Enhancement of Wood Preservation Technology by Pressure and Non-pressure Process and comparison of their properties.

Md.Amzad Hossain, Prof.Dr.A.N.M.Mizanur Rahman, Md.Mahmudul Hasan, Srabani Karmakar, Md.Asad-uz-zaman

Abstract-Wood is a very valuable thing in this world. Wood is used in various purposes say for making house utilities, as a fuel. Most of the People around the world don't have proper knowledge about wood preservation. Since the total amount of wood is reduced day by day hence it is the time to maintain environment al equilibrium by proper utilization of consumption of wood. First time ever in Bangladesh, the variation of wood properties was observed by applying most two effective methods namely pressure and non -pressure processes .the properties like as Moisture content (%), weight reduction (%), penetration depth, retention, nature of preservative coating was observed carefully. By applying full cell pressure process and various non- pressures process (Brushing, Deeping, and Steeping), it was observed that the treated wood life is increased by 5 to 10 times and it is clear from this project that the durability of wood under pressure process is much more greater than that of the durability of wood founded by non-pressure process. It is very effective method of wood preservation which protects the wood from various insects, termites, torrents etc. Hence in order to stable the Bio conservation and maintain the environmental equilibrium such types of wood preservation techniques will control and reduce the consumption of excessive wood and hence makes the environment more fresh and powerful.

Index Terms-wood preservation technology, enhancement of wood properties by new technology, preservation cost minimization

1 INTRODUCTION

WOOD is one of the earth's most valuable and abundant renewable natural resources. It is a gift of nature and is the only working material that is self-generating. Wood preservation can play an important role in bio-conservation and protection of environment. The main enemies of wood which damage it are fungus, termites, beetles, carpenter ants and marine borers.

• *Md. Amzad Hossain is a Lecturer and currently pursuing master's degree in Department of Mechanical Engineering at Khulna University of Engineering & Technology, Bangladesh. E-mail: amzad59@mail.com*
• *Prof.Dr.A.N.M.Mizanur Rahman is a Professor, Department of Mechanical Engineering at Khulna University of Engineering & Technology, Bangladesh. E-mail: drmizan@me.kuet.ac.bd*
• *Md. Mahmudul Hasan is a student of Department of Mechanical Engineering at Khulna University of Engineering & Technology, Bangladesh. E-mail: parvej.me@gmail.com*
• *Srabani Karmakar is a Masters student of Department of Mechanical Engineering at Khulna University of Engineering & Technology, Bangladesh. E-mail: sshraboni@rocketmail.com*
• *Md. Assad-Uz-Zaman is a student of Department of Mechanical Engineering at Khulna University of Engineering & Technology, Bangladesh. E-mail: assad_kuet08@yahoo.com*

Besides this temperature, rain and the ultra violet ray can damage the timber. The amount of damage by the second is negligible in comparison to the first enemy. By proper preservation method, it is possible to protect the wood from these enemies. Preservation is the way and the only appropriate way to make the timber toxic and protect it [1]. With suitable chemical treatment, the life of timber can be increased to 5-10 times its normal life and its fire resistive property to 2-3 times the normal. The preservative treatment depends on the wood species, moisture content and its anatomical structure. . The widely used preservation method in Bangladesh is Full-cell pressure process. Beside this, soaking or dipping method are used for different wood species because it is very simple method and anyone can treat wood by this method. Wood, bamboo and sun grass were treated with Chromated-Copper-Arsenate (CCA) but after some laboratory trials at Forest Research Institute (FRI), Chromated-Copper-Arsenate (CCA) is being replaced by Chromated-Copper Boric acid (CCB) due to low cost and availability in the market [4.] Chromated-Copper-Boric acid (CCB) is not only low cost material but also environmental friendly. A pilot system for wood preservation was developed at KUET where domestic aspect was in consideration. There is no doubt that huge amount of wood is still in use commercially without precise knowledge of wood preservation. So, there is a huge loss of timber which reduces the limited resources of wood. To find out the best way of saving wood and also find out the cost effective way it is necessary to treat wood commercially. So treating wood commercially is the main concern of this project.

2MATERIALS AND METHODOLOGY

2.1 Materials Selection and Methods:

2.1.1 Material:

In the study, it appeared that mango was highly treatable. Maximum penetration occurred along the grain while the least in the tangential-radial directions in all the species studied. This is in agreement with the literature that longitudinal permeability of preservatives is usually several thousand times greater than transverse permeability Wood structure pore size, pit aspiration and moisture content influence permeability. Out of that only moisture content was controlled.

Comparative studies of various species are illustrated below.

Table 3.1: Comparative study of life, durability and treatability of various species.

Name	Botanical name	Specific gravity	Maximum life(month)	Average life(month)	Durability	Treatability
Mango	*Mange/era indica*	0.54	9	6	Non-durable	A
Rain Tree	*Samania saman*	0.59	15	10	Durable	C
Neem	*Azadiracta indica*	0.76	>37	30	Highly durable	D
Jack fruit	*Artocarpus heterophyllus*	0.49	>48	40	Highly durable	C

- A-Highly treatable, penetration range more than 4 cm
- B-Treatable, penetration range 2-4 cm
- C-Moderately treatable, penetration range 1-2 cm
- D-Very hard to treat, penetration below 1 cm

2.1.2 Method of Preservation:

A process of preservative treatment of wood is that, which uses a pressure vessel and first draws a vacuum on the charge of wood and thee introduces the preservative without breaking the vacuum. This process is also known as Bethell process. The sequence of procedures used in the full cell process is shown in Figure 3.1, and is summarized below:

a)Dried wood were enclosed in a pressure cylinder or retort.

