THE INVESTIGATION OF INTERNAL STRESSES IN GLULAM

Viktor Medov , Anatoly Chubinskii
Saint- Petersburg Forestry University , Saint-Petersburg, Russian Federation

Keywords: glulam, durability, internal stresses

ABSTRACT
Laminated wood constructions (or Glulam) are one of the most perspective materials used in different spheres of industrial- and civil engineering. It is rightfully considered that Glulam is the most responsible products of modern woodworking, because buildings, created on it, must provide trouble-free exploitation behavior for a prolonged period. This paper investigates the problem of understanding and modeling the durability of laminated wood constructions. One of the main unaccounted factors in the process of calculating the structure is the value of internal stresses. In this regard the paper proposesa new method of evaluation.

1. INTRODUCTION

According to our reckoning durability of laminated wood constructions is the facility of structure to provide bespoken properties during the exploitation period. Expert poll results of how different factors influence to Glulam's durability [2] shows priority of system "wood-glue" in refusing of adhesive bond, but this problem doesn't have any methods to evaluate and investigate it. The first aim of our research is to formulate an approach to understanding the nature of laminated wood construction durability.
Internal stresses appear in Glulam for natural reasons: it is the reaction of a heterogeneous material onto variation of environment properties. They appear during manufacturing process and may develop over an exploitation period. There are four types of internal stresses: moisture, temperature, shrinkage and stresses that appear in consequence of wood elastic recovery. Investigation of internal stresses is important because of fact that its value is adding to the total stress condition of structure [2]. The second aim of our research is creating a new method that will accurately capture the distribution of internal stresses in laminated wood construction specimen.

2. RESEARCH

For the further investigations it is important to have a theoretical basis that can explain different strength effects in a solid. Special science literature analysis has shown that the most detailed model of failure is described bykinetic theory of strength [3]. It was formulated and proofed in the middle of XX century in Leningrad, USSR by a group of scientists under auspices of academician SerafimZhurkov. It determines time of being under define loading value as the main criteria of strength. The main law of this theory is stated as (1):

$$\tau = \tau_0 exp\left[\frac{U_0-\gamma(\sigma_l+\sigma_{in})}{kT}\right]. \quad (1)$$

Where
τ_0 – durability "pole" constant, s;

U_0 -initial energy of activation, $kkal \cdot mol^{-1}$;

γ – parameter, influenced by physical and chemical structure of substance;

σ_l - general strain in consequence of loading, MPa;

σ_a - additional strain in consequence of other effects, MPa;

k – Boltzmann constant (1,3806488(13) · 10^{-23}), $J \cdot K^{-1}$

T – temperature, K.

Longtime period of destruction is explained by the process of initial defects uprising on submicroscopic level and growing up to main cracks.

In context of our research the most interesting parameter is σ_a - additional strain - in consequence of other effects. It can characterize the degree of internal stresses influence on structure durability. Yet, this is not always taken into consideration, but often significantly increases the overall structural stress.

The process of measuring the stresses is as follows (Fig. 1): putting points on the surface of a structure or a pre-cut slice of the design section for a given marking, measurement of points coordinates markup before puncturing (x_0) and after puncturing of samples (x_c), loading samples by stretching or compression to the initial values of the coordinates (x_0) necessary for latching of the load *F*. The value of the internal stress acting between any pair of points is determined by the ratio of the applied load to the cross-sectional area of the test sample.

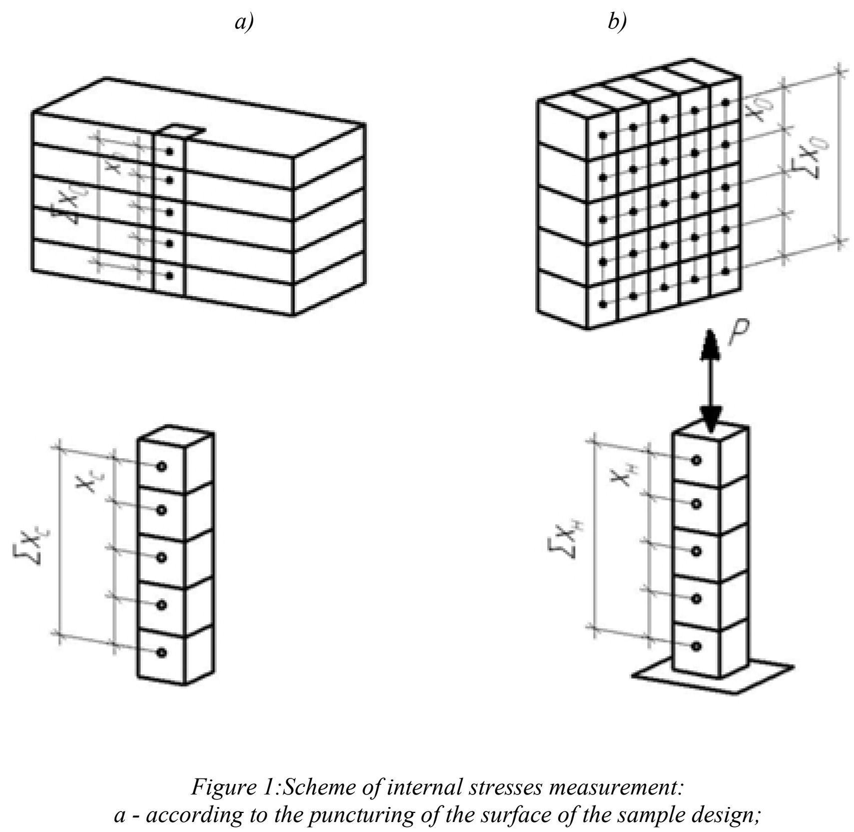

Figure 1:Scheme of internal stresses measurement:
a - according to the puncturing of the surface of the sample design;
b - splintering on samples cut of structure.

