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Effect of relative humidity on shear modulus of particleboard

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Abstract: *Effect of relative humidity on shear modulus of particleboard*. The effect of relative humidity on the shear modulus of particleboard was presented in the paper. Panel specimens were conditioned at 55, 65, 75, 85 and 95% RH. The moisture content and shear modulus of particleboard were determined on these specimens by the twisted square plate method. The relationships between the shear modulus and the moisture content of particleboard and relative humidity were defined.

Keywords: particleboard, relative humidity, moisture content, shear modulus, twisted square plate method

INTRODUCTION

The mechanical properties of case furniture first of all depend on the properties of the materials used to produce its panel elements and the joints used to combine them. The stiffness of case furniture is greatly influenced by the shear modulus (G) of panel elements fixedly connected to each other. Most of them, e.g. sidewalls, top and bottom panels, partitions, are generally made of particleboard that is commonly used in the furniture industry.

The mechanical properties of wood-based panels significantly depend directly on their moisture content (MC), and indirectly on the relative humidity (RH) in which they are used. The effect of RH and MC on the modulus of elasticity (MOE) of particleboard has already been relatively well defined. The investigations into it were carried out by, among others, Halligan and Schniewind (1974), who for particleboards with various densities described the relation between MOE and MC using a polynomial of the third degree. They found that MOE significantly decreases with increasing MC. McNatt (2009), Han *et al.* (2006), and DeXin and Östman (1983) determined the effect of RH on the MC and MOE of particleboard, confirming the reduction of elastic properties with increasing RH. Similar results for OSB were obtained by Wu i Suchsland (1997). Bekhta and Niemz (2009) and Kociszewski and Grzelczak (2013) examined fiberboards and MFP, respectively, demonstrating that the MOE of these panels nonlinearly decreases with increasing RH, whereas the relationship between MOE and MC is approximately linear. All previous research has focused on the study of the elastic modulus of wood-based panels. However, the effect of RH on other elastic properties of particleboard has not been studied yet. Therefore, examinations were carried out to determine a relationship between the shear modulus of particleboard and the relative humidity and moisture content.

MATERIALS AND METHODS

The tests were made on the particleboard (UF) with a thickness of 18 mm, density of 650 kg/m^3, MOE of 2580 MPa, and MOR of 13,3 MPa.

Twenty four specimens with the dimensions of 500×500 mm were cut out of panel sheets, and seasoned for a month in the laboratory at a temperature of 25°C and RH of about 40%. Afterwards the specimens were measured and weighed, then randomly divided into 6 groups of 4 pieces. The first group of specimens were tested immediately after seasoning in the laboratory. The second group of specimens were placed in a climatic test chamber, and kept at a temperature of 25°C and RH of 55%. Two specimens were weighed every day until the difference in their masses was less than 0.05% between successive weighings. After the equilibrium moisture content had been achieved by the specimens, they were taken out of the chamber, then they were measured and weighed as well as their G was determined. To determine G the twisted square plate method described in the ASTM 3044 standard was employed (Fig. 1a). However, its modified version was adopted, that is three corners of the specimen were supported, and the load acting perpendicular to the plane of the panels was applied to the fourth corner (Fig. 1b). This version was developed by Lee and Biblis (1977), and its correctness was confirmed by Kociszewski (2011). The test stand used to determine the shear modulus of particleboard is shown in Figure 2.

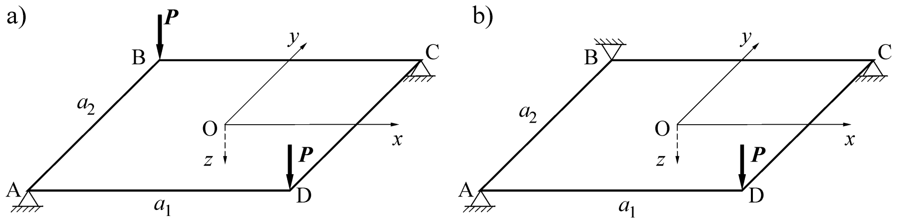

Figure 1. Method used to determine shear modulus in plane of the panel: a) according to ASTM D 3044, b) modified version.

