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ERROR DETERMINATION OF THE FORMULAS USED FOR RECALCULATION OF WOOD STRENTH FACTORS ON 12% MOISTURE CONTENT

The article snows that while recalculating wood strength factor on the standard 12% moisture content the formulas used give a considerable error. Especially substantial error (7–9%) is observed at recalculation of the wood strength tested at the extreme values of the bound moisture range (0% and 30%). Depending on the wood moisture during testing the established error values permit to introduce the necessary corrections into the recalculation results according to the formulas. A method of more precise recalculation of wood strength on 12% moisture content is given in the article.

Introduction. Because of the fact that wood strength depends on the moisture content in it, comparative estimation of wood properties is possible only at the identical moisture content in experimental models. Therefore in wood science the received tests results are always recalculated on standard 12% moisture content according to the corresponding formulas.

These formulas are given in standards for mechanical wood tests, and the formula choice depends on the wood moisture content at the testing moment. So, if before the test the samples were exposed to air-conditioning up to the normalized moisture content (11–13%), the following formula is used:

$$\sigma_{12} = \sigma_w[1 + \alpha(w - 12)], \quad (1)$$

where σ_{12} – strength factor at 12% moisture content, σ_w – strength factor at the wood testing moment, α – correction factor on moisture content, w – wood moisture content at the testing moment.

For non-conditioned samples, i. e. samples with moisture content more than 11–13%, strength recalculation on 12% moisture content is done according to the formula:

$$\sigma_{12} = \sigma_w / K_{12}^w, \quad (2)$$

where K_{12}^w – recalculation factor found in the special table taking into account the actual density of wood under study.

If density determination was not done, the recalculation factor is taken to be equal to the average value for the species under study and is found in the corresponding table. In case of doing wood samples air-conditioning up to moisture content equal to or more than fiber saturation point, the following formula is used for recalculation on 12% moisture content:

$$\sigma_{12} = \sigma_w / K_{12}^{30}, \quad (3)$$

where K_{12}^{30} – recalculation factor at wood moisture content of 30% and more, depending on wood species and equal for example for pine wood to 0.450.

Thus, four ways of factors recalculation of the mechanical wood properties are suggested, received at the moisture content at the testing moment, on standard 12% moisture content [1].

Main part. It is of interest to recalculate on 12% moisture content according to different formulas of wood samples in the humidity range from 0 to 30 %, to compare strength recalculation factors with the true value at 12% moisture content and to determine their error value. For this purpose 6 samples with 20×20×30 mm dimensions were sawed sequentially from 10 pine wood laths with 20×20×300 mm dimensions and with density from 391 to 521 kg/m^3 at 12% moisture content for compression tests along fibers, the first samples were intended for strength determination in absolutely dry state, the second ones – at wood moisture content of 4–5%, the third ones – at moisture content of 8–9%, the fourth samples – at the normalized moisture content (11–13%), the fifth ones – with moisture content of 20–22% and the sixth ones – with moisture content more than 30%.

To gain the necessary moisture content the samples were kept in the corresponding temperature-humidity environment conditions. Tests results of the pine wood strength at compression along fibers at different moisture content are given in Table 1. Pine wood moisture content strength diagram was plotted at compression along fibers according to the results of strength average values at different moisture content indexes, it is presented in Fig.1 and mathematical expression of this dependency is determined. As it is clear from the drawing, this dependency is well described by the polynomial equation:

$$Y = 0{,}0505x^2 - 3{,}4121x + 78{,}451, \quad (4)$$

where x – wood moisture content, %.

Table 1

Compression strength along fibers of pine wood samples at different moisture content

Sample number	Ultimate compression strength along fibers (MPa) at moisture content of							Density, kg/m^3
	0%	4–5%	8–9%	11–13%	12%	20–22%	>30%	
1	74.9	60.0	54.8	47.1	48.4	31.1	19.2	468
2	70.3	58.8	41.7	46.4	44.9	30.5	21.8	496
3	84.0	68.5	59.6	52.0	51.8	32.4	20.6	492
4	69.2	59.5	41.8	37.3	36.8	27.8	20.9	410
5	58.0	45.1	37.8	31.9	33.2	24.2	17.3	391
6	95.9	76.1	57.5	48.6	50.9	33.0	21.0	504
7	94.2	72.2	61.5	52.9	54.6	35.2	23.9	521
8	87.8	71.3	56.2	47.0	49.8	33.3	20.5	489
9	81.5	66.1	48.7	42.8	43.0	30.1	20.9	485
10	77.3	64.8	46.1	39.2	40.7	28.9	21.7	460
Average actual	79.3	64.2	50.6	44.5	45.4	30.7	20.8	472
Average calculated	78.5	65.2	54.4	44.1	44.8	30.4	21.5	–

