IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 8 Issue 1, January 2021
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

Properties Of Light Weight Engineered Wood Composite Made Using Foaming Chemical

B.S. Mamatha[1], Sujatha.D[2], Uday D. N[3], Prakash V[4], Kiran M.C[5]

[1]Scientist E., Indian Plywood Industries Research and Training Institute, MoEF&CC, GoI,Bangalore,India,

[2]Scientist F., Indian Plywood Industries Research and Training Institute, MoEF&CC, GoI, Bangalore, India

[3]Scientist F., Indian Plywood Industries Research and Training Institute, MoEF&CC, GoI, Bangalore,India, [4]Scientist D., Indian Plywood Industries Research and Training Institute, MoEF&CC, GoI, Bangalore,India, [5]Scientist D., Indian Plywood Industries Research and Training Institute, MoEF&CC, GoI,Bangalore, India

Abstract

In this study characteristics of foaming and pot life of the ammonium carbonate, ammonium bicarbonate and sodium carbonate in phenol formaldehyde (PF) and Melamine urea formaldehyde resin (MUF) were analysed to understand the best possible formulation. The light weight wood composites of varied formulations were manufactured in a single step with and without veneer overlay for a thickness of 12mm and density 500=700Kg/m3. Influence of Polyethylene glycol (PEG) along with foaming chemical on the properties of the board were analysed. Physical and mechanical properties of the composites were evaluated. As per IS:3087. Results indicated that ammonium carbonate of 4.5- 10% with Phenol formaldehyde resin and Melamine urea formaldehyde resin has reduced the total weight and density of the products. Viscosity changes with temperature for ammonium carbonate incorporated adhesive has been displayed Veneer overlaid wood particle composite has shown high strength properties. light weight composite panels can be successfully manufactured using foaming agent.

Key words: Foaming agents, Light weight panels, particle board wood composites, engineered, veneer overlay

I. Introduction

At present there exist a healthy competition among particleboard manufacturers and pulp mills. Thus, there is acute shortage of raw material for the manufacture of wood composites which has led to the search of alternative panel product. Lightweight panels are increasingly used in construction sectors, which include doors, house hold furniture, cabinets, shelving, etc. The main reasons for the lightness of engineered panel are design trends, easy to handle, transport cost would be reduced and ease of assembly for the customers. The reduction in the amount of raw material required to make these panels light weight due to the non-availability of wood is also one of the important factor for the necessity of light weight panels.

Engineered wood composites such as particle board are manufactures using any lops and tops of trees or any agri residues. Using of the low density materials allows reducing the structural weight of products. That may result in substantial savings of material. It has been reported that a weight saving of over 27% is attainable in most of the structures due to the lower density of composites without compromising with their inherent properties. Density of the panels were also tried to reduce by the foaming process, the low density of the light intermediate layers can be achieved in an efficient manner. Many studies have carried out the foaming process by thermally activating an aerating agent, in particular, with subsequent physical or chemical reaction of the aerating agent. The main reason is that porous components allow reducing the amount of raw materials and fuelling consumption at the same time The lightweight wood composite panels could provide a solution for housing constructions that accomplish the similar task as conventional panels with less quantity of raw material input.

R. F. Sterling (1990) describes a phenol-formaldehyde resin formulation using peroxide as a foaming agent at a temperature between 110° C and 350° C. Peter J. Crook et al (1975) synthesized a self-catalyzing phenol-formaldehyde resin foam formulation by cross linking a strong acid moiety into the resin as a pendant sulphonyl group. Honeycomb boards with the phenolic foam of a density of 7-20 Kg/m^3 on both sides in the cavities of the honeycomb was the method developed by Yasuhiko Watanabe et.al (1990). Phenol-formaldehyde resin foam was developed using nitrogenous modifier, capable of permitting dispersion of the blowing agent in the resin, and a surfactant along with an acid catalyst system dispersed in a liquid polyhydroxy compound by krishan sudan & Antonnie Berchrm (1983). GAO, M., et.al (2016) have used dicyandiamide as a toughening agent to alter the brittleness of the phenolic foam. Hang et.al. (2010) have reported that Melamine Formaldehyde (MF) foam has attracted much attention all over the world. D.W Wang et.al (2012) has prepared MF resin foam by microwave radiation. Ali Shalbafan et.al (2010, 2011 & 2013) has developed foam core particle boards using expandable microspheres and polystyrene as core layer. The development of lightweight wooden structure followed different patterns for core density reduction in earlier days. The use of composite structures has become an increasingly important factor in engineering design. The light weight panels if characterized apart from being light with fire-resistant, thermally insulating, and of high strength are much useful for building panels, and also in transportation equipment. Many studies have been worked on the utilisation of plastic foams in the manufacture of light weight panels, whereas fewer studies were conducted on the utilisation of foaming chemicals in the manufacture of wooden panels. However, the load capacity and functionality of lightweight engineered wood panels is highly dependent on compacting their cover layers as much as possible and on minimizing the density of the intermediate layers. Hence a study was carried out to study the properties of light weight particle board made using foaming chemicals.

