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LONG-TERM WOOD STRENGTH

Yu.M. IVANOV
Central Research Institute for Structural Engineering

An article by Barrett and Foschi [8] recently published in Canada using data published by N.L. Leontiev [4] and Yu.M. Ivanov [3] in the Forestry Magazine contains conclusions that do not conform to the experimental data and the results of its analysis provided in the articles [3, 4]. Given that the errors made by Barrett and Foschi are crucial to further investigation into long-term wood strength, we hereby propose a number of objections concerning this matter.

1. The article [8] contains Leontiev’s data [4] on long-time tests for shear of spruce specimens along the grain but it fails to provide the data by the same author [5] concerning identical bending tests carried out with the same stress levels concurrently in the same laboratory room.

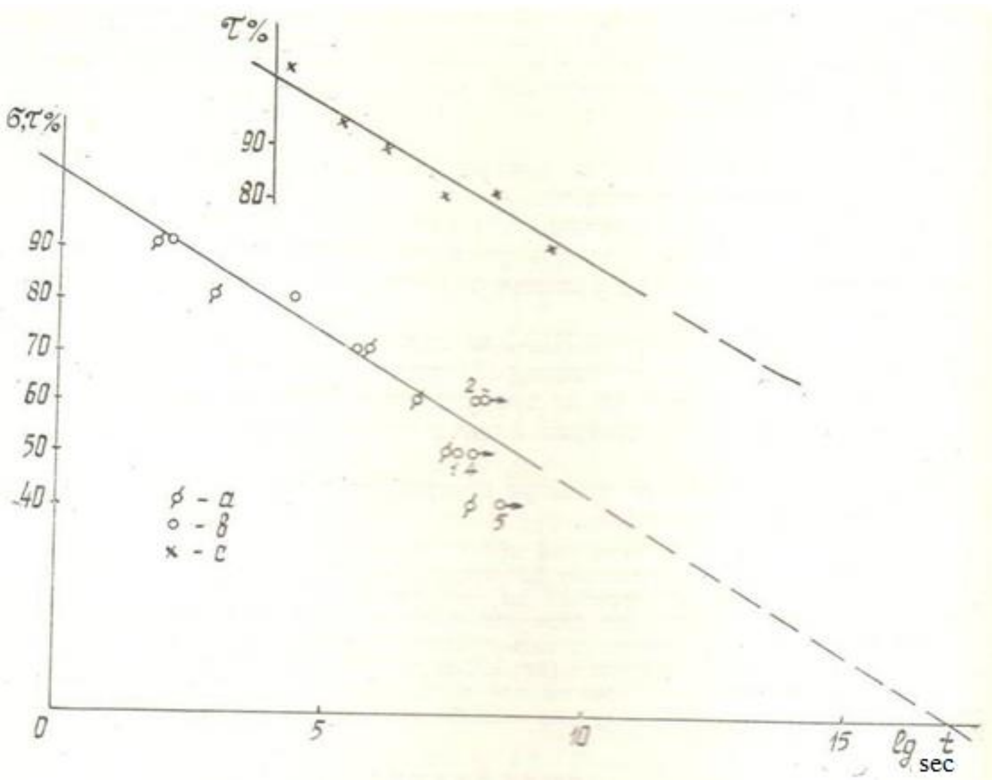

Fig. 1. Test results

a – test with continuous loading of spruce wood for shear along the grain; *c* – test of bending along the grain; *b* – test with stepwise loading of Oregon pine for shear (after reduction of t_1 to 1) [10]

A comparison of the results of both these tests is of specific importance because the results of the long-time bending test differ substantially from the data provided by Barrett and Foschi in their article [8]; the results of both tests are shown here in Fig. 1, a and b, where we also plot the straight line of long-term wood strength [2, 3] based on the following equation:

$$\lg t = 17.1 - 0.166\sigma, \qquad (1)$$

where σ – stress, % versus breaking strength σ_{br} at $\lg_{sec} t = -0.290$.

Fig. 1,a shows the downward deviation from the straight line (1) of the test points for shearing, which indicates a shorter time to rupture for these specimens, as observed by Barrett and Foschi [8], whereas the specimens did not break under the same levels of bending stress (Fig. 1,b): for σ = 50%, 4 out of 5 did not break (shown by the arrow and 4); and for σ = 40%, all 5 specimens did not break (shown by the arrow and 5), even though they were subjected to continuous stress for 8.24×10^4 hr ($\lg_{hr} t = 4.916$ in Fig. 2), or 9.4 years in a row.

So the reduction in the time to rupture as a result of long-time shear tests accentuated by Barrett and Foschi [8] is not supported by the results of long-time bending tests [5] published later (of which the authors of the article [8] might not have been aware).

