Formulation of Emulsion Paint Derived from Expanded Polystyrene as a Binder

Abstract

Emulsion paint was formulated from waste polystyrene as a binder. The formulated emulsion paint which underwent a three-staged process had a pH of 7.82, density of 1.31 g/cm3, the drying time was 15-20 and 85-90 minutes for the set to touch and set to hard drying times respectively, viscosity of 10.4 Cp. The formulated paint exhibited good adhesion, tackiness, opacity, flexibility and stability properties. The paint also possessed good resistance to blistering; which indicates that it has good external exposure resistance and thus; can perform well when exposed to environmental conditions such as rain and sun. Effects of concentration on viscosity, density, melting point, refractive index, moisture uptake, turbidity, elongation at break and water solubility were studied for the polystyrene binder to ascertain for its suitability. Fourier transform infrared spectrophotometer was employed to characterized the binder. This investigation revealed favourable properties of a conventional emulsion paint inherent in the formulated polystyrene binder derived emulsion paint.

Keywords: Binder, Emulsion, Polystyrene, Paint

1 Introduction

In the coatings industry, paint is a complex blend of ingredients intended to give a decorative and protective layer on a variety of surfaces. Concrete, wood, metal, and other substrates can be used as these surfaces. Industrial paints are designed to endure severe weather conditions and tight performance specifications [1]. For thousands of years, paints have been an essential component of human civilization, providing both decoration and protection. Paints are composed of a blend of several ingredients, including pigments, binders, solvents, and additives, which combine to form a long-lasting and aesthetically beautiful layer. According to Ngozi[2], they are extensively utilized in DIY projects, construction, and many sectors.

The characteristics of paint, such as resistance to external influences, adhesion, durability, and color retention, are essential to understanding how well it works. Paints are made to provide resistance against chemicals, weathering, and wear in addition to protecting and improving the surface they are applied on [3]

Because of its remarkable qualities, polystyrene—a synthetic polymer derived from styrene monomers—finds extensive application across a range of sectors. Using polystyrene as a binder in various materials and goods is one important usage for it. Polystyrene is a vital component in many industries because it functions as a binder, improving the cohesiveness and strength of materials.

The construction sector is one where polystyrene is used as a binder. Because polystyrene foam boards have good thermal resistance, they are frequently utilized as insulation materials. According to Xiaoyang [4], the polystyrene in this application serves as a binder, keeping the foam cells together and giving the insulating panels a structural framework. Polystyrene is a binder used in building materials that contributes to increased energy efficiency and decreased heat loss in structures. Furthermore, polystyrene is also used in the production of composite materials as a binder. Composite materials are widely employed in the automotive, aerospace, and marine industries to build lightweight, high-strength components.

The mechanical characteristics of the composites are improved due to the increased adhesion between the reinforcing fibers caused by the presence of polystyrene[5].

A common kind of water-based paint used in a variety of situations, including commercial, industrial, and residential ones, is emulsion paint. It is made up of pigment particles scattered throughout a polymer binder or aqueous emulsion, resulting in a stable and user-friendly paint mixture. Emulsion paints are a popular option for a variety of surfaces due to their adaptable qualities. Emulsion paint's outstanding adherence to a variety of substrates is one of its primary characteristics. Emulsion paint's polymer binder creates a strong bond with surfaces to produce a finish that is long-lasting and resilient [6].

Emulsion paint's low volatile organic compound (VOC) concentration is another noteworthy feature. Volatile organic compounds (VOCs) are dangerous substances that can escape into the atmosphere when traditional solvent-based paints dry and cure. Conversely, emulsion paints are safer and more environmentally friendly for interior use due to their low volatile organic compound (VOC) levels[7]. Emulsion paint's water-based composition also makes it simple to use and clean up after. Emulsion paints are diluted and washed with water, as opposed to solvent-based paints; this simplifies the painting process and lessens the need for hazardous chemicals[6].

This research work will aid in justifying the importance and utilization of polystyrene (PS) as a binder and its impacts in the formulation of an emulsion paint. The result derived thus, will help in establishing a blue-print for the coating industry on its suitability and further applications of the PS binder.

2 Materials and method

2.1 Materials

Waste expanded polystyrene was obtained from dustbin in Sangere Adamawa State, Nigeria.

2.2 Methods

2.2.1 Preparation of PS binder solution

With a small tweak, theAbdul-Karim and Al method were applied[8], with gasoline serving as the solvent. Known weights of PS 5g, 10g, 15g, 2g, and 25g were dissolved in a fixed volume (100ml) of gasoline to formulate the PS binder solution, which was then agitated for 45 minutes at 30 ℃.

2.2.2 Viscosity determination of the PS binder

The Osemeahon and Barminas method [9] was utilized to assess the viscosity of the resin. For the measurement, a 100ml graduated glass micro syringe manufactured by Phywe was utilized. A 20% (w/v) sucrose solution with a viscosity of 2.0 mPa.S at 30 ℃ was used to standardize the device. At 30 ℃, the viscosity of the PS was compared to that of the conventional sucrose solution. For every sample, three readings were obtained, and the average of the results was determined.

2.2.3 Density determination of the PS binder

The density of the PS binder was calculated using the method enumerated by [10]. By weighing each resin within a density bottle with a weighing balance, the densities of the various resins were ascertained. The mass volume relationship was used to calculate the density. For every sample, three readings were obtained, and the average value was determined.