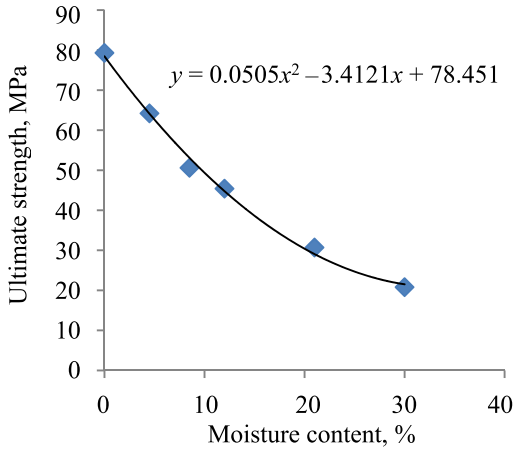

Fig. 1. Pine wood ultimate strength moisture content dependency at compression along fibers

The received equation permitted to determine the pine wood strength at compression along fibers at different moisture content values with an interval of 2% with the subsequent recalculation of the determined strength values on 12% moisture content according to the formulas given earlier. To determine the magnitude of formulas error the recalculated strength values on 12% moisture content were compared to the actual strength value at this humidity.As it is practically impossible to create in wood the moisture content of exactly 12%, therefore we take the value calculated according to the above-stated formula and equal to 44.8 MPa as the true (actual) strength value at 12% moisture content. The received results are given in Table 2, and the graphic interpretation of this data is shown in Fig. 2.

As it is clear from table 2, and especially in Fig.2, the recalculation formulas give an appreciable error at wood strength recalculation received at certain moisture content on 12% moisture content, and the greatest error is observed for extreme values of the moisture content range under study (0 and 30%). So, this error, i.e. deviation of the recalculated strength indexes on 12% moisture content from the actual strength value at 12% moisture content, for example, for wood with moisture content of 30% and recalculation according to the formula (1) can be 17.6% towards reduction, according to the formulas (2) and (3) – 6.7%, according to the formula (2) taking into account wood density – 9.4%, and in three last cases towards overestimate. At recalculation of wood strength indexes in the absolutely dry state on 12% moisture content all used formulas give an error of about 8% towards understating.

From the given Table 2 and Fig. 2 it is also clear that when the wood being tested approaches 12% moisture content value, both from lower and higher moisture content, difference between the received recalculated indexes of wood strength on 12% moisture content and actual ones at 12% moisture content gradually decreases.

As wood is a biological material also has natural variability of properties, it is generally assumed that if the deviation of the property under study from the average value does not exceed 5%, so the observational results are within the research accuracy limits and are quite reliable. In that case for each of the considered recalculation formulas with reference to pine wood at compression along fibers it is possible to determine the moisture range of their application. In particular, for the formula (1) such range is wood moisture content within the limits from 2 to 16%, for the formula (2) – from 6 to 20%, for the formula (2) taking into account actual wood density – from 6 to 26%.

Table 2

Recalculation value of the pine wood ultimate strength at compression along fibers depending on the applied recalculation formula and moisture content at the moment of wood testing

