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Evaluation of the Partial Compressive Strength according to the Wood Grain Direction*1

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ABSTRACT

Bearing occurs by the rotations of members induced from horizontal or vertical load at traditional wooden joint in frame. The bearing between wooden members is not occurring at the whole surface of joint, but occurring only at the particular bearing area. In this study, partial bearing according to the different grain direction was evaluated. The partial compressive strength showed 3 times higher than pure compressive strength perpendicular to grain, 1.5 times higher than parallel to grain and 3.3 times higher than both of them. It is expected that this result can be very importantly applied when evaluating and analyzing the actual behavior of traditional wooden mortise and tenon joint.

Keywords : embedment, partial compressive strength, mortise and tenon joint, wood grain

1. INTRODUCTION

Bearing behavior to wood members occurs at inner part of the connection and does in between post and beam member of the connection when it is subjected to horizontal or vertical load, which is the formal characteristic of the connection of Korean traditional post-beam structure. In the past, researchers applied compressive strength of wood according to wood direction and Hankins' equation for the structural analysis of mortise and tenon joint. However it is apt to face two problems as considering behavior of the real connection; 1) bearing of wood is not the result of the whole compression but the result of partial compression, 2) not easy to apply Hankins' equation because the contact area changes with the rotational angle although surface which subjected to compression have angle to the grain,

Partial compression means the bearing subjected not to the whole surface but part of the surface. In this case, the shear behavior occurs at the boundary between two members and the compression to the grain act on the contact area at the same time. It leads to higher strength than the previous whole compression strength (Fig. 1).

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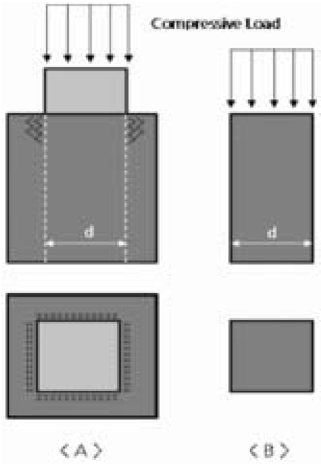

Fig. 1. Outline of the partial compression.

In addition, the area can be expressed as the function of the rotational angle because the surface area changes according to the change of the rotational angle. And theoretically only plastic area exists as soon as bearing started on the basis of material mechanics.

Kim (2011) conducted compressive test with structural sized lumber and reported that skin timber with even 25% of cross section area showed almost 50% compressive performance of solid timber. This means that the resistance is not exactly proportional to the area and it would have greater effect on timber because it is nonhomogeneous material. Kang *et al.* (2001) made a research on compressive behavior by separating early wood and late wood of Japanese Sugi and concluded that early wood has one fourth of maximum strength and MOE compare to late wood. In particular, late wood shows short elastic range and long plastic range while early wood shows linear deformation behavior. That is, the behavior differs from the bearing of early and late wood in traditional joint and proves that the effect of early and late wood should be considered. Jang (2000) reported that compressive strength is proportional to velocity of ultrasonic wave according to the angle of wood grain. It means that the performance of the joint with mortise and tenon is more complicated because of the cross of wood grains of wood members.

Generally, compressive deformation induces shear stress between close cells and separates middle lamella or parenchyma cell. And it is occurred by the tiny kink which means local deformation of micro-fibril structures after the separation of the outer and middle lamella of the tracheid.

Bearing of wood regarding the behavior of traditional connection occurs in joint, under joint and upper horizontal member of connection. But the type of bearing is different from compression behavior typically used. It shows partial bearing behavior accompanied with shear one. Not only the bearing of wood, but also the shape of every part of member would change. In this study, compressive strength of the partial bearing will be evaluated according to the wood grain.

2. MATERIALS AND METHODS

2.1. Materials

Domestic Larch (*Larix kaempferi*) was used and moisture contents (M.C.) was 12.8% (standard deviation : 0.5). Average specific gravity was 0.53 (standard deviation, 0.08). Specimens were manufactured with the compressive surface of 20 × 20 (mm), the replication of test was ten. To reduce the variation within materials, specimens were selected from 6 different material groups. Compressive length was controlled to 70 mm. Specimen were manufactured to have different grain direction and compressive surface as shown in Fig. 2 (Perpendicular to the grain, Parallel to the grain and both of them). To compare the result, pure compressive specimen was made with the parallel to the grain. After the test, M.C. and specific gravity of each specimen were measured.

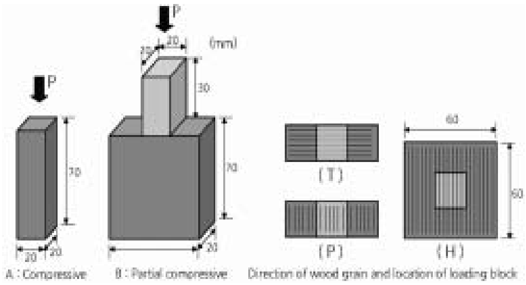

Fig. 2. Schematic diagram of specimen, angle of grain and location of loading block.

Fig. 3. Photograph of compressive test.

