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ABSORPTION DIFFERENCES OF CORSICAN PINE AND SITKA SPRUCE TREATED WITH TANALITH-C

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ABSTRACT

Absorption differences of the two British softwood species, Corsican pine (*Pinus nigra* var. *maritima* (Ait.) Melville) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.), were examined on the basis of (i) sapwood and heartwood, and (ii) the three structural directions of sapwood under the same treatment condition of the full-cell process (i.e. 640 mmHg vacuum and 6 bar pressure for 5 minutes). Accordingly, conclusions on indication of the flow characteristics are listed separately for the general purpose of the work on account of the percentage of void volume filled by tanalith-C: (i) Significant differences between the two species within a set of triple flow on sapwood and heartwood. The penetration of sapwood was much greater than that of heartwood, although Corsican pine was more readily treated according to Sitka spruce in either zones. (ii) Very highly significant differences among the three structural directions in both species showing the descending order of the fluid absorption as longitudinal>tangential>radial, although in that any cases Corsican pine was much more permeable than in Sitka spruce.

Key Words: Permeability, Absorption, Corsican pine, Sitka spruce, Full-cell process

TANALİTH-C İLE KORUNMUŞ KORSİKA ÇAMI VE SİTKA LADİNİ TÜRLERİNİN İÇERME FARKLILIKLARI

ÖZET

Bu çalışmada, İngiliz yumuşak ağaç türlerinden Korsika çamı (*Pinus nigra* var. *maritima* (Ait.) Melville) ve Sitka ladini (*Picea sitchensis* (Bong.) Carr.) türlerinin koruyucu sıvı içerme düzeyleri dolu hücre yöntemiyle yapılan aynı koruma koşulları (5 dakika 640 mmHg vakum ve 5 dakika 6 bar basınç) ile (i) diri odun ve öz odunu ve (ii) üç farklı anatomik geçirgenlik yönü bağlamında araştırıldı. Geçirgenlik özellikleri ağaç malzeme boşluk hacminin tanalith-C tarafından doldurulma yüzdesi gözönüne alınarak aşağıdaki gibi sıralandı: (i) İki ağaç türünün diri odunu ile öz odunu arasında koruyucu sıvı içerme düzeyi bakımından oldukça önemli farklılığın olduğu görüldü. Korsika çamı'nın Sitka ladini'ne göre daha fazla geçirgen olduğu belirlenirken koruyucu sıvı içerme düzeyinin her iki türde de öz odununa göre diri odunda daha yüksek olduğu saptandı. (ii) Her iki ağaç türünde de üç farklı anatomik sıvı akma yönü arasında oldukça önemli farklılığın olduğu görüldü. Sıvı akma yönlerine göre yapılan koruyucu sıvı içerme düzeyi sıralaması her iki türde de çoktan aza doğru boyuna>teğet>radyal şeklinde belirlendi. Buna ek olarak, her yön için yapılan karşılaştırmada Korsika çamı'nın koruyucu sıvı içerme düzeyi bakımından Sitka ladini'ne göre daha yüksek olduğu saptandı.

Anahtar Kelimeler: Permeabilite, Sıvı İçerme, Korsika çamı, Sitka ladini, Dolu-hücre yöntemi

1. INTRODUCTION

Wood is a biological material with remarkable variability in its quality (e.g., wood structure, density, permeability, and other associated properties). For a single species, wood quality varies not only from tree to tree (intertree) but also within trees (intratree). The intratree variation is the major source of variability [1] in wood quality [2; 3].

Variation in wood quality makes it difficult to predict precisely the performance of timber and therefore process and utilize it efficiently. For example, wood density (one of the most important factors affecting timber properties) has been shown to influence significantly both the yield and quality of fibrous and solid wood products [4]. The factors which control density and influence its variability within tree in planted species are well-known, but there is little information on optimum preservative absorption levels for individual wood species.

The main objective of this study is therefore to find out within tree and between species variation in permeability, used here synonymously with fluid absorption, in two planted softwood species (Corsican pine and Sitka spruce) grown at the same trial site in Great Britain. Such information would be useful in understanding the influence of silvicultural control on the wood structure which in turn influences the quality of wood.

