Improving Water Resistance Property of Medium Density Fibreboard (MDF)

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Abstract: Water resistance is a very important physical property of Medium Density Fiberboard (MDF). Urea Formaldehyde (UF) resin is used as a binder with fibers during Manufacturing of MDF. UF resin is easily soluble in water, having fast rate of reaction but has a poor water resistance. So there need to be modification of UF resin. This research investigates to analyze the UF resin to improve water resistance properties of MDF. The Melamine resin and Basic Green (Malachite Green) 4 crystal were introduced into UF resin separately to improve its water resistance properties. In both cases the water resistance properties were improved. Also economic analysis was carried out for both additives and finally it was concluded that Melamine is not only improved water resistance properties but also economically feasible. The addition of the Melamine has represented in an improved quality of MDF with strong mechanical adhesion, and water resistance. For example the mechanical adhesion (which is called internal bond) was increased by 5 %, and the Water resistance was increased by 15 %.
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1. Introduction

Medium density fiberboard (MDF) is a type of wood sheet produced under optimum Pressure and temperature by using wood fiber or other plant fiber as a raw materials and applying the urea formaldehyde resin. [1]. The density of MDF in production is generally control between 690 – 750 kg/m3. The performance index of MDF is divided into three categories, i.e. Physical performance, Mechanical performance and Biological performance.

The Physical performance mainly include: Density, Moisture content, thickness swelling etc. The Mechanical performance mainly include: internal bonding, Modulus of Elasticity (MOE), Modulus of rupture (MOR), screw holding force (face and side).

The Biological performance mainly include: the release of Formaldehyde. [1]

1.1 MDF Production Process Flow

MDF production process consists of different stages, i.e. materials preparation, Fiber separation, Fiber treatment, Mat forming, Hot pressing, Board trimming and sanding, as shown in MDF process flow chart in figure.1.

1.2 Malachite Green

Basic green (Malachite green) is an organic compound, basically green powder with Metallic luster. The molecular formula of Malachite green is $C_{52}H_{54}N_4O_{12}$.

Properties of Malachite green are:

a. It is easily soluble in water

b. It is extremely soluble in Ethanol.

c. Its solution in water is Blue-green.

d. Basic green dyes become yellow in concentrated sulphuric acid

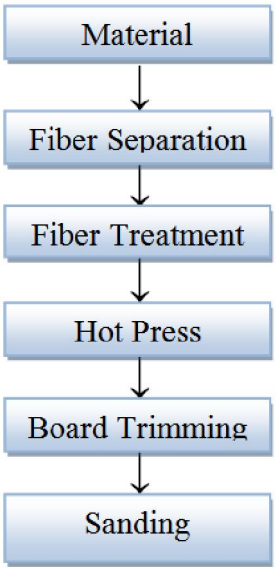

Figure 1.1: Production Process flow of MDF [2].

Figure 1.2: Basic Green 4 (Malachite green)

2. Material and Methods

UF and Melamine formaldehyde resin and Malachite Urea Formaldehyde resin have some properties, i.e. PH value, Gel time, Viscosity, Specific gravity, Solid content etc.

In order to calculate the above properties the following methods and procedures are used.

2.1 PH value Calculation

There are two methods for calculating the PH value of the Resin. One way of measuring the PH value is the use of PH paper.

Procedure: The PH strip is immersed in UF resin for a minute. Then the strip is taken out and compare the pH value with PH scale (0- 14) numbers. The PH value of UF resin is from 7.5 – 8.5 means that the UF is alkaline.

Figure 2.1(a): A PH strip is immersed in Resin

In second method, a PH meter is used to measure the PH (acidity or alkalinity) of UF. It consists of a glass electrode and electronic meter as shown in fig. The electrode is connected to the electronic meter that measure and display the PH value.

