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The Research on Methods of Glue-lumber Compressive Properties Test

[1]Guo Nan, [1]Liu Xiu-Xia and [1]He Tie
[1]Northeast Forestry University, Harbin, Heilongjiang, 150040, Province, China

Abstract: The compressive performance is the basic mechanical properties of the glue-lumber, in order to measure the elastic modulus and compressive strength of the glue-lumber accurately, the compressive test was conducted on three batches which totally including 18 first-grade SPF specimens, the experimental results were compared and analyzed, the appeared errors were studied and the improvement scheme was given out. The results showed that, with the influence of the laminates distribution, the strain can't be measured accurately by the strain gauge; The prism glue-lumber specimens was used to decrease the influence of the end local pressure, which can get the most accurate data; In the middle of the specimen, double-clip type extensometer was used to measure the deformation, which can get the most proceed data. The achievements can be the basis for the improvement of the timber compression properties test.

Key words: Glue-lumber specimens, elastic modulus, compressive strength parallel to grain, test method

INTRODUCTION

The timber structural building is famous for the characteristics of energy saving, environmental protection, safety, suitable settlement etc. In developed countries such as American and Europe, lots of buildings are timber structure (Josef, 2008; Sui *et al*., 2009; Kohler and Svensson, 2011).With the background of vigorously extended green architecture, the timber structure will have a more wider development space.

The glued laminated timber is formed with timber mainly glue together along the grain, whose thickness is less than 45 mm. Glue laminated wood members are widely used because of its typical advantages. The compression property is the basic mechanical properties of glue-lumber. How to accurately measure the compressive strength and elastic modulus to evaluate its compressive properties is important.

At present, the researches of its compressive properties are mainly concentrated on force performance. Through compressive test on larch glue-lumber, the elastic modulus is determined (Wang, 2013).Through compressive test of parallel to grain on larch glue-lumber to study its failure mode(Dai and Zhou, 2012). Through compression test of citibank pine glue-lumber specimen to study the compressive strength(Zhang, 2011). But under the same test condition, studies on the test method of glue-lumber cube specimens compressive properties is comparative little, thus, it's feasible and necessary to study the test method mentioned in the study.

Based on the size requirement mentioned in «timber structure test standard» (GB/T 50329, 2012), square section is adopted to measure elastic modulus. Three batches of specimens were made to conduct the test, each batch consists of six specimens. The former two batches were cube glue-lumber specimens, while the third batch was prism glue-lumber specimens. Through analysis of the test data, the reasons of the appeared errors can be found out, then the improvement scheme will be given out.

TEST SCHEME

Specimen making: The specimens were divided into three batches, all the wood used were first-grade SPF and were bonded by seven layers of glue-lumber plate, the thickness in the middle layer was 16 mm,the rest were all 14 mm. As shown in Fig.1

The size of the former two batches was 100×100×100 mm. In every batch, six specimens were processed. The size of the third was 100×100×300 mm, six specimens were processed. As shown in Table 1.

Loading system: Loading process contained elastic and failure stage, elastic stage was controlled by force, loading speed was 2 kN sec^{-1}. The first loading cycle was preloading, from 0 to 50 kN then unloading to 10 kN; Other five loading cycles were loading from 10 to 50 kN then unloading to 10 kN. As shown in Fig. 2. Failure stage was controlled by displacement, uniform loading speed was 2 mm min^{-1}, the target displacement was 10 mm.

Corresponding Author: Guo Nan, School of Civil Engineering, Northeast Forestry University, Harbin, Heilongjiang, 150040, Province, China

Table 1: Glue-lumber specimens

Batch	Material	No. of layers	Amounts
1st	First-grade SPF	Seven	Six
2nd	First-grade SPF	Seven	Six
3rd	First-grade SPF	Seven	Six