2.2.4 Melting point determination of the PS binder

Melting points of each resins of the binders were determined by using Stuart melting point machine (Model SMP 10). Triplicate determinations were made and average value was taken[7], [10].

2.2.5 Refractive index determination of the PS binder

The refractive index of the resin was determined by using Abbe refractometer [10]. Three readings were taken for each sample and average value was determined.

2.2.6 Moisture uptake determination of the PS binder

Memmert desiccators were used to measure how much moisture was absorbed by various resin films. Three grams of various samples were added to desiccators that held one gram of sodium chloride in a saturated solution. Every sample's moist weight was tracked until it reached its maximum weight. [10], [11] identified the moisture uptake by resin by taking the difference between the wet weight and dry weight.

2.2.7 Turbidity determination of the PS binder

Turbidity of the binders were measured using Labtech Turbidity meter (Model AVI-654). The results of each of the samples were reported in NTU. Triplicates determinations were made and average value was calculated[10].

2.2.8 Elongation at break determination of the PS binder

Utilizing an Intron Tensile machine based on ASTEMD 638, the elongation at break was determined. The binder film, measuring 5 cm in length, 2 cm in width, and 0.2 cm in thickness, was fully loaded with 150g for each sample and clamped onto a stand. All samples underwent three runs, and the average elongation was calculated as a percentage [10]

2.2.9 Water solubility determination of the PS binder

To find PS's water solubility, 2 milliliters of the resin were mixed with the necessary 20 milliliters of distilled water. According to Osemeahon and Dimas [7], the transparency or cloudiness of the samples indicated whether they were soluble or insoluble in water.

2.2.10 Formulation of PS modified paint

Basically, emulsion paint was formulated in respect to the method reported by Fadawa, [12], [13] The method splits the production process into three main stages as follows:

First Stage

At the first stage, additives such as dispersants, defoamer, thickener, anti-skin, drier, wetting agents, stabilizer, pH adjuster and preservatives were added. The basic purpose of this stage is to provide a favourable environment for wetting and dispersion of particles. A volume of 185 ml of distilled water was introduced into a litter mixing tank and the overhead stirrers switched on after the addition of 12.7g of the additives as shown in Table below. This mixture was stirred using a high-speed stirrer for 15 minutes.

Second Stage

In the second stage, also known as “mill base”, pigments and extenders were dispersed in the mills. Immediately after dispersion, the stirrer speed in the mill base stage was increased to a very high speed and the mixture was stirred for another 15 minutes. In mill base, binder was not added to avoid its structural deformation under high mechanical forces.

Third Stage

Finally, binder plus the rest of the additives used in the first stage were mixed with 15ml of water. This stage is called “Letdown”. In this stage, the mixture was stirred at moderate speed for another 15 minutes. Energy losses in the mill based were minimized by adding thickeners before the dispersion stage of the production process. The details of the formulations are presented in Table 1 below.

Table 1 Emulsion Paint Formulation Recipe

Stage	Reagents	Quantity of PS *(g)*
	Water	185
	Anti-foam	0.2
	Drier	0.2
First	Calgon	1.16

	Genepour	1.16
	Bermocoll	2.5
	Troystan	1.14
	Dispersant	0.2
	Butanol	5
	Ammonia	0.54
	TiO_2	50
	$Al_2(SiO)_3$	11.2
Mill base	Na_2CO_3	0.58
	Kaolin	2.52
	$CaCO_3$	123
	Binder	200
	Water	15
Letdown	Dispersant	0.2
	Nicofoam	0.2
	Anti-skinning agent	0.2
	Total	**500**

2.2.11 pH determination of the emulsion paint

A pH meter was used to measure the paint samples' pH. To get the reading, the electrode was dipped into paint samples [10]. After standardizing the electrode's pH with a buffer solution at pH 7, distilled water was used to rinse it.

2.2.12 Adhesion test of the emulsion paint

On a metal panel, a coat of paint film was applied using a film applicator, and it was left to dry for 48 hours. A sharp nail was used to draw two sets of lines on the paint film, one of which crossed over the other perpendicularly. Using the thumb, firmly push an adhesive tape over the entire perpendicular line interaction. After being forced to release its ends, the sticky tape was taken off the panel. Poor adherence was indicated by the removal of more than 50% of the paint film's square lines. For every sample, a triplicate determination was performed at 27 ℃, and the average value was noted [10], [14].

2.2.13 Resistance to blistering of the emulsion paint

The method used to measure resistance to blistering was applying an undiluted paint sample with an applicator to a glass panel to provide a wet film thickness, then letting it dry for a full day. Two milliliters of distilled water were applied to the film in the shape of circular drops at the conclusion of this time. Poor water resistance was indicated by the occurrence of blistering, wrinkling, swelling, or cracking within 30 minutes. Each sample's three duplicate determinations made up the quality evaluation record [10]

2.2.14 Viscosity measurement of the emulsion paint

500ml of each of the paint produced was used to determine their viscosity. This was carried out by using BROOKFIELD DV-E Viscometer, model (LVDE) the result obtained was calculated using standard[10], [15].