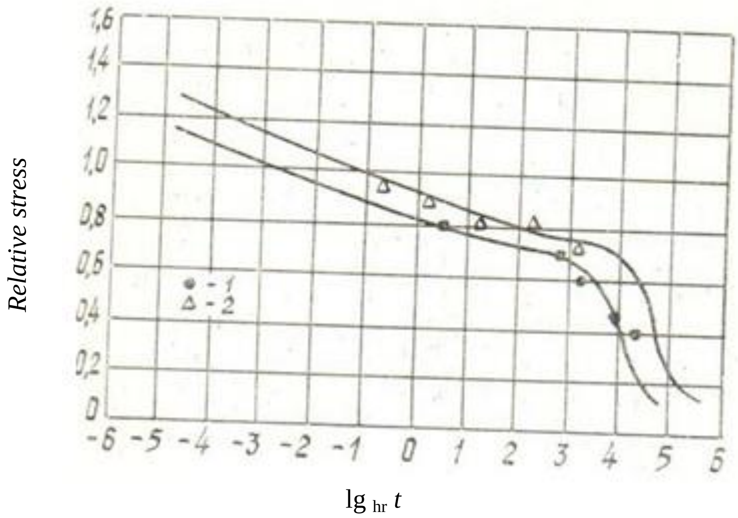

Fig. 2. Results of wood tests under continuous load [4] (*1*) and stepwise load (*2*)
(Fig. 6 in article [8])

The data of long-time shear tests of small pure specimens obtained by Leontiev in an isolated case apparently do not apply to the performance of wood in structural elements. On the other hand, the data of long-time bending tests agree with the straight line of long-term wood strength found using equation (1) for the above duration of loading, which demonstrates lack of credibility in the general conclusion made by the authors of the article [8] concerning some kind of "creep rupture threshold" beyond which the reduction in time to rupture supposedly progresses. In reality, there is a certain threshold according to the kinetic concept of hardness of solid bodies [6] but, beyond this threshold, the time to rupture increases rather than decreases, which can be explained as follows: under low stress levels (below ~20% of σ_{br}), the proportion of acts of regeneration of valence bonds accountable for strength grows equalises with the proportion of acts of their decay and preventing accumulation of faults caused by such decay [6].

2. In Fig. 2 (Fig. 6 in the article by Barrett and Foschi [8]), which demonstrates the results of shear tests carried out by Leontiev [4], the horizontal coordinates of the test points are represented by logarithms of time to rupture under continuous stress and, according to the results of the shear tests by B. Madsen, the horizontal coordinates of the test points are represented by logarithms of the overall duration of stepwise loading up until the breaking moment. The horizontal coordinates of test points for these two types of test are thus characterised by different time scales. Let us evaluate this difference.

The time to rupture under continuous stress σ is defined using the following equation:

$$T = Ae^{-\alpha\sigma}, \tag{2}$$

if we proceed from the molecular process of accumulation faults, as we have been in our works since 1972 [2], in defiance of the statement made by the authors of article [8, page 506].

Under the influence of stress σ during the time period Δt, the relative proportion of the decrease in the time to rupture will be $\Delta t/Ae^{-\alpha}$; in the event of continuous change of stress over time, the equation for the rupture condition will be as follows [7, 1]:

$$\int_0^{t_p} \frac{dt}{t(\sigma)} = 1 \tag{3}$$

where $t(\sigma) = Ae^{-\alpha\sigma}$ (t_p is specified as t below).

In testing at a continuous rate of stress increase $\bar{\omega}$, equation (3) is used to calculate the time to rupture [1]:

$$t = \frac{1}{\alpha\bar{\omega}}, \qquad (4)$$

where $\bar{\omega} = \frac{\sigma_t}{t_1'}$;

t_1' – duration of the test with an increase in stress from 0 to σ_{br} (also see [9]);
using formulae (1) and (4), we can take t_1' to calculate *t* with the help of the formula below:

$$t = \frac{t_1'}{2.3(\lg A - \lg t)'}, \qquad (5)$$

which is solved by successive approximations (for wood, according to straight-line equation (1) [3], at a normal temperature lg *A* = 17.1).

Stepwise loading with enough steps can be deemed continuous loading with a constant average rate. For the example below, equation (5) can be simplified as follows (with an error of ~3%):

$$t \approx \frac{t_1'}{2.3 \times 17.1} \approx \frac{t_1'}{39.3}; \qquad (6)$$

$$\lg t \approx \lg t_1' - \lg 39.3 \approx \lg t_1' - 1.594. \qquad (7)$$

Hence, the horizontal coordinates of lg t_1' for stepwise loading must be reduced by 1.594 to reduce them to the same time scale as lg *t*. By way of illustration, we plot the test points in Fig. 1 based on the results of Madsen’s [10] torsional shear tests with stepwise loading of tubular specimens of Oregon pine (we did not have in our possession Madsen’s work based on which the points are plotted in Fig. 6 in the article [8] with horizontal coordinates lg $t_1' - 1.594$, which are positioned close to the straight line under equation (1) (confidence range ±5.59% at confidence factor of 0.95), i.e., near the straight line plotted over the test points with horizontal coordinates of lg *t* for constant continuous loading (for example, in the event of bending – Fig. 1,b).

Consequently, we observe no isolation of the results of tests with stepwise loading from the results of tests with continuous loading (as presumed in the article by Barrett and Foschi [8]). On the contrary, the results of tests with both kinds of loading (if represented on the same time scale) closely match the straight-line equation (1) at the magnitude of deviations that corresponds to the accuracy of plotting the straight line [2, 3], which indicates that the wood complies with equation (1) regardless of the loading conditions.

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