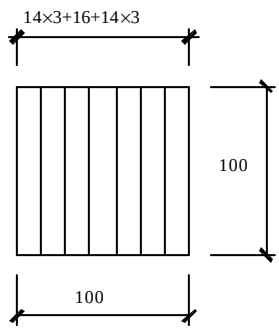

Fig. 1: The section size of specimens

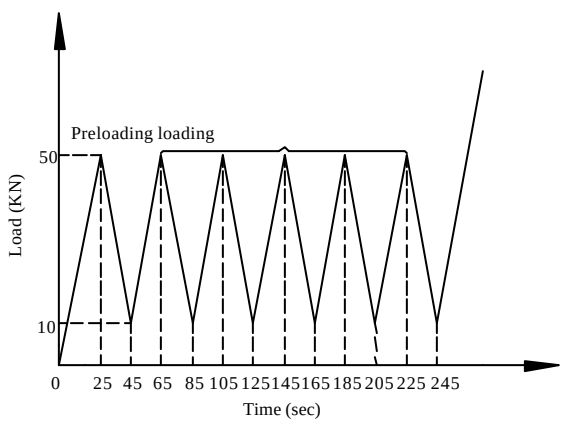

Fig. 2: Loading system

Experimental results: In elastic deformation stage,the elastic modulus can be calculated according to the following formula:

$$E = \frac{\Delta\sigma}{\Delta\varepsilon} = \frac{\frac{N_2 - N_1}{A}}{\frac{\Delta L_2 - \Delta L_1}{L_0}} \quad (1)$$

In the formula, N_1, N_2 was the initial force and terminate force in one cycle; ΔL_1, ΔL_2 was the deformation measured by strain gauge; A was the compression area (mm^2); L_0 was the standard distance of extensometer.

For the five elastic modulus measured by five elastic cycle, take average of the three closest values as the elastic modulus of specimen(GB/T 50329, 2012).

In the failure stage,the compressive strength can be calculated according to the following formula:

Table 2: Elastic modulus and compressive strength of the first batch of specimen

	Elastic modulus /Mpa			Strength /Mpa		
Specimen No.	Data	Average	Standard deviation	Data	Average	Standard deviation
SPF1-1	2805.00	2564.91	197.95	35.69	35.50	0.34
SPF1-2	2324.75			35.28		
SPF1-3	2598.33			33.99		
SPF1-4	3040.37			34.96		
SPF1-5	2076.64			35.88		
SPF1-6	2531.54			35.16		

Fig. 3: Test device of 1st batch of specimen

$$f_c = \frac{F_u}{A} \quad (2)$$

In the formula, F_u was the load at the time of specimen eventually damage; A was the specimen section area (mm^2).

Because of the existence of uncertain factors influencing the test result, for the six elastic modulus and compressive strength of each group of specimens, taking average of the four most closest values as the test result.

TEST OF THE 1ST BATCH

Test scheme: Compression test was conducted on the 200 kN electro-hydraulic servo universal tester. The elastic modulus and compressive strength data was output by universal testing machine, the test device was shown in Fig. 3.

Test results: After calculation of the output data, the elastic modulus and compressive strength was shown in Table 2. The SPF1-2 stood for the second specimen of the first batch.

Error analysis: The elastic modulus of first-grade SPF in «design code for timber structure» (GB50005-2003) was 9000 Mpa, which was larger than that of the test

Table 3: Elastic modulus and compressive strength of the second batch of specimen

	Elastic modulus /Mpa(strain gauge)			Elastic modulus /Mpa(displacement meter)			Strength /Mpa		
Specimen No.	Data	Average	Standard deviation	Data	Average	Standard deviation	Data	Average	Standard deviation
SPF2-1	113840.8	14038.38	10951.23	7411	6699.00	735.2	42.12	40.26	0.46
SPF2-2	18301.96			7112			40.83		
SPF2-3	4963.02			2683			34.95		
SPF2-4	36835.05			5742			40.29		
SPF2-5	24087.31			6531			40.27		
SPF2-6	8801.21			5152			39.75		

Table 4: The data of strain gauge

Specimen No.	Elastic modulus /Mpa			
	Strain gauge 1	Strain gauge 2	Strain gauge 3	Strain gauge 4
SPF2-1	319053.2	-136755.0	6104.9	19948.6
SPF2-2	39601.4	11168.0	4136.5	-53182.2
SPF2-3	-141016.6	-109182.8	5152.2	4773.8
SPF2-4	80776.6	25333.6	4394.9	-96397.6
SPF2-5	-128177.6	52875.4	5613.3	13773.2
SPF2-6	8290.5	-168371.8	9311.9	-41220.0

result, the compression strength was smaller, also was of large discreteness.The error analysis was as follows.

The pressure F applied on the specimen was subjected from universal testing machine and the deformation L was output by it directly, the deformation of the specimen itself was small, while the beam of universal testing machine has certain deflection, so the displacement output was larger, thus the elastic modulus is relatively small, the influence of the bearing plate leads to the larger compression strength. Thus the test scheme was modified.