2.2.15 Opacity test of the emulsion paint

The approach outlined by Osemeahon and Barminas [9] was employed to determine the paint samples' opacity test. Yellow paint was used as a primer on the ceiling board, and it was allowed to air dry. In a beaker, 25 milliliters of the various paint formulations were added. To prevent the brush from absorbing too much paint, the brush to be used was dipped into the paint sample before being dipped into the 25ml paint in a beaker. The ceiling board was then painted, and the area of the painted surface was measured to determine the paint's opacity.

2.2.16 Drying time of the emulsion paint

By employing Osemeahon method[7], the paint samples' drying times were assessed. Every 25-milliliter paint sample was formulated was applied to a ceiling board that had been primed with yellow paint and allowed to cure at room temperature. The drying times of each sample were recorded using a stopwatch.

2.2.17 Dry to touch and dry to hard test of the emulsion paint

The paint sample's dry test was assessed using the methodology described by Kalu [10]. Using a brush, each paint sample was applied to a ceiling board that had been primed with yellow paint, and it was left to dry. Dry to hard was measured when the paint film resisted finger prints, and dry to touch was measured when the paint could no longer cling to the finger.

2.2.18 Flexibility test of the emulsion paint

Using a paint applicator, paint samples were applied to the aluminum panel mix. For seven days, the paint sample's film was left to dry at ambient temperature (27 ℃). It took one to two seconds for the film panel to be smoothly bent through 1800. After being put back in its original condition, the panel was checked for adhesion loss and cracking and any break or loss of adhesion suggested rigidity or brittleness [16]

2.2.19 Tackiness of the emulsion paint

This was also determined on the film of each of the paints formulated by hand feeling to find out if the paint is sticky or not. Stickiness of a dried film indicates that the film is tacky [10].

2.2.20 Stability test of the emulsion paint

The paint samples were completely sealed in a container and keep at room temperature (27^0C) for 2 months. At the end of this incubation period, the various paint samples were re-examined for any change in viscosity or coagulation of the emulsion paint. Absence of coagulation or any change in viscosity was regarded as “pass” [10].

3 Instrumentation

Thefilmcomposition of the PS binderwasconfirmed byFTIRspectroscopy.Thepreparedthin filmswere examinedusing AttenuatedTotalReflectionFTIR(ATR-FTIR)technique.Theywere scanned ata resolutionof4 cm^{-1} with 16 scans overwavenumber region peaks ofIR transmission spectraof 400– 4000 cm^{-1}usingFTIR spectrophotometer(Perkin Elmer, USA).

4 Result and discussion

4.1.1 In-situ characterization of the PS binder

4.1.1.1 Effect of Concentration on the Viscosity of PS binder

As shown in Figure 1, the viscosity of PS fell between 0-5%. Then viscosity increases gradually with increase in PS concentrations, between 20-25%, there is sharp increase of viscosities. This may be attributed to the increase in molecular weight and the degree of polymerization due to crosslinking interactions between the resins macromolecules [7] being the base component, the viscosity of the binder is very important in the effects of paint factors such as sagging, leveling, flow rate, adhesion et cetra.

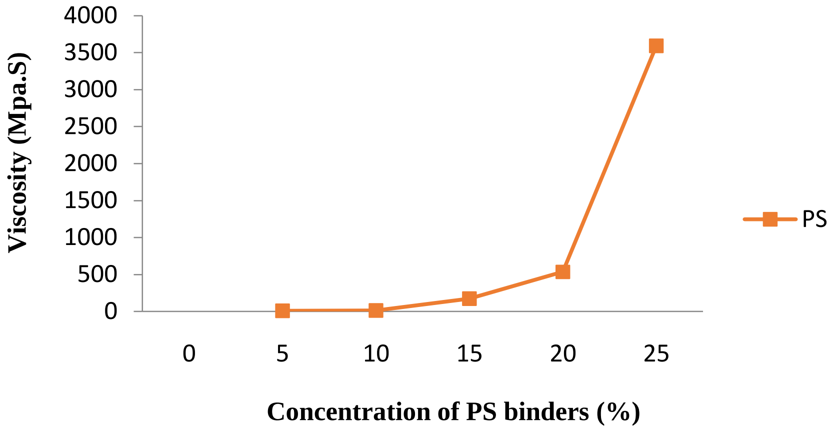

Figure 1 Variation of PS binder concentrations with viscosity

4.1.1.2 Effect of Concentration on the density of PS binder

Figure 2 shows the effect of concentration on the density of PS binder. It can be seen that the density of the binder increases gradually with the increase of binder concentrations. This may be due to the increase of binder concentration [17]. The density of the paint binder has a profound influence factors such as brushability, leveling, sagging, dispersion and stability of pigment, and can also be used to determine the critical pigment volume concentration, spreading capacity and consistency of the paint [13]