1.1. Absorption of sapwood and heartwood

Most of the knowledge concerning the permeability of different species of wood has shown that different species of wood vary widely in permeability and this has enabled most of the common timbers to be classified into grades according to whether they have a high, intermediate or low permeability [5]. As mentioned by Dinwoodie [6], because of their simpler structure and their greater economic significance, much more attention has been paid to flow in softwood timbers than in the hardwood timbers.

In softwood, sapwood is several times more permeable than heartwood [7; 8]. As stated by Siau [9], pine (*Pinus* spp.) sapwoods are among the most permeable softwoods and may have values as high as 1 to 8 darcys whereas the spruces (*Picea* spp.) and cedars (*Cedrus* spp.) are usually much lower in the 10^{-1} darcy range, and Douglas-fir (*Pseudotsuga menziesii* var. glauca) heartwood in the range of 10^{-3} darcy making it extremely refractory to impregnation.

1.2. Absorption in the three structural directions

It is well known that wood is a highly anisotropic material, and the permeability of wood varies markedly in the three structural directions [10]. The longitudinal flow of softwoods is much greater than the tangential flow which is usually superior to the radial flow in most conifers [11; 9]. The flow differences between the considered directions are explained by the anatomical features of the softwood [12]. The structural shape and arrangement of the wood cells in the living tree are probably related to the fluid permeability [13]. Because, the way in which preservatives flow through timber depends principally on the routes that were established for the conduction of water, minerals and food substances whilst tree was growing [6].

2. MATERIAL AND METHODS

2.1. Absorption of sapwood and heartwood

A total of 6 specimens of same size 140x25x25 mm was produced from sapwood and heartwood of the kiln dried (equilibrium moisture content of 12 %) defect free Corsican pine (*Pinus nigra* var. *maritima* (Ait.) Melville) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) to determine the triple flow (i.e. all faces of the specimens are left open).

All of the experimental specimens were firstly weighed to obtain the green weight. Following the loading of the specimens into impregnation cylinder, full-cell process, similar to normal vacuum/pressure treatment as described by [11] were carried out. The initial vacuum was created at 640 mmHg and held for 5 minutes [12]. Afterwards, the CCA (Commercial Tanalith C, Hicksons) preservative that was prepared in 2 % strength and checked by hydrometer for concentration [13], was flooded into the cylinder whilst maintaining the initial vacuum which was laterally closed and 6 bar pressure was applied for 5 minutes [14]. This pressure was then immediately released and the excess preservative was drawn back to the working container. After the treatment operation, the treated specimens were taken out from the cylinder and put on the absorbent paper for a few seconds [15], and then re-weighed for the treated weight to determine the amount of fluid absorption.

Thereafter, the maximum possible preservative uptake of each specimen was calculated as a percentage of void volume filled on a whole-block basis (1);

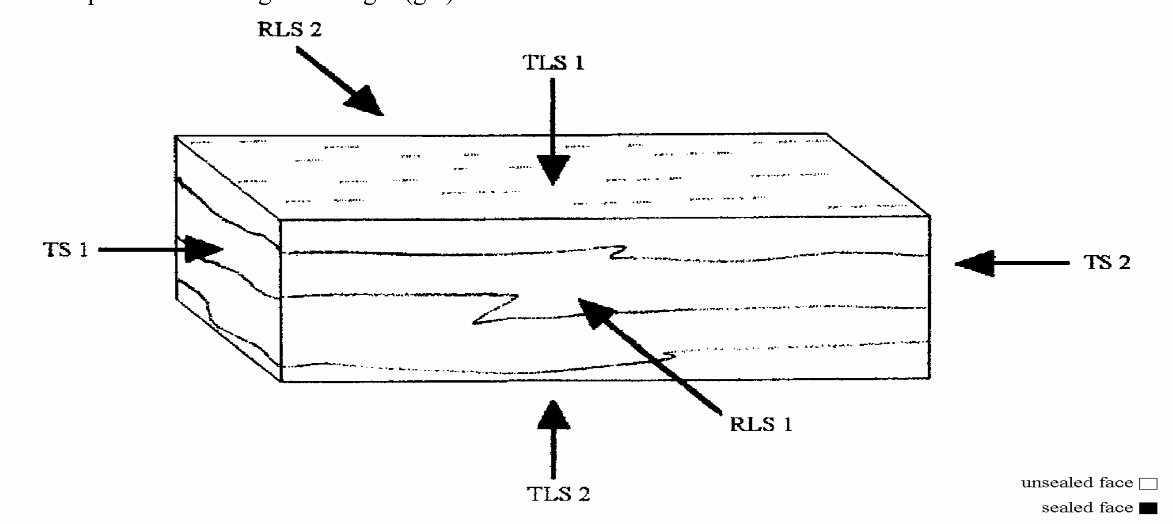
$$VVF\% = [(tw - gw) / v] / vv \quad (1)$$

