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Comparison of the Swelling and Shrinkage Characteristics of Corcisan Pine (*Pinus nigra* var. mantima)

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Abstract: The objective of this study was to determine the volumetric swelling and shrinkage characteristics of air-dried Corsican pine in the longitudinal, tangential and radial directions. For this purpose, the swelling of the wood was caused by the wood being increased in water whilst placed in a swelling jig, and the shrinkage made in an oven by drying. The experimental results showed that although the differences in swelling or shrinking occur in the first 5 hours, both swelling and shrinkage are then negligible in the three directions. The values of swelling-shrinkage showed considerable difference among different directions; for instance, swelling-shrinkage in the tangential direction was as nearly twice as greater than in the radial direction, and during the experimental period it was considered negligible in the longitudinal direction.

Analyses of the data collected during this study suggest that the difference of swelling-shrinking between the tangential and radial directions is caused by the anatomical structure of wood species studied. It is therefore concluded that particularly the wood rays are an important contributory factor in the anisotropy of swelling and shrinkage in Corsican pine.

Korsika Çamı (*Pinus nigra* var. mantima)'nın Daralma ve Genişleme Özelliklerinin Karşılaştırılması

Özet: Bu çalışma ile hava kurusu rutubette bulunan Korsika çamı'nın boyuna, teğet ve radyal yöndeki boyutsal genişleme ve daralma değerlerinin değişim eğiliminin belirlenmesi amaçlandı. Bu nedenle, içi su ile doldurulmuş bir ıslatma kabına bırakılan ağaç malzemenin içerisine su alarak boyutlarının genişletilmesi ve kurutma kabininde kurutularak boyutlarının daraltılması sağlandı. Elde edilen bulgularda, hem suya batırmanın hem de kurutmanın ilk 5 saati içerisinde ağaç malzemenin boyutsal genişleme ve daralma değerlerinin boyuna, teğet ve radyal yönler de farklı şekillerde oluştuğu ancak daha sonraki deney süresi içerisinde tüm yönlerde boyutsal değişimin aynı düzeyde kaldığı görüldü. Ayrıca, ağaç malzemenin genişleme ve daralma değerleri birbirinin asimetriği olmak üzere yönlere göre farklı oranlarda oluştu, örneğin, teğetsel yöndeki genişleme-daralma radyal yöndeki genişleme-daralma'nın iki katı oranında fazla olurken, boyuna genişleme-daralma en az oranla ve deney süresince hep aynı düzeyde kaldı.

Bu deney süresince elde edilen bulguların analizi sonrasında teğetsel ve radyal yöndeki genişleme-daralma''ın test edilen ağaç malzemenin anatomik özelliklerine bağlı olarak değiştiği ve bu bağlamda da öz ışını sayısının fazla olmasının teğetsel ve radyal yönlerde oluşan genişleme-daralma oranları arasında büyük bir farkın oluşmasına neden olduğu belirtildi.

Introduction

It is well known that wood is an anisotropic material which presents differential dimensional changes in different structural directions. The change in dimensions as a consequence of changes in the moisture content of wood is of great practical importance in seasoning which has a direct effect on the manufacture of furniture and joinery [1]. Wood swells when it comes in contact with water, therefore it is obvious that the wood absorbs water and thus increase in size to incorporate the water [2]. This means that if a dry piece of woodwork is unprotected and comes into contact with water, its dimensions change and the piece of wood might not work as designed, i.e. a door frame made from wood gets wet which causes swelling and stops the door fitting. Wood also shrinks when dried which can cause similar problems.

Since swelling and shrinking of wood can cause so many problems, millions of pounds are spent on varnishes and paints each year to try to stop water getting into wood. In determining the properties of wood one circumstance to be taken into consideration is their variation in three main directions. This paper, therefore, deals with the anistropy of both swelling and shrinkage in the longitudinal, tangential and radial directions of Corsican pine, which is mostly used for joinery in the UK.

Materials and Methods

Air-dried defect-free (i.e. no knots or decay) Corsican pine blocks with dimensions of no longer than 20 mm were selected from the sapwood zone. In this case the dimensional length in the longitudinal, tangential and radial directions were made as 9 mm, 17 mm and 17 mm, respectively.

For the swelling study, a first measurement was made of the dimensional lengths of an air-dried block before each block was fitted into a swelling jig; and the reading recorded before the block was completely immersed in water. Readings from the swelling jig were taken one every 10 minutes for 1 hour, and then one every 30 minutes for 4 hours. Thereafter, one reading was taken every hour for 5 hours, and then one every 5 hours for 20 hours.