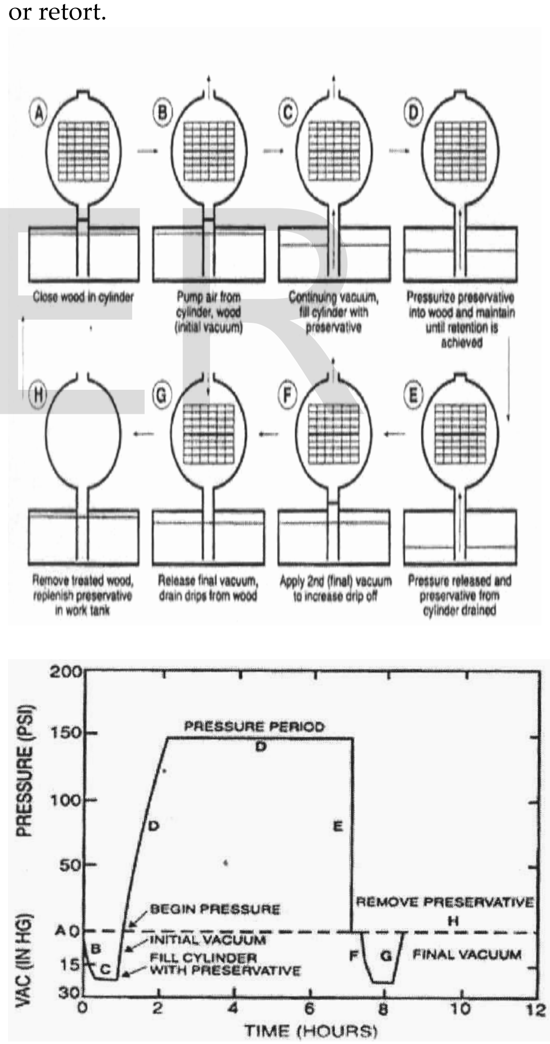

Fig. 3.1: Treating sequences and pressure change in the full cell process.

b) A vacuum pump to remove most of the air from the cylinder was used. A partial vacuum of about 550 mmHg was hold to allow air to be removed from the wood.
c) Without releasing the vacuum, the cylinder was allowed to fill with preservative.
d) A pressure 7 bar was applied to the preservative by an air compressor to force into the wood cell previously occupied by air, now occupied by a partial vacuum.
e) When the desired and measured amount of liquid preservative has been absorbed; applied pressure was released and drained the cylinder.
f) A "final" vacuum 550 mmHg was applied to expand the air remaining in the wood. This forced excess liquid to exude from the surfaces and run off.
g) Final vacuum was released. As the remaining air in the cells contacts, much of the surface wetness was reabsorbed into the wood. At last the treated wood products were released from the Cylinder.

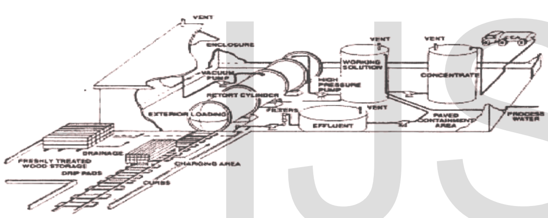

Fig 3.2: Conceptual view of CCB Pressure Treating Plant.

Features of the Full Cell Process Include

It gives the deepest possible penetration and the highest loadings (retentions) of preservative with easily-treated species. Virtually all of the air in the wood cells can be replaced with preservative. Sometimes this may produce a higher loading than necessary. The degree to which penetration and retention of preservative occurs depends on the permeability of the wood. For effective treatment, some species may need special preparation such as incising, steaming, or boultonizing. No vacuum-pressure process is more effective than the full cell in maximizing the uptake or penetration of preservative.

2.1.3 Method of Determining the Preservative Penetration

Penetration is the depth to which there has been penetration of preservative. After dipping, the samples were dried for the determination of penetration and retention. The penetration of preservatives into the timber can easily be determined on site by using color reagents.

Method for Determining the Penetration of Boron

Reagents: The indicator solutions were prepared in the laboratory following AWPA standard A3 (1996).

Solution I:

Exactly 10 gm turmeric with 90 gm ethyl alcohol was taken and was filtered to obtain clear solution.

Solution 2:

Dilute 20 ml of concentrated hydrochloric acid was diluted to 100 ml with ethyl alcohol and then it was saturated with salicylic acid. Generally 13 gm salicylic acid is required per 100 ml solution.

Procedure

The sample for penetration assay was dried prior to make the final cut to expose the surface for spraying. A smooth surface shows the results of the spot test better than a rough surface. The surface must be dried otherwise the test will not be satisfactory. Solution I was applied, preferably by spraying, or with a dropper, on the surface to be treated. The surface being treated was then allowed a few minutes to dry. Solution 2 was then applied in a similar manner to the areas that had been coloured yellow by the application of solution l. The color changes were observed carefully and had shown up a few minutes after application of the second solution. In the presence of boron, the yellow color of the turmeric solution was found turned red.

Method for Determining the Penetration of Copper

Solution:

Exactly 0.5 gm Chrome Azurol S concentrated and 5gms sodium acetate was dissolved in 80 ml of water and dilute to 500 ml

Procedure:

The solution was sprayed over freshly cut surfaces of treated wood sample. Deep blue color reveals the presence of copper and dried wood gave better results. The chemical needed for testing the penetration of boron and copper is not available and these are also costly. As this testing procedure is not cost effective so these methods have not been done but easy method has been done to measure the penetration by using extended borer.