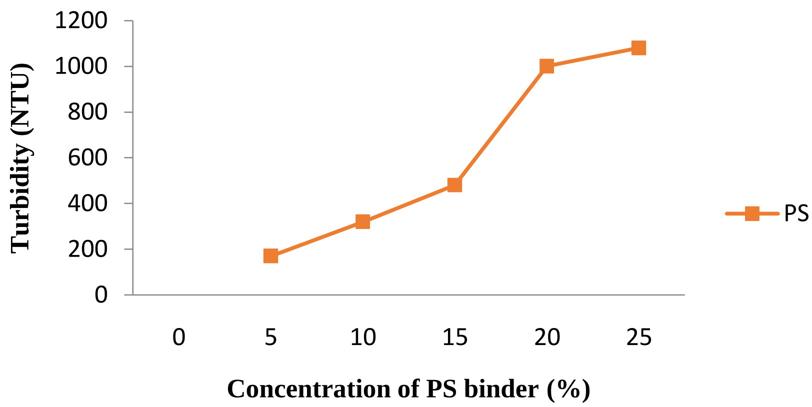

Figure 2 Variation of PS binder concentrations with turbidity

4.1.1.3 Effect of Concentration on the melting point of PS binder

Figure 3 shows decrease in the melting point of the binders as the amount of PS increases. The melting point of PS binder rose sharply between 0-5% concentration. Decreasing melting point indicate decreasing hardness and increasing flexibility of the binder [13]

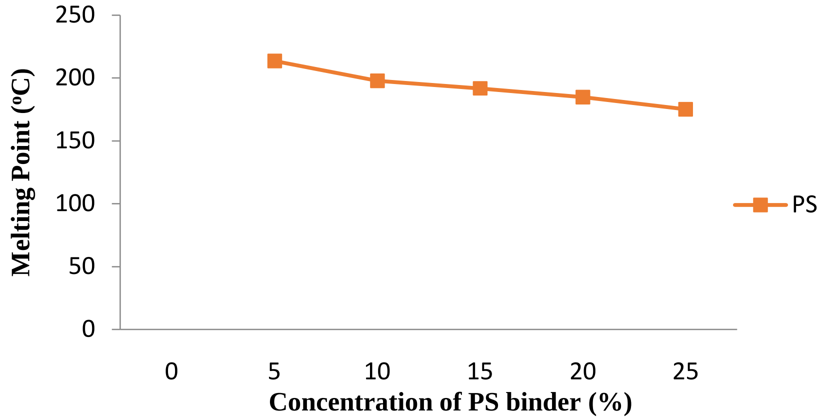

Figure 3 Variation of PS binder concentrations with melting point

4.1.1.4 Effect of Concentration on the refractive index of PS binder

Figure 4 shows that as the PS binder concentration is increased, the refractive indices also increase. These may be due to increasing discontinuities in the molecular structure of the blends. It may also be attributed to a possible rise in crosslinking density as the concentration of the PS increases [13]. Gloss which is a qualitative property of paint has been reported to be a function of refractive index [10]. And the binder plays a vital role in the exhibition of this property.

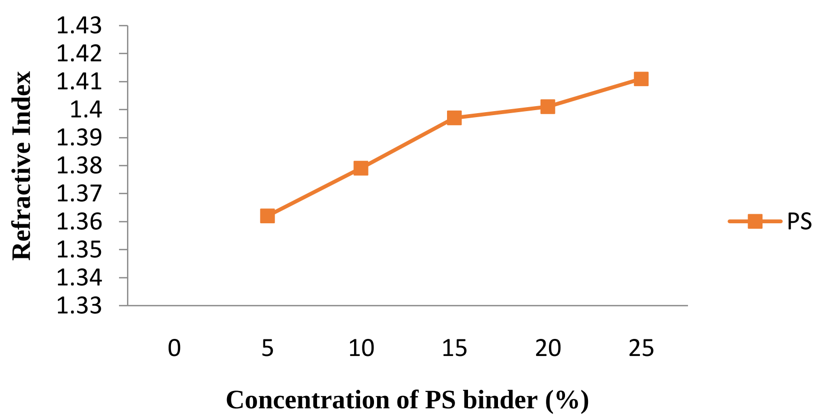

Figure 4 Variation of PS binder concentrations with refractive index

Effect of Concentration on the moisture uptake of PS binder

Figure 5 shows the reduction in moisture uptake of the PS binder with the increase of binder concentrations. The moisture uptake of PS rises between 0-5%, decreased from 5-25%, and flat out between 20-25% concentrations. These behaviors can be associated with the decrease in the amount of PS binder[13]. Moisture uptake in polymeric materials is very crucial on both physical and structural levels. In synthetic resins used as binders, it is responsible for blistering, alligatoring, brooming of paint film. It also affects the mechanical properties of paint in a way that might lead to paint's failure [10], [13].

