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Short Note

NON-STANDARD TEST METHOD FOR GLUE LINE SHEAR STRENGTH

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ABSTRACT

The relevant standards for glueline shear strength testing were summarized and analyzed in this paper. Depending on these existing test standards, the resulting stress in glueline is not pure shear stress, but a combination of shear and normal stresses. In order to overcome this deficiency, a symmetrical structure was proposed for making samples. Some comparative testing was accomplished by using these symmetrical samples, the results showed that the normal stress could be avoided during testing. These results were also confirmed by finite element method (FEM), the simulation results showed that the shear stress in glueline was uniform.

KEYWORDS: Glueline, shear strength, test method, FEM.

INTRODUCTION

Shear strength is a key index in quality control of glulam. Shear strength testing should be regulated by some standards. To a certain extent, these relevant standards have large effect on accuracy of these testing. In order to achieve a well-defined and uniform state of shear stresses in test zone, block shear tests, off-axis tension or compression and in-plane shear loading were applied for glue line shear testing (Yoshihara and Matsumoto 2005), frequently. Liu et al. (1996)

applied a new butterfly-shaped specimen in shear tests to improve the Arcan shear test for wood. Only the shear strength parallel to grain was yielded in the new testing method. Yoshihara and Matsumoto (2005) measured the shearing properties of wood by in-plane shear test using a thin specimen. The validity of in-plane shear test for measuring shear strength was verified by the finite element method. The results showed that in-plane shear test was effective for measuring shear strength. Xavier et al. (2004) investigated the applicability of Iosipescu and off-axis test methods for the shear characterization of clear wood. The results indicated that the Iosipescu test gave lower and upper bounds of shear strengths, where as the off-axis test gave only a lower bound, directly from the measured loads.

Among these test methods, one-sided block shear test is regarded as the most efficient method for glue line shear testing, due to its simple fabrication of samples and easy test process and rapid analysis of the test results. However, the block shear test has several shortcomings. Firstly, a non-uniform shear stress distribution will be acquired by the block shear testing. There is a difference between experimental result and theoretical result. Secondly, the results from different devices cannot be compared directly. The results are influenced by samples and the type of shear tools. It is necessary to create a novel method to instead of the block shear test. In this paper, different standards for block shear testing were summarized and compared. Then, a non-standard and novel test method was proposed to avoid these shortcomings of these existing standards.

MATERIAL AND METHODS

Methods

In Europe, the block shear test which carried out according to EN 14080 is used for continuous factory control of glue line shear strength. A principle schematic for the shear tool was presented in this standard. In order to get a uniform stress field in width direction, the shear force should be applied self-aligning by a cylindrical bearing. The load surfaces should be smooth and parallel to each other. The specimens for this method should be of width b and of thickness t between 40 and 50 mm. The specimens and shear compression tools were shown in Fig. 1.

The shear strength can be calculated by the following formula:

$$f_{v,a} = k\frac{F_u}{A} \quad \text{with} \quad k = 0.78+0.0044t$$

With A = sheared area = $b \cdot t$, F_u = ultimate load and k being a modification factor for test pieces where the thickness in the grain direction of the sheared area is less than 50 mm.

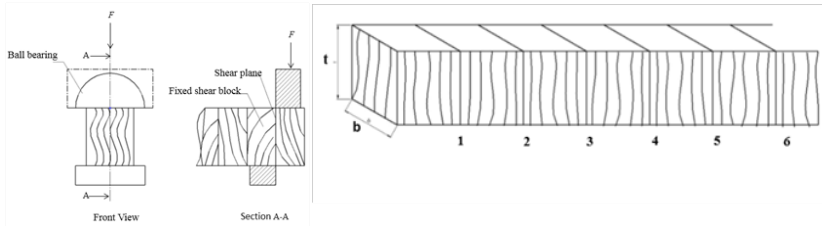

Fig. 1: The shear compression tools and specimen.

Chinese standard GB/T 17517-1998 and American standard ASTM D 905-03-2003 are applied to test glue line shear strength in China and USA, respectively. The specimens shall have uniform glue line. These two standards provide schematic diagram and samples similar to EN 14080.

In order to improve accuracy of test, a novel and non-standard sample was proposed (shown in Fig. 2). The samples had symmetrical structure. They were stable in shear testing. The shear area was same to samples in GB/T 17517-1998.

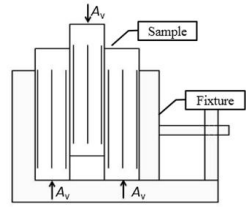

Fig.2: Schematic diagram of non-standard test method.

Materials

The feasibility and accuracy of non-standard test was validated by the confirmation test. The wood species was pine (*Pinus sylvestris* L.) which collected from the north of Sweden. The gluing parameters for these samples were shown in Tab. 1. The samples were made by Chinese standard GB/T 17517-1998 and this non-standard method. Before shearing test, these samples should be treated in the climate chamber to balance the moisture content. The temperature and relative moisture content were 20°C and 65%, respectively. The processing time is two weeks.

Tab. 1: The gluing parameters.

