COMPARISON OF ANATOMICAL, PHYSICAL AND MECHANICAL PROPERTIES OF *ABIES PINDROW*, *CEDRUS DEODARA* AND *PINUS WALLICHIANA* FROM DRY AND WET TEMPERATE FORESTS

K.M. Siddiqui, J.A. Khan and Iqbal Mahmood*

Abstract

In this study, anatomical, physical and mechanical properties of three softwood species growing in dry and wet temperate forests of Pakistan are compared. The wood samples from dry temperate forests exhibit slow growth rate and high density and strength properties than those from wet temperate forests. The results of this study would enable efficient and economical utilization of scarce coniferous timber resources in the country.

Introduction

The temperate forests are widely distributed in Himalayan, Karakorum and Suleiman mountain range of Pakistan and its neighbouring countries. These forests grow under a variety of ecological conditions. The altitudinal range of these forests is 1500 to 3300 metres. The precipitation, especially summer rainfall, varies considerably in this region from zero to 1800 mm per annum. Whereas, wet temperate forests are common in north and north-east mountain ranges, the dry temperate forests are confined to minor mountain ranges beyond the effective range of south-west monsoon (1). The principal coniferous species of commercial importance in both types of the temperate forests are; deodar (*Cedrus deodara* London), biar or kail (*Pinus wallichiana* spach) and partal (*Abies pindrow* and *Picea smithiana*). Another pine, namely, chilgoza pine (*Pinus gerardiana* Wall), is also commercially important, but is found in dry temperate forests only (2).

In Pakistan, timber from wet temperate forests comes from Azad Kashmir, Murree, Hazara and Malakand regions. This timber is harvested and marketed by the provincial forest departments and is consequently properly recorded. On the other hand, the timber supplies from dry temperate forests are mostly from western forested areas in North West Frontier and Baluchistan provinces and from adjoining localities in Afghanistan. The timber harvesting and trade are carried out by private parties in an irregular manner. It is marketed in the form of axe-squared blocks commonly called "Bannu Blocks" in the local markets. Though major supplies of coniferous timber in Pakistan are from wet temperate forests, still, the quantities from dry temperate forests are substantial. Further, the wood properties of the former type have been investigated and published since long, but very little is known about the latter (3, 4, 5). This study was carried out to compare anatomical,

*The authors are Director, Wood Seasoning and Preservation Officer and Assistant Wood Seasoning Officer, Forest Products Research Division, Pakistan Forest Institute, Peshawar.

physical and mechanical properties of three coniferous species of deodar, fir and kail from wet and dry temperate forests. It is hoped that the results of this study would prove useful to engineers, architects, builders etc.

Material and Methods

In order to study the anatominal, physical and mechanical properties of fir, deodar and kail, three scants of each were procured from timber market in Peshawar. These originated from dry temperate forests. At the same time logs of different sizes were also obtained from Kaghan valley in Hazara region which belongs to wet temperate region. The experimental material consisting of scants and logs was converted into 7 cm thick planks, which were air-dried to about 12% moisture content in an air-seasoning shed. The test specimens were prepared from the planks in accordance with the procedures given in standard methods(6). An effort was originally made to condition air-seasoned specimens to a uniform moisture content of 12% before testing. Some test specimens however, had a moisture content slightly higher or lower than this level. For this reason, the air-dry strength values were adjusted to values for moisture content of 12 percent as provided in the standard procedures. The test specimens of the following sizes were prepared from each plank for determination of different strength properties.

(i)	Static bending	2 cm x 2 cm x 30 cm
(ii)	Impact bending	2 cm x 2 cm x 30 cm
(iii)	Compression parallel to grain	2 cm x 2 cm x 6 cm
(iv)	Tensile strength perpendicular to grain	2 cm x 2 cm x 7 cm
(v)	Cleavage	2 cm x 2 cm x 4.5 cm
(vi)	Hardness	2 cm x 2 cm x 10 cm
(vii)	Shear strength	2 inch x 2 inch x 2.5 inch
(viii)	Compression perpendicular to grain	5 cm x 5 cm x 5 cm

All strength tests were made in accordance with ISO and BS 373 except the shear test. For anatomical features about fifty observations were made on a wood specimen of all three species from two localities. Most of the gross and minute anatomical features were studied from permanently stained cross-sections mounted on the slides, while tracheid length was measured from the macerated wood material. For measurement of cell dimensions eye-piece and stage micrometers were used. Simple averages, cummulative averages, standard deviation and coefficient of variation were computed for each parameter.

Results and Discussion

Anatomical Characteristics: The anatomical characteristics of fir, kail and deodar woods from wet and dry temperate zones is given in Table 1. From the results it may be seen that the tracheid dimensions are in general higher for the material from the wet temperate zone as compared to that from the dry zone. This is true for all the three species.

