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Study on anatomical and mechanical properties of plantation grown Melia dubia & Populus deltoids and its suitability for plywood manufacturing

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Abstract— **The anatomical properties of three poplar timber clones viz., G-48, S7C15 and Wimco A26 were studied. From the studies it was observed that the Populus deltoids S7C15 and Wimco A26 clones were showing lower strength value as compared to Melia dubia species. Populus deltoids Clone G48 has shown good anatomical and strength properties when compared with Melia dubia. The anatomical properties of three clones have shown lesser values as compared to Melia dubia. Plywood samples were prepared for three clones, and tested for physical and mechanical properties viz. moisture content, Modulus of rupture (MoR), Modulus of Elasticity (MoE) and water resistance showing pass standard results as per Indian Standard IS: 303 to study their suitability for making plywood.**

Index Terms— **Populus deltoids, Clones, Modulus of rupture (MoR), Modulus of Elasticity (MoE) and Physical properties.**

I. INTRODUCTION

To satisfy the increasing demand for forest products, fast-growing trees such as poplar species grown on managed plantations are being seriously considered for future supply needs. Hybrid poplar species offer a possible solution to the potential shortage of native poplars species. Studies made on mature-juvenile wood characteristics have indicated that parent with high or low wood density produce by hybridizing poplar timbers, the positive characteristics of two fast-growing species can be combined to make an even more harder and faster growing variety. The variability in anatomical characteristics has profound influence on properties of wood. Poplar timbers are one of the easily cloned woody species, which allows for greater availability of promising crosses. During the past 30 years, much work has focused on genetics of *Populus* species (Riemenschneider et al. 1996a) to develop improved hybrids.

Wood from hybrid that have superior growth, improved form, greater adaptability and improved fiber characteristics for paper may be less suited to solid wood processing than wood from parent tree. The mechanical properties of particular hybrid poplar clones for structural lumber have been investigated (Holt and Murphey 1978; Bendtsen et al. 1981; Hall et al. 1982; Brashaw 1995; Kretschmann et al, 1999). This research has shown that the mechanical properties of these trees are comparable with similar native poplar species. Fast-growing clones, however, reach harvestable size more rapidly and therefore contain greater proportions of juvenile wood.

Studies on strength properties of *populus spp*., are have been made by the FRI, this studies includes suitability of *Populus ciliate* for plywood (Rajwat et al, 1989) effect of compression on strength properties (Shukula & Bhatangar, 1989) variation in Density and strength properties (Shukula et al,1991). The relative density of wood is most strongly influenced by the vessel-to-fiber ratio, as well as the diameter and wall thickness of fibers. Poplar species also possess a number of characteristics that present challenges to utilization. Poplar species in general are known to have stems with wet wood pockets, which makes uniform drying difficult. Poplar species stems are susceptible to discoloration and decay, discoloured and decayed wood can be a major defect that limits the value of wood for certain finished solid-wood products such as cabinetry or mouldings of vessel elements.

Poplars develop tension wood quite readily (Isebrands and Parham 1974; Holt and Murphey 1978). Tension wood is reaction wood that is formed on the upper sides of branches and the upper, usually concave, side of leaning or crooked stems. It is characterized anatomically by the lack of cell wall lignification and often by the presence of a gelatinous layer in the fibers. Holt and Murphey's work also showed that planting hybrid poplar trees at different spacing's does not affect the physical, chemical or anatomical properties of one hybrid poplar clone. The suitability of different poplar clones for paper making has been investigated by Labosky et al, 1983. Their work suggests that in general, hybrid poplar species have a high proportion of very short cells (<0.2 mm) and high lignin content compared with trembling aspen. (Murphy et al, 1979) studied the selected wood properties of young Poplar hybrids, within the clones, fiber length increased each year for all three clones and hybrid NE-388 had significantly greater fiber length among clones for each of the 2, 3, 4 yr. Variation of fiber length and fiber width for seven poplar clones was reported by (Yang and Zuo, 2003). Poplar wood is used for the manufacture of a large number and variety of primary and secondary forest products in North America. These products include pulp and paper, lumber, veneer and plywood, composite panels, structural composite lumber, pallets, furniture components, fruit baskets, containers, and chopsticks. In view of rapidly shrinking natural forests the country has to by and large depend on fast growing plantation species for the requirement of wood.