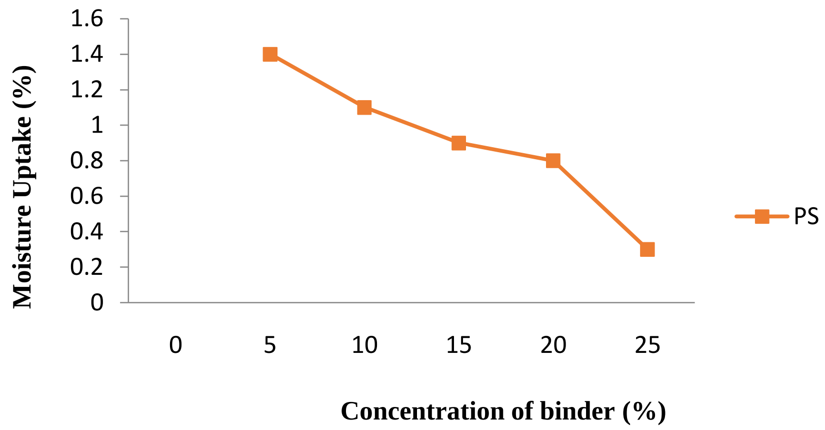

Figure 5 Variation of PS binder concentrations with moisture uptake

4.1.1.5 Effect of Concentration on the turbidity of PS binder

Figure 6 shows the effect of PS concentration on the turbidity of each of the solution. It can be observed that there was initial sharp fallen of turbidity of PS binder. The turbidity increased gradually with rapid rise of the turbidity of PS between 15-20% concentrations. This may be due to the progressive increase of PS concentrations. The particles in the solutions absorbed and refract light. As the concentrations increases, the solutions become denser, less light passes through the solutions at higher concentration [9]. Turbidity in addition to the pigment is a factor that enhances the opacity of the paint films [13]

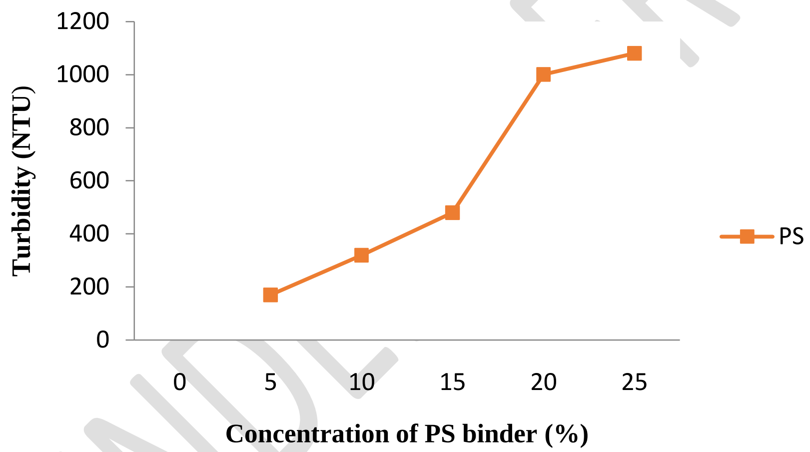

Figure 6 Variation of PS binder concentrations with turbidity

4.1.1.6 Effect of Concentration on the elongation at break of PS binder

Figure 7 shows the decrease in Elongation at break of PS binder between 0-5% and the gradual increase in Elongation at break between 5-25% concentrations. This implies that an increase in concentration improves the ductility of the film which allows for large deformation or large extension [7].

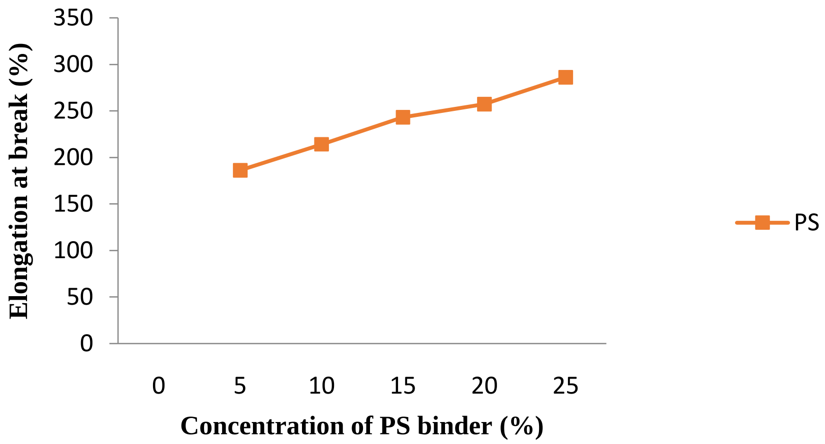

Figure 7 Variation of PS binder concentrations with elongation at break

4.1.1.7 Effect of Concentration on water solubility of PS binder

As presented in Table 2, the PS binder was soluble in water up to 15% concentration and above 15%, the solution became insoluble in water. This hydrophobic behavior is expected as the amount of the hydrophobic PS resins increases in the matrix. It could also be attributed to the high molecular weight of PS binder. Resin solubility or dispersibility is an important factor in the resin's acceptability as a binder for emulsion paint formulation[13].

Table 2 Water solubility of PS binder

PS Concentration	Solubility
5g	Soluble
10g	Soluble
15g	Partially soluble
20g	Insoluble
25g	Insoluble

4.1.2 FT-IR Characterization of the PS binder

In PS Spectrum shown in Table 3, peaks corresponding to –OH hydroxyl group was observed at3824.5/cm. Similar bands were observed by [10] for Sesamum indicum seed oil (SISO), Egbuna and Aninwede [18] and Khalid [19] for the Jordan valley tomato oil alkyd resin.The medium peaks found at 2905.8/cm and 2869.4/cm suggest for the presence of an alkane C-H stretching in the PS binder, similar observations were found and reported by Kalu [10], and Khalid [19].The less intense peak at 2633.5/cm suggests the presence of an asymmetric stretch of the carbonyl groups present in the PS binder [10], similar observations were reported by Ezugwu [20] for Albizia *lebbeck* oil modifiedalkyd resin.Peaks due –C=O carbonyl group was observed at 2266.5/cm.Kalu [10] also observed similar peak at 2290.18/cm in SISO and similar observations were recorded by Egbuna and Aninwede[18] for castor/soybean seed oil alkyd resin blend and Onukwli [15].The medium peak found at 1445.6/cm for PS binder suggest the presence of a –CH bending of the methyl groups, similar observations were reported by Kalu [10] whose SISO displayed at 1454.38/cm, Isaac [21]and Ezugwu[20] also had similar observations.The medium peak at