2.1.4 Determination of Preservative Retention

Retention refers to the weight of dry salt absorbed per cubic meter of wood. Preservative retention of wood samples was calculated by the volumetric analysis. To determine the retention, two weights of every sample were taken i.e., oven dry weight before treatment and oven dry weight after treatment. Then the weight of preservative solution penetrated in the sample, was calculated from the difference of that two weights. Retention was expressed as lb/cu ft. Finally, the following formula was used to determine the retention

$$\text{Retention} = \frac{\text{Weight of salt (preservative)}}{\text{Volume of sample}}$$

2.2 Design a Treating Chamber

The treating chamber is filled with preservatives and wood specimen is dipped into this preservative solution and the pressure will apply for treatment the wood efficiently. So, considering the pressure and the amount of preservative that use in treatment process, the design specification is made.

Calculation of cylinder wall thickness (for diameter 0.60m):

Considering,

Material AISI C1020 As Rolled

Yield strength, $S_y = 3.27*10^8$ N/m^2

Factor of safety, $N_{sy} = 5$

Cylinder diameter D = 0.60m

Working pressure P = 7 bar = $7*10^5$ N/m^2

Design stress = (48/5) = $6.53*10^7$ N/m^2

According to the book of "strength of materials, fourth edition" the following formulas are used [15]:

$$\text{Hoop stress, } \delta_t = \frac{PD}{2t}$$

$$\text{Or, } 6.53*10^7 = \frac{7*10^5*0.60}{2t}$$

$$\text{Or, } t = \frac{7*10^5*0.60}{2*6.53*10^7}$$

Or, $t = 3.32*10^{-3}$ m

Or, t = 3.32 mm

Considering a welded joint with welding efficiency, η = 70%

$$\text{The thickness } t = \frac{PD}{2*\delta_t*\eta}$$

$$\text{Or, } t = \frac{7*10^5*0.60}{2*6.53*10^7*0.7}$$

Or, $t = 4.67*10^{-3}$ m

Or, t ≡ 4.67 mm

Or, t = 5 mm

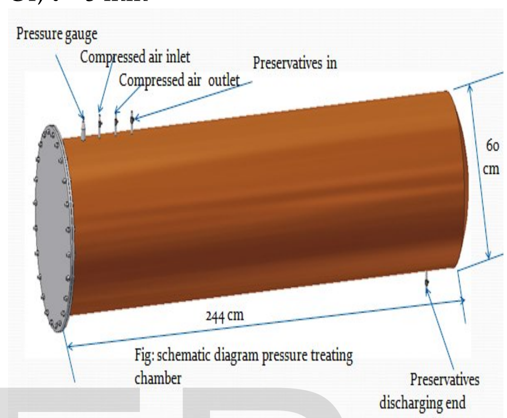

Fig 3.3: Preservative Treatment Cylinder.

Pressure chamber is designed considering its resistance to withstand pressure 10 bar (Fig 3.3). The design specifications are:

Cylinder diameter = 60 cm, Cylinder length = 244 cm

- Gate diameter = 71 cm
- Cylinder flange, outer = 71 cm, inner = 60 cm
- Cylinder bottom = 60 cm

2.3 Selection of Vacuum Creating Device:

In full cell vacuum pressure process, a vacuum creating device (Fig 3.5),vacuum pump or air compressor with reverse flow of air is connected with the treating chamber to create initial vacuum about 550 mm Hg, or 73.36 kPa inside the closed chamber. The vacuum pump is selected of capacity 64 l/min or 1 hp.

2.4 Design of a Seasoning Chamber:

The seasoning chamber (Fig 3.4) has been designed and constructed considering the temperature of that chamber. It consists of three major parts namely solar collector, storage and a chimney. The dimension of the storage is 244 cm×107 cm×153 cm. The dimension of the collector surface is 244 cm×183 cm. The temperature inside the dryer has increased up to 53^0 C when outside temperature was 33^0C.

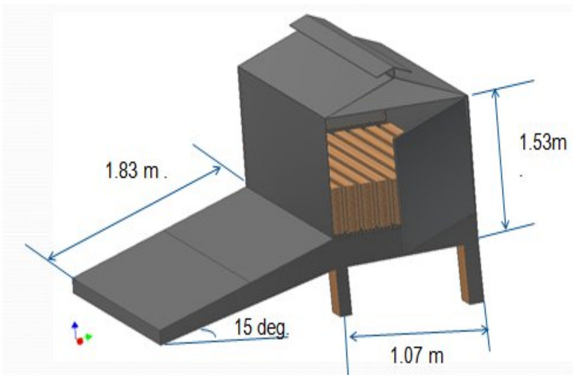

Fig 3.4: Schematic diagram of a Seasoning Chamber

2.5 Selection of Pressure Creating Device:

A certain amount of pressure required to penetrate the preservatives into the wood specimen which is developed by pressing device. In full cell process, it is required to attain pressure ofabout 5 bars to 7 bars. A v-type2 cylinder compressor (Fig 3.6) is selected whose capacity rating is 8 bar and motor having capacity of 7.5 KW.