II. Materials and methods

Poplar particles were used for the manufacture of light weight panels. Phenol formaldehyde resin (PF), Melamine urea formaldehyde resin (MUF), were used for the study. Phenol Formaldehyde resin with weight ratio of phenol to formalin being 1:1.6 and 1:1.8 with 6-8% of catalyst was synthesized in a batch reactor. Melamine Urea Formaldehyde resin with weight ratio of (0.5M+0.5U): 2F was synthesized in the resin kettle at a pH of 8.5-9.0. The flow properties of the resin were maintained as given below in **Table 1**.
Phenol Formaldehyde resin/ Melamine Urea Formaldehyde resin having the above properties were taken in a beaker. A known percentage of ammonium carbonate, sodium carbonate and ammonium bi carbonate (which acts as foaming agent) were added to the resin. Stearic acid of about 1% on the weight of liquid phenol formaldehyde resin and 2.5% of melamine were added to the resin admixed using mechanical stirrer with the foaming agents. 10% poly ethylene glycol was also used in this study.

In the rheometry experiments a TA Instruments AR 1000 model rheometer was used to characterize the cure of both resins. a temperature ramp of 10°C per minute was used upto a temperature of 150C. An initial gap of 0.5mm was used that allowed for enough sample to gather data.

The resin admixed with the above ingredients were heated at 100°c to evaluate the time taken for the formation of foam and the foaming behavior of the resin. An amount of foam formed is quantified using the measuring jar, electronic balance and stop watch. The said formulations with different foaming agents were kept at 25^0C in the laboratory to study the pot life of the adhesive at 30, -,200 minutes.

Manufacturing process: Particles of slenderness ratio around 50-8- for core and 160-180 for face respectively were used for the manufacturing of three layered particle board. However, for single layer particle board, slenderness ratios of 80-160 were used. Particles were dried to a moisture content of 3-4% before blending with the adhesive incorporated with the foaming agents. Light weight panels of three compositions were manufactured viz: single layered (B1, B2), Multi layered (B3, B4, B5) and veneers of 1.6mm were overlaid on single layered particle board in single step process (B6, B7). The details of the boards formulated are given in Table 2, 3, 4. The particles were blended with resin on dry solid basis. The glue blended particles were placed into a mat forming box with base dimensions of 330mm x 330mm.Prepressing and compression of the particles were done by pressing a matching wooden plate on the mat in the forming box by applying manual pressure. Considering the foaming agent added in the glue Care was taken to mat form and press the boards accordingly. Supporting rods to control the thickness to12mm were placed on either ends of the assembly. The assembly was then loaded into a hot press of size 350mm x 350mm wherein temperature of the platens was maintained at 165 – 170 °c for particle board. Pressure of 25 kg/sq cm for compression cycle and 12 -14 kg/cm^2 for curing cycle with requisite curing time for respective resin systems were employed.

The boards were kept for stabilization for about 24 -48 hours to attain equilibrium moisture content and then trimmed. The trimmed boards were further dimensioned to required sizes and subjected for testing as per relevant specifications.

Table-1: Properties of Resin

Sl. No.	Particulars	MUF	PF
1.	Flow time of resin in B4 flow cup	22 ±2 seconds	24 ±4 seconds
2.	Water tolerance	1:2- 1:3	1:8- 1:10
3.	Solid content	50%	48%
4.	Shelf life	One month @ ambient temperature	One month @ ambient temperature

Table 2. Compositions of Single Layered Particle board

Composition	B1	B2
MUF resin(g)	144	144
Ammonium chloride(g)	0.6	0.6
Ammonium carbonate(g)	14.5	14.5
Polyethylene glycol (ml)	14.4	0
Stearic acid(g)	1.5	1.5
Wax(g)	1.5	1.5

Table 3. Compositions of Multi layered Particle board

Compositions	B3		B4		B5	
	Face	Core	Face	Core	Face	Core
MUF resin(g)	55	76				
PF Resin(g)			55	76	55	76
Polyethylene glycol(ml)	-	-	5.5	7.6		
Ammonium Carbonate(g)	2.75	3.8	2.75	3.8	2.75	3.8
Stearic acid(g)	1.5	2	1.5	2	1.5	2
Melamine(g)	3	3	-	-	-	-
Wax(g)	0.6	0.8	0.6	0.8	0.6	0.8

