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Evaluation of *Mesua ferrea* L. seed oil modified polyurethane paints

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ABSTRACT

Two types of stoving paints have been prepared from *Mesua ferrea* L. seed oil (MFLSO) modified poly(urethane ester) (PUE) binder systems. One stoving paint system was prepared from partially butylated melamine formaldehyde (MF) resin modified MFLSO-based PUE (70:30 weight ratio) and other one comprised of bisphenol-A-based epoxy resin modified with MFLSO-based PUE (50:50 weight ratio). Paints made with these two resin systems as binders were evaluated against the standard paint system. The physical properties of the paint systems viz. non-volatile content, specific gravity, viscosity, drying time, flexibility, adhesion, scratch hardness, gloss, etc. and chemical properties such as corrosion resistance, salt spray resistance, UV resistance, etc. were measured as per the standard methods and were compared. Thermal stability and surface morphology of the paints were also studied by using thermogravimetric analysis (TGA) and scanning electron microscopy (SEM), respectively. The performance characteristics of both the test paints were found to be comparable with the corresponding industrial standard paints. Out of the two test paints, the epoxy modified PUE-based stoving paint has been found to be preferred.

1. Introduction

Looking back to the prehistoric era, peoples used to decorate their caves by painting with natural paint systems [1]. However, after the introduction of cheap mineral oil, the use of renewable resources in paints and coatings declined gradually [2,3]. But due to the depletion of petroleum-based feedstock and consumer environmental awareness, use of environment friendly paints and coatings are again growing in all aspects since last few years.

The chief component of paint is the binder, which is generally a natural or synthetic resin, vegetable oil, natural protein or fat. They are responsible for the film formation and adhesion to various surfaces [2,3]. The binder along with solvent system is often called as vehicle. The basic properties of paint such as drying, gloss, durability, flexibility, adhesion, scratch resistance, abrasion resistance, chemical resistance, etc. depend on the nature and composition of the binder, though slight variation can also be made by modifying the other components of the paint. Along with the vehicle, the paint composition consists of pigment(s) and some other additives such as dispersing agents, wetting agents, viscosity controlling agents, anti-settling agents, anti-skinning agents, anti-foaming agents, anti-oxidants, adhesion promoters, dessicants, driers, biocides, light stabilizers, etc. [4,5]. The role of the pigment in a paint formulation is multipurpose. It provides required color and hiding to the paint, protects the paint from UV light and corrosion, and can also increase elasticity, hardness and abrasion resistance. The efficiency of a pigment depends on its particle size distribution and the dispersion in the binder system [6]. The ease of processing and wetting of pigment can be facilitated by reducing the viscosity through introduction of proper solvent system. The solvent system should be sufficiently volatile so that no trace remains after finishing of the paint.

Among the existing binder systems, highly versatile polyester polyol-based polyurethane resins are dominating the market due to their excellent performance characteristics. They possess excellent corrosion resistance, abrasion resistance, scratch resistance, flexibility and chemical resistance. Polyurethanes have particularly found immense numbers of applications in high performance coatings for the automotive, appliance and wood industries. The polyurethane binder in the present communication has been developed from *Mesua ferrea* L. seed oil (MFLSO), which is a non-drying oil [7]. A few other polymers from *M. ferrea* L. seed oil have also been reported from the same laboratory [8–10]. The blends of *M. ferrea* L. seed oil-based polyurethanes [11,12] with commercially available partially butylated melamine formaldehyde (MF) [13] and bisphenol-A-based epoxy resin [14] have also been reported. Both the blends have excellent potential as surface coatings [13,14], binder for composites [15] and electrically insulate lacquer [16,17] materials. As epoxy resins provide durable coatings of high mechanical strength and good adhesion

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to most of the substrates [4,6,18], hence *M. ferrea* L. seed oil-based polyurethane/epoxy blends were used as binders for the test paint in the present investigation. Similarly, paints based on polyester resin combined with MF are highly durable [5,19,20]. Thus, polyurethane/MF blends are also expected to possess similar characteristics. Hence *M. ferrea* L. seed oil-based polyurethane/MF blends were also used as binders for the test paint.

In the present communication, the authors wish to discuss the preparation and characterisation of paints from *M. ferrea* L. seed oil-based polyurethane blends with MF and epoxy separately as binders. The performance characteristics of these paints were compared with conventionally used resin in the standard paint systems.

2. Experimental

2.1. Materials

M. ferrea L. seeds were collected (Jorhat, Assam, India) and utilized to extract the oil by solvent extraction method. Metallic sodium, n-hexane, sodium hydroxide, diethylether, xylene, polyethylene glycol (number average molecular weight = 200 g/mol), glycerol and lead mono oxide were used (Merck, Bombay, India) as received. Poly(urethane ester) (PUE) of *M. ferrea* L. seed oil was obtained as per the earlier reported method [12]. Toluene diisocyanate (TDI) and dibutyl tin dilaurate (DBTDL) (Merck, Schuchardt, Germany) were used without further purification. Other materials related to paint formulations such as titanium dioxide, MF resin, epoxy resin, n-butanol, barytes, silica, solvent CIX (nine carbon containing hydrocarbon) and urea formaldehyde (UF) resin were all commercial grade and obtained from Mumbai, India. The epoxy resin (viscosity—450–650 mPa at 25 °C, epoxy equivalent—182–192 g/equiv. and density 1.15 g/cc at 25 °C) and melamine resin (application viscosity—20–25 s (GP-02) at 25 °C, thin with 90:10 (v/v) xylene: n-butanol (60% solid content) and density 1.2 g/cc at 25 °C) are used for this study and were obtained from Ciba Geigy, Mumbai (Araldite LY 250)and gifted sample from Asian Paint, Mumbai (partially butylated melamine formaldehyde).