where, VVF%: percentage of void volume filled (%), tw: treated weight (g), gw: green weight (g), v: volume of specimen (m^3), vv: void volume of specimen (m^3) [16].

2.2. Absorption in the three structural directions

The stakes were taken from only the sapwood zone of the kiln dried defect free Corsican pine (*Pinus nigra* var. *maritima* (Ait.) Melville) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.). A total of 6 specimens of same size (140x25x25 mm) was produced for each flow direction, i.e. longitudinal, tangential and radial.

The specimens were initially weighed to obtain uncoated weight. Thereafter, all surfaces were sealed with ABS solvent cement (polymer dissolved in methyl ethyl ketone, Durapipe) except ends along the grain to allow for longitudinal flow but for radial flow all surfaces/ends were sealed except tangential dimensions, and for tangential flow only the radial dimensios were unsealed (Figure 1). The specimens were then re-weighed for sealed weight, and were then loaded into impregnation cylinder for the treatment operation that was exactly done similar with the study of sapwood and heartwood. For calculation of the maximum possible preservative uptake of each specimen, Equation 1 was again used in which only the sealed weight (sw) have been re-placed with the green weight (gw).



flow directions	aspect of the sections					
	transverse		tangential - longitudinal		radial - longitudinal	
	TS1	TS2	TLS1	TLS2	RLS1	RLS2
longitudinal			■	■	■	■
radial	■	■			■	■
tangential	■	■	■	■		

Figure 1. The sealing and unsealing faces of the specimens for examination of absorption

3. RESULTS AND DISCUSSION

3.1. Absorption of sapwood and heartwood

The percentage of void volume filled (VVF%) by tanalith-C in sapwood and heartwood of both Corsican pine and Sitka spruce are shown in Table 1 and in Figure 2. The results showed that the VVF% was markedly greater in sapwood than in heartwood in either species, and also Corsican pine was more permeable in both zones according to that for Sitka spruce. Mean VVF% spread differed significantly ($p \leq 0.002$) among the originate of the specimens. VVF% was 91.3 % and 66.8 % in sapwood of Corsican pine and Sitka spruce respectively, and was 59.1 % and 38.6 % in their heartwood. VVF% of sapwood varied from 89.5 % to 93.4 % in Corsican pine, and from 62.9 % to 71.7 % in Sitka spruce, although that for heartwood ranged from 52.9 % to 64.5 % and 34.8 % to 41.3 %.

Table 1. The results of the percentage of void volume filled by preservative in both species

specimen	Corsican pine		Sitka spruce	
	sapwood (%)	heartwood (%)	sapwood (%)	heartwood (%)
1	90.4	52.9	66.9	34.8
2	93.2	62.2	62.9	36.9
3	89.7	64.5	65.3	38.1
4	91.1	56.1	71.7	41.3
5	89.5	62.4	70.8	39.6
6	93.4	56.3	63.1	40.8
mean	91.3	59.1	66.8	38.6
std. dev.	1.72	4.57	3.78	2.44