The average tracheid lengths of wood samples from the wet zone were found to be 42% higher in the case of deodar, 43% in the case of kail and 10% in case of fir than those from the dry zone. Similarly considerable differences were also recorded in tracheid diameter and tracheid wall thickness in the materials from the two localities. In the case of deodar, however, the difference in the tracheid diameter was very small the values being 33 and 31 microns respectively for Kaghan and Bannu. The variaion in three characteristics was also found to be small in all samples.

On the other hand the percentage of late wood came out to be higher in the case of the material from the dry temperate zone than that in from the wet zone. This again happened in all the three species. The reason for this was the slower growth rate in the dry temperate zone than in the wet temperate zone. The difference in growth rate from the two localities is evident from the results of the ring width. The average ring width in all the three species came out to be smaller in the case of the material from the dry zone as compared to that from the wet zone. The difference in the ring width in the two localities was, however, highest in the case of kail wood and smallest in deodar wood.

Physical and Mechanical Properties

Wood density: Th average wood density of the material from the dry temperate zone in all the three species came out to be higher than that from the wet zone. The reason for this is the slower rate of growth in the dry zone. This has also been explained earlier in the case of the anatomical characteristics. Contrary to the differences in the ring width which came out to be the highest in the case of kail and least in case of deodar, the differences in wood density were found to be in the reverse order i.e. maximum in the case of deodar and minimum in kail. No logical explanation can be given for this behaviour. In fact in a natural composite material such as wood, a large number of factors contribute towards a single character and it becomes very difficult to assess the effect of each factor in the overall results.

Mechanical properties: The average mechanical properties of the three species from the dry and wet zones is given in Table 2. From the results, it can be seen that the strength properties of the material from the dry temperate zone with the few exceptions are generally higher than those from the wet zone. This may be due to the larger percentage of the latewood, slower growth rate and higher density in the case of the dry zone material as compared to the material from the wet zone. No definite trend however could be observed between the individual tests in relation to density of the wood, anatomical characteristics or the locality.

The degree of variations in the results from the two localities varied differently for various strength properties of the three wood species. The percentage difference in strength from the two localities also varied from one test to other. As it has already been mentioned that in most cases the strength of the material from the dry temperate zone came out to be higher than that from the wet zone there have also been some exceptions. The most important of those is the higher value of the modulus of elasticity of deodar wood from the wet zone in comparison to the dry zone. Though the modulus of rupture in

deodar from the dry temperate zone is higher than the wet zone the situation is otherwise in the case of modulus of elasticity. This suggests that the material from the dry zone is stronger in overall bending but less stiffer than the material from the wet zone. It is believed that the anatomical characteristics and especially the fibre length would have contributed towards this behaviour.

In order to find out whether the differences in the strength properties of the materials from the two localities are statistically significant a one way analysis of variance of the data was done (Table 3). On the basis of the results it was observed that most of the strength properties from one locality were significantly different from the other at 5% probability level. However, tensile strength and hardness of fir, compression strength of deodar and shear and cleavage of kail wood showed non-significant differences. The percent coefficient of variation in the case of all the strength properties and for all the three species were found to be within the limits permissible (7). Certain values of the coefficient of variation were, however, much smaller than the reported value. This was probably due to the smaller sample size in general for both the localities. Higher variations in the results were recorded in the case of kail and deodar as compared to in fir. Another important observation in this study is the small variation in the material from the Bannu (dry temperate) area as compared to that from Kaghan (moist temperate) indicating that the former is more uniform than the latter.

Conclusions

On the basis of the various tests carried out on the three commercially important softwoods from the dry and wet temperate zones in Pakistan it was observed that considerable differences exist in the anatomical, physical and mechanical properties of the wood from the two localities. The material from the dry temperate zone has larger percentage of the late wood and higher wood density due to slower growth rate and exhibited better strength properties than that from the moist temperate zone. These results would be of special interest to engineers, architects, etc. for proper design of structures of these woods. This would also facilitate efficient and economic utilization of scarce softwood resources in the country.

Table 1

Anatomical characteristics of kail, deodar and fir from wet and dry temperate zones

S.No.	Property	Kail		Deodar		Fir	
		Kaghan	Bannu	Kaghan	Bannu	Kaghan	Bannu
1.	Ring width (mm)	2.09	1.31	0.57	0.44	1.76	1.42
2.	Latewood (%)	13	18	29	31	31	21
3.	Resin canal diameter ( )	170	116	—	—	—	—
4.	Tracheid Length (mm)	4.17 (0.528)	2.91 (0.364)	3.56 (0.426)	2.51 (0.516)	4.68 (0.584)	4.24 (0.452)
5.	Tracheid diameter ( )	51 (6.620)	37 (6.640)	33 (6.130)	31 (5.170)	49 (10.010)	38 (5.930)
6.	Tracheid Wall ( ) thickness	5.8 (1.170)	4.2 (0.565)	4.4 (0.725)	3.7 (0.508)	5.2 (0.889)	4.5 (0.644)

The value in the parentheses are the standard deviations

Table 2

Density and Strength Properties of Kail, Deodar and Fir from Wet and Dry Temperate Zones