1773.5/cmsuggests the presence of a carbonyl group which could be attributed to an aromatic ester C-O stretch present in the PS binder [10], similar observations were reported by Akpan[22]for castor seed oil alkyd resin samples and Uzoh[23]reported similar observation.The weak bands at 1639.2/cm suggests for the presence of a C=C stretching for aromatics in the PS binder, similar observations were reported by Kalu [10] whose SISO gave peak at 1652.60/cm. Khalid[19]and Akpan [22] also reported similar observations.Some in-plane and out-plane stretching vibrations were recorded at 727.8/cm which suggests for the presence of the $–CH_2$ rocking modes in the PS binder [10], similar observations were reported by Akpan[22] and Kalu [10].

Table 3 FT-IR spectral analysis of PS binder

S/n	Peaks (cm^{-1})	Functional group assignment
1	3824.5	–OH, hydroxyl group
2	2905.8	Alkane C-H stretching
3	2869.4	Alkane C-H stretching
4	2633.5	Asymmetric stretch of the carbonyl groups
5	2266.5	–C=O, carbonyl group stretch
6	1639.2	C=C, stretching for aromatics
7	1445.6	–CH, bending of the methyl groups
8	1173.5	Aromatic ester C-O stretch
9	727.8	$–CH_2$, rocking modes

4.1.3 Physic-mechanicalproperties of the formulated PS emulsion paint

The physic-mechanical properties of the formulated PS Paint have been highlighted in Table 4. It was observed that the pH of the PS emulsion paint was in the permissible range of 7 to 9 stipulated by NIS [24]having a value of 7.98 and SON [25] whose limits are 7 to 8.5, the pH was investigated under ambient temperature, similar observations were made by Kalu [10], who had a pH of 7.82 for a *Sesamum indicum* semi-gloss paint formulation. The effect of pH in paints can be significant and can influence various aspects of their performance. The pH level of a paint can impact its color stability, adhesion, drying time, corrosion resistance, and overall durability [10]. Furthermore, the pH of paint can affect the stability and compatibility of different components within the formulation. Extreme pH levels, either too acidic or too alkaline, can lead to the degradation of binders, resins, or other components, resulting in reduced adhesion, cracking, or peeling [26]. The density of PS paint formulated is 1.34g/cm^3. The density of the formulated PS paint falls within the standard stipulated by SON [25]in the range 1-12g/cm^3 which indicate that the binder possesses better coverage ability, which is the ability to cover or hide the underlying surface. Paints with higher densities typically have more pigments, fillers, or solids within the formulation, allowing for better hiding power and coverage on the surface [10].Similar results were achieved by Kalu [10] with a density of 1.31g/cm^3, Oladipo [14] who had a density of 1.01 g/cm^3.Additionally, density can affect the drying time of paints. Higher density paints can take longer to dry due to their thicker consistency, while lower density paints may dry more quickly [10].The viscosity of the formulated PS emulsion paint was found to be moderate and lower with a value of 10.04 Cp (Centi poise) when compared to results by Aigbodion[27] who obtained a viscosity 4.89 Cp for rubber seed oil as a binder and Oladipo [14]who obtained 130 Cp for wild olive oil as a binder. The obtained value was slightly higher than the standard stipulated by SON [25] of 6 to 15 Cp but, was found to be in the range 22 to 150 Cp stipulated by NIS [24]. It has been suggested that High-viscosity paints tend to be thicker and more difficult to spread, requiring more effort to achieve an even application. Higher viscosity paints take longer to dry because the thicker consistency slows down the evaporation of solvents or water present in the paint formulation. Conversely, lower viscosity paints tend to dry more quickly due to the faster evaporation of solvents [10]

Table 4 Physic-mechanical Properties of PS Paint in Comparison with the SON Standard.

Properties	PS	SON standard
pH	7.98	7-8.5
Density	1.34	1-12
Viscosity	10.4	6-15
Touch dry	20-25	20
Hard dry	85-95	120
Opacity	Pass	Pass
Blistering	Pass	Pass
Tackiness	Pass	Pass
Flexibility	Pass	Pass
Adhesion	Pass	Pass

The dry to touch of PS emulsion paint was are 20-25 minutes while hard-to dry was 85-95 minutes respectively, which is in conformity with the standard stipulated by SON [25] of values 20 minutes for dry to touch and 120 minutesfor hard to dry. Similar drying times were obtained by Aigbodion [27]whose values were in the range 25 to 35 and 80 to 85 minutes for dry to touch and dry to hard respectively; Kalu [10] had values of 15 to 20 and 85 to 90 minutes for a 40 % alkyd resin, 20 to 25 and 90 to 95 minutes for a 60 % alkyd resin and 25 to 30 for dry to touch and 95 to 100 minutes for dry to hard respectively.The touch-dry time is the period at which the particles mixed and sticking together as the solvent evaporates, while hard-dry is the period of optimum sticking and cohesion of the film to a desired stage, further coat can be satisfactorily applied[9]. The formulated PS emulsion paint sample exhibited touch to dry and hard to dry times within permissible ranges.The opacity test of the formulated paint was carried out in the laboratory with the aid of ceiling board and brush. The opacity result of PS formulated paint was recorded as pass. This indicated that the PS binders was good for the formulation. The paints samples produced passed the opacity test, indicating the ability to stabilize pigment dispersion [10].The PS paint formulated exhibited a good blistering resistance as there was no blistering, wrinkling, swelling or cracking within a period of 30 minutes after addition of distilled water in the form of circular drop. This is an indication that these paints can be used for both interior and exterior decoration [25].

