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ORIENTATION DEPENDENT MODULUS OF ELASTICITY AND STRENGTH OF OSB/4 BENT IN THE PLANE OF PANEL

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SYNOPSIS. Mechanical properties of structural-grade oriented strand board depend on the orientation of the sample with respect to the OSB face grain direction. The samples of 12-mm thick OSB/4 cut at 0°, 22.5°, 45°, 67.5° and 90° with respect to the longer OSB sheet edge were tested in static bending by the load applied in the plane of the panel. The modulus of elasticity and the modulus of rupture of OSB/4 were obtained for each type of the sample orientation. The question of the orthotropy of oriented strand boards is discussed.

KEY WORDS: oriented strand board (OSB), bending, modulus of elasticity, bending strength, orthotropic

INTRODUCTION

Oriented strand board (OSB) fabricated from slender wood strands glued with water-resistant resins (OSB/3 and OSB/4 grades) usually are formed of three crossing at right angle layers (Piotrowski and Strykowski 2002). The production of OSB in Europe is still at the initial stage of the growth (Oniśko 2001, 2002); in Poland OSB is fabricated since 1997 (Hikiert 2001). Oriented strand board is a composite, wood-based panel product designed as a structural replacement for plywood (Nishimura et al. 2004). OSB plates, especially the OSB/3 and OSB/4 grades, have been more and more frequently used not only as a shield material but also as carrying elements (webs) of composite beams.

The manufacturer of the domestic OSB plates recommends to locate the plate element in the structure in such a manner that the direction of the normal stress σ (due to the tension, compression or bending) is parallel to the longer edge of the OSB sheet. Because strands at the outer layers of the OSB sheet are oriented parallel to their longer edge, plate elements cut in this way should show about

2.5-times higher rigidity and load capacity than the elements cut perpendicular to this longer edge (Hikiert 2001).

The national standards for the elastic and strength properties of wood-based panel products (PN-EN 310: 1994 and PN-EN 789: 1998) require to determine the modulus of elasticity (MOE) and modulus of rupture (MOR) during the bending tests, in which the plate samples are loaded perpendicular to the sheet surface. This procedure seems to be acceptable for such wood-based materials as multi-layered plywood, common particle board or hardboard, when the assumption of material orthotropy or even plane isotropy is possible. OSB is, in general, three-layered board with orthotropic layers, what makes it a non-homogenous (throughout its thickness) material. This way determined MOE and MOR are strictly apparent values then (Thomas 2003).

The national standard PN-EN 300: 2000 describing requirements toward OSB plates also uses the values of MOE and MOR determined from bending tests with the load perpendicular to the sheet surface. The "modulus of elasticity" determined in accordance with the standards mentioned above turned out to be actually 1.8 to 2-times bigger for samples oriented parallel to the longer edge of the OSB sheet than for samples oriented transverse (Plenzler and Górecki 2002). Similarly, "modulus of rupture" was 1.5 to 1.7-times bigger for samples oriented parallel to the longer edge of the OSB sheet.

OSB used as a web of the composite beam (Plenzler et al. 2005) bent by the load applied at the plate plane is in a different, two-dimensional stress state (plane stress). Neglecting the non-homogenity throughout OSB thickness and assuming its orthotropy a designer of composite beams needs 4 elastic constants of this plate, for example two moduli of elasticity: E_x and E_y, modulus of rigidity G_{xy} and Poisson's ratio ν_{xy}. These elastic properties should be determined from tests in which the samples are loaded at the plane of the OSB panel, similarly as Pałubicki and Plenzler (2004) reported. Under such a stress state OSB plate with an 18-mm thickness exhibits the modulus of elasticity at the direction parallel to the longer edge 1.5-times (Wilczyński and Gogolin 1999) or 1.53-times (Thomas 2003) bigger than at the transverse direction. Moreover, the values of the modulus of elasticity in bending and the bending strength of OSB loaded perpendicular and parallel to the plate plane turned out to be completely dissimilar (Kociszewski et al. 2003). This paper presents the results of tests to determine the influence of the sample orientation at the OSB/4 sheet on their modulus of elasticity in bending in the plane of the panel.

