2.0 Methods and Materials

2.1 Choice and Preparation of the specimens

All of the experiment specimens were cut from one single log of red oak to minimize material variation. The log was felled in West Virginia on Dec. 9, 1996, and transferred to Virginia Tech, Blacksburg, on Dec. 10, 1996. The log was 335cm long, with slight taper. The diameter of the small end was 38.1cm, and the larger end was 44.5cm.

Five 5cm-thick boards were sawn at the Brooks Center, Wood Science Dept. of Virginia Tech on Dec. 11, 1996, according to the cutting diagram shown as Figure 2.1. Each board was then cut into two parts, each 167.5cm long, for the convenience of storage. The number and letter were marked on the board after it was sawn as shown in Figure 2.2. All the boards were wrapped immediately in heavy plastic film and stored at the outside corner of the lab building without sunlight to keep them green until they were cut into smaller specimens for the tests. The average temperature of the season was -4°--2°C.

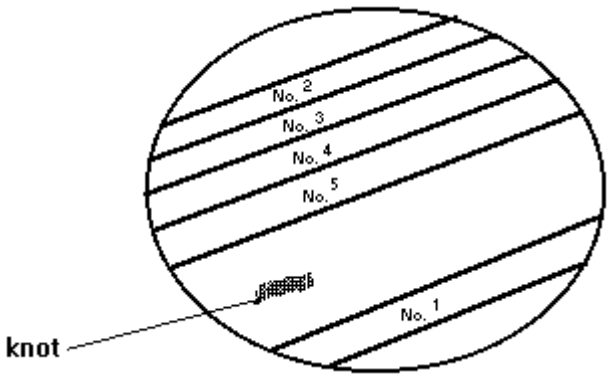

Figure 2.1.Diagram for cutting the log.

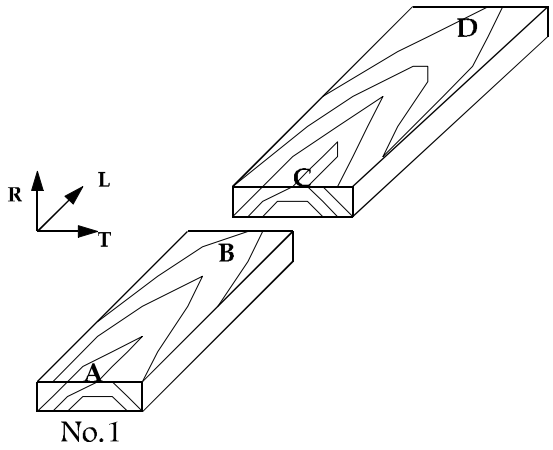

Figure 2.2.The board cut from the log with the letter on it.

2.2 Comparing the four techniques for measuring the moisture gradient

The 167.5cm-long board of No.1-AB was end trimmed into the dimension of 150cm-long×10cm-wide×4cm-thick and then cut into five 30cm-long sections shown as Figure 2.3, marked as No.1-AB-1,-2,-3,-4,-5. All five sections were wrapped immediately with plastic film, leaving the No-1-AB-1 for the test immediately, and for transfering the others to the kiln for drying. The 4cm thickness was chosen based on the convenience of the equipment for measuring the moisture gradient during the kiln drying. And the thick testing blocks will help to compare the moisture gradient results measured by the four techniques.

Section No.1-AB-1 was used to measure the moisture content under the green condition, and the other four sections No.1-AB-2,-3,-4,-5 were put into the kiln which had already been set for a certain drying schedule for drying thick-board red oak. The condition in the kiln was set at 40°C of Dry-Bulb-Temperature and 37°C of Wet-Bulb-Temperature. So the relative humidity in the kiln was about 83% and the equilibrium moisture content was about 16%. By drying under this low temperature and low humidity condition, checking and splitting of the thick red oak board could be

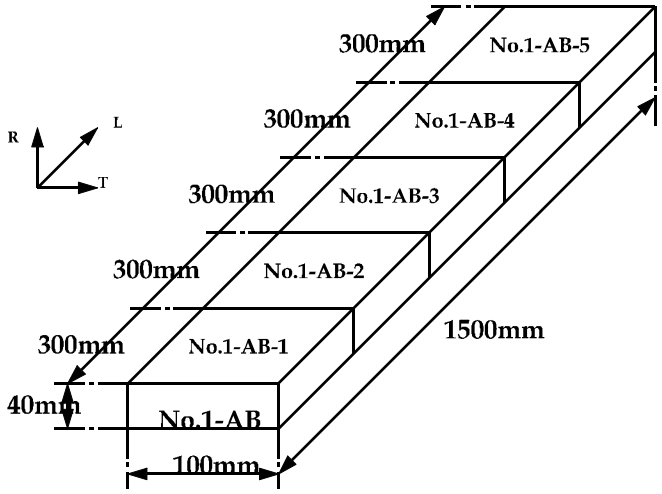

Figure 2.3. Five sections cut from No.1-AB board for the test of comparing four techniques for measuring moisture gradients in red oak.

prevented or reduced. Checking or splits occurring on the testing boards might bring some problems to the later slice cutting procedures.