Figure 2.1(b): Digital PH Meter

Procedure: Before using the Ph meter, the electrode is washed with distilled water. Then the PH meter is calibrated with Buffer solution of PH 4, 7 or 10. The UF resin or Melamine resin or Malachite added resin,s sample is taken in a beaker and set it on room temperature, i.e. 25 Cº. The glass electrode is then dipped to resin sample. The PH value on the display is allowed to stabilize. After stabilizing the final reading is taken from display indicator.

2.3 Specific Gravity Calculation

The specific gravity of UF, Melamine or Malachite added resin is measured by an apparatus called Hydrometer. Hydrometer consists of a graduated tube and a bulb at its end as shown in fig.3.

Procedure: The resin is taken in a graduated cylinder and adjusted its temperature to 25 Cº. A hydrometer is inserted in the graduated cylinder in such a manner that the bulb of the meter is dipped down. The mercury is raised in the meter and after stabilizing it on graduated cylinder, the reading is taken.

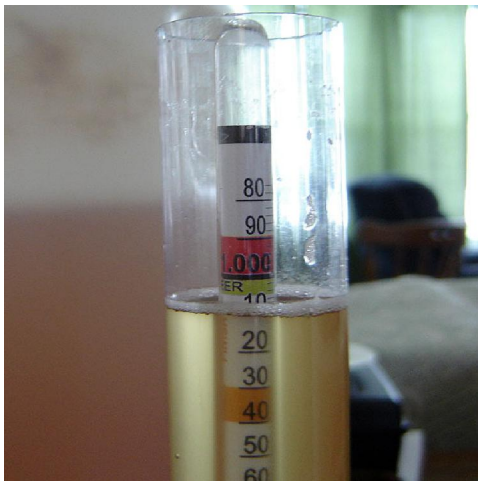

Figure 2.2: Hydro Meter

2.2 Gel Time Calculation

The gel time of the resin is the time period in which it becomes too viscous to flow. The gel time has a very important role in MDF manufacturing. The gel time measurement is illustrated below.

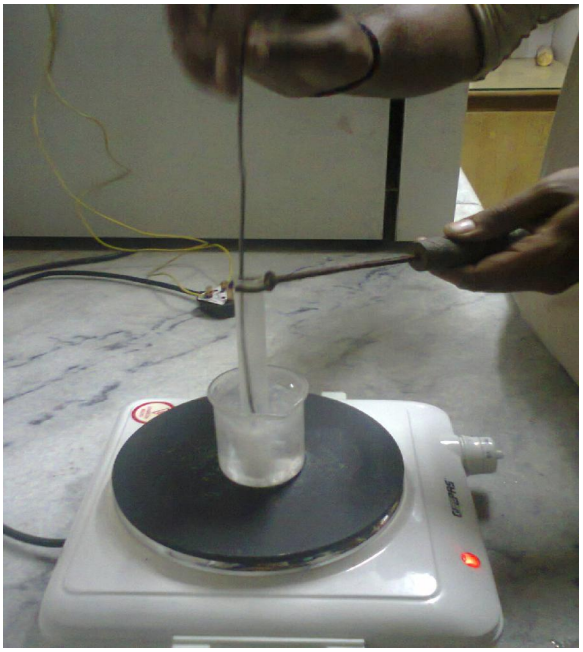
Figure 2.3: Gel Time Measurement Apparatus

Procedure: Take 50 ml UF resin in a beaker. Now add 1.4 ml of hardener (Ammonium Chloride) (NH4Cl) to UF resin and mix it. Now take a sample of mix UF resin in a graduated cylinder and put it in water bath at 100 □ C) and on stop watch. Stirrer the resin till it becomes solid and stops the stop watch. Now note down the time from stop watch.

2.4 Viscosity Calculation

Viscosity is the resistance of a liquid to flow. The viscosity of UF, MUF or Malachite added resin is generally measure with viscosity cup as shown in fig.5. The viscosity cup has an orifice of 3mm (ISO standard) at the bottom.

Procedure: A known volume of UF resin is passed through this orifice and note down the time flow through stop watch. The viscosity of UF resin is between 200 – 300 cps (centi poise).