2.2. Instruments and methods

The physical properties like viscosity, specific gravity and non-volatile content of *M. ferrea* L. seed oil-based PUE/MF and PUE/epoxy paints (test paints) along with the standard paints were measured using the standard IS methods [21–23]. The fineness of ground particles during paint preparation was checked using Hegman Gauge (Sheen Instrument Ltd., UK). The performance characteristics of all the paints were evaluated by determining scratch hardness [24], flexibility, adhesion [25] and gloss [26] as per the ASTM methods. The tests for corrosion resistance [27], salt spray resistance [28] and UV exposure resistance [29] were also performed using the standard IS methods.

The thin films of all the paint samples were prepared by drawing the homogeneous mixture of the blend solutions on glass plate using a micro adjustable thickness gauge (Sheen Instrument Ltd., UK) under ambient conditions. After removal of sufficient amount of solvent under atmospheric conditions, the coated strips were degassed under vacuum at (45 ± 5) °C for 45 min to remove the last trace of solvent and volatile compounds. Then the coated plates were cured by heating at 130 °C in an oven for specified time periods. The cured paint films were kept under ambient conditions for 24 h before further studies. The dried films from the glass plates were peeled off by immersing the plates in warm water followed by drying in a desiccator under vacuum and were stored for 7 days before scanning electron microscopy (SEM) analysis. The dry coating thickness of the films was measured by Pentest, coating thickness gauge (model 1117, Sheen Instrument Ltd., U.K.) and were found to be in the range of 30–35 μm.

The thermogravimetric analysis (TGA) of the cured paint samples was done by Shimadzu TG 50, thermal analyzer under the nitrogen flow rate of 30 mL/min at the heating rate of 10 °C/min from 50 to 600 °C. The surface morphology of the paints was studied by using a JEOL scanning electron microscope of model JSM–6390LV SEM after platinum coating on the surface of the samples.

2.2.1. Preparation of poly(urethane ester) resin

The polyurethane resin with NCO/OH ratio 0.5 was prepared as reported earlier [12] by using toluene diisocyanate and monoglyceride of *M. ferrea* L. seed oil along with polyethylene glycol (PEG of number average molecular weight = 200 g/mol) as chain extender, dibutyl tin dilaurate as the catalyst and xylene as the solvent. This resin is treated as test resin and the industrially castor oil-based resin is taken as standard resin. The physical characteristics of the standard resin and test resin are as follows. The standard resin is colorless with acid value (mgKOH/g)—12, hydroxyl value (mgKOH/g)—166, saponification value (mgKOH/g)—340, iodine value (gI_2/100 g)—76, specific gravity—0.76 and inherent viscosity (dL/g)—0.16. The test resin, on the other hand, is light brown in color with acid value (mgKOH/g)—10, hydroxyl value (mgKOH/g)—156, saponification value (mgKOH/g)—365, iodine value (gI_2/100 g)—53, specific gravity—0.66 and inherent viscosity (dL/g)—0.1.

2.2.2. Preparation of paints

Both the polyurethane test paints were prepared in two different porcelain ball mills using butylated MF and epoxy modified polyurethane resins as respective binders in the grinding stage. At first, the pigment titanium dioxide, extenders, respective resins and around 20% of solvent were charged in the ball mill. The formulations utilized for the standard as well as test paints are given in Table 1. The grinding of the pigments and extenders was done for around 18 h to attain the grinding particle sizes of 10 μm, as measured by Hegman Gauge. After attaining the required grinding size, the materials were dropped into some containers and mixed with polyurethane ester resin and finally adjusted with remaining solvents and other additives to achieve application viscosity of paint

Table 1
Formulations for test and standard paints.

Ingredients	PUE/epoxy paint	PUE/MF paint	Function
TiO_2	10	24	White inert pigment with high opacity and tint resistance
Barytes	12	–	Acts as fillers and imparts physical reinforcement to the paint film
Silica	15	–	Acts as filler used to control viscosity of any solvent-based paint
Epoxy	20	–	Important binder to impart chemical resistance, adhesion and flexibility to the paint film
PUE/standard resin	18	46	Binder
Xylene	16	7	As a polar solvent for polar binder system
n-Butanol	8	5	As a polar solvent for polar binder system
UF resin	1	–	Acts as flow promoter
MF/standard resin	–	16	As a crosslinking resin for stoving paint
Solvent CIX	–	2	As a polar solvent for better flow property to the paint system

All data are in weight percent.