Opacity and Washability Properties of Emulsion Paint with Natural Rubber Latex/Polyvinyl Acetat e Blend Binder

Bahrudin1, Zuchra Helwani1, Ivan Fadhilla1, Rayya1, Rumi1, Arya Wiranata1, Joni Miharyono2

1Chemical Engineering Department, University of Riau, Pekanbaru 28293, Indonesia
2PT. Warna Indah Tirta Asia (WITA), Pekanbaru 28291, Indonesia
bahrudin@lecturer.unri.ac.id

Abstract. Polyvinyl acetate (PVAc) has long been known as a binder material to improve the washability, opacity (hiding power), and viscosity of commercial emulsion paints. This study aims to study the properties of opacity (hiding power), washability resistance, and viscosity of emulsion paint added with a binder from a mixture of natural rubber latex (NRL) and PVAc. Emulsion paint samples were made with a binder content of 4, 6, and 8% w/w. The binder was made from a mixture of NRL and PVAc with various NRL levels of 0%, 15%, 25%, 35%, 50%, and 100% w/w. Testing of paint samples includes washability using a digital BGD 526 Wet Abrasion Scrub Tester and viscosity testing using a HAAKE 6R digital viscometer. At the same time, the opacity test uses the Indonesian Standard (SNI 3564:2009). The results showed that the opacity met the standard emulsion paint for all binder levels, except for the composition of NRL 100% w/w at all binder levels. The higher the NRL content in the binder causes the washability resistance and paint viscosity to decrease and become unstable. The best washability resistance and viscosity properties were obtained at NRL in a binder of 15% w/w and a binder content of 8% w/w, with washability resistance properties of 50 times and a viscosity of 3300 cp.

1. Introduction
Riau Province is the third-largest natural rubber producer of the Havea Brasiliensis type in Indonesia. Natural rubber has been used in various needs, such as household rubber, safety equipment, and the final product (consumption). Tires and piping are the most widely used rubber products [1]. One type of upstream product from natural rubber plantations that can also be produced is natural rubber latex. Natural rubber latex consists of colloidal rubber particles suspended in serum (water). The latex's dry rubber content (DRC) is around 30-40% [2].

The utilization of natural rubber into commercial products requires engineering or modification so that the product is resistant to ozone, heat, oxidation, weather, or oil [3]. Physical modification of the structure can be done by blending natural rubber with synthetic rubber. In contrast, chemical modification can be done by reacting to certain chemicals to change the molecular structure of natural rubber, such as epoxidation, hydrogenation, chemical degradation, chlorination, grafting, and cyclization of natural rubber [4].

The characteristics of natural rubber can be improved by the grafting method with polystyrene [5]. The styrene graft copolymerization process at 150 °C resulted in changes in the mechanical properties...
of DPNR-graft-ps, which was initiated by increasing the thermoplastic properties of natural rubber (TPNR). The chemical depolymerization method can modify natural rubber latex into liquid natural rubber (LNR) [6]. The resulting product has a low molecular weight and is liquid at room temperature. The resulting LNR has better characteristics than natural rubber latex due to its structure and bonding between particles [7].

The nature of natural rubber latex is very strong, elastic, and flexible, allowing NRL to be modified or mixed into a binder in emulsion paints. Previous research has been carried out by comparing the results between pure methylol urea (MU) and a mixture of methylol urea/natural rubber (MU/NR) in the emulsion paint formula [8]. The addition of a mixture of MU/NR to emulsion paint can produce characteristics that are more water-resistant and have better viscosity, flexibility, hardness, stickiness, dry time, gloss, and storage time than using MU alone. The mixture of natural rubber latex (NRL) with polyvinyl acetate (PVAc) as a binder in emulsion paints showed that the binder mixed with a ratio of NR/PVAc 25/75 had better characteristics in emulsion paints than other binder mixtures [9]. The resulting paint is also able to protect the exterior and interior walls. Natural rubber latex serves to increase water resistance and fluidity, while PVAc serves to strengthen the film layer on the paint. NRL/PVAc binder mixture (w/w); NRL is prevulcanized before blending. High tensile and elasticity values are found in the binder with an NRL/PVAc ratio of 30/70. The scrub value and elasticity decreased when the NRL content was higher than PVAc [10].

The most important characteristics of emulsion paints are scrubbing power, covering power, and paint life. Emulsion paints are environmentally friendly and have features similar to oil paints, such as strong adhesion and fast drying time. The characteristics of emulsion paints depend on pigments, solvents, extenders, binders, and other paint additives [11]. This study used a mixture of NRL and PVAc as a binder for emulsion paint and studied how it affects the scrubbing properties and viscosity of the emulsion paint.