Before putting the four sections into the kiln, they were unwrapped and end coated on four sides, leaving the two surfaces for the moisture movement so that moisture in the boards could move out only along the thickness direction.

Section No.1-AB-1 was tested without any drying to get the initial moisture content in the block. Two initial moisture content specimens, marked as I_1 and I_2, shown in Figure 2.4, were cut 2cm inside from the two ends, dried in the oven with 103°C and reweighed to obtain the average initial moisture content of the board according to the ASTM D2016-83 (1986). The specimen that was 10cm-wide×5cm-long×4cm-thick, marked as B, was cut for the bandsaw slicing technique. The specimen, marked as O, which was 10cm-wide×10cm-long×4cm-thick, was used for the Forstner bit layering technique. The specimen, marked as F, 10cm-wide×5cm-long×4cm-thick, was for the flaking technique. And the last specimen with 10cm-wide×1cm-long×4cm-thick, marked as R, was used for

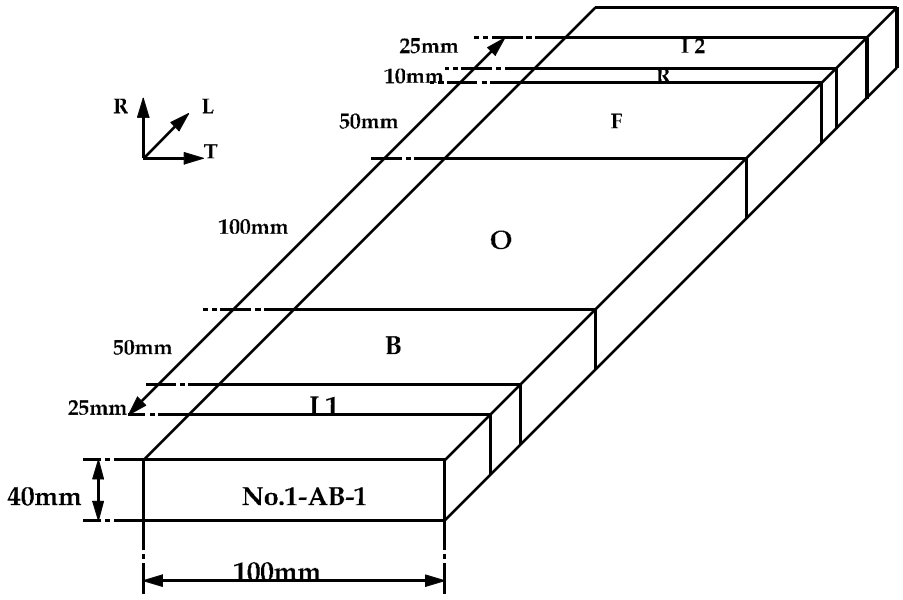

Figure 2.4. The specimens cut from the section No.1-AB-1 for comparing the four techniques on each testing day.

the razor blade slicing technique. All the specimens cut from the section were wrapped immediately and unwrapped upon the tests.

2.2.1 Test with the bandsaw slicing technique

Due to the equipment requirement, the specimen No.1-AB-1-B was trimmed into the dimension of 5cm-wide×5cm-long×4cm-thick. Then sixteen slices, with 2mm-thick each, were cut alternatively from the two surfaces of the specimen as shown in Figure 2.5, with the Powermatic bandsaw in the Wood Physical Properties Lab of Brooks Center, Virginia Tech shown as Figure 2.6. Each slice was weighed immediately after cutting, using the digital electronic scale to precision of 0.01g, which had been set near the bandsaw. After cutting sixteen slices from the specimen, the middle part of the specimen which was 8mm-thick would remain intact. Since the middle part had

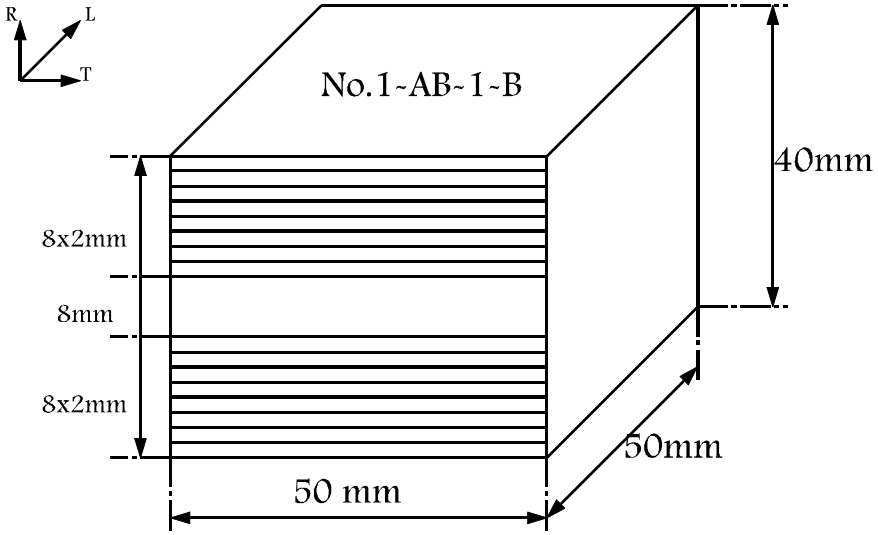

Figure 2.5. The specimen for measuring the moisture gradient with the bandsaw slicing technique.

