The above property was determined according to standard methods [12]. The density of the different paints was determined by taking the weight of a known volume of the paints inside a density bottle using metler (Model, AT400) weighing balance. Three readings were taken for each sample and average value calculated. The specific gravity bottle was weighed to determine the actual weight of the cup. Known amount of the paint sample is poured into the bottle and weighed to determine the weight of both the bottle and the paint sample and the actual weight of the bottle were subtracted from it to determine the weight of the sample. The density was then calculated using the density formula.
- Viscosity: The viscosities of the paint's samples were determined using an I.C.I. Rot thinner viscometer. The 500 ml tin sample container of the instrument was filled with paint sample under test to 0.3 mm of the top rim of the depth gauge. The sample was stirred, while maintaining constant temperature at 27°C. The container with the paint sample was placed in the processing ring on the turntable and the lever pulled down to switch on the motor automatically. The disc was allowed to run until a steady state is reached (5 minutes). At the end of the required time, the viscosity was recorded in poises. Triplicate determinations were made for each sample and mean value recorded
- Solid Content: To determine the solid content, a carbon foil was used. A certain amount of the paint sample was put into a carbon foil of known mass and weighed and then heated in the oven for 30 minutes at temperatures between 162^{0}C and 165^{0}C. The carbon foil containing the sample was weighed again in order to determine the sample weight after drying. Thus, the percentage content is calculated as:

$$\%SC = \frac{\text{Weight of sample before drying}}{\text{Weight of sample after drying}} \text{ x } 100$$

The standard range is usually between 30-35%

This analysis was carried out in duplicates and the average determination be taken.

- Storage Stability: The paint samples were put in plastic sample cans which were covered and the edge of the covers sealed with masking tape to ensure air tightness so as to prevent loss of moisture from the cans. The samples of the emulsion paint variant were stored at 27^{o}C for 4 months. The stored samples were periodically monitored for any adverse changes in the paint quality such as coagulation, changes in colour and odour, viscosity loss, pH drift, phase separation etc.
- Refractive index: The refractive indices of the paint's samples were determined with Abbe refractometer.
- Drying Time: Dry time was evaluated by applying the paints samples on a metal plate surface with the aid of bar applicator, and allowed to dry. Dry to touch was taken when the paint film is no longer sticking to the finger, and

dry to hard was taken when the film resisted finger print. Triplicate evaluations were made for each sample and mean value assessment recorded.

