Swelling Behavior of Cells in Compressed Wood
by
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Compressed wood is used as building interior material such as the floor material after fixed permanently by such as steam treatment. However, the compressed wood is swollen by absorbing water without recovering large amount of compressed deformation, despite it was fixed permanently. The dimensional stability of compressed wood for moisture is very important for safe use of building material. Therefore, swelling behavior of cell was observed in compressed wood and the relationship between cell shape and swelling behavior of cell was discussed. The swelling in radial direction of wood compressed 50% was four times larger than that of uncompressed wood. In the visual fields of a microscope, four different deformation types of cell lumens were observed. The increase in area of cell lumens is different among the four types. The increase in area of cell lumens is much different between S-shape cells and elongated shape of cells. In particular, the cells deformed to S-shape are hard to be increased the area of cell lumens by swelling. This result suggests that deformation types of cell lumens affect the swelling behaviors of compressed cells. From the above results, it might be possible to improve the dimensional instability of the compressed wood by giving deformations as increasing the S-shape cells.

Key words: Japanese cedar, Compressed wood, Swelling behavior, Feret’s diameter, Area of cell lumen

1 Introduction

In recent years, to increase density of soft wood such as Japanese cedar, many studies and technological development for compressed wood have been made. The compressive deformation is fixed temporarily when water-saturated wood is dried in the compressed state. However, the compressive deformation is almost recovered when the wood has absorbed the water again [1,2]. It is essential to fix the compressive deformation permanently when the compressed woods are used as materials. Therefore, to fix the compressive deformation permanently, many treatments such as heat treatment, steam treatment, and impregnation treatment of resin were tried [3-5]. And many studies to elucidate the mechanism of fixation have been made [6-9]. In addition, various studies about utilization of the compressed wood have been made. From these studies, it is clarified that tensile and bending strengths are increased with increase of compression rates [10,11].

On the other hand, it was reported that the dimensional stability of the compressed wood for the moisture was lower than that of uncompressed wood [12]. The dimensional stability of the compressed wood for the moisture is very important for use as materials. However, the study to improve the dimensional stability of compressed wood was not made.

Therefore, swelling behavior of cell was observed in compressed wood and the relationship between cell shape and swelling behavior of cell was discussed. From the results obtained, it was considered the mechanism of dimensional instability of the compressed wood by observing the shapes of water-saturated cells in detail.

2 Materials and methods

2.1 Materials

Compressed and uncompressed woods made of Japanese cedar (Cryptomeria japonica) provided by My Wood-Two Co., Ltd. were used. The compressed wood was fixed permanently by steam treatment and the compress ratio was about 50%. The cross sectional size of uncompressed wood was 3mm(radial direction (R)) × 12mm(tangential direction (T)) and compressed wood was 1.3mm(R) × 12mm(T). From these sample, specimens having parallel annual rings from the top to bottom surfaces were cut. The dimensions of uncompressed wood specimen was 10mm(L) × 30mm(R) × 20mm(T) and compressed wood specimen was 10mm(L) × 13mm(R) × 20mm(T).

2.2 Measurement of swelling

The compressed and uncompressed wood specimens were dried at 105°C and dimensions were measured in
oven-dry condition. Then, the same specimens were soaked in water at room temperature for several days after water was injected into the specimens under decompression for a night. The dimensions were measured in water-saturated condition.

2.3 Measurement of dimension and area of the cell

The same cells in compressed wood specimen were observed by digital microscope (KH-1300 by HIROX) in oven-dry condition and water-saturated condition. The magnification was 1400. In each condition, Ferret’s diameters of the radial and tangential directions and areas of cell lumens were measured in visual field of a microscope by image analysis software (Motic Image Plus 2.2s by Shimadzu RIKI Corporation). Photographs used in the measurement are shown in Fig. 1. The area of the cell was measured in compressed and uncompressed portions of compressed wood both in dry and water-saturated condition.

![Image of area and cell lumens](image)

Fig. 1. An Example of photo image used for measuring areas and Ferret’s dimensions of cell lumen. Top: photograph of cross section which shows boundary between uncompressed and compressed portions. Bottom: A photograph of cell lumen in a compressed portion. From these photographs Ferret’s diameters in tangential and radial directions and areas of cell lumens.