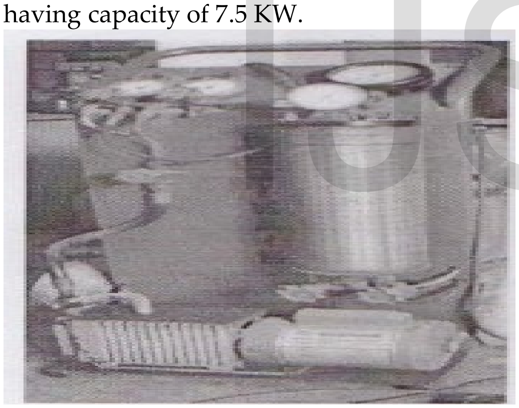

Figure3.5: Photograph of Vacuum Pump

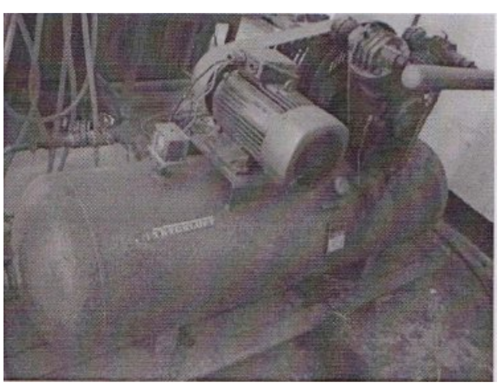

Figure 3.6: Photograph of Air Compressor

Figure 3.7A: photograph of seasoning chamber

Figure 3.7B: wood stacking phenomena.

Figure 3.7C: photograph of pressure treating chamber.

2.6 Construction of Treating System:

2.6.1 Material Used in Treating System:

To construct the treating cylinder the following material were also used.

Table 3.2: Table of components and materials

Components	Materials
1. Main Cylinder	5 mm thick and 0.60m dia. MS sheet
2. Cylinder Gate	10 mm thick and 0.71m dia. MS plate
3. Sealing Material	0.71 m dia. rubber tube
4. Nuts and Bolts	24 nos MS nut and bolts
5. Valve	5 nos
6. Pressure Gauges	10 bar capacity
7. Solution Tank	Plastic Tank
8. Reservoir Tank	Plastic Tank

2.6.2 Construction of Preservative Cylinder

According to design consideration, the thickness of cylinder was chosen 5 mm and material was chosen MS plate which was bended and welded to desired shape as a cylinder. Gate of the cylinder was made by 10 mm thick MS plate whose diameter was 0.71 m.

3.0 Experimental Setup and Data Collection

3.1 Preparation of Solution:

The components of preservative chemicals as Potassium Dichromate ($K_2Cr_2O_7$), Copper Sulphate (CuS04) and Boric Acid (H3BO3) which are available in local market. The entire components are commercial grade, which should have in excess of 95% purity as per American Wood Protection Association (AWPA) Standard P5, 2002.

Since the moisture content of the testing sample is around 15% hence the required amount of chemical solution is 5% of CCB. So, for the first charging, the weight of Potassium dichromate, copper sulphate and boric acid in preparing CCB chemicals solution of 291 litres are given below:

Potassium Dichromate- 5.8 kg
Copper Sulphate- 5.8 kg
Boric Acid- 2.9 kg
Total- 14.50 kg

CCB chemicals of 14.50 kg weight having P^H = 4 and mixed 291 litres of water for making 5% solutions. After first charging, the volume of chemical solution absorbed by testing wood sample is 111 litres. Hence, for the second charging, the remaining chemical solution is reused and mixed with new chemicals in order to create a solution of 347 litres .These volume of chemical solution is totally depends on the volume of testing wood sample placed in pressure treating chamber and also depends on the volume of air gap allowed here. For second charging, the P^H of the chemical solution was maintain about 4.3 and for making 347 litres of chemical solution the total weight of the chemical component are:

Potassium Dichromate- 6.94 kg
Copper Sulphate- 6.94 kg
. Boric Acid- 3.47kg
Total- 17.35 kg

The numbers of treated wood samples are 52 pieces of size 183 cm×30.5 cm×2.54 cm and after that, these wood samples are placed in a seasoning chamber then all the physical properties of wood are measured.

3.2 Experimental procedure:

In non-pressure process, green wood was first dried in seasoning chamber. When sufficient amount of moisture was reduced then wood is coated by coal-tar creosote. This coated wood was further dried in seasoning chamber up to oven dried weight. Then several properties of wood were measured.

In pressure process, firstly oven dried wood were placed in pressure treating chamber. Then chemical was charged into the pressure treating chamber and applied high pressure and kept it for 1 day in order to gain proper penetration of chemical preservative into the wood. Then treated wood was released from pressure treating chamber and kept it in to seasoning chamber. When the oven dried weight was found then several properties of wood were measured.

3.3 Experimental Data:

In order to compare the properties of treated and untreated wood several required data were collected. These are listed below:

Variation of Wood Properties for Non-pressure Process:

3.3.1 Weight Reduction:

At solar kiln wood was dried and all the data after removal of moisture was measured and presented here with Table 4.1.