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Although some species like eucalypts, poplar, rubber wood etc., have great potential for producing standard quality swan timber but these fast grown species will tend to be harvested with short rotation periods will contain higher proportions of juvenile wood. Hence the present study helps to analyse the properties of short rotation timbers for their suitability to plywood manufacturing.

II. MATERIAL AND METHODS

Three Clones of *Populus deltoids* logs G-$_{48}$, S_7C_{15} and Wimco A_{26} about 8 years old with average girth of 1.25m and length of 2.54m supplied by M/s Wimco seedlings division, R&D Centre Bagwala, Rudrapur, were taken for the study. All the logs were peeled and converted into veneer sheets. The process is as follows:

Veneer Peeling

Poplar Logs were peeled on a Cremona lathe to obtain face and core veneers. In rotary cutting, the quality of veneer peeled depends on to a great extent, on lathe settings. These are mainly (i) pressure bar compression or associated horizontal gap and vertical gap between tips of knife and pressure bar, (ii) knife angle, (iii) knife bevel angle and (iv) knife height with reference to spindle centers. Among these variables, horizontal gap and knife angle are the most critical ones which require careful adjustment to get better quality veneers.

Four horizontal gaps 95%, 85%, 75% and 65% of the set thickness of veneer and two knife angle sets of at maximum diameter of log 93^0 30' and 93^0 were selected for the study. The knife angle was set to decrease by 1^0 30' from the maximum bolt diameter to minimum bolt diameter positions of the lathe. Veneers of 1.0 mm, 1.6 mm and 2.4 mm thickness were peeled.

The horizontal and vertical gaps were kept uniform throughout the length of the knife and knife edge was aligned horizontally with spindle centers. Horizontal gap, knife angle, knife height measurements were made respectively with a horizontal opening indicator (Sivananda V, 1972), a knife angle indicator and knife height gauge. Vertical gap was set initially using a feeler gauge and was measured to be 0.3 mm and 0.55 mm for peeling 1.0 mm/1.6 mm and 2.4 mm thick veneers respectively. Knife bevel was measured with a bevel protractor and was found to be 19^0.

The effect of horizontal gap and knife angle on veneer quality was evaluated by measuring thickness variation, lathe checks and roughness of green veneer sheets. Five sheets of veneer approximately 1.3 m x 0.6 m size in each lathe settings were studied for quality evaluations.

Thickness measurements were made at 3 positions on each veneer sheet one each at the ends and the other at the center (Sivandnad.V., et al. 1973). Average thickness and range of thickness were calculated for each sheet of veneer. A dial gauge with an accuracy of 0.01 mm having opposing anvil heads and suitably spring loaded to exert uniform pressure on veneer surface was used for thickness measurements. Table 1 desired lathe settings which were determined for peeling core veneers from the species.

Table 1: Suggested lathe settings for peeling face and core veneers

Nominal veneer thickness (mm)	Horizontal gap (mm)	Knife angle	
		At max. dia. of log (degrees)	At min. dia. of log (degrees)
1.0	0.75	93^0 30'	92^0 00'
1.6	1.30	93^0 30'	92^0 00'
2.4	2.05	93^0 00'	91^0 30'

Drying

Shrinkage characteristics were conducted using Cremona single deck band track jet dryer heated by thermic fluid. Dryer temperature was kept at 180°C at the feeding end of the dryer. Conveyor speed of dryer was varied depending on thickness of veneer. Moisture content of green veneer varied considerably from sapwood to heartwood.

Preparation of Phenol Formaldehyde (1:1.8) Resin:

The phenol formaldehyde resin was manufactured by reacting phenol and formaldehyde in the ratio of 1:1.8 weight ratio in the presence of an alkali catalyst in the reaction kettle. The resin flow time through B4 cup flow time was measured 15 seconds at 85±2 °C with total dry solid content being 48%-52% and possesses water tolerance of 1:16. At ambient temperature the flow time of the resin was about 24±2 seconds.