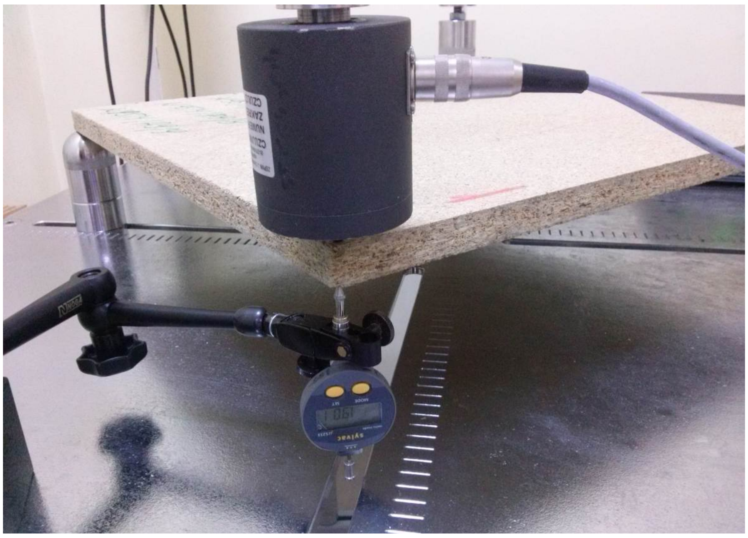

Figure 2. Stand for testing particleboard specimens by the twisted square plate method

The shear modulus G in the plane of the specimen was calculated using the formula (Kociszewski 2011):

$$G = \frac{3Pa_1a_2}{tu} \tag{1}$$

where: a_1, a_2 – length of the edge of the specimen,

t – thickness of the specimen

u – deflection of the point to which the load was applied

A similar procedure was performed four more times, setting humidity in the chamber sequentially to 65, 75, 85, and 95%. After completion of testing all specimens were dried at 103°C for 48 hours, then weighed to determine their dry mass. Basing on the data obtained, mean MC and G were calculated for each group of specimens. The significance of differences between respective mean values was tested by means of the one-way analysis of variance (ANOVA) and Tukey's test. To do that, the STATISTICA v.10 software was used.

RESULTS AND DISCUSSION

The relationship between the MC of the panel tested and the RH in which the panels were kept shows Figure 3a. Each point in the graph is the mean MC of 4 panel specimens at a given humidity. Error bars assigned to the point represent the value of standard deviation. The MC of the panel substantially depends on RH (F=5109.6; p=0) and increases nonlinearly with an increase of this humidity. Within the tested range of RH the MC of the panel increases the more, the higher RH, reaching the value of 17,9%. For the 65% RH, at which furniture particleboard is tested, the moisture contents of the panel is 8,4 %.