MATERIALS AND METHODS

Three-layered OSB/4 panels with a 12-mm nominal thickness were examined. These panels designed for applications at higher loadings and for dry and wet conditions were produced by the factory of Kronopol Żary, Poland. Bending samples 600 by 34 mm were cut in such a manner that their longer edge (600 mm) was at 0°, 22.5°, 45°, 67.5° and 90°, with respect to the longer sheet edge (Fig. 1).

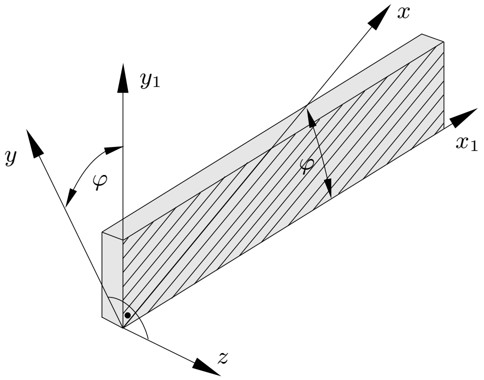

Fig. 1. Axis system and outer layers grain angle

Seven samples for each orientation type, in total 35 pieces, were randomly selected from the larger group. All test pieces were conditioned in 22°C and 30% of relative humidity, so that their moisture content during the bending tests was equal 6.02 ±0.08%. The density of the OSB/4 panels measured at that moisture content level was 692 ±17 $\mathrm{kg/m^3}$.

The national standard PN-EN 310: 1994 requires to determine MOE of wood-based panel products at the static three-point bending test. This way obtained value of MOE is yet burdened by an indeterminate error due to the influence of shearing stresses on the beam deflection. Therefore other loading conditions, i.e. four point bending following the method described in PN-EN 789: 1998 were chosen and deflections of the samples were measured at the zone of pure bending only (Fig. 2). Due to another arrangement of bending samples than recommended by the standards mentioned above another dimensions of the samples and the test stand were assumed too. The span size l_2 between the loading heads was 547 mm and the distance l_1 between the inner supports 416 mm. The samples were loaded in the plane of the panel, the size 34 mm was their depth than, and 12 mm (thickness of OSB) was their width. The load was applied from the FPZ 100 testing machine with unconventional equipment.

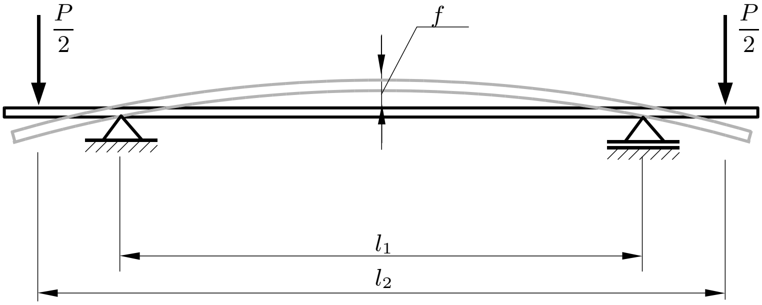

Fig. 2. Bending tests diagram

The basic tests were preceded by mechanical conditioning consisting of three times repeated loading from zero to 400 N and unloading. It was supposed to eliminate the influence of the permanent set on deflections of the samples and, in consequence, on calculated values of the modulus of elasticity E_φ. Then each sample was loaded six times from zero to the maximum load of 300 N with the speed of deformation of 1.365 mm/min and rapidly unloaded. The loading phase lasted 39 s to 59 s depending on the orientation and stiffness of each sample. Under the maximal load the normal stress σ in outer fibres of the OSB samples reached the maximum value of ± 4.43 MPa, i.e. about 20% of the bending strength and below the proportional limit. The accuracy of the force measurement during the elastic tests amounted 2 N. Deflections of the samples were measured at the zone of pure bending by means of the dial gauge with 0.01-mm accuracy. After the elastic tests were completed each sample was subjected to the destructive test at the same loading conditions (Fig. 3) to obtain the bending strength of the OSB/4 plates loaded in the plane of the panel. The speed of deformation during the destructive tests was the same as during the elastic tests, but the accuracy of the force measurement amounted 10 N.