Table 4 Compositions of Single layered particle board overlaid with Veneer

Composition	B6	B7
PF resin(g)	90	90
Polyethylene glycol (ml)	-	9.0
Ammonium carbonate(g)	7.2	7.2
Stearic acid(g)	2.5	2.5
Wax(g)	1.5	1.5

III. Results and Discussions

The pot life of the formulations was visually observed and measured in B6 flow cup once in 30 minutes for each percentage addition of chemicals to understand the working conditions of the adhesive. It was observed that the adhesive prepared using sodium carbonate and ammonium bicarbonate thickened in both the amino resin and

ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

phenolic resin individually at a 1-2% addition on the percentage of liquid resin. The adhesive thickens with shorter span of 45 - 60 minutes at ambient temperature, and started gelling within a shorter duration indicating a faster reaction. With increase in viscosity in shorter period, the adhesive penetration and its interaction with the wood particles would inhibited bonding forming the starved joint leading to the failure of bond between resin and wood particles. Hence, sodium carbonate, and ammonium bicarbonate practically was not feasible, whereas ammonium carbonate yielded better pot life up to 150-170 minutes.

To quantify Foam Formation, for every 50ml adhesive taken the foaming of 50 ml was measured with the foaming agent of ammonium carbonate, ammonium bicarbonate while for sodium carbonate the foam formed was 25ml on the weight of the resin taken. Hence based on the foaming behavior and the pot life of the adhesive mix achieved on the laboratory, the adhesive mix with ammonium carbonate was employed for the manufacture of light weight composites.