Table 4.1: Table for change of weight of wood specimens during drying

Date	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6
12-04-11	1320	1380	1320	1330	1410	1330
13-04-11	1200	1290	1235	1215	1290	1220
14-04-11	1135	1220	1160	1145	1222	1150
15-04-11	1100	1160	1118	1090	1180	1110
16-04-11	1055	1118	1080	1040	1125	1060
17-04-11	1020	1080	1040	1002	1090	1030
18-04-11	990	1053	1010	970	1060	1002
19-04-11	970	1034	992	950	1040	988
20-04-11	955	1025	980	935	1021	975
23-04-11	920	972	933	910	982	940
24-04-11	905	968	922	896	969	930
26-04-11	891	964	911	882	956	920
01-05-11	878	960	900	869	943	910

3.3.2 Percentage of Weight Reduction:

Initially the amount of moisture contained in woods specimen is high so the rate of weight reduction is greater. During the seasoning process, the moisture of wood specimen is gradually decreased hence the percentage of weight reduction is also decreased. The percentages of weight reduction of selected wood specimen are given below:

Table 4.2: table for change of percentage of weight reduction:

Date	Sample-1 W.R%	Sample-2 W.R%	Sample-3 W.R%	Sample-4 W.R%	Sample-5 W.R%	Sample-6 W.R%
13-04-11	9.09	6.52	6.44	8.65	8.51	8.27
14-04-11	4.92	5.07	5.68	5.26	4.83	5.26
15-04-11	2.66	4.35	3.18	4.14	2.98	3.01
17-04-11	2.65	2.75	3.03	2.86	2.48	2.26
18-04-11	2.27	1.96	2.27	2.41	2.13	2.11
19-04-11	1.51	1.37	1.36	1.5	1.42	1.06
20-04-11	1.14	0.36	0.91	1.23	1.35	0.98
24-04-11	1.13	0.289	0.83	1.05	0.93	0.75
26-04-11	1.05	0.25	0.80	0.98	0.92	0.73
01-05-11	0.98	0.23	0.77	0.94	0.88	0.69

3.3.3 Density:

Due to change of weight, density of wood specimen also changed and this change is listed below at Table 4.2A & Table 4.2B.

Table 4.2A: Change of density of sample wood specimens treated by Brushing process:

Sample No	Before Treat-ment Weight in, kg	After Treat-ment Weight in, kg	Density before treat-ment in, kg/m^3	Density after treat-ment in, kg/m^3
01	0.801	0.918	678.82	777.97
02	0.812	0.925	688.13	783.90
03	0.839	0.929	711.02	787.29
04	0.834	0.940	706.78	796.61

Table 4.2B: Change of density of sample wood specimens treated by Dipping process:

Sample No	Before Treat-ment Weight in, kg	After Treat-ment Weight in, kg	Density before treat-ment in, kg/m³	Density after treat-ment in, kg/m³
01	0.790	0.915	669.49	775.43
02	0.802	0.930	679.66	788.14
03	0.837	0.949	709.33	804.24
04	0.840	0.950	711.86	805.08

3.3.4 Retention:

After treatment of wood with preservative solution, it was dried at solar kiln and weight was measured and subtracted this weight with the weight of untreated wood which indicate the amount of preservative was retained and dividing it with unit volume of wood specimen retention was found. Retention of preservative in test wood specimen was calculated and listed in Table 4.2C & 4.2D.

Table 4.2C: Retention at different wood specimens treated by Brushing Process:

Sample No	Before Treatment Weight in, kg	after Treatment Weight in, kg	Retention in, kg/m³
01	0.801	0.918	99.15
02	0.812	0.925	95.76
03	0.839	0.929	76.27
04	0.834	0.940	89.83

Table 4.2D: Retention at different wood specimens treated by Dipping Process:

Sample No	Before treatment Weight in ,kg	After treatment Weight in ,kg	Retention in, kg/m³
01	0.790	0.915	105.93
02	0.802	0.930	108.48
03	0.837	0.949	94.92
04	0.840	0.950	93.22

3.3.5 Moisture Contents:

For the good treatment of wood ,moisture content should maintain below 25%.At solar kiln, wood was dried and moisture content was reduced to average 71.5%.This reduction of moisture is listed below at Table 4.2E.

Table 4.2E: Percentage reduction of moisture content of wood specimens.

Date	R.M.C Sample 1	R.M.C Sample 2	R.M.C Sample 3	R.M.C Sample 4	R.M.C Sample 5	R.M.C Sample 6
13-04-11	7.89%	9.84%	6.30%	8.73%	9.98%	8.37%
16-04-11	26.43%	30.37%	27.36%	24.55%	28.18%	24.78%
20-04-11	37.98%	44.56%	39.90%	34.98%	41.00%	37.37%
24-04-11	47.18%	51.63%	46.74%	44.52%	50.00%	45.46%
26-04-11	54.64%	59.62%	53.40%	51.72%	57.02%	54.56%
30-04-11	63.07%	60.72%	56.98%	60.80%	59.86%	62.29%
02-05-11	68.04%	62.21%	64.24%	68.10%	63.96%	65.65%
04-05-11	70%	66%	68%%	72%	67%	69%
08-05-11	72%	70.5%	70%	72.5%	71%	71.5%

Variation of Wood Properties by Pressure Process:

3.3.6 Density:

Due to change of weight, density of wood specimen also changed and this change is listed below at Table 4.3A

Table 4.3A: Change of density of sample wood specimens treated by Full-cell Pressure process:

Sample No	Before Treat-ment Weight in, kg	After Treat-ment Weight in, kg	Density before treat-ment in,kg/m³	Density after treatment in, kg/m³
1	3.8	4.0	357.68	376.52
2	7.0	9.3	539.67	716.94
3	6.1	8.1	470.29	624.48
4	7.5	9.0	578.22	693.86
5	6.8	10.0	524.25	770.96
6	7.9	9.1	609.06	701.57

3.3.7 Retention:

After treatment of wood with preservative solution, it was dried at solar kiln and weight was measured and subtracted this weight with the weight of untreated wood which indicate the amount of preservative was retained and dividing it with unit volume of wood specimen retention was found. Retention of preservative in test wood specimen was calculated and listed in Table 4.3B.