S. No.	Property	Kail				Deodar				Fir			
		Kaghan		Bannu		Kaghan		Bannu		Kaghan		Bannu	
		X	S.D.	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
1.	Wood density: gms/cm³ (air dry)	0.480	0.020 (4.16)	0.482	0.040 (8.30)	0.520	0.050 (9.61)	0.591	0.030 (5.07)	0.410	0.010 (2.44)	0.426	0.010 (2.35)
2.	Modulus of rupture: N/mm²	77	6.48 (8.41)	86	14.10 (16.39	89	9.50 (10.67)	93	6.40 (6.88)	80	5.30 (6.62)	84	4.40 (5.24)
3.	Modulus of Elasticity:N/mm²	8877	788 (8.87)	8907	656 (7.36)	9165	1413 (15.42)	7004	541 (7.72)	8431	561 (6.65)	8564	492 (5.74)
4.	Max. crushing strength parallel to grain:N/mm²	32	6.43 (20.09)	37	6.43 (17.38)	40	4.85 (12.12)	44	4.7 (10.68)	25	4.00 (16.00)	27	3.40
5.	Compressive strength parallel to grain at elastic limit: N/mm²	23	5.06 (22,00)	26	4.31 (16.58)	30	3.67 (12.23)	31	3.20 (10.32)	22	2.10 (9.54)	23	2.70 (11.74)
6.	Compressive strength perpendicular to grain at elastic limit:N/mm²	3.40	0.57 (16.76)	2.90	0.50 (17.24)	3.70	1.06 (28.65)	3.20	0.30 (9.37)	2.30	0.20 (8.69)	2.70	0.20 (7.40)
7.	Max. shearing strength:N/mm2	8.40	1.49 (17.74)	8.80	0.81 (9.20)	9.40	1.58 (16.81)	11.30	0.70 (6.19)	8.00	0.50 (6.25)	8.50	0.60 (7.06)
8.	Cleavage: N/mm	15	2.32 (15.46)	16	1.17 (7.31)	19	2.47 (13.00)	20.00	1.20 (6.00)	15	0.50 (3.33)	18	0.40 (2.22)
9.	Max. tensile strength perpendicular to grain limit: N/mm²	1.48	0.33 (22.30)	1.30	0.20 (15.38)	1.73	0.36 (20.80)	2.00	0.10 (5.00)	1.20	0.10 (8.33)	1.30	0.10 (7.69)
10.	Impact bending:m-N/test	14.50	2.50 (17.24)	12.00	4.60 (38.33)	10.90	2.04 (18.71)	10.00	2.10 (21.00)	10.10	1.10 (10.89)	10.00	0.90 (19.00)
11.	Hardness: (Nx100) Side:	23.13	3.01 (13.01)	29.30	5.21 (17.78)	27.6	4.39 (15.91)	35.20	1.90 (5.39)	22.00	1.90 (8.64)	22.00	1.10 (5.00)
	End	27.67	3.78 (13.66)	88.40	5.74 (14.95)	43.6	3.43 (7.87)	52.40	3.60 (6.87)	35.60	1.70 (4.77)	36.30	2.30 (6.34)

The values in the parentheses are the coefficients of variation

Table 3

Statistical analysis of results of kail, deodar and fir from two localities (F. values)

S.No.	Property	Kail	Deodar	Fir
1.	Density	20.00 *	8.70 *	9.85 *
2.	Static bending	22.64 *	9.48 *	13.43 *
3.	Compression	42.70 **	0.34 N.S.	7.41 *
4.	Tension	12.50 *	12.24 *	0.007 N.S.
5.	Shear	1.32 N.S.	4.92 *	3.92 *
6.	Hardness	56.72 **	97.8 **	1.87 N.S.
7.	Cleavage	1.62 N.S.	12.75 *	25 **

N.S. Non-significant
** Highly significant
* Significant

Literature cited

1. Champion, H.G., S.K. Seth and G.M. Khattak 1965. Forest types of Pakistan, Pakistan Forest Institute, Peshawar.

2. Siddiqui, K.M., J.A. Khan and Iqbal Mahmood. 1983. A note on physical and mechanical properties of Chilghoza pine (*Pinus gerardiana* Wall.) wood. Pakistan Jour. For. 33(4): 227-231.

3. Limaye, V.D. and L.N. Seaman; 1933.The physical and mechanical properties of woods grown in India. Third interim report on Project 1. Indian Forest Records, Government of India, Manager of Publications, Delhi.

4. Pearson, R.S. and H.P. Brown: 1932. Commercial Timbers of India. Central Publication Branch, Calcutta.

5. Siddiqui, K.M., M. Ayaz and Iqbal Mahmood. 1985. Properties and uses of Pakistani timbers. Division of Forest Products. Bull. No. 3. Pakistan Forest Institute, Peshawar.

6. Organization For International Standards. 1975. Wood-sampling methods and general requirements for physical and mechanical tests 150:3129-1975 (E).

7. U.S. Department of Agriculture (1955). Wood Hand Books — Agriculture Hand Book No. 72. The Forest Products Laboratory, U.S. Forest Service.