Measurements were made until a steady weight was recorded. The percentage of swelling was then calculated according to the following equation:

$$Sw=[(D_s-D_g)/D_s]x100 \qquad \text{(Equation 1)}$$

where, Sw = percentage of the swelling (%), D_s = the swelling dimension of the block (mm), D_g = the green (original) dimension of the block (mm).

For the shrinkage study, the three dimensional measurements in green condition were made for radial, tangential and longitudinal lengths and each experimental block was then weighed before the blocks were placed in an oven. Thereafter, all the blocks were dried in the oven at 105°C to make the blocks shrink. Readings from the oven were made as in the swelling study. Each experimental block was consequently removed from the oven according to the set time and immediately put back in the oven after weighing on a scale and dimensional measuring by a veneer calliper, and this continued until a steady weight was recorded. The percentage of shrinkage was then calculated by the following formula:

$$Sh=[(D_g-D_{od})/D_g]x100 \qquad \text{(Equation 2)}$$

where, Sh = percentage of the shrinkage (%), D_g = the green (original) dimension of the block (mm), D_{od} = the oven-dry dimension of the block (mm).

Results and Discussions

The mean percentage of both swelling and shrinkage in either of the three directions of the experimental blocks is shown in Table 1.

Table 1. Mean percentages of swelling and shrinkage versus time in the directions

time	tan	rad	long	T/R
(hour)		swelling (%)		
0-1	3.24	1.59	0.46	2.04
1-5	6.24	2.94	0.56	2.12
5-10	6.47	3.00	0.56	2.16
10-20	6.74	3.00	0.56	2.25
		shrinkage (%)		
0-1	3.86	2.11	0.48	1.83
1-5	7.72	3.96	0.58	1.95
5-10	8.18	4.06	0.58	2.01
10-20	8.40	4.06	0.58	2.08

The percentage swelling and shrinkage in the three directions of the experimental blocks are shown in Figure 1 according to the experimental time. There was an increase during of the first 5 hours (300 minutes) and there was steady line thereafter.

Figure 1 shows that the shapes of the curves are the same and the difference in swelling occurs in the first 5 hours. After, the swelling is negligible in the three directions. The swelling values, in Table 1 and Figure 1, show considerable difference among different directions, i.e. tangential swelling is always greater than radial, and longitudinal swelling is considered negligible. The reasons for the difference between radial and tangential swelling are not clear. This is partly attributed to the presence of rays, which (due to their radial orientation) exercise a restraining influence on the radial swelling [3]. There are two possible reasons for this difference. The first is that wood has passages running from the core to the bark; these are called rays and are fairly numerous. If the fibers are joined to the rays, they anchor the fibers in place. The rays do not hinder but help swelling in the tangential plane. Another possible reason for the different amounts of swelling in the radial and tangential plane could be the different swelling abilities of earlywood and latewood.