uniform and higher moisture content than that of the surface and was very difficult to dry, especially during the first period of drying, the moisture gradient in the middle part of the specimen could be assumed as uniform.

After weighing all the slices and the middle part of the bandsaw specimen, they were put into the oven with 103°C temperature for 24 hours' drying, reweighed to obtain the oven-dry weights and then calculate the moisture content of each slice and the middle part. The moisture gradient across the thickness of the specimen could be plotted.

2.2.2 Test with the Forstner bit layering technique.

The specimen No.1-AB-1-O, shown as Figure 2.7, with the dimension of 10cm-wide×10cm-long×4cm-thick, was fixed into the Craftsman Forstner bit drill equipment with special shaving collector, in the Wood Physics Lab, Brooks Center, Virginia Tech, shown as Figure 2.8. The Forstner bit drill to be used for getting each layer of

Figure 2.6. Photograph of the Powermatic bandsaw for the test with the bandsaw slicing technique(PDF, 328K, bandsaw.pdf).

wood removed was 7.62cm in diameter. The total weight of the shaving collector and the specimen was determined before the test. The shaving collector with the sample was clamped to the drill press table. Six successive layers of the specimen with 2.5mm thickness each were removed by the Forstner bit chucked in the drill press. The thickness of each layer was controlled by the depth scale attached to the Forstner bit drill to the precision of 1mm. Shavings from each layer were carefully transferred to a special container, which had been pre-weighed before the test. The collector with the remaining specimen was weighed before and after removal of each layer, using the scale to the precision of 0.01g set near the drill. After removing six layers from one side, the specimen was turned over and fixed into the shaving collector again. The same procedure was repeated to remove another six layers from the other side. All the shavings and the middle 10mm-thick part were put into the oven with 103°C temperature for 24 hours' drying, reweighed to obtain the oven-dry weight and the moisture content of each layer and the middle part was calculated. Then the moisture gradient across the thickness of the specimen could be plotted.

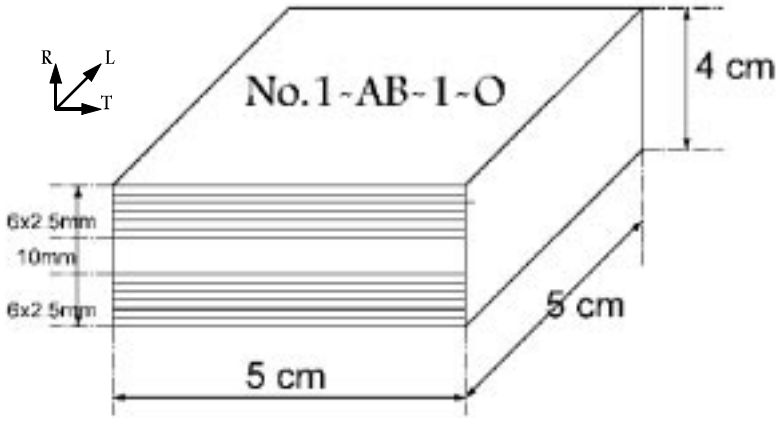

Figure 2.7. The specimen for measuring the moisutre graident with the Forstner bit layering technique.

Figure 2.8. Photograph of the Craftsman Forstner bit drill for the test with the Forstner bit layering technique.(PDF, 356K, forstner.pdf)

2.2.3 Test with the flaking technique

The specimen No.1-AB-1-F, shown as Figure 2.9, was unwrapped and trimmed into the dimension of 5cm-wide×5cm-long×4cm-thick for the convenience of using the CAE Flaker equipment, which is in the Wood-Based Composite Lab, Wood Forest Products Brooks Center, Virginia Tech, shown as Figure 2.10. The specimen was pressed to the knife by air pressure when cutting each flake. Twenty-eight flakes were cut alternatively from the two sides of the specimen. The specimen was weighed before and after each flake cutting, with the scale to the precision of 0.01g set near the flaking machine. And the thickness of the specimen was also measured before and after each cutting with a digital caliper to the precision of 0.01mm. Thus the weight and thickness of each flake were obtained. Then all the flakes and the middle part were put into the oven with 103°C temperature for 24 hours' drying, reweighed to obtain the moisture content of each flake and the middle part. The moisture gradient across the thickness of the specimen could be plotted.