2. Methodology

2.1. Materials
The natural rubber latex used comes from rubber plantations in Kampar Regency, Riau, Indonesia. Polyvinyl acetate (PVAc) comes from PT Duta Karisma Persada, North Jakarta, Indonesia. The reagents used are from the emulsion paint industry, PT. Warna Indah Tirta Asia, Pekanbaru, Indonesia.

2.2. NRL Preparation
The NRL pretreatment process begins with an anticoagulation process that aims to maintain and prevent bacterial growth, and the anticoagulant used is ammonia [12-14]. Furthermore, the NRL concentration (evaporation) process increases the DRC from NRL to 63%. There are four methods of NRL concentration, namely evaporation, electrocantation, centrifugation, and creaming. Evaporation is a method of concentrating NRL from DRC of 30% to 80% [15]. The evaporation process is also effective for removing ammonia, indicating that there is no ammonia smell in the NRL sample. NRL was added with 30% ammonia as much as 6% (w/w latex) as anticoagulation. NRL mixed with a small amount of concentrated ammonia is called low ammonia natural rubber (LATZ, pH 9.8). The LATZ was then evaporated to obtain 63% DRC to obtain NRL with 0% ammonia. Furthermore, the NRL/PVAc blends were made as the binders with NRL content of 0%, 15%, 25%, 35%, 50%, and 100% w/w.

2.3. Paint Production
The formulation for making emulsion paints follows the organization of Indonesian paint industry standards with a modified binder (Table 1). At first, the water, hydroxyethyl cellulose, ultramarine blue, and pH solution were mixed into the tank and stirred evenly. Next, 1-carboxyethylene, alkyl phenol ethoxylate, and fatty alcohol were added to the mixture. When stirring, the mixture was added
dehydroxylated aluminum, CaO, CaCO₃, and polyacrylic acid. After 20 minutes, the modified binder made previously was added, with varying levels of 4%, 6%, and 8% (w/w paint). The last step is adding perfume to the emulsion paint mixture. Then, the washing ability resistance was tested with the BGD 526 Wet Abrasion Scrub Tester and the viscosity with the HAAKE 6R digital viscometer. At the same time, the opacity test uses the Indonesian Standard (SNI 3564:2009).

### Table 1. Emulsion Paint Formulation

| Material                        | Mass (g) Paint Emulsion 1 | Mass (g) Paint Emulsion 6 |
|---------------------------------|----------------------------|---------------------------|
| Water                           | 300                        | 300                       |
| Hydroxyethyl Cellulose          | 1.8                        | 1.8                       |
| Ultra Marine Blue               | 0.4                        | 0.4                       |
| PH Solution                     | 1.3                        | 1.3                       |
| 1-Butynylethylene               | 1.8                        | 1.8                       |
| Akyl Phenol Ethoxylate          | 0.2                        | 0.2                       |
| Fatty Alcohol                   | 3.5                        | 3.5                       |
| Dehydroxylated Aluminium        | 1.8                        | 1.8                       |
| CaO                             | 20                         | 20                        |
| CaCO₃                           | 140                        | 140                       |
| Polyacrylic Acid                | 1.5                        | 1.5                       |
| PVAc (Binder 1)                 | 40; 60; 80                 | 0                         |
| NRL (Binder 2)                  | 0                          | 40; 60; 80                |
| Perfume                         | 0.2                        | 0.2                       |

3. Results and Discussion

### 3.1. Opacity (Hiding Power)

Opacity is the ability of paint to cover the entire surface of a particular medium. Emulsion paint binder serves to glue the paint particles to protect the media evenly. The stronger the bonding power of the binder, the more evenly the surface of the media covered with paint will be. Based on the test data, as shown in Table 2, Table 3, and Table 4, it can be seen that almost all emulsion paint samples were declared successful through the hiding power test, except for paint sample 6, which failed the opacity (hiding power) test. Paint sample 6 failed the hiding power test because the paint with a 100% NRL binder could not cover the media evenly, indicated by the difference in color that was more faded than the standard paint sample. This may be due to protein content in the NRL, which inhibits the paint gluing process. Protein functions as a protective agent and stabilizer of latex in the liquid phase. As a result, latex is difficult to dry quickly [16]. The paint sample 6 at a binder content of 8% w/w also did not pass the hiding power test, mainly because the NRL was not well homogenized with the paint material. It is characterized by the formation of clumps (coagulants) on the paint surface.