TEST OF THE 2ND BATCH

Test scheme: The pressure was measured by pressure sensor, the deformation in elastic stage was measured by strain gauge with size of 5×60 mm,the paste order of the strain gauge was shown in Fig. 4. Two displacement meters were added to measure the deformation in failure stage,the deformation can be reflected by the displacement change between the upper and lower supports in the machine, in this way, the errors can be eliminated. The test device was shown in Fig. 5.

Test results: The strain in elastic stage was measured by strain gauge, the experimental data was collected by DH3816N static strain acquisition system, the data recorded by the displacement meter was used for verification. The data was calculated in Table 3.

The elastic modulus calculated from the data measured by displacement meter was closer to true value, but the errors still exist, the data measured by strain gauge had large discreteness. The data of the strain gauge from 1 to 4 was of large difference. As shown in Table 4.

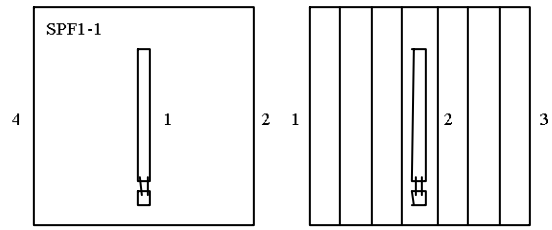

Fig. 4: The paste order of the strain gauge

Fig. 5: Test device of 2nd batch of specimen

Error analysis: In making process of glue-lumber, the laminates were pasted together, so the initial stress existed, the deformation was uneven in the compression process.

The lateral deformation of specimen was constrained by friction between specimen and compressor interface, leading specimen to the state of three-directional pressure and data larger. With the analysis of the error, the test scheme of the second batch of specimen was modified.

TEST OF THE 3RD BATCH

Test scheme: To decrease the influence of end friction, the prism specimen with the size of 100×100×300 mm was determined instead of the cube specimen (GB/T50329, 2002).

Table.5: Elastic modulus and compressive strength of the third batch of specimen

	Elastic modulus /Mpa(strain gauge)			Elastic modulus /Mpa(displacement meter)			Strength /Mpa		
Specimen No.	Data	Average	Standard deviation	Data	Average	Standard deviation	Data	Average	Standard deviation
SPF2-1	8753.93	8653.84	249.78	8623.54	8981.47	19.87	22.87	22.72	0.13
SPF2-2	12332.82			8963.37			22.69		
SPF2-3	15973.85			8966.34			23.78		
SPF2-4	8296.98			9004.23			22.55		
SPF2-5	8873.99			8780.94			22.75		
SPF2-6	8690.45			8991.95			22.30		

Fig. 6: Double-clip type extensometer

Fig. 7: Test device of 3rd batch of specimen

The test device was modified as follows: by refitting the two ordinary extensometers, double-clip type extensometer with the standard distance of 100 mm and the range of 1 mm was formed. As shown in Fig. 6. The extensometer clamping edge length was 100 mm to make the deformation real and uniform. The range was 1 mm to improve accuracy and decrease test error. In this case, the test device was shown in Fig. 7.

Test results: The deformation in the middle 100 mm range of the specimen was measured by double-clip type extensometer, displacement was measured by displacement meter and pressure was measured by pressure sensor. The displacement meter was used to verify the data measured by double-clip type extensometer. The data as shown in Table 5.

Analysis of results: According to the data in Table. 5, the elastic modulus measured by double-clip type extensometer was closer to that of displacement meter and had less discreteness.

Contrast the elastic modulus and compression strength measured by displacement meter in Table 3 to 5,the prism glue-lumber specimen had the precise data, the reason was that the middle of the prism glue-lumber specimen was typical unidirectional compressed state, thus the influence of the end friction was avoided.

CONCLUSION

- The laminates were pasted together in glue-lumber specimen, so the initial stress exist, the deformation was uneven in the compressive process. The strain value measured in different laminates had large discreteness, so the way to measure the elastic modulus with strain gauge was not recommended
- The end friction had little influence on the prism glue-lumber specimen, in order to get the accurate result, it suggested that the prism glue-lumber specimen should be used when the press test was conducted, the height of which should be 2 to 4 times of the section side length
- In the middle of the specimen, the deformation was measured by double-clip type extensometer, the data had less discreteness and more precision because of little influence of end friction

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