As shown in table 4 below, the PS paints sample exhibited good adhesion as it was tested using an adhesion tape [7]. It has been suggested that the quality and durability of a coating is related to it adhesion [10].The PS paint formulated was observed to be sticky when felt with hand after 12 minutes of application. This indicated that the binders are of high viscosity and adhesion property which make it very good for emulsion paint formulation [9]. The formulated PS emulsion paint exhibited good flexibility characteristics, the effect of flexibility in paints is related to the long-term durability and performance of the painted surface. A paint film that is too rigid may crack or flake when subjected to movement or changes in temperature, while a paint film that is too flexible may lack adhesion and may be prone to sagging or deformation [10]. The PS paint sampleexhibited good flexibility as it withstood the bending force applied to them without deforming or broken after bending of the metal panel with the film smoothly through 180°[9]. This characteristic makes these paints suitable in their flexibility consideration as there was no cracking or loss of adhesion[12].The PS paint samples showed absence of coagulation or any change in viscosity and was recorded as "pass" [16]. This is indicative of its stability over a two months period.

As presented in Table 5, the PS binder is soluble in water up to 15% concentration and above 15%, the solution becomes insoluble in water. This hydrophobic behavior is expected as the amount of the hydrophobic PS chemical species increases in the matrix[28]. It could also be attributed to the high molecular weight of PS binder. Resin solubility or dispersibility is an important factor in the resin's acceptability as a binder for emulsion paint formulation [13]

Table 5 Water Solubility of PS Binder

PS Concentration	Solubility
5g	Soluble

10g	Soluble
15g	Partially soluble
20g	Insoluble
25g	Insoluble

Conclusion

The formulated PS emulsion paints were evaluated based on their conventional properties. It can be concluded that the PS paint met with the requirements by the coating industry according to already established standards by SON and NIS. In working towards an environmentally friendly society waste plastic was successfully converted as binder for emulsion paint formulation which should encouraged the conversion or recycling of waste in our environment. It can also increase the quantity of emulsion paints in the market and lower its price.

References

[1] Moore, M., and Bailey, A., Polymer Science and Technology: Plastics, Rubbers, Blends, and Composites. CRC Press., 2012.

[2] H. Ngozi Nzewi and O. Mary Chiekezie, “Entrepreneurial Skills and Competitiveness in the Nigerian Painting Industry,” Online, 2015. [Online]. Available: http://ssrn.com/abstract=2694720

[3] Z. Y. Abba, S. M.Gumel, A. A.Idris, and M. A.Ibrahim (2020). “Formulation of Paint using Natural Pigment from LawsoniaInermis Leaves,” *International Journal of Advanced Chemistry*, vol. 8, no. 1, p. 155, doi: 10.14419/ijac. v8i1.30712.

[4] X. Ni, Z. Wu, W. Zhang, K. Lu, Y. Ding, and S. Mao(2020). “Energy utilization of building insulation waste expanded polystyrene: Pyrolysis kinetic estimation by a new comprehensive method,” *Polymers (Basel)*, vol. 12, no. 8, doi: 10.3390/POLYM12081744.

[5] Choy, K. K. H., Tan, C. Y., Liau, L. A., Zhou, X., & Phee, S. F. (2017). A Review on Natural Fiber Reinforced Polymer Composites. In Handbook of Natural Fibres (pp. 1-60). Woodhead Publishing.

[6] Breeuwer, H. M., Belisario-Ferrari, M. R., & Spanjaard, J. A. (2012). Emulsion Paint Morphology: A Confocal Laser Scanning Microscopy Study. *Journal of Coatings Technology Research*, 9(2), 201–210. doi: 10.1007/s11998-011-9378-3

[7] Osemeahon S.A., Barminas J.T., Aliyu, B.A. (2009). Development of emulsion paint from a copolymer composite of methylolurea and soyabeanoil. *Journal of Chemical Society of Nigeria*, 34(2): 134-139.

[8] A. Khalid. J. Al-Bermany and S. A. Jabbar, (2012). “Study the Effect of adding PVA on Some Physical Properties of CMC Polymer as aqueous solutions,” 2012. [Online]. Available: www.iiste.org

[9] S. A. Osemeahon and Barminas. (2007). “Development of amino resin for emulsion paint formulation: reactive blending of methylol urea with soybean oil,” *African Journal of Biotechnology*, vol. 6, no. 6, pp. 803–809,[Online]. Available: http://www.academicjournals.org/AJB

[10] Kalu, K.M.,Emmanuel, M., Chinedu, E.K., Akinterinwa,A. Titus, U., Kenneth, R., Haruna, N.A. andAliyu, B.A. (2023) Extraction, Synthesis andCharacterization of an Alkyd Resin fromSesamum indicum Seed Oil. *Open AccessLibrary Journal*, 10: e10447.https://doi.org/10.4236/oalib.1110447

[11] J. U. Ezeagba, U. J. M. Ikezu, and E. O. Iloh, (2014). “Formation of an oil paint using Alkyd resin from Soyabean oil,” *World Applied Science Journal*, vol. 32, no. 1, pp. 83–87doi: 10.5829/idosi.wasj.2014.32.01.84128.