### 3.2. Viscosity

Viscosity is the resistance of a fluid to the velocity of the fluid flow. Natural rubber latex with 38% DRC has a viscosity of 4.6 times greater than the viscosity of water [17]. The viscosity of the paint is affected by the binder, so the quality of the binder is an important parameter of the paint. In addition, paint viscosity can affect other paint characteristics, such as density, adhesion, drying time, and hiding power. The results of the paint viscosity test can be seen in Table 2, Table 3, and Table 4. It can be seen that the viscosity value of each emulsion paint has fluctuated changes. Paint sample 2 with a binder content of 4% and a binder composition of NRL/PVAc 15/85% w/w has a viscosity value of 5400 cp, which is similar to the viscosity of commercial paint (that is, with a binder of 100% PVAc) of 5500 cp. These results are not much different from the paint products of previous studies [9,10,12]. The lowest paint viscosity value is 2200 cp, namely the viscosity of emulsion paint with a binder of
4% (NRL/PVAc 35/65% w/w). Based on previous research, the viscosity of the paint will decrease with the addition of NRL levels in the binder, but in this study, the viscosity value fluctuated. This may be caused by the mixture of NRL binder with PVAc, which was not completely homogenized [11]. The binder with a high NRL composition will form 2 phases, resulting in unstable viscosity and adhesion [10].

Table 2. Characteristics of Emulsion Paint Samples with 4% Binder Content

| Parameter             | Emulsion Paint |          |          |          |          |          |
|-----------------------|----------------|----------|----------|----------|----------|----------|
|                       | 1             | 2        | 3        | 4        | 5        | 6        |
| Opacity               | P             | P        | P        | P        | P        | F        |
| Viscosity (cp)        | 5500          | 5400     | 3600     | 2200     | 3400     | 2700     |
| Washing Ability (times)| 10            | 8        | 5        | 4        | 3        | 2        |

Table 3. Characteristics of Emulsion Paint Samples with 6% Binder Content

| Parameter             | Emulsion Paint |          |          |          |          |          |
|-----------------------|----------------|----------|----------|----------|----------|----------|
|                       | 1             | 2        | 3        | 4        | 5        | 6        |
| Opacity               | P             | P        | P        | P        | P        | P        |
| Viscosity (cp)        | 4800          | 3800     | 3500     | 3100     | 2800     | 2600     |
| Washing Ability (times)| 45            | 41       | 26       | 18       | 13       | 3        |

Table 4. Characteristics of Emulsion Paint Samples with 8% Binder Content

| Parameter             | Emulsion Paint |          |          |          |          |          |
|-----------------------|----------------|----------|----------|----------|----------|----------|
|                       | 1             | 2        | 3        | 4        | 5        | 6        |
| Opacity               | P             | P        | P        | P        | P        | F        |
| Viscosity (Cp)        | 3500          | 3300     | 2600     | 3000     | 2300     | 3700     |
| Washing Ability (times)| 58            | 50       | 34       | 27       | 19       | 4        |

Key: P and F indicate pass and fail of emulsion paint products, Paint 1: 0% NRL; Paint 2: 15% NRL; Paint 3: 25% NRL; Paint 4: 35%; Paint 5: 50% and Paint 6: 100% NRL.

3.3. Washability Resistance

Washability resistance is the ability of paint to resist scratches due to water splashes [9]. Figure 1 shows the effect of NRL on the washing resistance of emulsion paint. It is seen that the paint with 14/85% w/w NRL/PVAc binder has a wash resistance of 8 times, which is similar to the adhesion of commercial paints (i.e., with 100% PVAc binder). A significant decrease in washability occurred when the NRL/PVAc binder composition was 25/75% w/w. The binder content of 8% has the best resistance to washing. This is because the higher the binder content of the paint, the greater its resistance to washing.

The decrease in washability resistance may be due to impurities (i.e., protein) and polymer chain length of the NRL. The protein in NRL functions as a stabilizer. As a result, the elasticity and adhesion characteristics of NRL are reduced. The proteins contained in the paint cause the decay process to be fast and reduce the quality of the paint [10]. People with protein allergies cannot use paints containing protein because they can cause skin irritation [18]. In addition, the shorter polymer chain of the NRL can cause the greater the adhesion and elasticity [19].
Fig 1. Effect of NRL contents in PVAc on Washability Resistance of Emulsion Paint.

4. Conclusion
The study results concluded that the opacity met the standard for emulsion paint for all binder levels, except for the composition of NRL 100% w/w at all levels of the binder. The higher the NRL content in the binder causes the washability resistance and paint viscosity to decrease and become unstable. The best washability resistance and viscosity properties were obtained at the composition of NRL in the binder of 15% w/w and the binder content of 8% w/w, with washability resistance properties of 50 times and viscosity of 3300 cp. It is still possible to improve the opacity and washability resistance of emulsion paint with NRL binder or a mixture of NRL and PVAc by modifying the natural rubber polymer (NRL) molecule so that the adhesive characteristics of NRL are further improved.

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