The constituent was as given below:-

1. Phenol = 1000 grams
2. Formalin = 1800 grams
3. Caustic = 80 grams
4. Water = 160 grams

First the caustic solution was prepared by adding 80.00 gram of caustic in 160 gram water and cool this solution up to room temperature. Then loaded the 1000 gram molten phenol into kettle following by 1800 gram formalin. After loading formalin immediately the stirrer and condenser was started. Then caustic solution was added into the kettle. The temperature inside the kettle automatically increases because of exothermic reaction. When temperature stopped increasing, heated oil circulated to heat the kettle until temperature inside the kettle reached 50^0C and then hot oil circulation was stopped and cooling of water is circulated. Due to exothermic reaction temperature inside the kettle automatically increases up to 90 ^{0}C. The temperature was maintained inside the kettle at 85±2 ^{0}C until precipitate is formed in water and flow time in B_4 flow cup reached 14 to 16 seconds. Then the cooling was started and continued until temperature inside the kettle reached room temperature and the resin was unloaded. The properties of resin are given in Table 2.

1. Preparation of plywood: 3-ply plywood measuring 1ft x 1ft with PF glue was prepared. The details of the plywood preparation are as follows.
   Glue formulation:
   PF resin=1000 gms
   CSP= 80 gms mix in sterer for 30 mints.
   Glue spread: 30-35 gms /sq feet
   Pressing parameter
   Species: *Populus deltoids and Melia dubia*
   Thickness:1.6mm/1.6mm/1.6mm 3 ply
   Pressure: 14 kg/cm^2
   Time of pressing: thickness + 3minutes i.e. 7 minutes for mm thickness ply.
   The samples were stocked for 24 hours for stabilization and then taken for testing.
2. Testing: Plywood samples were prepared and tested as per IS-303 and 1734 respectively.

Table 2: Properties of resin

Sl. No.	Particulars	Results
1	Flow time of resin in B4 flow cup (at 85±2 ^{0}C)	14-16 seconds
2	Flow time of resin in B4 flow cup (at room temp.)	24±2 seconds
3	Water tolerance	1:10±2
4	Practical Solid content	48.23

Anatomical studies: From the lower portion of each log a billet of length 2.54 m was taken and converted into small square blocks to study the anatomical properties. 10 cm wooden discs were collected at three different heights of log. A total of 10 samples were analysed for wood density and moisture content as per the IS 1734 (part 1)-1983.

Fibre Morphology: Small radial chips from sample were macerated to determine vessel diameter, fiber length, width and lumen diameter using image analysis software system microscope. Five grams of wooden chips were taken in a test tube and 15ml of 50% nitric acid and 2g potassium chlorate was added to the test tube. The test tubes were kept under sunlight for four days until the chips turned milky white. Then the chips were washed two to three times with water and few drops of safranin were added. The macerated chips were mixed and spread over a glass slide. The stained macerated material from each growth ring was placed on microscopic slides and mounted in glycerine. Twenty five observations of fibre length, outer diameter, lumen, diameter, vessel element and diameter at each radial position were taken under the compound microscope.

RESULTS & DISCUSSIONS:

The average density and moisture content of *Populous deltoids* clones and *Melia dubia* results are shown in the Table 3. From the table it was found that density varies from bottom to top along with moisture content. Highest density was observed at the bottom position of G_{48}, whereas lowest density was found at the top position of Wimco A_{26} species. Moisture content of green log varies from 90% to 30% at different heights. Results indicates that density of the each clone was found to be more at Bottom position as compare to Top portion.

Table 3: Density and moisture content of Poplar clones and *Melia dubia*

Species Name		Density (Kg/m^3)		Moisture content (%)	
		Bottom	Top	Bottom	Top
Poplar clone	G_{48}	425	415	90	63
	S_7-C_{15}	387	356	80	60
	Wimco A_{26}	320	316	84	57
Melia dubia		500	475	95	65

Anatomical properties:

The details of anatomical properties of three clones along with *Melia dubia* species are presented in the Table 4. From the results it is observed that fibre length of clone G_{48} is 1297 to 1434 µm whereas fibre length of clone A_{26} was 1014µm to 662 µm and clone S_7C_{15} 1122 µm to 1666 µm respectively. Fiber length of *Melia dubia* species was observed higher than the poplar clones. Similarly fiber width, fiber lumen diameter and vessel diameter also was higher as compared to *Populous deltoids* species. From the above results intra clonal variations in anatomical properties of the three clones indicates that wood properties varies within the population of same species and it may also vary from clone to clone. The results indicated that clone G_{48} and A_{26} were higher in fiber length, width, fiber lumen diameter and vessel diameter with respect *Melia dubia* species.