[12] F. G. Fadawa, S. A. Osemeahon, P. M. Dass, And B. A. Aliyu, (2008). "Characterization of Composites from Dimethylol Urea and Hydroxylated Black Seed Oil for Possible Application as an Emulsion Paint Binder," [Online]. Available: www.Ftstjournal.Com

[13] A. Akinterinwa, S. A. Osemeahon, I. I. Nkafamiya, and P. M. Dass, (2015). "Formulation of Emulsion Paint from a Copolymer Composite of Dimethylol Urea/Polystyrene," vol. 7, no, [Online]. Available: www.iiste.org

[14] G. O. Oladipo, I. C. Eromosele, and O. M. Folarin, (2013). "Formation and Characterization of Paint Based on Alkyd Resin Derivative of Ximenia americana (Wild Olive) Seed Oil," *Environment and Natural Resources Research*, vol. 3, no. 3, doi: 10.5539/enrr. v3n3p52.

[15] Onukwli, D. and Igbokwe, P.K. (2008) Production and Characterization of CastorOil-Modified Alkyd Resins. *The Journal of Engineering and Applied Science*, 3,161-165.

[16] Abbas K.A, Muhammed K.Y, and Olufemi K.S, (2014). "Characterization of Emulsion Paints Formulated using Reactive – Dyed Starch as a Pigment," *International Institute of Engineers*. doi: 10.15242/iicbe.c614005.

[17] J. A. Gidigbi, S. A. Osemeahon, A. M. Ngoshe, and A. Babanyaya, "Coating Industry," (2019). [Online]. Available: www.ijriar.com

[18] S. O. Egbuna and C. S. Aninwede, (2018). "Comparative Analysis of Alkyd Resins Produced from Castor and Soybean Seed Oils,". *International Journal of Novel Research in Engineering and Science*. Vol. 5, Issue 1, pp: (24-32), Available at: www.noveltyjournals.com

[19] K. A. Ibrahim, K. A. Abu-sbeih, I. Al-Trawneh, and L. Bourghli, (2014). "Preparation and Characterization of Alkyd Resins of Jordan Valley Tomato Oil," *Journal of Polymer Environment*, vol. 22, no. 4, pp. 553–558, doi: 10.1007/s10924-014-0664-9.

[20] C.O. Akintayo, K.O. Adebowale. (2019). "Synthesis and Characterization of Alkyd Resin from Albizia lebbeck (frywood) seeds," *Scientific Research Journal*, vol. 07, no. 09, pp. 118–141, doi: 10.31364/scirj/v7.i9.2019.p0919703.

[21] I. O. Isaac and O. D. Ekpa, (2014). "Comparative Study on the Kinetics of the Preparation of Melon Seed and Cottonseed Oils Based Biopolymers," *American Journal of Polymer Science*, vol. 2014, no. 1, pp. 7–15, doi: 10.5923/j.ajps.20140401.02.

[22] U. G. Akpan, A. Jimoh, and A. D. Mohammed, (2006). "Extraction, Characterization and Modification of Castor Seed Oil,", [Online]. Available: http://ljs.academicdirect.org

[23] C. F. Uzoh and J. T. Nwabanne, (2016). "Investigating the Effect of Catalyst Type and Concentration on the functional Group Conversion in Castor Seed Oil Alkyd Resin Production," *Advances in Chemical Engineering and Science*, vol. 06, no. 02, pp. 190–200, doi: 10.4236/aces.2016.62020.

[24] NIS (Nigerian Industrial Standards), "Standard for Paints and Vanishes Part 3. Nigerian Industrial Standard, Lagos." 1989.

[25] Standards Organization of Nigeria (SON), "Specifications for Emulsion paint for Decorative Purposes, Lagos, Nigeria," 2008.

[26] N. O. Sanyaolu, A. Awosanya, O. I. Sonde, F. A Kareem, S. T. Yussuf, F. Akinwunmi and A. A. Ibikunle (2019). "Comparative Evaluation of the Alkyd Resins of the Composite Oils of Soybean (*Ricinus Communis*) and castor (glycine max) seed oils with castor seed oil for alkyd paint formulation," *Journal of Chemical Society of Nigeria*, Vol. 44, No. 5, pp 914 -921.

[27] A. I. Aigbodion and C. K. S. Pillai, (2001). "Synthesis and Molecular Weight Characterization of Rubber Seed Oil-Modified Alkyd Resins as Binders in Surface Coatings" *Indian Journal of Chemical Technology*. Vol. 8, pp 378-384.

[28] S. A. Osemeahon, I. I. Nkafamiya, O. N. Maitera, and A. Akinterinwa, (2015). "Journal of Polymer & Composites Synthesis and Characterization of Emulsion Paint Binder from a Copolymer Composite of Dimethylol Urea/Polystyrene,". [Online]. Available: www.stmjournals.com