- Opacity: Opacity was determined using the Standard Mohest Chart. The paints samples were applied on Mohest chart (i.e., hiding power chart) and allowed to dry for 24 hours. The opacity was then evaluated by comparing the dried sample film with hiding power chart. Three determinations were made for all the samples and mean assessment recorded.
- Gloss: Gloss at 85^o of paint sample was determined by using gloss meter (Digital instrument Model RSPT-20). Paint film was prepared by using 4 mesh (100 mioons) applicator over a pre-cleaned glass panel and the film was allowed to dry for 24 hrs. The ASTM gloss-meter was allowed to warm up for 10 mins and using the black glass standard held against the pot-hole, the adjusted to read 92.5%. The sample cast on the glass panel was then held against the pot-hole in three separate positions along its length and the mean gloss was calculated in % with difference of not more than 5% between the highest and the lowest. Triplicate measurements were made for each sample and mean value recorded.
- Flexibility: Paints samples were applied on a metal plate with the aid of paint applicator. The films were allowed to air dry under room temperature (27-30°C) for 7days. The panel with the film was bent through 180° with a smooth action (taking 1-2 seconds). The metal plate was removed and examined for cracking or loss of adhesion. Any crack or loss of adhesion indicates inflexibility or brittleness. Triplicate determinations were made at 27-30°C for each sample for quality assessment.
- Adhesion: To evaluate adhesion property of paints, a coat of paint film was applied with film applicator on a degreased metal panel and allowed to dry for 48 hours. Two sets of lines, one crossing perpendicularly over the other were drawn with a crosshatch tester on the paint film. An adhesive tape was pressed firmly with the thumb covering all the interactions of the perpendicular line. The adhesive tape was held at its loose ends and forcibly removed from the panel. Removal of more than 50% of the square lines of the paint film indicates a poor adhesion. Triplicate determinations were made at 27-30°C for each sample for quality assessment.
- Tackiness: This was done on the dried film qualitatively by hand feeling to find out if the paint film is sticky or not. Stickiness of a dried paint film is an indication that the film is tacky. Triplicate samples were used for each determination and the average quality assessment recorded.
- Resistance to Blistering: Resistance to blistering was carried out by applying undiluted paint sample to a metal panel with an applicator to give a wet film thickness of about 120 μm, which was allowed to dry for 24 hours. At the end of this period 4 ml of distilled water in the form of circular drop was placed on the film. The presence of blistering, wrinkling, swelling or cracking within a period of 30 minutes indicates poor water resistance. Quality assessment recorded was the mean of triplicate determinations of each sample.
- Scratch Resistance: This was done by using nails to scratch the surface of the coated sample paint, if the paint peels, then it is said to have a poor scratch resistance otherwise, it is excellent.
- Water Resistance: A draw-down of each of the paint sample was inserted into a container of water and stored in the fridge overnight. If there is no change in the colour of the paint, it indicates that it is an excellent water-resistant sample.
- Soap Resistance: A draw-down of each of the paint sample was put on top of the white soap and left overnight. If there is no absorption of the sample into the soap, then the sample is said to have an excellent soap-resistance.
- Stain Resistance: Stain resistance property of the various paints were carried out by staining an applied paint coat of each paint film with film applicator on a degreased metal panel and allowed to dry for 48 hours, after which it was stain wash with soap water.
- Chemical Resistance: The chemical resistance of the paint films was carried out thus; three flexible aluminium panels (150mm x0.3) were used as the test panels. A coat of paint with paint applicator was applied on the panel. One litter glass beaker was filled with 0.1M NaOH solution to a depth of 150mm and the test pieces immersed for 48 hours to the depth of approximately 120mm. The test piece was removed, washed with running water and stood to dry for 2 hours. The above procedure was repeated using 0.1M NaCl and 0.1M HCl respectively. Poor chemical resistance will be indicated by the presence of any surface defects such as cracking, blistering, peeling or changes in colour.

4. Results and Discussion

The results of various tests carried out on white emulsion satin paints produced with the selected glycols are discussed herein. Although the glycols were varied from simpler and lower molecular weights glycols to higher ones, higher molecular weight glycols had more pronounced effects on paint quality and form the basic framework for this discussion. Table 2 shows the result of the assessment of the physical parameters.

Properties	Additives						
	EG	PEG	PG	PPG	BG	DBG	SON
pH	8.20	8.18	7.90	7.65	7.60	7.87	7 – 8.5
Density	1.00	1.25	1.05	1.23	1.12	1.20	1 – 12
Viscosity	10.10	14.06	9.70	15.28	15.20	16.55	6–15
Solid content	30.00	33.00	31.00	33.04	33.00	32.85	30 – 35
Refractive Index	1.143	1.284	1.197	1.330	1.338	1.499	1.567
Drying Time	DT 45.20	46.00	51.05	45.50	45.00	43.00	20.00
	DH 126.00	125.00	128.00	122.10	121.00	122.0	120.00

Table 2: Result and Comparison of Some Physical Properties of Satin Paints

Some properties such as pH, viscosity, density and solid content of all the formulated emulsion paints falls within the acceptable ranges for paints [13]. The pH values showed little variation with different glycols. This is not unexpected because pH values of emulsion paints can be affected by many factors such as the pH of the resin and other components as well as amount of ammonia used [14]. The pH of emulsion paint can however, be adjusted to the desired level by the use of ammonia which is widely used for that purpose in emulsion paint formulations.