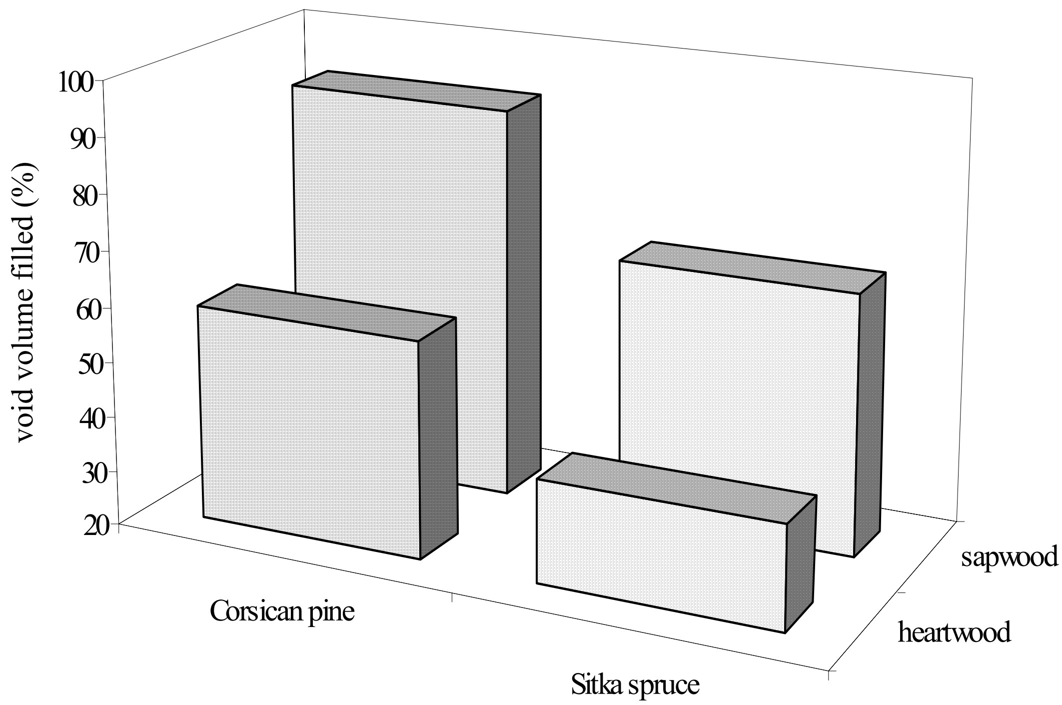


Figure 2. Mean VVF% in sapwood and heartwood of Corsican pine (*Pinus nigra* var. *maritima* (Ait.) Melville) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.)

Figure 2 shows that sapwood in Corsican pine (91.3 %) was more readily permeable than in Sitka spruce (66.8 %). The reason for this variability in permeability of these species is that the degree of pit aspiration which have been showed by Phillips [17] in pine (*Pinus* spp.) as in the region of 93 % while in spruce (*Picea* spp.) it was in the region of 97 %.

In this experiment, it has particularly been found that sapwood (66.8 %) of Sitka spruce was low permeable as its heartwood (38.6 %). This result is in confirmity earlier reported by either Phillips [17] or Wilkinson [18] whom stated that the sapwood of spruces (*Picea* spp.) are nearly as difficult to penetrate by preservatives as their heartwood after seasoning. This is partly because the pits of the earlywood tracheids aspirate on drying and these cells become unable to conduct liquids [19; 20; 21]. On the other hand, it was also found that heartwood had the lowest permeability in both species. The primary causes of heartwood and sapwood permeability differences are due to differences in aspiration and to the amounts and character of the extractives [8], which in wood tend to reduce permeability especially in the heartwood [22], and can have a significant effect on the treating results [23; 24]. An additional reason for the differences in permeability through heartwood and sapwood is that tracheids of sapwood are longer [25; 26] and have larger lumina in comparison to that for the heartwoods [3].

3.2. Absorption in the three structural directions

The experimental results of the percentage of void volume filled (VVF%) by tanalith C in longitudinal, tangential and radial flow directions in both Corsican pine and Sitka spruce are shown in Table 2 and in Figure 3. It was found that the permeability of softwood under pressure was the most in longitudinal direction, and was the least in radial direction. This results fit the findings of Behr *et al.* [27], Petty [28], and Siau [29]. The results also showed that Corsican pine was more permeable than Sitka spruce in either of the three flow directions.