Table 4.3B: Retention at different wood specimens treated by Full-cell Pressure process:

Sample No	Before treatment Weight in ,kg	After treatment Weight in ,kg	Retention in, kg/m³
1	3.8	4.0	19.78
2	7.0	9.3	177.32
3	6.1	8.1	154.19
4	7.5	9.0	115.65
5	6.8	10.0	246.71
6	7.8	9.1	100.25

4.0 RESULT AND DISCUSSION

4.1 Result:

This process is an adaptation of the Bethell process for use with waterborne preservatives like CCB. It achieves full penetration with a reduction in the weight of water left in the wood. So, drying is important before preservative treatments. Multistage solar kiln was used to dry the sample woods. At first wood specimen was sized as required dimension and collected and arranged in different stages. Proper sealing reduce the heat loss inside the chamber and helps to utilize the heat and dry quickly. A solar collector was attached with it to increase the amount of heat gain inside the kiln chamber. Transparent plastic was used to produce green-house effect and trap heat. This heat vaporized the water particle inside the wood and dried it.

Different types of relevant data were placed in chapter IV. Now the graphical representations of those data are given below:

- Graphical representation of wood properties treated by Non-pressure process:

The graphical representation of Table 4.2 is

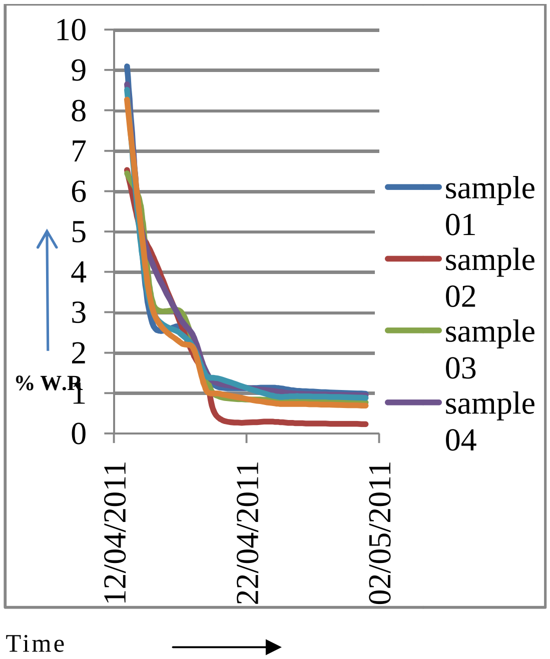

Figure 5.1: Percentage of weight reduction Vs. Time

The graphical representation of Table 4.2A is:

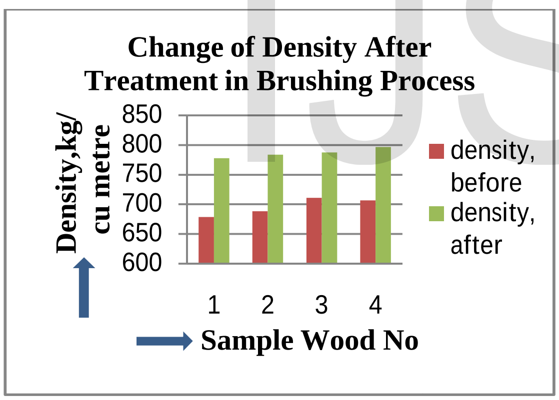

Figure 5.2A: Change of density before and after treatment for individual four test sample in Brushing process.

The graphical representation of Table 4.2B is:

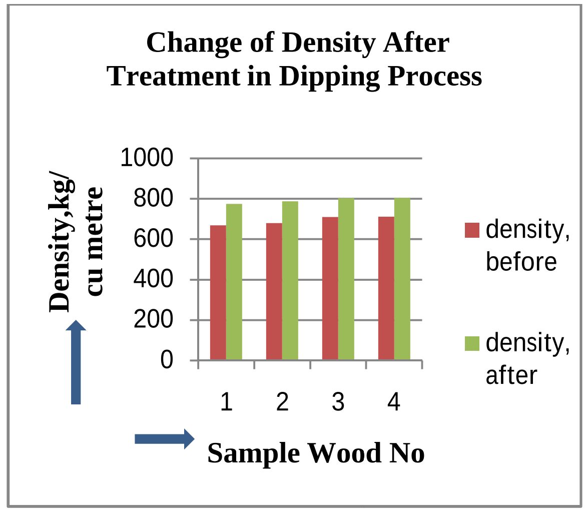

Figure 5.2B: Change of density before and after treatment for individual four test sample in Dipping process.

The graphical representation of Table 4.2C is:

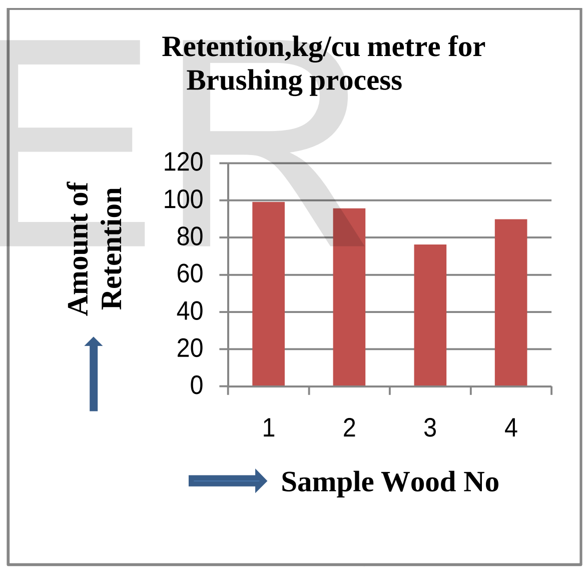

Figure 5.2C: Retention of different test wood specimen in Brushing process.