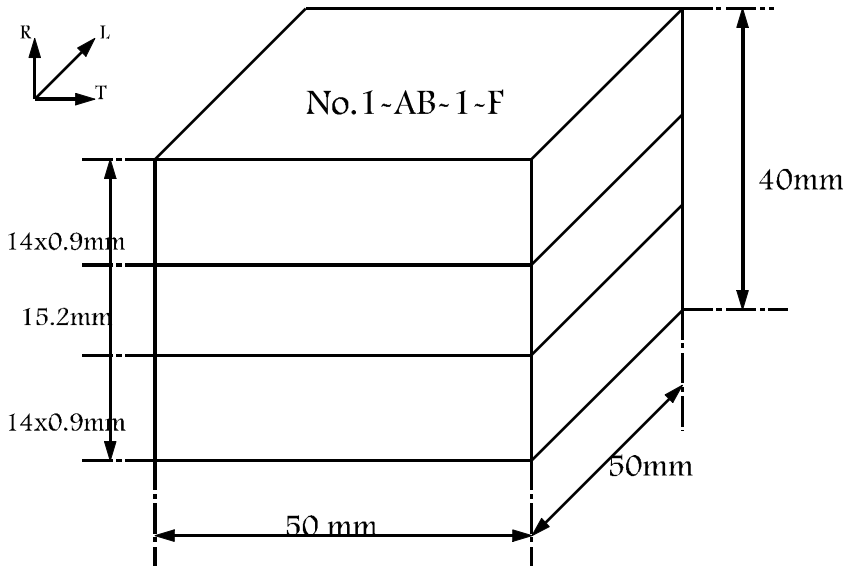

Figure 2.9. The specimen for measuring the moisture gradient with the flaking technique

Figure 2.10: Photograph of the CAF Flaker equipment for the test with the flaking technique.(PDF, 311K, flake.pdf)

2.2.4 Test with the razor blade slicing technique

The specimen No.1-AB-1-R, shown as Figure 2.11, was unwrapped and trimmed into the dimension of 5cm-wide×1cm-long×4cm-thick for the convenience of using the razor blade equipment developed for this study in the Wood Micro-mechanical Lab, Brooks Center, Virginia Tech, shown as Figure 2.12. Lines for each 2mm-thick slice were drawn on the specimen before the test. Twelve slices were cut alternatively from the two sides. The specimen was weighed before and after each slice's cutting, with the scale to the precision of 0.01g set near the razor blade equipment, to get the weight of each slice. All of the slices and the middle part were then put into the oven with 103°C temperature for 24 hours' drying, reweighed to obtain the moisture content of each slice and the middle part. So the moisture gradient across the thickness of the specimen could be plotted.

The same testing procedure for comparing the four techniques was repeated every second day during the kiln drying of red oak boards until the other four sections No.1-AB-2,-3,-4,-5 were all tested. The total number of the slices, flakes or layers of wood removed on each testing day is shown in Table 2.1. after testing all the specimens.

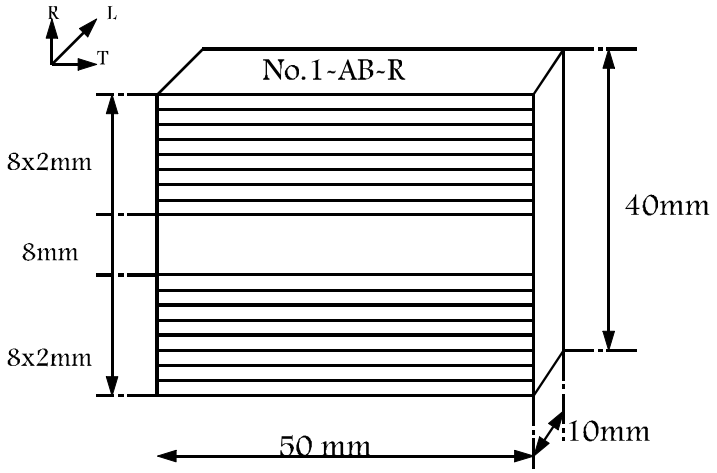

Figure 2.11. The specimen for measuring the moisture gradient with the razor blade slicing technique.

Figure 2.12: Photograph of the razor blade equipment for the test with the razor blade slicing technique.(PDF, 244K, razor.pdf)

Table 2.1. The number of slices, flakes and layers of wood removed for the four techniques on each of the five testing days

Days of drying	green	2 days	4 days	6 days	8 days	TOTAL
Bandsaw slicing technique	16	16	16	16	16	**80**
Forstner bit layering technique	12	12	12	12	12	**60**
Flaking technique	28	28	28	28	28	**140**
Razor blade slicing technique	16	16	16	16	16	**80**

2.3 Testing the slice thickness effect on measuring the moisture gradients

The board marked as No.2-AB was unwrapped and end trimmed into the dimension of 5cm-wide×150cm-long×4cm-thick, shown as Figure 2.13. Five 30cm-long sections were cut from the board, marked as No.2-AB-1,-2,-3,-4, -5, and wrapped with the plastic film immediately, leaving the No.2-AB-1 for measuring the moisture content under the green condition and carrying the other four specimens to the kiln which was also set at the condition of 40°C dry-bulb-temperature 37°C for wet-bulb-temperature.