The percentage of void volume filled by preservative liquid (tanalith-C) in longitudinal (L), tangential (T), and radial (R) directions varied significantly ($p \leq 0.05$). As given in Table 2, the values increased from 72.7 % to 86.7 % and rose to 100 % in Corsican pine as the order of the flow directions ascended from R to T and to L. Likewise, this range in Sitka spruce was that 39.3 %, 71.7 %, and 86.8 %.

Table 2. Mean of VVF% by tanalith-C in the three flow directions in both species

species	flow direction		
	Longitudinal (%)	Tangential (%)	Radial (%)
Coriscan pine	100	86.7	72.7
Sitka spruce	86.8	71.1	39.3

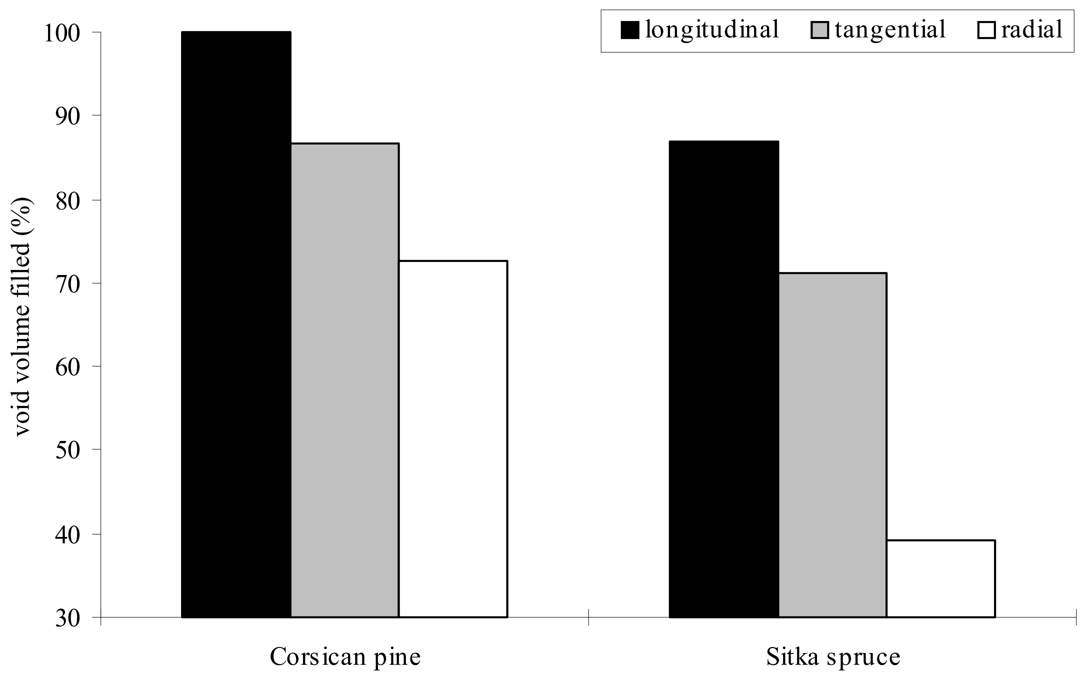


Figure 3. Mean VVF% by tanalith-C in the structural directions of Corsican pine (*Pinus nigra* var. *maritima* (Ait.) Melville) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.)