Fig. 3. MOE and MOR bending tests set-up

The modulus of elasticity in bending in the plane of the panel for differently oriented samples ($\varphi = 0°$, $22.5°$, $45°$, $67.5°$ and $90°$) was calculated by using the equation

$$E_\varphi = \frac{3}{8}\frac{P(l_2 - l_1)l_1^2}{bh^3 f} \tag{1}$$

where: P – force,
l_1, l_2 – span size between the loading heads and the outer supports, respectively,
b, h – width and depth of the sample, respectively,
f – deflection measured in the middle of the span.

Equation 1 comes from an elementary theory of bending, but is correct even for the fully anisotropic material (LEKHNITSKII 1977).

The strength in bending in the plane of the panel for differently oriented samples was calculated by using the equation

$$R_{\varphi} = \frac{3}{2}\frac{P_{\max}(l_2 - l_1)}{bh^2} \tag{2}$$

where: $P_{\max}$ – destructive force.

RESULTS AND DISCUSSION

The results of static bending MOE and MOR for differently oriented OSB/4 samples are illustrated in Figures 4 and 5, respectively. From Figure 4 it is evident that the bending modulus of elasticity of the OSB/4 plate loaded in the plane of the panel attains the maximum value for the samples cut at $\varphi = 0°$ with respect to the longer sheet edge of $E_x = 6323 \pm 606$ MPa (average ± standard deviation). For the samples cut crosswise ($\varphi = 90°$) the average value of MOE amounted $E_y = 5053 \pm 303$ MPa, i.e. the ratio of the moduli of elasticity, E_x/E_y, was merely 1.24 (in comparison to results reported by WILCZYŃSKI and GOGOLIN (1999) or THOMAS (2003)). The smallest value of MOE, 4733 ±287 MPa showed, however, the samples cut at $\varphi = 45°$ with respect to the sheet edges. This value was about 1.07 times smaller than obtained for $\varphi = 90°$ and 1.34 times smaller than for $\varphi = 0°$. Such the minimum at the relationship $E = E(\varphi)$ is not out of the question for orthotropic materials, as proved ASHKENAZI (1978).

From Figure 5, it is evident that the bending modulus of rupture of OSB/4 loaded in the plane of the panel assumes the maximum value of 27.43 ±4.46 MPa for the samples cut at $\varphi = 0°$ with respect to OSB face grain direction. The smallest value of MOR, 19.07 ±3.06 MPa, showed the samples cut at $\varphi = 67.5°$ with respect to the longer sheet edge. This value was 1.44 times smaller than obtained for the $\varphi = 0°$ direction. The value of MOR of 20.14 ±1.85 MPa for the samples cut crosswise ($\varphi = 90°$) was 1.36 times smaller than obtained for samples cut lengthwise. The differences between the values of MOR for the samples cut at $\varphi = 45°$ and 90° did not exceed 9.6% of the minimum value MOR.

To state, if the OSB/4 plate in plane stress may be considered an orthotropic material it is necessary to know apart from E_x and E_y two other elastic constants, for example G_{xy} and ν_{xy}. Than all the elastic constants should to satisfy the equation, known for the orthotropic body (LEKHNITSKII 1977):

$$\frac{1}{E_\varphi} = \frac{\cos^4\varphi}{E_x} + \left(\frac{1}{G_{xy}} - \frac{2\nu_{xy}}{E_x}\right)\sin^2\varphi\cos^2\varphi + \frac{\sin^4\varphi}{E_y} \tag{3}$$

where: E_φ – MOE at the angle φ with respect to OSB face grain direction.