2.2. Methods

In order to evaluate partial compression of wood, tests were conducted in accordance with KS F 2206 which defines wood compression test. Length of the specimen was 70 mm and loading speed was set up at 0.3 mm/min with universal test machine (Zwick, 100 kN). And loading block was manufactured parallel to grain using same species to achieve the objective of this study which aimed to evaluate the performance of wood to wood connection. Specimens were prepared in different type as shown in Fig. 2 considering the characteristic of surface which the wood grain was broken by the loading block. Test for compression strength was conducted as shown in Fig. 3 Compressive strength was divided into parallel and perpendicular to grain. In case of partial compression, the location of loading block was divided into tangential(T), parallel(P) and both of them to the grain on contact area as shown in Fig. 2 To secure the accuracy of experiment, compressive specimens used for comparison were taken from the same member.

3. RESULTS AND DISCUSSION

3.1. Evaluation of Compression Strength

Compressive strength of wood has significant difference according to the grain of angle. Tests to evaluate compressive strength were coducted in two directions, parallel and perpendicular to the grain. Compressive strength showed devition between material groups. The result showed that compressive strength perpendicular to the grain was 1/13 compared to that of parallel to the grain, and the value was 4.3 MPa on average. As compressive behavior of traditional connection occur perpendicular to the grain of horizontal and vertical members, partial compressive strength was evaluated based on compressive strength of perpendicular to the grain. Test results were shown in Table 1.

3.2. Evaluation of Partial Compressive Strength with Two Shear Surfaces

Evaluation of partial compressive strength was conducted as shown in Fig. 4. Failure mode was shown in right side of the Fig. 4. And that failure occurred by both the bearing which acts perpendicular to the grain and the wrecking failure of edge.

The result shows increase of strength compared to the whole compressive strength and different value according to the direction of loading block. As shown in the Table 2, the strength when the

Table 1. Compressive strength of pure compressive specimen

Load direction	qe	Compressive strength (MPa)	Average (MPa)	Strength ratio
Parallel to grain	Group F	46.96	55.41	12.79
	Group E	64.87		
Perpendicular to grain	Group A	2.97	4.33	1
	Group B	4.66		
	Group C	5.08		
	Group D	4.62		

Table 2. Partial compressive strength

Materials	Load direction		Compressive strength (MPa)	Strength ratio
Group A	Perpendicular	2.97	1	2.89
	Partial (Perpendicular, T)	8.94	3.01	
Group B	Perpendicular	4.66	1	
	Partial (Perpendicular, T)	12.91	2.77	
Group C	Perpendicular	5.08	1	1.46
	Partial (Parallel, P)	7.32	1.44	
Group D	Perpendicular	4.62	1	
	Partial (Parallel, P)	6.90	1.49	

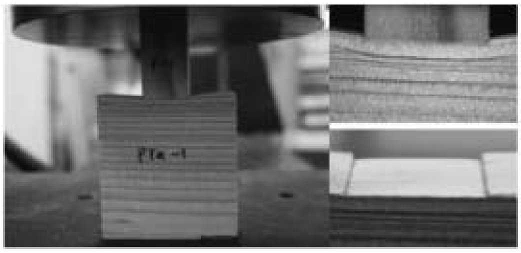

Fig. 4. Photograph of partial compressive test.

loading block was located in the direction perpendicular to the grain has increased about 3 times compared to the whole compressive test and about 1.5 times when the block located parallel to the grain.

The difference of strength ratio is caused by the location of the boundary between two members. In the partial compression perpendicular to grain on the contact area, the fibers cross the boundary and break off by the loading block so the strength increased. In parallel to grain, the fibers were divided and split perpendicular to fiber.

From the result, the direction and the number of the boundary should be considered in the structural analysis of wood to wood joints such as the mortise and tenon joint. In structural design of post and beam structure, the design value of compressive strength was utilized and the results generally did not consider.

3.3 Evaluation of Partial Compressive Strength with Four Shear Surfaces

Based on the test shown above, compressive test of specimen which had 4 interfaces was conducted. In these cases, breaking off and splitting of the wood fibers occur at the same time. Failure modes are shown in Fig. 5.

As much as 3.5 times higher strength com-

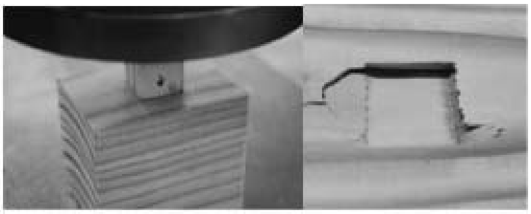

Fig. 5. Photograph of partial compressive strength test.

pared to the whole compression test was expected from the previous results and the actual strength was similar (Table 3). the splitting between wood fibers is less effective on the other hand, the breaking off the fiber is more effective.

Table 3. Partial compressive strength

Materials	Load direction	Compressive strength (MPa)	Strength ratio
Group A	Perpendicular	2.97	1
	Partial (Perpendicular, H)	9.76	3.29
	Predicted result	10.40	3.5

CONCLUSIONS

In design and analysis of wood to wood joint, the compressive strength of the whole area has been utilized to evaluate and predict the behavior and design values of the joint. However compressive strength was different according to the direction and location of the boundary between wood members which were manufactured wood to wood joints. In this study, the results show about 3 times increase in strength when the boundary was perpendicular to the grain on compressive surface, 1.5 times when it was parallel to grain and 3.3 times when it had both of them. The results should be considered in the design and analysis of wood to wood to joint especially, traditional wood joint with mortise and tenon so it would increase the accuracy of calculation.

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