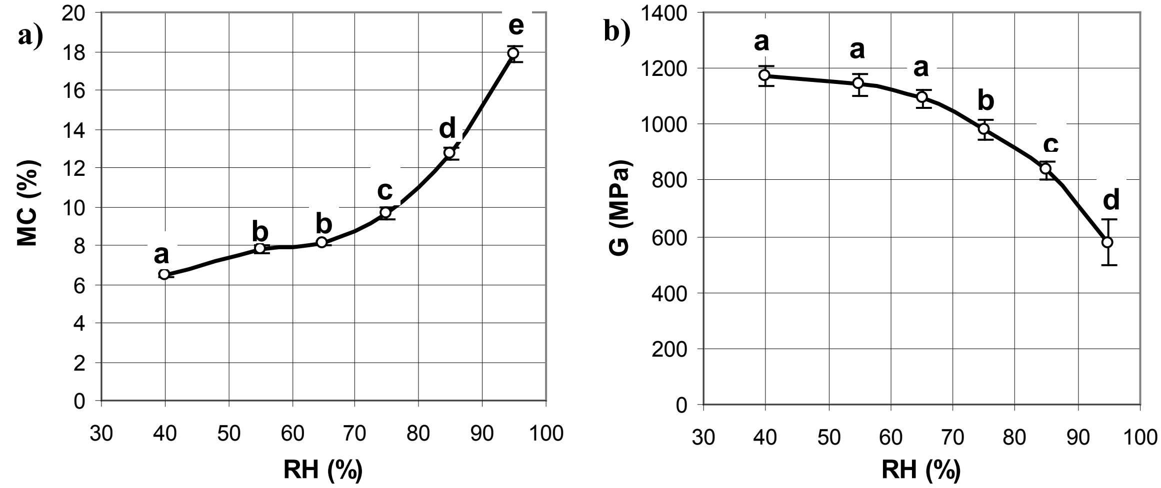

Figure 3. Relationship between MC (a) and G (b) of the panel and RH
Mean values marked with the same letter are not statistically different at the 5% significance level

Figure 3b shows the relationship between G and RH. The shear modulus decreases with increasing RH. This decrease is non-linear, is the greater, the greater RH. The analysis of variance confirmed the significance of the relationship between G and RH (F=100.0; p=0). Tukey's tests showed that the starting from the RH of 65% the differences between the average values of G are statistically significant. Increasing RH from 65 to 95 % causes a decrease of G by 47%.

The relationship between G and MC of the panel is shown in Figure 4. Each point in the graph is the value of G determined for one of the four specimens of the panel at its defined MC. For the points in the graph, regression lines were drawn, and their equations and coefficients of determination were calculated. The shear modulus decreases with increasing MC of the panel and this relationship is close to being linear. The change in the MC of the panel by 1 % results in a change in G by 54,8 MPa, which with regard to the initial value gives a decrease by 4,7% for 1 % of the MC of the panel. The high value of the coefficient of determination confirms the high correlation between the G and the MC of the panel.

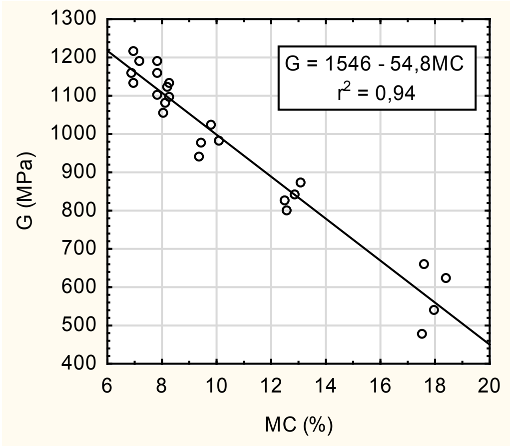

Figure 4. Relationship between G of the panel and its MC

CONCLUSIONS

1. The shear modulus of particleboard significantly depends on the relative humidity in which they are used, especially at higher values of humidity.
2. The moisture content of particleboard nonlinearly increases with increasing relative humidity, reaching 18 % at 95 % RH.
3. Relative humidity up to 65 % of its value does not significantly affects the values of shear modulus. An increase in RH to over 65 % causes a considerable reduction of this property.
4. An increase in relative humidity to 95 % causes a reduction of shear modulus by about half.
5. The shear modulus decreases proportionally with increasing the moisture content of the panel. The change in the moisture content of the panel by 1% results in the change of shear modulus by about 4.7%.

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Streszczenie: Wpływ wilgotności otoczenia na moduł ścinania płyty wiórowej. W pracy zaprezentowano wpływ zmiennej wilgotności otoczenia na wilgotność płyty wiórowej oraz jej moduł ścinania. Próbki płyty były klimatyzowane w warunkach 40, 55, 65, 75, 85 and 95% wilgotności powietrza. Dla próbek przetrzymywanych w tych warunkach oznaczono wilgotność płyty oraz moduł ścinania. Wyznaczono zależności modułu ścinania od wilgotności otoczenia oraz od wilgotności płyty wiórowej.

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