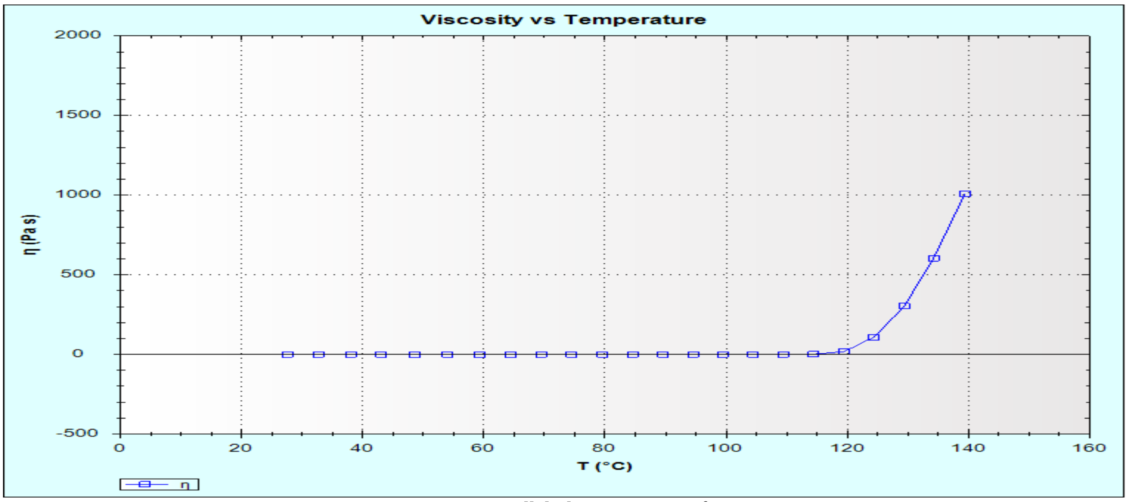

Fig.1. parallel plate viscosity of PF resin

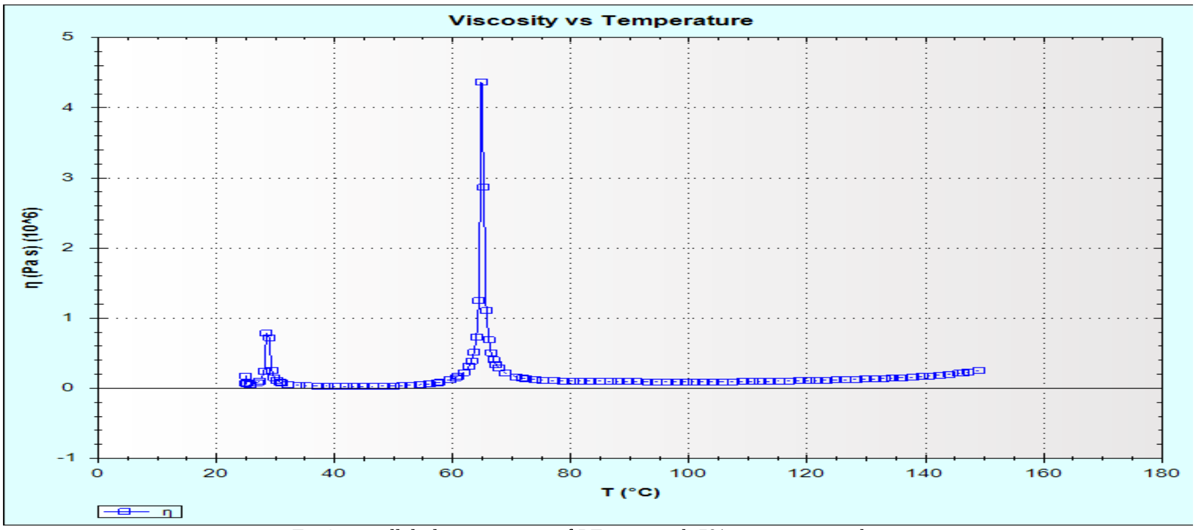

Fig.2. parallel plate viscosity of PF resin with 5% ammonium carbonate

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 8 Issue 1, January 2021
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