The values of density for the various paints sample as presented in table 2 falls within the standards (1 – 12) indicating the stability of the binder used. However, PEG, PPG and DBG paints show higher values of densities. These higher densities could be as a result of the higher molecular weight of the glycols. The viscosity dropped and increased with different glycols. The viscosities of all the paints samples falls within the accepted standard by SON, this phenomenon can be explained in terms of specific interactions between components of the paints. In a dilute system, there are strong specific interactions and the complexes are isolated from each other with the formation of compact structure, which reduced the viscosity of the solution [15]. However, as the molecular weight increased viscosity of the polymer system also increases which is in agreement with work of Akintariwa et al., [11].

A solid content is the term which indicates the proportion of the solid contacting the paint on a volume basis. The solid content of the various paint's samples produced which include EG, PEG, PG, PPG, BG and DBG satin paint falls within the accepted standard though lower in value compare to that of a commercial satin paint

Touch-dry and hard-dry are respective stages in coating dry-film formation. The touch-dry time is the period of particle coalescence and cohesion as the solvent evaporates, while hard-dry is the period of optimum adhesion and cohesion of the film to a stage if desired, further coat can be satisfactorily applied [16]. All the tested paint samples exhibit relatively longer touch dry time compare to standard which is in agreement with the work of Akinterinwa et al., [11]. However, all the paint samples exhibit hard-dry time longer than the SON standards' maximum limit. In a different fashion, PG paint exhibits the longest hard-dry time followed by EG, PEG, BEG, PPG and EG respectively. The shorter hard-dry time for EG paint can be said to be consistent with the touch-dry time. The presence of glycols extent the drying time which is accomplishes by preventing the surface from drying due to its slower evaporation rate, it could also be attributed to their molecular weight and hence high crosslink density of the paint samples [17]. Another contributing factor however, resulting in the long drying time displayed by the paints could be due to the low vapour pressure of the glycols and the specific interactions between components of the paints.

The gloss of a paint film is a function of refractive index of the surface and particle size [18]. According to the work of Osemeahon [19], the amount of light transmitted through or reflected from the surface of the paint surface is responsible for varied degrees of opacity or transparency of the paints sample. This property is called the refractive index. Table 2 observed that the refractive index increases with variation in glycols. This observation can be explained in terms of molecular features of the copolymer [20] and depending on cross linked density hence, resulting to differences in their interaction with light.

4.1. Performance Property of the Formulated Paints Samples

The action of paint relative to a surface is very important property as it helps to determine the value of the paint in the market. This physical property is called the performance action of a paint as presented in table 3. The paint samples except for EG and PG exhibit good adhesion as the quality and durability of a coating is directly related to the nature of adhesion [21], good opacity, soap resistance, tackiness and scratch resistance according to the standard for paint samples in the coating industry [13]. EG and PG shows poor resistance to blistering and washing away by water as a result of poor adhesion to a painted surface.

EG fails in the gloss test. Other samples base on their refractive index values proof to pass in their test for gloss, which shows they all possess good glossy properties and can be clearly observed when applied on a coated surface. Since the major characteristic of a satin paint is it glossy (sheen) property. The poor performance of EG can be as a result of its low molecular weight which makes it unsuitable for the production of satin paint.

The test of flexibility proof that some paints withstand the turning force applied to them without deforming or broken after bending of the metal panel with the film smoothly through 180^{o} [22]. This characteristic of paints makes them very suitable in their flexibility considerations as there was no crack or loss of adhesion indicating inflexibility or brittleness of the paint's samples. EG, however undergoes some sort of deformation when turning force was applied to it.
Further laboratory test showed that some paints coatings (BG, PEG and PPG) applied to a metal plate repelled acids, bases and organic solvents. EG, PG and DBG fail in this test as they could not withstand the washing away of oil and greases from the surface. BG, PEG, PPG formulations were durable, remaining intact on the surface after washing away of stain. Other

properties such as water resistance, blistering, and flexibility were found to be poor for EG, PG and DBG which are consistent with that obtained for the adhesion, as blistering signifies adhesion failure [23].