Table 4: Anatomical properties of Poplar clones and *Melia dubia*

Species Name		Fiber length (µm)		Fiber width (µm)		Fiber lumen diameter (µm)		Vessel diameter (µm)	
		Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top
Poplar clones	G_{48}	1434	1297	26.11	17.92	13.79	12.01	42.00	48.00
	S_7-C_{15}	1666	1122	24.36	14.94	16.86	12.77	32.00	52.00
	Wimco- A_{26}	1014	662	18.33	16.6	11.81	10.22	41.00	33.00
Melia dubia		1662	1253	39.35	27.96	27.53	19.18	75.00	48.00

Physical and Mechanical properties test:

The physical and mechanical properties of plywood samples were evaluated and results are presented in the Table 5. The average values of Modulus of rupture (MoR) and Modulus of elasticity (MoE) from pith to periphery of three clones are showing highest modulus of elasticity (MoE) values in clone G_{48}, as compared to the other two clones and *Melia dubia* species. Glue adhesion values of plywood results are given in the Table 5 indicates that panels confirms to BWR grade and all the three clones has conformed to BWR grade plywood as per IS: 303-1989 respectively. Among the three clones of *Populus deltoids* clone Wimco A_{26} appears to be light in weight and also from strength point view it is showing lesser values. Strength properties of *Melia dubia* were carried out earlier in the institute projects showing glue adhesion strength values of MR and BWR grade plywood (IPIRTI research report 112-2000) and mechanical properties studied has shown good results in both Clone G_{48} and *Melia dubia* species. The present results indicate that *Melia dubia* species showing more MoR and MoE values as compared to clone $G_{48.}$ Whereas clone S_7C_{15} and Wimco A_{26} were showing lesser values as compared to both *Melia dubia* and G_{48} clone.

Table 5: MoR, MoE & Water resistance of *Populus deltoids* clones & *Melia dubia* plywood samples.

Sl No	Tests	Prescribed Limits	Results			
			(*Populus deltoids* clones)			
			G-$_{48}$	S_7C_{15}	Wimco A_{26}	*Melia dubia*
1	**Moisture Content,%**	5-15	9.48	8.25	9.52	8.7
2	**Modulus of Rupture, N/mm^2 (Parallel to face grain)**					
	Average	40	84.2	82.16	72.44	107.98
	Minimum individual	36	71.38	66.42	64.57	103.68
3	**Modulus of Elasticity, N/mm^2 (Parallel to face grain)**					
	Average	5000	10590	10206	9966	10565
	Minimum individual	4500	9843	7807	8314	9683
4	**Resistance to water, Adhesion of plies (3 cycles of 8hr boiling & 16 hr drying @ 65±2°C)**	Min. Pass Std.	Pass Std	Pass Std	Pass Std	Pass Std

*Sample **Conforms** to Moisture Content, Modulus of Rupture, Modulus of Elasticity and Resistance to Water of BWR grade as per IS 303-1989.*

III. CONCLUSION:

From the above studies low density and lesser mechanical properties were observed in Wimco A_{26} clone of *Populus deltoids* as compared to other two clone studies. Whereas, anatomical studies carried out throughout the length of the log at different heights shows high variation in fiber length, width and vessel diameter. The physical and mechanical properties of plywood made from clones G_{48} results are showing higher specific gravity and better strength properties as compared to S_7C_{15} and Wimco A_{26} poplar clones. Whereas *Melia dubia* species showing better strength properties as compared to all the three poplar clones species. From the present studies it is seen that there is increasing trend in specific gravity and better anatomical properties with respect to mechanical properties of clone G_{48} clone species.

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