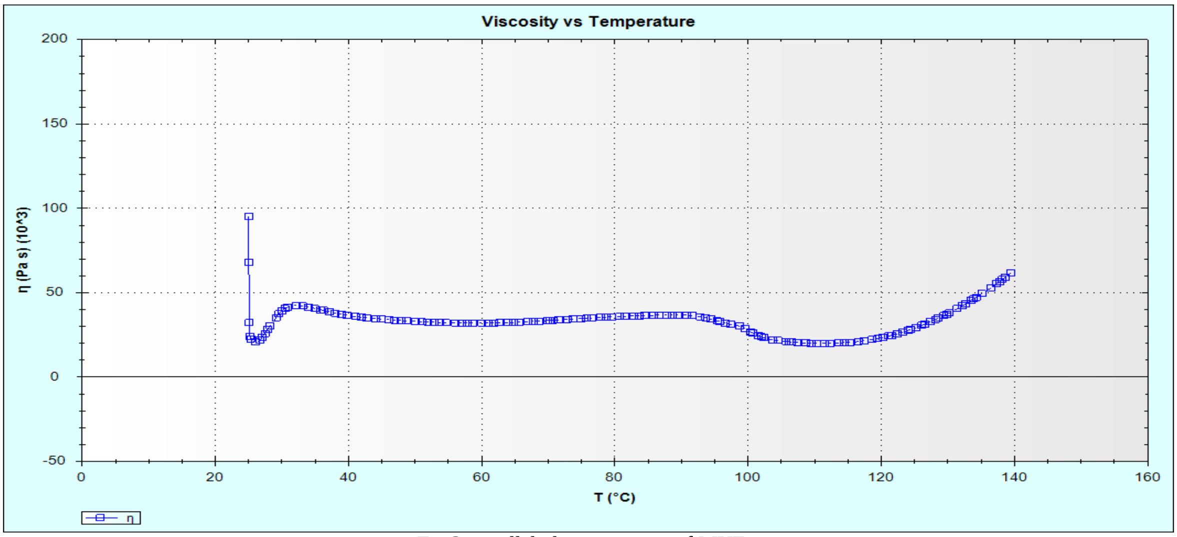

Fig.3. parallel plate viscosity of MUF resin

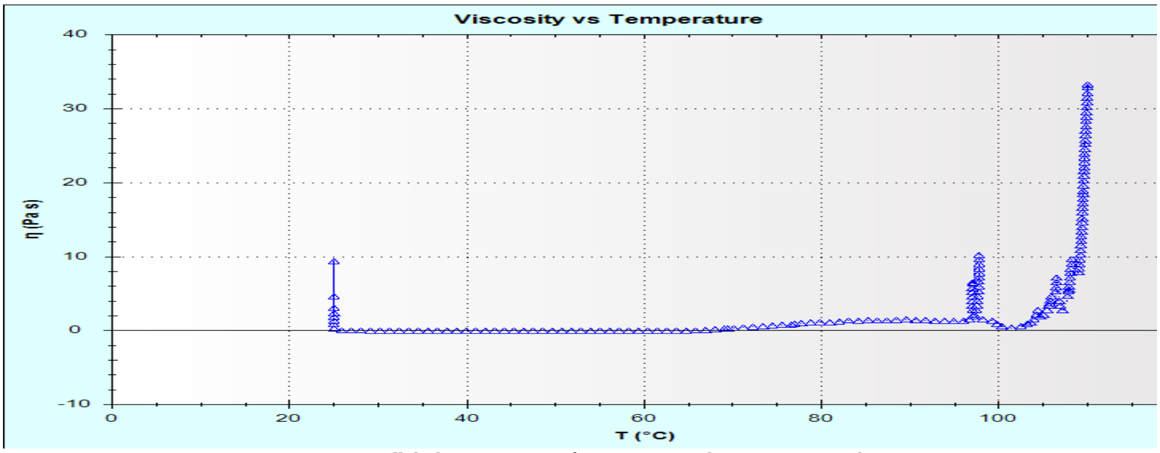

Fig-.4. parallel plate viscosity of MUF resin with Ammonium carbonate

With the rheological method different modules and other physical properties of material are measured as a function of temperature. Based on these parameters, which depend on the curing temperature and time, the whole curing process of PF and MUF resin with and without ammonium carbonate (Fig 1-4), was determined. The parallel plate rheometer showed that the PF resin initiated curing after 130^{0}C as the increase in viscosity was observed after 125C (Fig-1). peak after 60^{0}c in the ammonium carbonate incorporated PF resin (Fig-2) was observed. MUF resin (Fig-3) showed the systematic mobility of molecules till 100^{0}C. slight decrease in viscosity was observed for 100-120 C, then increase in viscosity was observed after 120 C indicating the crosslinking of the reaction. MUF resin incorporated with ammonium carbonate showed rise in viscosity after 102^0 C indicating the onset of curing. (Fig-4). Ammonium carbonate presence has decreased the curing temperature.