Section No.2-AB-1 was tested under the green condition. Section No.2-AB-2, -3, -4, -5 were all unwrapped and put into the kiln for drying under the same drying condition as the first test. One of them was taken out for the test every second day during the first period of drying according to the following procedure.

Upon testing, each section was cut into smaller specimens shown as Figure 2.14. Two initial moisture content specimens were cut 35mm inside from the two ends of the board, and put into the oven for 24 hours' drying, and reweighed to obtain the initial moisture content of this section. Three specimens with 5cm-wide×5cm-long×4cm-thick, marked as F_1, F_2, F_3, were used for the flaking technique. Another three specimens with 5cm-wide×1cm-long×4cm-thick, marked as R_1, R_2, R_3, were used in the razor blade slicing technique. All the specimens were wrapped immediately after their cutting,and taken to the razor blade equipment and CAF flake equipment for the tests.

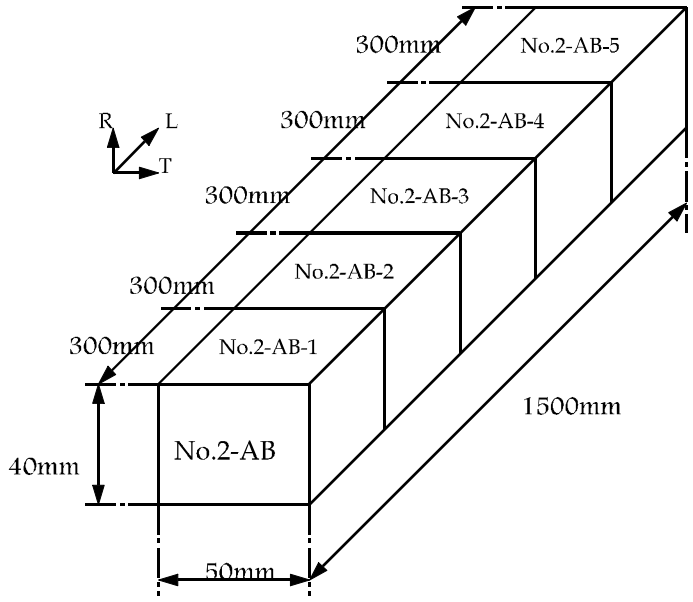

Figure 2.13. The five sections used in the experiments for testing the slice's thickness on measuring moisture gradient.

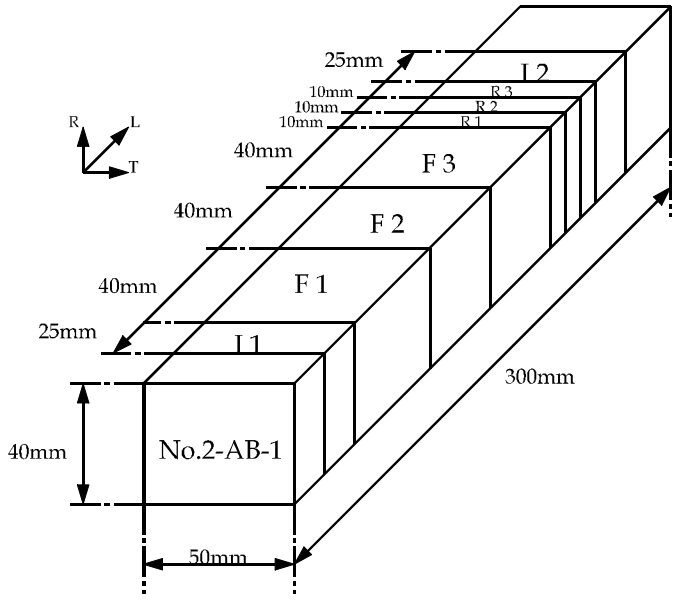

Figure 2.14. The specimens cut from one section for testing the slice's thickness effect with the flaking and razor blade technique on each testing day.

2.3.1 Three thickness series tests with the razor blade slicing technique

Specimen R1 was used to produce the 2mm thick slices. 16 slices were cut alternatively from the two surfaces of the specimen R1, with the razor blade equipment, shown as Figure 2.15. The specimen was weighed before and after each slice's cutting to get the weight of each slice. The total 16 slices and the residual part from specimen R1 obtained after the test were ovendried for 24 hours to determine the moisture content. Then the moisture gradient across the thickness of the specimen could be plotted.