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The graphical representation of Table 4.2D is:

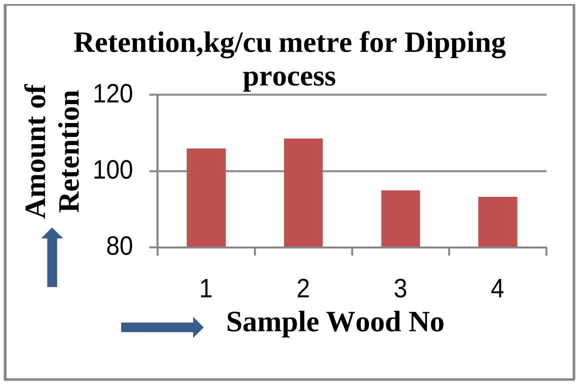

Figure 5.2D: Retention of different test wood specimen in Dipping process.

The graphical representation of Table 4.2E is:

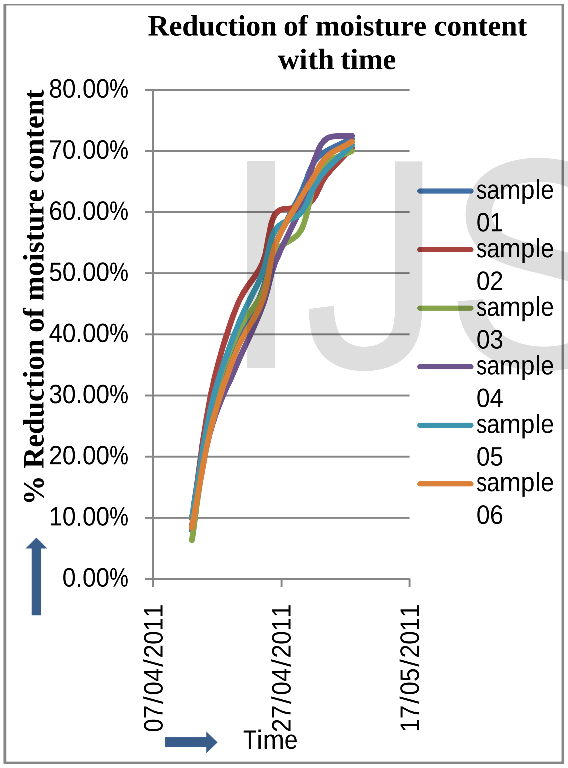

Figure 5.2E: Percentage change of reduction of moisture content.

➢ Graphical representation of wood properties treated by Full-cell Pressure process:

The graphical representation of Table 4.3A is:

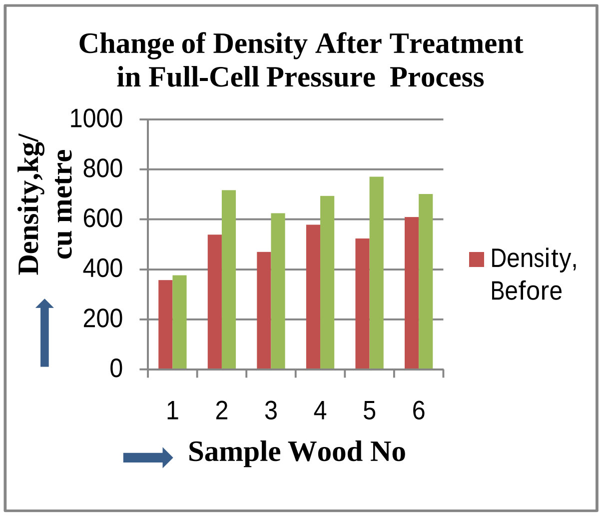

Figure 5.3A: Change of density before and after treatment for individual six test sample in Full-cell pressure process.

The graphical representation of Table 4.3B is:

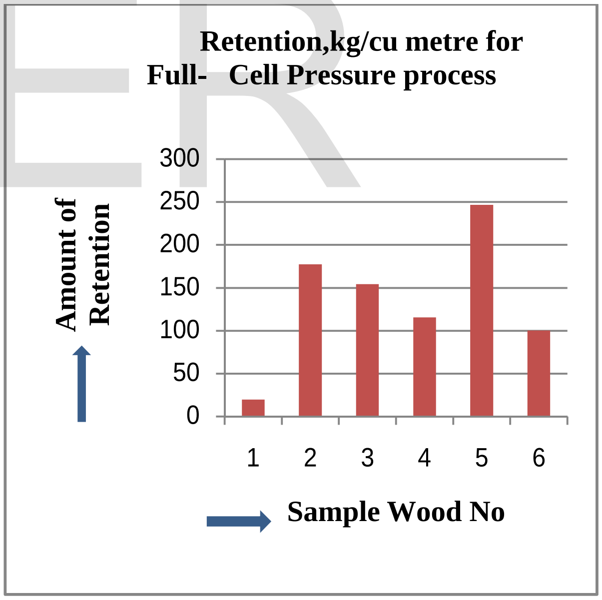

Figure 5.3B: Retention of different test wood specimen in Full-cell pressure process.