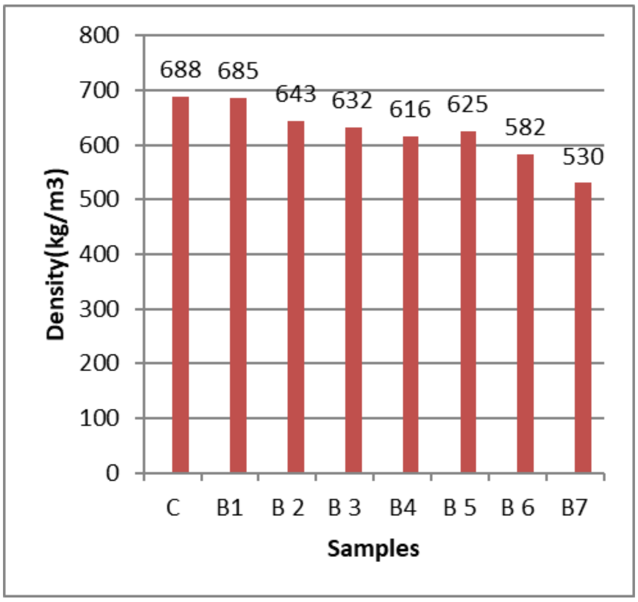

Fig-5 Density of light weight panels

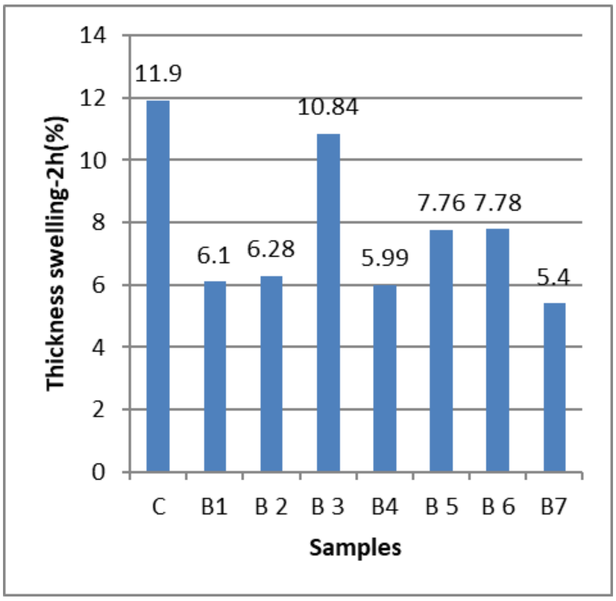

Fig-6Thickness swelling properties of light weight panels

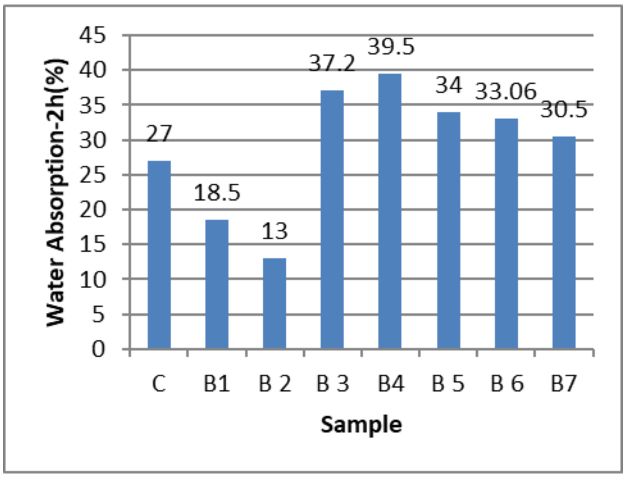

Fig-7 Water absorption (2h) property of light weight panels

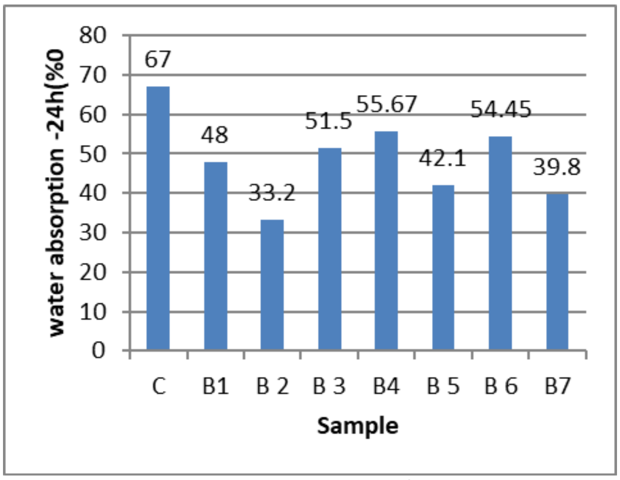

Fig-8 Water absorption (24h) property of light weight panels

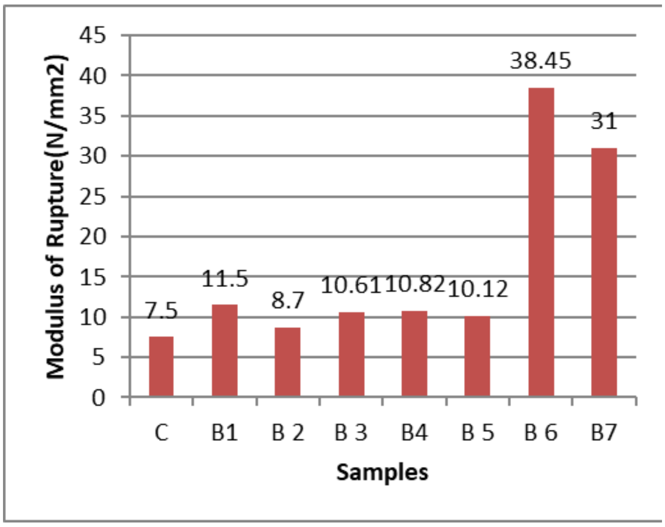

Fig-9 Modulus of Rupture of light weight panels

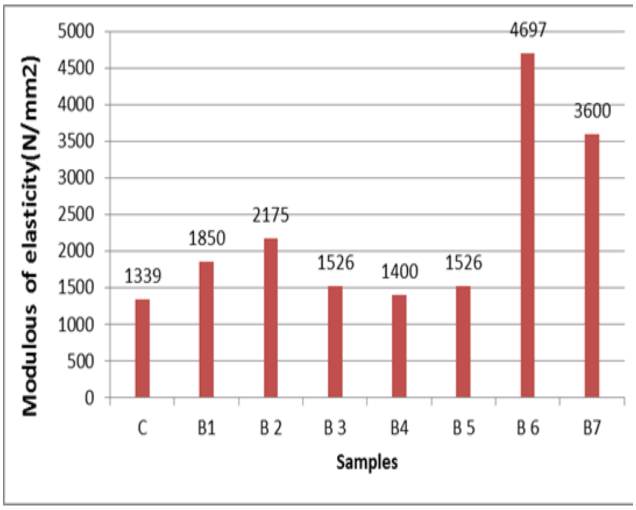

Fig-10 Modulus of Elasticity of light weight panels

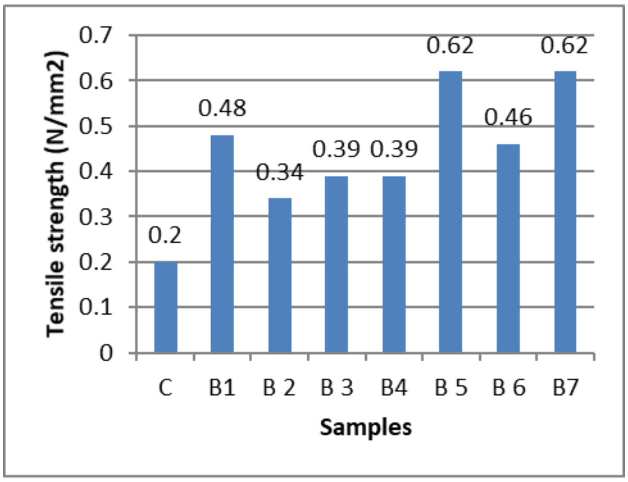

Fig- 11Tensile strength property of light weight panels

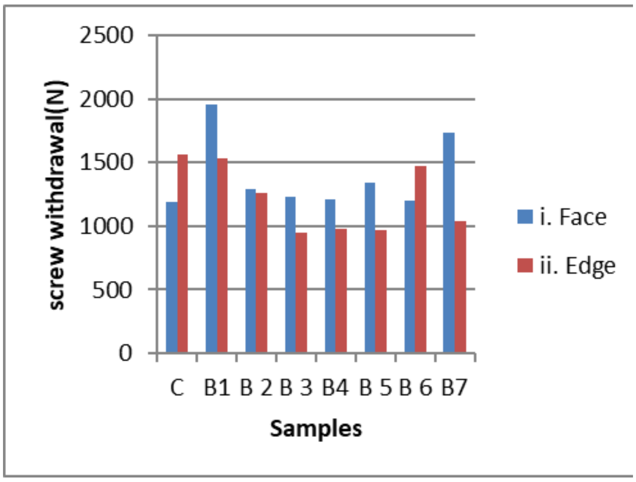

Fig- 12 Screw withdrawal property of light weight panels

All the panels' density was in the range of 530-680 kg/m3. Fig-1-7 shows the physical and mechanical properties of composites, of adhesive incorporated with the ammonium carbonate. All the boards made using foaming agent has shown better physical and mechanical properties than the controlled board. It can be observed that the density of the single layered boards made using MUF resin incorporated with ammonium carbonate is relatively equal. Board made by the addition of PEG along with ammonium carbonate in MUF resin yielded enhanced tensile strength, MOR and water absorption properties than the board made without PEG.

Phenolic based resin formulation along with ammonium carbonate has shown better properties than amino based resin incorporated foaming chemicals except MOR. Phenol formaldehyde resin is a non-gap filling adhesive, foaming agents made glue line more brittle. The brittleness of the adhesive has led to the reduction in the property of the panels. Incorporation of polyethylene glycol along with the ammonium carbonate in phenolic resin has shown negligible difference in all the properties except tensile strength properties. than the board made without PEG. Comparable properties were observed with the Boards made with the addition of Melamine in MUF resin and or the addition of PEG in PF resin along with ammonium carbonate. Small difference in the MoR and MoE of the boards made with and without PEG has been observed.