The same testing procedure was repeated for the specimens R2, R3, except that the slices were thicker and fewer. The specimen R2 was sliced to 2.5mm thickness slices, and 12 slices were obtained from it, shown as Figure 2.16.

The specimen R3 was sliced to 3mm thickness slices, and 10 slices were obtained, shown as Figure 2.17.

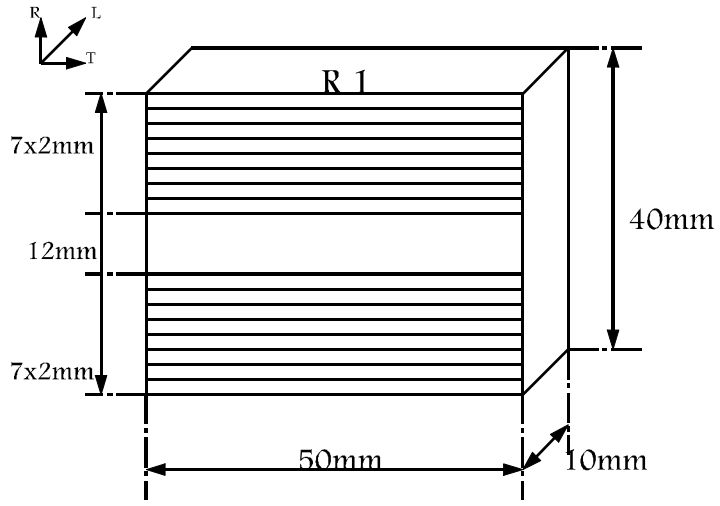

Figure 2.15. The specimen R1 for measuring moisture gradient with 2mm-thick slices

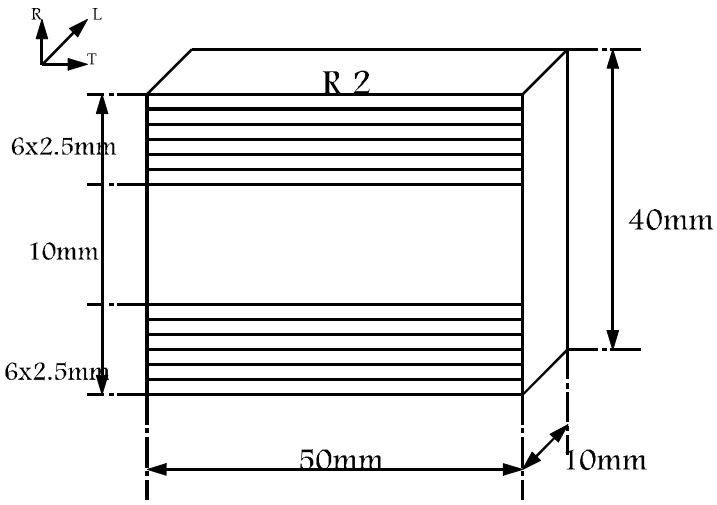

Figure 2.16. The specimen R2 for measuring moisture gradient with 2.5mm-thick slices

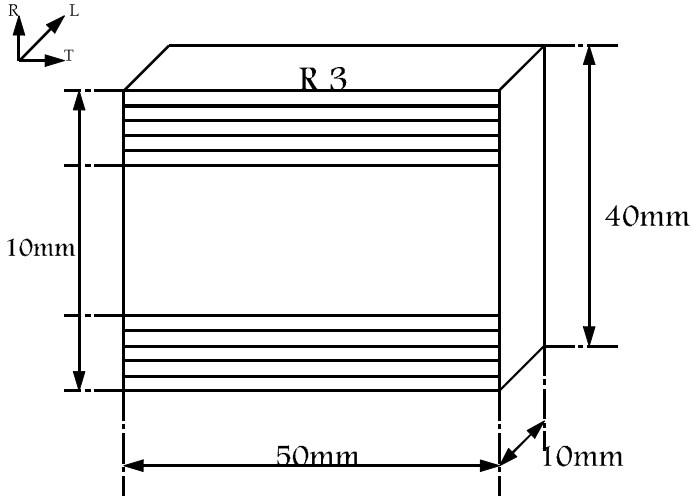

Figure 2.17. The specimen R3 for measuring moisture gradient with 3mm-thick slices

2.3.2 Three thickness series tests with the flaking technique

The procedure for testing the slice's thickness effect on the measured moisture gradient with the razor blade slicing technique was repeated with the flaking technique. Specimen F1 was used for flakes of about 0.6mm thick, Specimen F2 was used for flakes of about 0.9mm thick and Specimen F3 for flakes of about 1.2mm thick. Using the CAF flaking machine to cut the flakes, the thickness of each flake could not be exactly as the thickness required, but by adjusting the angle of the knife, the approximate three thickness levels for the flakes could be obtained, and by measuring the thickness of the specimen before and after each flake cutting, the accurate position of the moisture content for each flake could be calculated and plotted in the moisture gradient graphs.