The stability test of the paint indicates good storage characteristics for the paint samples except for PG, which fail in its storage stability as there was evidence of deterioration in the paint sample which manifests as changes in viscosity and colour, this could be due to the fact that PG have unbalance OH-group which can easily form a bond with other component of the mixture. There was no evidence of biochemical deterioration which often manifests as changes in colour, coagulation, viscosity loss, pH drift, development of offensive odour with rest of the formulations. This clearly shows the efficacy of the preservative used in the formulation. The low chemical reactivity of silica is also a contributory factor to the stability of the paints [14].

Properties	**Additives**					
	EG	**PEG**	**PG**	**PPG**	**BD**	**DBG**
Opacity	Pass	Pass	Pass	Pass	Pass	Pass
Gloss	Poor	Pass	Pass	Pass	Pass	Pass
Flexibility	Poor	Pass	Pass	Pass	Pass	Pass
Adhesion	Poor	Pass	Poor	Pass	Pass	Pass
Resistance to Blistering	Poor	Pass	Poor	Pass	Pass	Pass
Scratch Resistance	Poor	Pass	Poor	Pass	Pass	Pass
Water Resistance	Poor	Pass	Poor	Pass	Pass	Pass
Soap Resistance	Pass	Pass	Pass	Pass	Pass	Pass
Stain Resistance	Poor	Pass	Poor	Pass	Pass	Poor
Storage Stability	Pass	Pass	Poor	Pass	Pass	Pass

Table 3: Result and Comparison of Some Performance Property of Satin Paints

4.2. Chemical Properties

Almost all coatings will be exposed to chemicals and acids at some point, whether cleaning products, spills or fumes. The ability of these paints film to resist chemical attack is one of the desirable qualities of a good coating film. Table 4.3 presents the effect of the three typical mediums that is HCl, NaOH and NaCl respectively on the surfaces coated with the paint samples. All paint samples show no effect, hence a good resistance to the salt medium. Some like PEG, PPG, and BG satin paints are also unaffected by both the acid and alkali mediums, except for EG, PG and DBG.

While surface defect was observed in the case of DBG, PG, EG in alkali, the chemical resistances of some of the paint's samples are due to high molecular weight and cross-linked density of network which decreases their exposure to environment [24].

Formulations	**Mean Assessment**		
	0.1M HCl	**0.1M NaOH**	**0.1M NaCl**
Emulsion paint	Peeling	Blistering	No effect
EG Emulsion Paint	Peeling	Blistering	No effect
PEG Emulsion Paint	No effect	No effect	No effect
PG Emulsion Paint	Blistering	Peeling	No effect
PPG Emulsion Paint	No effect	Blistering	No effect
BG Emulsion Paint	No effect	No effect	No effect
DBG Emulsion Paint	No effect	Blistering	No effect

Table 4: Result and Comparison of Chemical Resistance of Satin Paints

5. Conclusion

The formulation and testing of satin paint with various glycols were successful. The satin paint formulated using some of the glycols exhibit good consistency, it was smooth and uniform. The paints showed excellent adhesion, flexibility and stain resistance. The latter is very important and forms the most important property of satin paints, resulting to its usability in demanding areas. It showed no cracks and has good resistance to acidic, alkaline and salt medium. Satin paint from PEG, BG and DBG, possess a good coverage, glossy and other physical properties which met the standard suiting their property. On the other hand, lower molecular weight glycols such as EG and PG showed less qualities in their formulations, properties such as gloss, flexibility, adhesion, blistering, stain, scratch, water and soap resistances do not fall within the range of standard.

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