The reason for the differences in permeability between the flow directions in softwoods has shown by Comstock [10] that longitudinal and tangential flow are controlled by the same factors but radial permeability is controlled independently. The major route for preservatives in softwoods is from tracheid to tracheid by passing the liquids between the cells through the interconnecting pits which more correctly known as bordered pit pairs that would be limiting factor controlling both longitudinal and tangential flow [30; 31; 32]. The longitudinal flow mostly occurs along the wood capillary structure from one tracheid lumen to another through the bordered pits of the axial tracheids [33; 34], whereas the tangential flow takes place between tracheids via the intertracheid bordered pit pairs [35] which are located along the tapered portions of the radial surfaces of both earlywood and latewood tracheids [36]. On the other hand, the minor pathway is along the rays [37], mainly along the ray tracheids [19], and between parenchyma cells [22]. As the fact that there are fewer pitted cross walls to transverse per unit length in the longitudinal than in the tangential direction [9], the longitudinal flow of both Corsican pine (100 %) and Sitka spruce (86.8 %) is much greater than their tangential flow (86.7 %, 71.1 %). The greatest permeability in longitudinal direction in either species could also be related to the axial resin canals which provides a useful route for preservative penetration [18], and to the rays where the fluid flows along the ray parenchyma cells and then into the axial tracheids from which further longitudinal penetration can occur [6]. On the other hand, the reason for the low permeability in tangential direction could be explained by the tracheid pitting that is concentrated on radial cell faces which favours flow in the tangential direction via a longitudinal route (i.e. along axial tracheids through tracheid pits, along axial tracheids through tracheid pits, etc.), and thus it gives a long path length for tangential flow [21]. The longitudinal penetration of Corsican pine was obviously greater than that of Sitka spruce under same condition of treatment. This suggests that much more preservatives were driven into the wood capillary system in Corsican pine than in Sitka spruce as the differences of both the diameter in tracheids [38] and the number of bordered pits in the region of overlap of two tracheid ends [29]. In Corsican pine, therefore the fluid flowed more effectively from one tracheid lumen to another via unaspirated bordered pits than across the wood capillary system, and this resulted in complete saturation or the more fillings of the void volumes along the grain. However, in Sitka spruce, there were less saturation and less retention of salts due to much more aspiration.

The obvious reason for less penetration in radial direction compared to longitudinal penetration could be due to the lower number of cells in the radial direction [9] and due to stored food materials in the ray parenchyma cells [39] that retarded fluid movement despite pressure been applied [40]. An additional reason for slower flow in parenchyma is that simple pits are imperforate in comparison to the bordered pits [30]. Further, encrustation of semi-bordered pits could have affected the penetration [8]. On the other hand, the main reason for the limited radial penetration of Sitka spruce could be related to the relatively small proportion of ray tracheids which they regard as the main radial pathways [19]. The fluid flows in radial direction are also probably through the ray parenchyma cells to the longitudinal tracheids across cross-field pit apertures and then back again to the other ray parenchyma cells [41; 16]. This suggests that the nature of the cross-field pits are recognizable influence on the radial permeability [9], and therefore the small elliptic pits in Sitka spruce are important factor in determining resistance to flow compare to the large window pores in Corsican pine.

4. CONCLUSIONS

4.1. Absorption of sapwood and heartwood

Sitka spruce sapwood, which is generally regarded as being very permeable to fluid before drying, was found to be much less permeable after drying likewise it was classified as resistant to preservative treatment by the other investigators. The cause of loss of permeability as it is generally believed that is axial tracheid bordered pit aspiration in the earlywood where the pit margo and torus are displaced when air bubbles move past the membrane as would typically occur during drying. On the other hand, the degree of pit aspiration is not higher in Corsican pine to reduce earlywood flow. It is therefore stated that this totally accounts for the differences in permeability of these two species.

It can also be deduced that sapwood more permeable than heartwood in both Corsican pine and Sitka spruce on account of more extractive content in heartwood through the heartwood extractives may reduce the permeability making the heartwood extremely refractory to impregnation.

4.2. Absorption in the three structural directions

The amount of preservative transported in the three structural directions have been compared between Corsican pine and Sitka spruce. Experimental results showed that permeability of wood was the most in longitudinal direction and the least in radial direction. It has also been found that Corsican pine was much more permeable than Sitka spruce in either of the three flow directions.

The reason for the differences in permeability between the flow directions in the considered species has shown that longitudinal and tangential flow are controlled by the same factors but radial permeability is controlled independently. The reason for the most permeability of longitudinal direction in Corsican pine was mainly related to the less degree of pit aspiration, whereas the reason for the least permeability of radial direction in Sitka spruce was particularly related to the relatively small proportion of ray tracheids.

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