Single layer particle board overlaid with Veneer manufactured in a single step has observed the board density 530-580kg/m^3. Incorporation of PEG in PF has shown 9% reduction in the density of the boards. With the veneer overlay of 1.6mm during the construction of the panel, the mechanical properties of the boards were 70 % increased

IV. Conclusions

From the research findings, it is concluded that ammonium carbonate can be used as a foaming agent with Phenol formaldehyde resin and Melamine urea formaldehyde resin to reduce the total weight and density of the products. All the boards using foaming agents achieved higher physical properties when compared to control boards. Veneer overlaid single layer light weight panel has shown excellent strength properties Multi-layered light weight panel without overlay showed lower density with optimum physical properties.

Acknowledgements: We thank IPIRTI, an autonomous body of MoEF&cc for funding the project.

REFERENCES

[1[Anon) Particle boards of wood and other lignocellulosic materials (medium density) for general purposes - *Specification 3087, IS: 12406*, New Delhi. 2005

[2[. Ali Shalbafan, Luedtke Jan., Welling, Johannes. and Thoemen, Heiko.. 'Multi–layered Lightweight Panels Made by In-process Foaming: Comparison of Core Materials', In; *Proceedings International Convention of Society of Wood Science* *and Technology and United Nations Economic Commission for Europe – Timber Committee,* Geneva, 11-14 October 2010, Geneva, Switzerland. 2010

[3]. Ali Shalbafan, Luedtke, Jan., Welling, Johannes Sandwich Panels Produced in a One-Step Process Following Different Pressing Schemes: Mechanical and Physical Properties. 1st Think Light – *International Conference on Lightweight Panels,* Ligna Hannover, Germany. .2011.

[4]. Ali Shalbafan., Welling Jan. and Luedtke Johannes. .Effect of Processing Parameters on Physical and Structural Properties of Lightweight Foam Core Sandwich Panels. *Wood Material Science & Engineering*,2013., 8(1):1-12.

[5]. Gao, M., Wu, W., Wang, Y. et al. Phenolic foam modified with dicyandiamide as toughening agent. *Journal of Thermal Analysis and Calorimetry*. 2016, 124(1): 189–195.

[6]. Hang Z. S, F. S Jang, F.Y Ju, S.J Ying, F.M Xu Advances in preparation and application of melamine foam. *Journal of Thermosetting Resin*, 2010. 25(4): 44-52.

[7]. Krishan K,Sudan, Antonie Berchem (. Phenol Formaldehyde Foams .*US patent 4417004A.* 1983.