Figure 2.4: Viscosity Cup

2.5 Solid Content Calculation

The solid content of UF, MUF or Malachite added resin is the remaining percentage after its drying.

Procedure: take one gram of UF, Melamine or Malachite added resin and put it in an aluminum foil cup. Now weight it. This will be "Wt". Now put the aluminum foil cup fill with UF or Melamine resin in oven at 105 □C) for 2 hours. After 2 hours take out the foil cup and find its weight. This will be W2.


Figure 3.5: solid content Measurement Apparatus

Then using the following formula find out the solid content:

Solid content (%) = Wt – W1 / Wt x 100

2.6 Thickness in Swelling Calculation

Thickness swelling is the difference of initial specimen thickness to the variation of final thickness after water soak test in percentage.

Figure 2.6: MDF pieces for Swelling in Thickness

Procedure: Take a piece of MDF specimen 50 mm X 50 mm and measure its thickness, i.e. T1. Now immersed the sample of MDF in cold water for 24 hours. The samples are then taken out from water tray and find its thickness, i.e. T2. The swelling in thickness (TS) is calculated by the following formula:

Ts (%) = T1 – T2 / T1 x 100

3. Results

3.1 UF Resin Properties

UF resin properties were determined using the above procedures and a table was formed.

Table 3.1. Properties of UF Resin

Properties	Values	
	Range	
Color	Trans--	Milky
Solid Content (%)	60-----	60 ± 1
Gel Time (s)	100----	100 ±5
pH	8.0-----	8.5
S.Gravity	1.26---	1.28
Viscosity	200 ---	300

3.2 Melamine Formaldehyde resin properties

Similarly, Melamine resin properties, i.e. color, PH value, Gel time, solid content, specific gravity and viscosity were determined and put in the form of table as illustrated in Table 3. 2.

Table 3.2: Properties of Melamine Resin

Properties	Values
Color	Transparent
Solid Content (%)	66
Gel Time (s)	195
pH	7.0
S.Gravity	1.2 ± 0.2
Viscosity(cps)	125 --150

3.3 Melamine Urea Formaldehyde resin properties

As earlier discussed that UF has poor water resistance. In order to increase its water resistance properties, 20 gm of Melamine resin was added in 1000 gm of UF resin. The mixture of both resin were poured into a beaker and shacked it for 5 minutes. The mixture of resins is then used for determining the following properties.

Table 3.3: Properties of Melamine Urea Formaldehyde Resin

Properties	Values
Color Transparent	/Milky
Solid Content (%)	60
Gel Time (s)	115
pH	6.7
S.Gravity	1.26
Viscosity(cps)	220

3.4 Formulation of Malachite Green

In order to prepare the solution of Malachite green, the following composition of ingredients were made.

Table 3.4: Composition of Malachite green solution

S. No	Ingredients	Quantity	Unit
1	Water (H2O)	80	Kg
2	Malachite green	6	Kg
3	Caustic (NaoH)	75	gm

Samples of the above solution were tests in laboratory for its PH value. The PH thus calculated through Ph meter was 3.2. This value indicates that the solution is highly acidic. But as we know that PH value of UF resin is 8.5.

The Malachite green solution was added in UF resin in such a proportion that its PH value maintain between 6 and 6.5.

Table 3.5: Composition of Malachite green Urea Formaldehyde Resin

S.No	Properties	Value
1	Color	Blue Green
2	PH	6
3	Gel Time	80 sec
4	Solid content	61 %
5	Specific Gravity	1.27 kg/m³
6	Viscosity	250 cps

For comparison and improved water resistance properties, the experiments were performed on 16mm boards. One was manufactured using only 10% Malachite UF resin and the other was manufactured using 10% Melamine UF resin.

Table 3.6: Constant parameters for 16 mm board

S.No	Parameters	Value	Units
1	Moisture content	9	%
3	Hot press temp	190	□C
4	Pres closing time	35	Sec
5	Thickness of board	16	Mm
6	Total press cycle	320	Sec
7	Wax	0.9	%

The other parameters were kept constant in both cases. The constant parameters are shown in table 3.6.