After the tests, totally 40 flakes and one middle part for Specimen F1, 28 flakes and one middle part for F2, and 22 flakes and one middle part for Specimen F3 were obtained, shown as Figure 2.18. The total number of the slices and flakes obtained on each testing day was shown in Table 2.2.

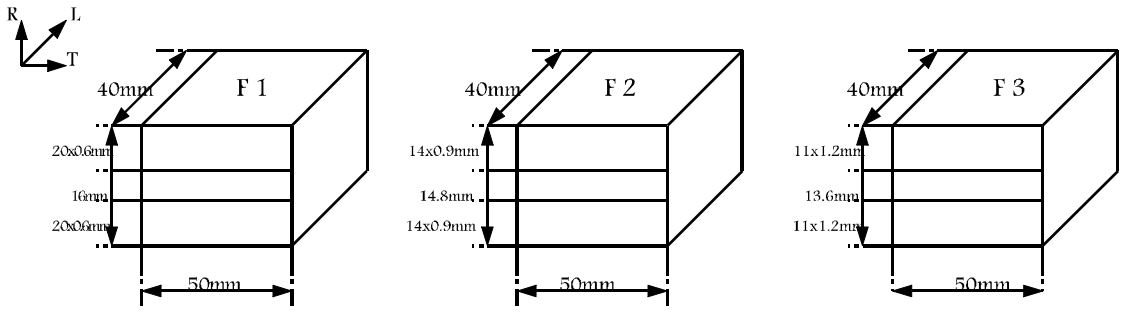

Figure 2.18. The specimens F1,F2,F3 for testing the thickness effect with the flaker technique..

Table 2.2. The number of slices and flakes on each testing day for testing the thickness effect on measuring the moisture gradients

Days of drying	green	2 days	4 days	6 days	8 days	TOTAL
Bandsaw slicing technique						
R1	16	16	16	16	16	**80**
R2	12	12	12	12	12	**60**
R3	10	10	10	10	10	**50**
Total	38	38	38	38	38	**190**
Flaking technique						
F1	40	40	40	40	34	**194**
F2	28	26	28	28	26	**136**
F3	22	22	20	22	22	**108**
Total	90	88	88	90	82	**438**

2.4 Testing the directional effect on the transverse moisture movement during drying

The radial board No.5-AB (shown in Figure 2.1) was used in this test because it allowed comparison of the difference in the moisture movement during drying between radial and tangential direction within one board to minimize the variations.

The board No.5-AB was unwrapped and split into two side-matched boards with the width of 4cm, and trimmed into the dimensions of 4cm-wide×150cm-long×4cm-thick. The two side-matched boards were randomly marked as No.5-AB-T and No.5-AB-R. The board No.5-AB-T was used to measure the moisture gradient in the tangential direction and the board No.5-AB-R was used to measure the moisture gradient in the radial direction. Five smaller sections 25cm-long were cut from each of the two boards, and marked as section No.5-AB-T-1,-2,-3,-4,-5, and No.5-AB-R-1,-2,-3,-4,-5, respectively, shown as Figure 2.19. All the 10 sections were wrapped with the plastic film immediately, leaving the first pair sections, No.5-AB-T-1 and No.5-AB-R-1, for the test immediately and the other four pairs for transfering to the kiln.

Section No.5-AB-T-1 and its side-matched section No.5-AB-R-1 were tested under the green condition. The other four pairs (8 sections) were all put into the kiln for drying under the same drying condition as the first two tests. Before being put into the kiln, four sections for testing tangential moisture gradient were coated on four sides with Lumber

End Coating TCB-701, only leaving the tangential direction as the moisture movement direction. The other four sections for testing the radial moisture gradient were also end-coated on four sides but leaving the radial direction as the moisture movement direction.

One pair of sections (radial and tangential section) were tested at each time. Upon the test, each of the two sections was cut into the smaller specimens with two initial moisture content specimens cut from 6cm inside of the two ends of each section, and two moisture gradient specimens a,b, shown as Figure 2.20. The two moisture gradient specimens were the cubes with 4cm on each side. The initial moisture content specimens were ovendried and reweighed to obtain the initial moisture content of this section. Two cubes from the tangential section, marked as No.5-AB-T-1-a, No.5-AB-T-1-b, and two cubes from the radial section, marked as No.5-AB-R-1-a, No.5-AB-R-1-b, were wrapped with the plastic film immediately after their cutting to take to the flake equipment for testing.

Each of the four moisture gradient specimens was unwrapped when testing with the CAE flake technique. 28 flakes, 0.9mm-thick each, were alternatively cut from the two sides of each specimen. The specimen was weighed before and after each flake cutting, with the scale set near the flaking machine, and the thickness of the specimen was measured before and after each cutting with the digital caliper. The weight and thickness of each flake could be calculated. All the flakes and the middle parts were ovendried to obtain the moisture content. Then the moisture gradient in these four specimens could be plotted.