[8]. Peter John Crook, Stephen Philip Riley. Foamed Reaction product of a resole with a sulphonated Novolac., *US patent 3870661.* 1975

[9]. Robert F Sterling (1953). Cellular expanded thermoset resins. *US Patent 2629698, 1953.*

[10]. Wang D.W, X.X Zhang, D.N Yang, S. Li. Advances in preparation and modification of melamine formaldehyde resin foam [J]. *Highlights of Science paper online* .2012, 5(9): 794-800.

[11]. Yasuhiko Watanabe, Nobuyoshi Nakamura,Yoshinori Kuriyama, Takuji Motegi. Method of making lightweight panels and their core materials. *US Patent 4917742.* 1990

Biography of Authors

Dr. Mamatha.B.S , Msc Chemistry, Ph.D polymer science ,Working as Scientist at Indian Plywood Industries Research & Training Institute [IPIRTI], Bangalore. 15 years in R & D related to Development in the field of Resins and Adhesives, bioadhesives using soya, black liquor lignocellulosic composites manufacturing viz, Bamboo and other agro based residues related technologies on product development. Wood geopolymer composite, transperant wood composite Have been involved in working with Ministry sponsored projects. About 18 papers published in journals/proceeding , 12 research reports, coauthor for the book synthetic resin adhesives for the manufacture of panel products. Life member of indian academy of wood science., bamboo society of India. Have organized 5 international training programme and have 2 patents.

Ms.Sujatha.D , Graduated, with chemical engineering discipline Have been serving as scientist at Adhesive Technology division of IPIRTI since 21 years in R & D related to the field of Resins and Adhesives, Plywood Manufacturing, Bamboo and other agro based residues related technologies on product development. Greater contribution is towards Development of Bio-adhesives, low formaldehyde emissions resins to address the global concerns of green house gas emissions. Chemical treatment to effluent discharged in plywood industries for recycling of water. Involved in the major MOEF&CC, Clean Technology Division funded projects on Development of Bio Adhesives, Field Demonstration & Development of Bamboo Composite/panels for housing in North Eastern region , study on energy auditing in production of panel products, life cycle assessment of wood and bamboo composite products and the data generated in this project has helped to minimize the energy and pollution levels during the manufacturing process of plywood and bamboo composites. Also contributed in all the bio- fibre utilization projects through the development of appropriate processing technology for producing value added composite panels from bamboo, rice husk, jute, coconut coirs, bagasse. wheat straw, chir pine needles, casuarina leaves, banana stem, rice straw, wheat straw etc.,Published one book on “ Synthetic resin adhesives for panel products in India” and contributed as Co-Author for the chapter “Forest Industries for value addition” in the book “Forests and People”. More than 22 research papers has been published in the journal , 20 paper in proceedings of the Seminar/international conference/lecture. 60 Research reports published based on the work carried out under institute funded projects and sponsored project. Published a book on “Synthetic resin adhesives for panel products in India.Co-Author for the chapter “Forest Industries for value addition” in the book “Forests and People”, Have 4 patents and reviewer for three journals

Mr.Uday .D.N B.E. (Mechanical Engg), have been working for 21 years as scientist at IPIRTI R&D related to – process development for manufacturing wood based panels from plantation timbers and other lignocellulosic materials, consultancy services in establishing and maintaining wood based industries, attending to floor level problems in wood based industries. Preparation of Plant layout, Machine specifications, supervision of machine installation and commissioning. Training and education –.Has more than 20 research papers has been published in the journal and 30 paper in proceedings of the Seminar/international conference/lecture. 40Research reports published based on the work carried out under institute funded projects and sponsored project. have 4 patents

Mr.prakash.V B.E. (Mechanical Engg), M.Tech (Mechatronics - Engg) have been working since 12 years as scientist at IPIRTI R&D related to – process development for manufacturing wood based panels from plantation timbers and other lignocellulosic materials, consultancy services in establishing and maintaining wood based industries, attending to floor level problems in wood based industries. Preparation of Plant layout, Machine specifications, supervision of machine installation and commissioning. Training and education – Conducting theory and practical classes for One year post graduate diploma course and short term courses related to Mechanical Engineering aspects involved in manufacturing of wood based panels. Has about 11 journal publications, 11 research reports and 9 papers published in proceedings. Co-Author for the chapter "Forest industry for value addition" in the book "Forests and People" Edited by Dr D. N. Tiwari (2017).

Mr.Kiran .M.C (Mechanical Engg), 12 years in R&D related to – testing and evaluation of products from wood and other lignocellulosic materials. Development of test methods/procedures. Formulation of draft standards for new materials. Issue of draft amendments to existing standards. Testing of wood and wood products. Has above 11 journal publications, 28 research reports and 5 papers published in proceedings.