![Swelling graph](image)

Fig. 2. Swelling of the compressed and uncompressed wood from dry to the water saturated condition. The average values were obtained from 5 specimens and error bars mean 95% confidence interval.

3 Results and discussion

3.1 Dimensional change of wood specimen and cell by swelling

Fig. 2 shows the swelling in the radial and the tangential direction of compressed and uncompressed wood specimen. In the uncompressed wood specimen, swelling in tangential direction was larger than that in the radial direction. This is the general tendency in wood.

On the other hand, the wood compressed 50% has specific gravity about twice as large as that of uncompressed wood. Generally, swelling of wood is increased linearly with increase of density, except for longitudinal direction. This is because the permanent pore such as a cell lumen does not make dimensional change as the cell walls by swelling [13]. Therefore, it is expected that swelling ratio is also increased two fold. However, swelling ratio in the radial direction of compressed wood was four times larger than that of uncompressed wood. In other words, it is considered that increase of swelling in compressed wood is caused by expansion of the cell lumen. On the other hand, the swelling ratio in tangential direction was smaller than that of uncompressed wood. This is caused by Poisson’s effect. From the above, it is considered that swelling behavior of cells in compressed wood is very complex in comparison with that of uncompressed wood.

Fig. 3 shows swelling of Feret’s diameters of cell lumens in the tangential and the radial directions in compressed wood which was compressed 50%. The 10 cells were selected randomly in each visual field of a microscope. In uncompressed portion, swelling was small in each cell and the differences of swelling among the cells were not large. On the other hand, variations in swelling ratio of each cell were large and some of the cells were shrink in both the radial and the tangential direction. This result suggests swelling behavior of compressed cells is not uniform and has a different swelling behavior for each cell.

![Swelling graph](image)

Fig. 3. Swelling of Feret’s diameters of cell lumens in the tangential and radial directions in compressed wood. The 10 cells were selected randomly in each portion. Left: cells in the uncompressed portion. Right: cells in the compressed portion.
3.2 Swelling behavior of the different deformation types of cell lumens

In the visual field of a microscope as shown in Fig. 4, four different deformation type of cell lumens were observed. S-shape cells were classified as type I, cells having 3 or 4 projections were classified as type II, cells with bulges in center or tip were classified as type III, and cells of elongated shape were classified as type IV. According to these classification types, increase in area of cell lumens was measured in the visual field of a microscope.

Fig. 5 shows the relationships between increase in area of cell lumens and the deformation type of cell lumens. The cells having decrease or small increase in area of cell lumens were almost classified as the type I. The cells having large increase in area of cell lumens were often classified as the type IV. The II and the III types of cells were distributed from 10% to 80% of increase in area of cell lumens.

Fig. 4 The deformation types of cell lumens in the compressed portion of compressed wood. S-shape cells were classified I. Cells having 3 or 4 projections were classified II. Cells with bulges in center or tip were classified III. Cells of elongated shape were classified IV.

Fig. 5 The relationships between increase ratio of area of cell lumen and the deformation types of cell lumens shown in Fig. 4.

Fig. 6 shows the average increases in area of cell lumens for different deformation types. Although the error range is large, the increase in area of cell lumens is much different between I and IV type of cells. This result suggests that deformation types of cell lumens affect the swelling behaviors of compressed cells. Especially, S-shape cells are hard to be increased the area of cell lumens by swelling. From the above results, it might be possible to improve the dimensional instability of the compressed wood by giving deformations as increasing the S-shape cells.

Therefore, in the future, it should be studied that the relationship between the compression conditions and deformations of cells, and investigated the effect of the deformation type of cells on dimensional change of compressed wood by swelling in detail.

4 Conclusion

The dimensional stability of the compressed wood for the moisture is very important for use as materials. To clarify the effect of swelling behavior of compressed cells on dimensional change of compressed wood, swelling behavior of cell was observed in compressed wood. The results obtained are as follows.

The swelling in the radial direction of wood compressed 50% was four times larger than that of uncompressed wood. In the visual field of a microscope, four different deformation types of cell lumens were observed. The increase in area of cell lumens is different among the four types. Especially, the cells deformed to S-shape are hard to be increased the area of cell lumens by swelling. This result suggests that deformation types of cell lumens affect the swelling behaviors of compressed cells.

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