Parameters	Values
Adhesive	PVAc
Adhesive spread($g \cdot m^{-2}$)	200
Pressing time(h)	1.2
Pressure (MPa)	1.2

Five group experiments were completed for these two different test methods. Thirty samples were included in each group. One half were tested by GB/T 17517-1998, the other half were tested by this non-standard test method.

RESULTS AND DISCUSSION

The force analysis of specimen and shortcomings of block shear testing

The state of static equilibrium in specimens was shown in Fig. 3. In shear testing, one portion of specimen was fixed on a support and the other portion was sheared off by a plunger. Due to the friction between plunger and wood specimen, both the shearing force and normal stresses perpendicular to the surface of shear were introduced by the plunger. These stresses were far from uniform and strongly influenced the condition of failure. Therefore, the resulting stress in glue line was not the pure shear stress but rather a combination of shear and normal stresses.

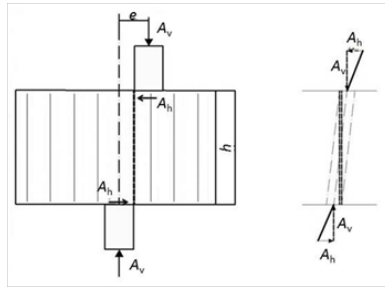

Fig. 3: The static equilibrium in specimens (Modified from Steiger et al. 2010).

Numerical analyses of the non-standard method

In order to get the stress field in the test section and check the feasibility of this non-standard test method, the numerical analyses of this non-standard test method was carried out using the finite element method. The ABAQUS software was applied to create modeling. After modeling process, the material parameters were defined. In this modeling, the boundary condition was set as symmetry to reduce calculation amount as shown in Fig. 4. The stress distribution in the glue line was shown in Fig. 5. It was obvious that the shear stress distribution was uniform and the normal force was almost zero (as shown in Fig. 5B). Only a little stress concentration in the edge of glue line (as shown in Fig. 5A). This result indicated that the non-standard test method could avoid the normal stress. The result of shear stress can correctly reflect the real value of shear strength.

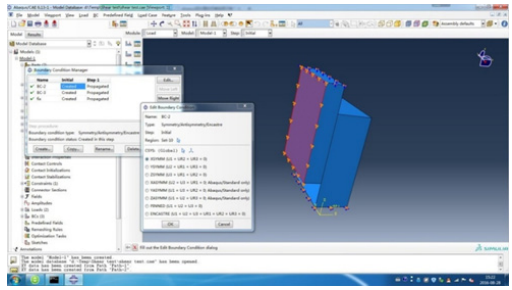

Fig. 4: Modeling of non-standard sample.

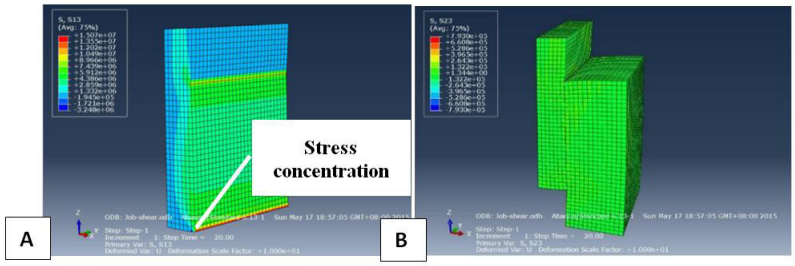

Fig. 5: The shear stress (A) and normal force (B) distribution in glue line.

In Tab. 2, it showed that mean value of shear strength from non-standard test method was higher than the value got from GB/T 17517-1998. As the results of variance analysis, this revealed that the results had significant difference between the non-standard and GB/T 17517-1998.

Tab. 2: Descriptive statistics forshear strength from different standards.

Standards	Mean in (MPa)	Std. deviation	Std. error	95 % confidence interval for mean	
				Lower	Upper
Non-standard	9.490	0.447	0.200	8.935	10.045
GB/T 17517-1998	8.976	0.176	0.079	8.758	9.194
ANOVA (P=0.05)	F=5.720	**Sig.**=0.044<0.05			

The results from mechanical analysis and numerical simulation revealed the true state of glue line during testing. The normal force perpendicular to shear surface was avoided effectively. It indicates that the non-standard test method is feasible for glue line shear strength test. Comparing to the results shown by Steiger et al. (2010) for glue line shear strength test method, here the non-standard test method is easier to execute due to simple fabrication of samples and shear tools. It has contribute to innovate the test method and update the test standards for glue line shear strength. Even these existing test standards are widely applied in quality control of glulam, it is necessary to research a novel test method to improve the accuracy for scientific research.

CONCLUSIONS

Aim to avoid the normal force in the glue line and increase the accuracy of test results, a novel and non-standard test method was proposed in this paper. Due to the symmetrical structure, the moment of normal force can be counteracted and the normal force can be avoided. From the FEM simulation, the results showed that the normal force was almost zero in the glue line and the shear stress was uniform in the whole glue line, but only a little stress concentration in the edge of glue line. At the same time, the results of confirmation test also indicated that the non-standard test method was feasible and effective to test the shear strength of glue line.

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