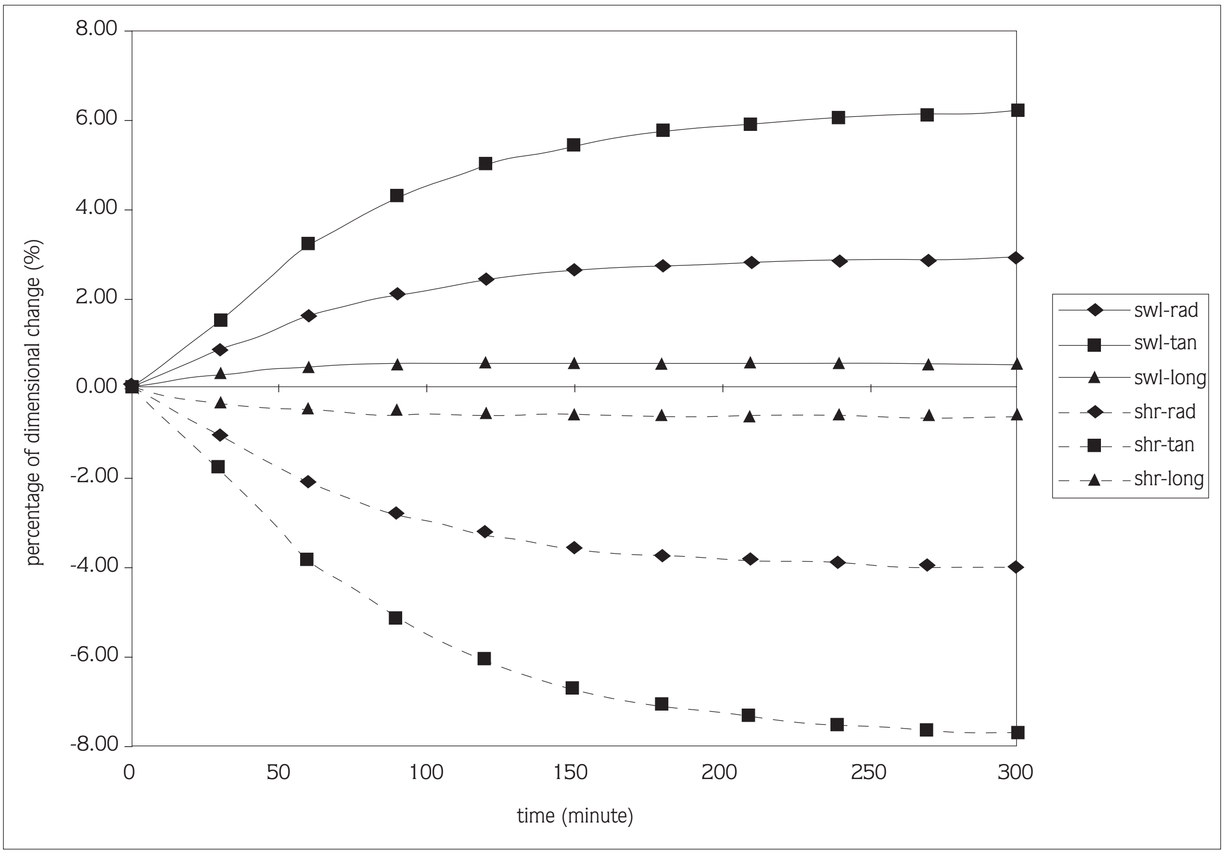

Figure 1. The percentage of swelling and shrinkage over time according to the experimental directions.

Trees grow at different rates during the year (this is often in rings as color change by growth rate).

The weight of the experimental blocks in the three directions before and after the blocks were dried in an oven, and loss of weight are listed in Table 2.

Table 2. The weights of the experimental blocks before and after the drying process.

	weight (g)		
directions	before drying	after drying	loss
radial	0.9077	0.6535	0.2542
tangential	1.1738	0.8451	0.3287
longitudinal	0.9881	0.7114	0.2767

The loss of weight observed during the oven drying process was highest in the tangential block (0.3287 g) and lowest in the radial one (0.2542 g), and was second highest in the longitudinal direction (0.2767 g). The reason for this could be related to the direction of moisture movement in the mass of wood where the movement of moisture through transverse surfaces (parallel to the grain) is faster in comparison with movement from tangential or radial surfaces [3].

The shrinkage values show considerable differences among different directions, i.e. tangential shrinkage (perpendicular to the grain and parallel to the growth rings) is always greater than radial (perpendicular to growth rings), and longitudinal shrinkage (along the grain) is considered negligible. The shrinkage values observed at the end of the experimental time (30 minutes) were significantly greater in the tangential direction (8.40 %) than either the radial (4.06 %) or longitudinal (0.58 %) directions.

This is readily accounted for by either the microscopic porous structure or sub-microscopic structure of the cell walls. Firstly, the structure of wood consists essentially of long hollow tubes, the axes of which coincide with the axis of the tree (microscopic porous structure); secondly, the bulk of cellulose molecules within the walls of the tubes are orientated parallel to the longitudinal walls, mostly at a small angle to the cell axis (sub-microscopic structure of cell walls). Microscopic and/or sub-microscopic features may thus be causative with respect to any one property, although it may be difficult to ascertain which of these factors is the predominant one [4].

Conclusion

The difference between tangential and radial swelling is caused by anatomical structure, principally, the restraining effect of the wood rays, whose long axes are radially oriented. It has been observed in this study that experimental blocks of Corsican pine with a higher ray content exhibit a greater difference between radial and tangential swelling.

To reduce the problems of wood swelling it could be suggested that in the direction of which swelling would cause the most problems place the wood in the longitudinal plan, and in the direction where wood swelling would cause the fewest problems place the wood in the radial plan, otherwise place it in the tangential plan. Regular covering of the wood in a water resistant material, i.e. paint or varnish is also recommended. The most important thing to reduce the problems caused by swelling wood is to match the wood to the conditions it will experience, i.e. do not fit wet wood inside the house or dry wood out side.

If wood properties are tested in the longitudinal direction, the numerical values obtained are generally quite different from those which are obtained if the properties are tested in the radial or the tangential direction. In light wood, such as Corsican pine which was used in this study, the numerical values of most properties will differ greatly for the longitudinal direction compared with both the radial and the tangential direction. Thus longitudinal shrinkage in light timber is invariably of a much lesser magnitude than either radial or tangential shrinkage. Therefore, to explain this difference, the structure as revealed by ordinary light microscope cannot be considered causative and thus the structure of the cell wall must be recognized as the dominant factor.

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