The measurement of the sample deformation under load carried cathetometer KM-6 with the range of measurement up to 300 mm and accuracy of 0.002 mm.

As reference frames during the tests metal rods of 1 mm in diameter have beenused. Using the metal template and hammer pins hammered into the surface structure produce an initial measurement by cathetometer of x_0 and gouged out a sample cross-section of 15x10 mm. Then immediately measure x_c punctured from the sample, as well as the value of x_h at loading strips.

Internal stress value determine by ratio (2):

$$\sigma_{\text{ВН}} = \frac{\sigma x_c \Delta x_c}{x_0 \Delta x_h}, \tag{2}$$

$$\Delta x_c = x_0 - x_c, \tag{3}$$

$$\Delta x_h = x_c - x_1, \tag{4}$$

Where

x_1 - distance between the outer frame in the loaded condition, mm.

In determining the value of Δx_c be considered a sign of difference $x_0 - x_c$. If the sign "-" - compressive stress, with the "+" - stretching.

3. RESEARCH RESULTS

Analysis of science literature shows that all Glulam durability evaluating methods were based on the group of limit state theories. This approach, in our opinion, can’t characterize behavior of structure for long time periods, because it determines destruction of body as instantaneous process, that occurs in moment when loading exceed value limit, but it can’t explain the situation when construction breaks after some years of being under approximate constant stress. Kinetic theory of strength is more correct, because it reviews destruction as a longtime process of appearance anddeveloping of microstructural damaging, that can be evaluated by a specialist. Tests have shown that the stress samples are distributed irregularly and balanced in length. The total stresses across the width and height of the cross sections were close to the equilibrium distribution, but their absolute values are significantly less than the voltage samples. As an example, Fig. 2and Table 1 show a marked pattern.

a) *b)*

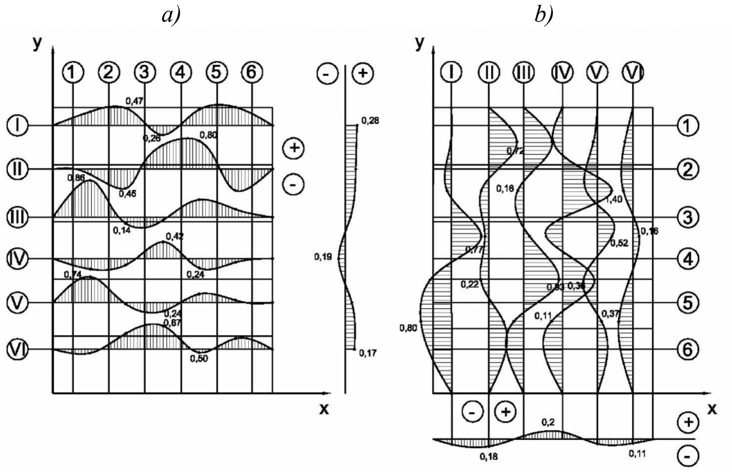

Figure 2: Internal stresses distribution by height (a) and width (b) of cross-section and its comparison with results of research as described in GOST 11603-73 “Wood. Method for determination of residual stresses”.

Table 1: Comparison of proposed and standardized internal stresses evaluation methods results

№/№	Internal stresses by the height of cross-section, MPa		Internal stresses by the width of cross-section, MPa	
	GOST 11603-73	Proposed method	GOST 11603-73	Proposed method
I	0,28	-0,26…0,47	-0,13	-0,77…0,80
II	0,25	-0,45…0,80	-0,18	-0,72…0,22
III	0,12	-0,14…0,86	0,08	-0,93…0,16
IV	-0,19	-0,24…0,42	0,20	-0,11…1,40
V	0,16	-0,24…0,74	0,11	-0,36…0,52
VI	0,17	-0,50…0,67	0,11	-0,37…0,16

Results of carried out researches showed that created method is more accurate than standardized one and can present the distribution of internal stresses in specimen. Furthermore GOST 11603-73“Wood. Method for determination of residual stresses” method gives undervalued results without any distribution indexes.

4. PERSPECTIVES

Results of the proposed method integrate necessary adjustments to the stress model. Further, this research will provide the basis for durability evaluation of laminated wood constructions with machinery of kinetic theory of strength.

5. CONCLUSIONS

Results of theoretical and empirical researches suggested that:

1. Durability can be considered as integral characteristic of laminated wood construction, depended on the level of manufacturing, assembling and exploitation of structure.
2. Method presented in GOST 11603-73 “Wood. Method for determination of residual stresses” gives undervalued results without any distribution indexes.
3. The new method of internal stresses and its distribution examination is proposed.

6. REFERENCES

[1] Kislyj V.V.:*Analizfaktorov, formiruyushhikhkachestvoderevyannykhkleenykhkonstruktsij,*SPbGLTA, 2010.

[2] Medov V.S.:*Ekspertnyeotsenkifaktorov, formiruyushhikhdolgovechnost' derevyannykhkleenykhkonstruktsij,*SPbGLTA, 2011.

[3] Yartsev V.P.:*Prognozirovaniepovedeniyastroitel'nykhmaterialovprineblagopriyatnykhusloviyakhehkspluatatsii,* Izd-voTamb. gos. tekh. un-ta, 2009.