5.0 Cost analysis and comparison

5.1 Cost for drying chamber:

Let, working days per year = 250

For drying each lot of wood requires 7 days in summer, 9 days in winter, 14 days in rainy season

Average required days for drying each season = 10days

So, total 25 lots can be dried in 250 days

Capacity of drying chamber i.e. amount of wood in each lot = (7 inch×2.75 inch×3.5 inch) = 67.375 ft^3 ≡ 70 ft^3 (here some spaces were kept free for easy loading and unloading).

Total construction cost of drying chamber = 13,000Tk.Economic life = 1 yr.

So, construction cost per lot = (13000/25) = 520 Tk.

Cost per cft = (520/70) = 7.43 Tk.

5.2 Cost for pressure treating chamber:

Here, one lot can be treated in each day

So, total 250 lots can be treated in a year

Amount of wood in each lot = 17 ft^3

Total cost of pressure chamber = 30,000 Tk.

Economic life = 5 yr.

So, cost per year = (30,000/5) = 6000 Tk.

Cost per lot = (6000/250) = 24 Tk.

Cost per cft = (24/17) = 1.41 Tk.

5.3 Chemical Cost:

- For pressure process: 17 ft^3 woods were treated in each charging Chemical cost per charging = 6000 Tk.
- Chemical cost per cft = (6000/17) = 353 Tk.
  For non-pressure process:
  Cost of coal-tar creosote per day = 780 Tk.
  Amount of treated wood specimen per day = 5 ft^3
  So, cost per cft = 156 Tk.

5.4 Labour Cost:

- For pressure process:
  Labour cost per cft = (200/17) = 11.76 Tk.
- For non-pressure process:
  Labour cost per cft = (200/10.08) = 19.84 Tk.
- Labour cost per cft during loading and unloading of wood sample in drying chamber = (loading or unloading time ×cost per working hour)/volume of wood sample per lot in drying chamber = (50/70) = 0.72 Tk.
  So, Actual labour cost per cft in pressure process = 11.76+0.72 = 12.48 Tk.
  And actual labour cost per cft in non-pressure process = 19.84+0.72 = 20.56 Tk.

Name of process / Cost per cft	Pressure process	Non-Pressure process
Cost of drying chamber/cft in tk.	7.43	7.43
Cost of pressure treating chamber/cft in tk.	1.41	---------
Chemical cost/cft in tk.	353	156
Labour cost/cft in tk.	12.48	20.56
Total cost/cft in tk.	374.32	184

5.5 Comparisons of wood properties:

The wood has been treated by pressure and non-pressure process but the change of treated wood properties are different .these differences are given below:

- The density of wood found by pressure process is better than non-pressure process. Again in non-pressure process the density of wood found by Dipping process is better than Brushing process.
- The chemical has penetrated highly in pressure process comparatively in non-pressure process. So, the depth of penetration is higher in pressure process than non-pressure process.
- The value of retention in pressure process is greater than non-pressure process.
- The cost per cft of wood in pressure process is greater than non-pressure process.

The above comparisons are shown in table (4.2A to 4.2D, 4.3A, 4.3B) and graph (4.2A to 4.2D, 4.3A, 4.3B). From the above discussion it can be said that the pressure process is better than non-pressure process.

6.1 Discussion:

Weight of test wood specimen was reduced as it was dried at solar kiln. At cabinet type solar drier, the temperature was not fixed but fluctuated with solar intensity. As a result the loss of weight was not uniform which was shown in Figure 4.1. According to the Figure 4.1 at first the weight of wood reduces rapidly downward but after some days, this change was comparatively low. The amount of preservative penetrated in test wood specimen was indicated in Art. 5.0 after adding the solution named chrome azurol. This solution was reacted with CCB chemicals and forms a dark color zone which showed the length of penetration. Variation of pressure and duration of time of treatment, the penetration was also varied. For this project, the pressure was chosen 7 bar considering the treatability of mango wood and kept this pressure about 16 hours. In first case, 291 litres of CCB chemical was charged and in second case, additional 167 litres were added with previous 180 litres measured after treatment, total 347 litres of CCB chemical was charged and analyzed their comparative penetration.

Due to the mechanical difficulties associated with sealing a high pressure chamber and also operating its valves and fluctuation of temperature in seasoning chamber.

The cost per CFT of treated wood sample in pressure process is 373.6 taka and in non-pressure process is 233.62 taka.

6.2 Conclusion:

Wood is a renewable natural resource that typically is preservative treated to ensure structural integrity in many exterior applications. Treating wood can withstand fungal decay and insect damage and it is critical to producing a high quality wood product. Necessity of wood in our country is increased but our resources are limited. Again the durability is not same for all wood species. So that wood preservation process help for better utilization of wood. But sometimes wood preservation process is so expensive which also increase the price of wood. So proper design of a wood preservation system will minimize the price of wood and make it available to all.

6.3 Recommendations:

In this project the following recommendation can be done.

- Natural preservatives like Neem extract and NECB can be used as it is non-toxic which will reduce the cost of chemicals for making CCB solution.
- Process time can minimize by increasing pressure within limit of process plant. By using glass instead of polythene in cabinet type solar drier, temperature inside drier can raise more and give better result for reducing moisture content in less time.
- Rain Tree can be used instead of mango tree as both of them are moderately durable but treatable species and have interlocked grain.

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