The whole testing procedure was repeated every second day during the first period of kiln drying until the other four side-matched pairs (tangential and radial) were all tested. The total number of the flakes on each testing day is shown in Table 2.3.

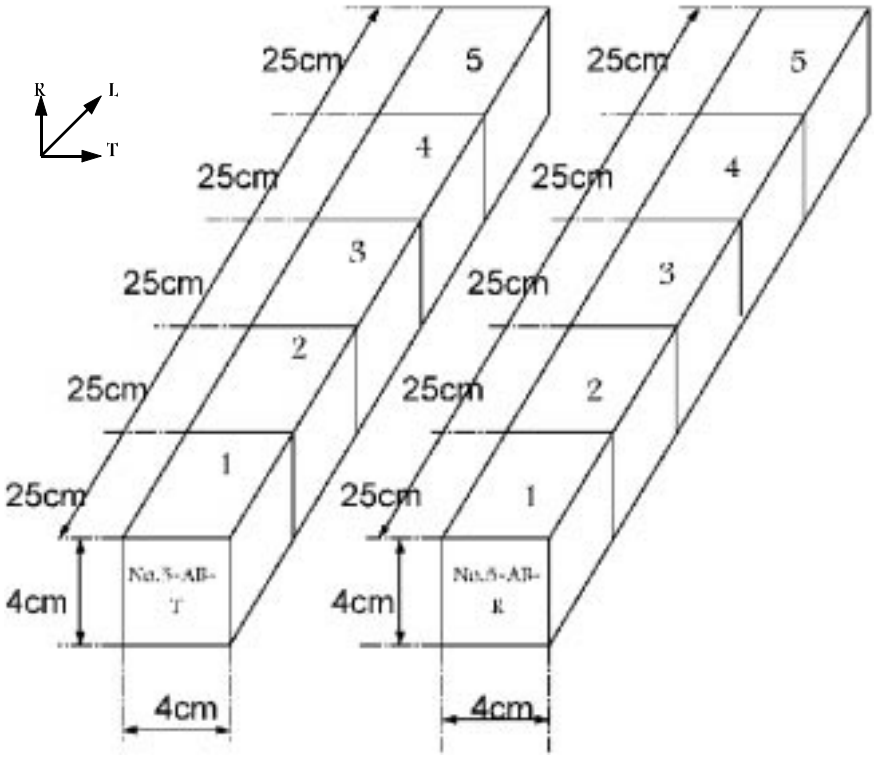

Figure 2.19. Two sections used in the test for comparing the directional effect on moisture movement.

Table 2.3. The number of the flakes obtained on each testing day for comparing the moisture movement in different directions

Days of drying	green	2 days	4 days	6 days	8 days	TOTAL
Radial specimen						
R-a	22	28	24	28	26	**128**
R-b	22	28	24	28	26	**128**
Total	**44**	**56**	**48**	**56**	**52**	**256**
Tangential specimen						
T-a	28	28	24	28	24	**132**
T-b	28	28	24	28	24	**132**
Total	**56**	**56**	**48**	**56**	**48**	**264**

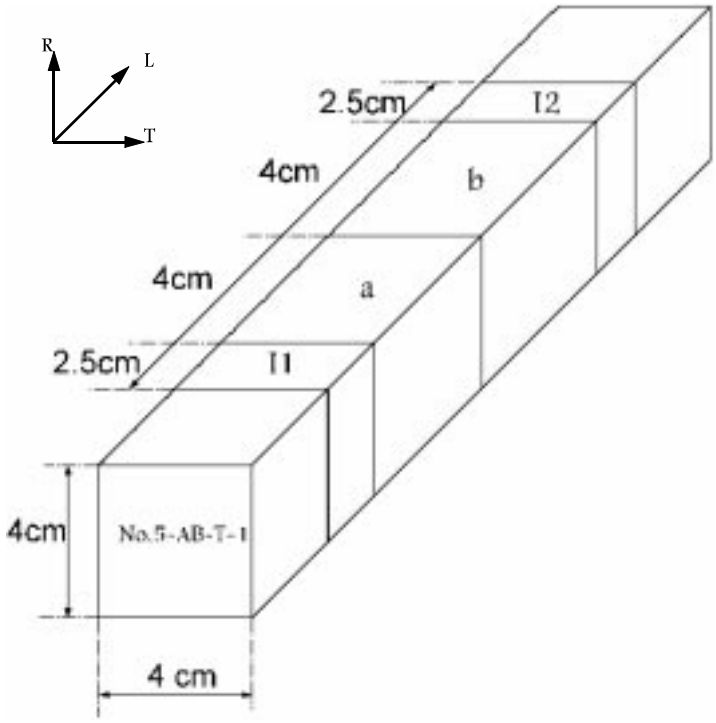

Figure 2.20. The specimens cut from one section for testing the directional effect on moisture movement with the flaking technique on each testing day.