Table: 3.7 Comparison of 16mm board Properties (UF)

S.No	Properties	Values	Units	EN standards	Test Method
1	Moisture content	7.5	%	7 ± 3	EN322
2	Density	730	kg/m^3	720-740	EN323
3	Swelling in thickness	15	%	≤ 12	EN317
4	Internal Bonding	0.65	N/mm²	≥ 0.6	EN319
5	Modulus of Elasticity	3100	N/mm²	2500	EN310
6	Modulus of Rupture	31	N/mm²	≥ 30	EN310
7	Screw Holding face	1015	N	≥ 1000	ASTM1761
8	Screw Holding edge	741	N	≥ 700	ASTM1761

Table: 3.8 Comparison of 16mm board properties with standard value using MUF Resin

S.No	Properties	Values	Units	EN standards	Test Method
1	Moisture content	8	%	7 ± 3	EN322
2	Density	725	kg/m^3	720-740	EN323
3	Swelling in thickness	12.8	%	≤ 12	EN317
4	Internal Bonding	0.7	N/mm²	≥ 0.6	EN319
5	Modulus of Elasticity	3150	N/mm²	2500	EN310
6	Modulus of Rupture	32.5	N/mm²	≥ 30	EN310
7	Screw Holding face	1040	N	≥ 1000	ASTM1761
8	Screw Holding edge	750	N	≥ 700	ASTM1761

Table: 3.9 Comparison of 16mm board properties with standard value using Malachite UF Resin

S.No	Properties	Values	Units	EN standards	Test Method
1	Moisture content	8	%	7 ± 3	EN322
2	Density	725	kg/m^3	720-740	EN323
3	Swelling in thickness	12.8	%	≤ 12	EN317
4	Internal Bonding	0.7	N/mm²	≥ 0.6	EN319
5	Modulus of Elasticity	3150	N/mm²	2500	EN310
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7	Screw Holding face	1040	N	≥ 1000	ASTM1761
8	Screw Holding edge	750	N	≥ 700	ASTM1761

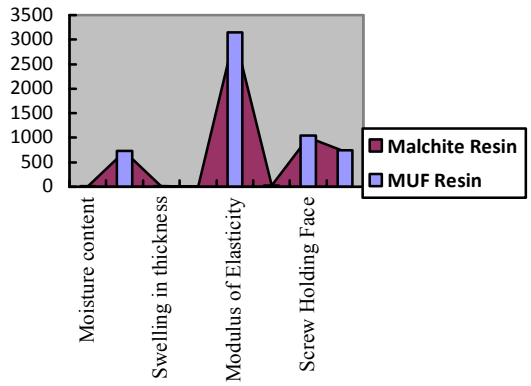

Fig: 3.6 Comparasion Chart b/w Malchite UF & MUF Resin Based Properties of MDF

4. Economic Analysis of Malachite Green and Melamine Resin

As we know from formulation that:

Melamine consumption /sheet = 0.19 (kg/sheet)

Price of 1 Kg of Melamine = Rs. 150/Kg

Melamine cost per sheet = Rs = 28.5

Similarly,

Malachite Green consumption / sheet = 0.07 (Kg/sheet)

Price of 1 Kg of Malachite Green = Rs = 700 / Kg

Malachite cost per sheet = Rs = 49

Cost Difference = Rs. 20.5

For a 154 M^3 capacity plant, Production/day = 3240 sheets (16mm)

Cost saving /day = Rs. 66420

So it is clear from economic Analysis that Melamine is also economically better than Malachite Green.

Discussions

The 16mm boards samples using Malachite UF and MUF resins were manufactured and properties were compared and it was found that almost all properties were according to the standards. Moreover, using MUF, the swelling in thickness property was improved by 15%. And Mechanical adhesion (which is called internal bond) was increased by 5 %. Economic Analysis was also carried out and it was analyzed that Melamine is economically better resin.

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