Index	Wood moisture content, %															
	0		0		0		0		0		0		0		0	
Ultimate strength determined according to the equation, at corresponding humidity	78.5	71.8	65.2	59.8	54.4	49.4	44.8	40.6	36.8	33.4	30.4	27.8	25.6	23.9	22.5	21.5
Ultimate strength recalculated on 12% moisture content according to the formula (1)	40.8	43.1	44.3	45.4	45.7	45.4	44.8	43.8	42.7	41.4	40.1	39.0	38.0	37.2	36.9	37.1
	91.1	96.2	99.0	101.5	102.0	101.5	100.0	97.9	95.3	92.5	89.6	87.0	84.7	83.0	82.4	82.7
Ultimate strength recalculated on 12% moisture content according to the formula (2)	41.4	41.8	42.1	42.7	43.5	43.9	44.8	45.1	45.7	46.1	46.8	47.6	47.8	48.2	47.9	47.8
	92.5	93.3	94.0	95.3	97.1	98.0	100.0	100.7	102.0	102.9	104.5	106.2	106.7	107.6	106.9	106.7
Ultimate strength recalculated on 12% moisture content according to the formula (2) taking into account density	41.1	41.5	42.2	43.2	44.0	44.7	44.8	45.1	45.5	45.6	45.8	45.8	45.8	46.3	47.4	49.0
	91.8	92.6	93.8	96.4	98.2	99.8	100.0	100.7	101.6	101.8	102.2	102.2	102.2	103.3	105.7	109.4
Ultimate strength recalculated on 12% moisture content according to the formula (3)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	47.8
																106.7

Note. Absolute ultimate strength values at 12% moisture content are in mega-Pascal in numerator, and in percentage points in denominator.

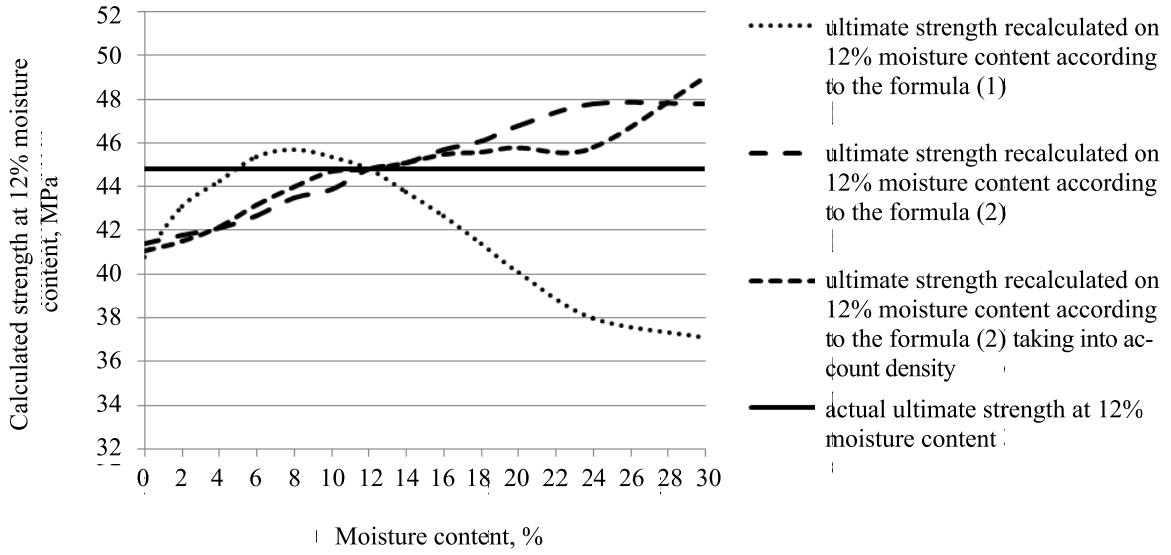

Fig. 2. Recalculated indexes of pine wood strength at compression along fibers on 12% moisture content depending on the recalculation formulas and wood moisture content

At wood testing in absolutely dry state the least recalculation error on 12% moisture content is given by the formula (2) – 7.5%, and at moisture content of 30% and more – formulas (2) and (3) – 6,7%. Therefore the actual results, received at wood testing with moisture content of 0 – 1%, should be increased taking into account the formulas error at the specified moisture content, on the average by 8%. For wood with moisture content of 22–30% the recalculation index will be rather close the actual one at 12% moisture content, if it is calculated as thearithmetical mean value of the indexes received according to the formulas (1) and (2). So, for example, if at humidity of 26% the recalculation strength index, calculated according to the formula (1), is equal to 37.2 MPa, and according to the formula (2) – 48.2 MPa, so their average value is 42.7 MPa, i.e. this average value is much closer to 44.8 MPa (to the actual strength index at 12% moisture content).

Conclusion. The revealed errors peculiarities of the recalculation formulas for the case of wood compression along fibers can be transferred onto other kinds of mechanical tests of wood, but with other numerical characteristics which can be determined with the help of the basic technique used in the present work.

References

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