It is necessary to emphasize, that all the constants in Equation 3 are then strictly apparent values because, as mentioned above, OSB/4 is a three-layered board with orthotropic layers, but non-homogenous throughout its thickness. Therefore, the assumption of the orthotropy for OSB bent by the load applied perpendicular to the plate surface seems to be inappropriate.

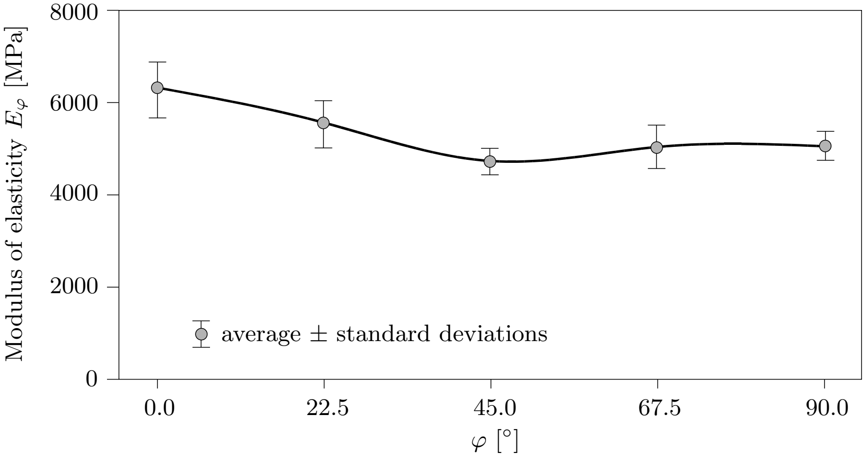

Fig. 4. OSB/4 modulus of elasticity (MOE) depending on outer layers grain angle

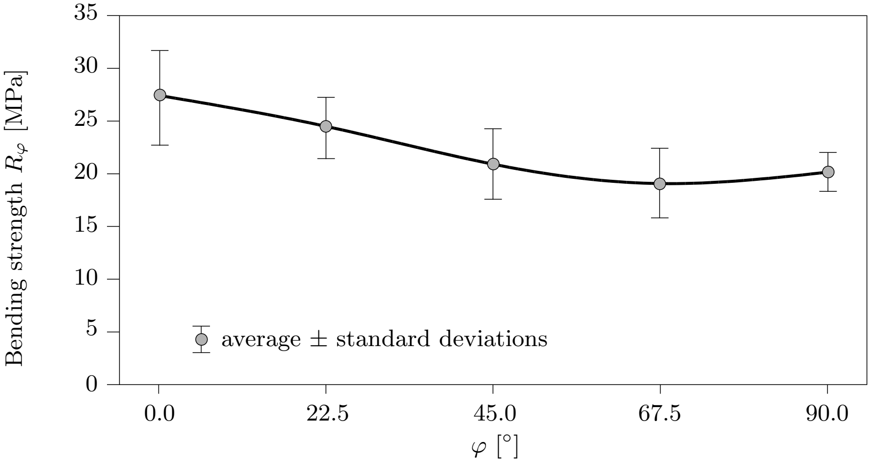

Fig. 5. OSB/4 bending strength (MOR) depending on outer layers grain angle

CONCLUSIONS

1. The bending modulus of elasticity of 12-mm thick OSB/4 loaded in the plane of the panel evidently depends on the sample orientation in respect to OSB face grain direction.
2. The maximum value of MOE, 6323 MPa, was shown by the samples cut parallel to OSB face grain direction and the minimum value of 4733 MPa by those cut at 45° with respect to the OSB sheet edges. The ratio of the moduli, E_x/E_y, i.e. for $\varphi = 0°$ and 90°, respectively, is about 1.24.
3. The modulus of rupture of 12-mm thick OSB/4 bent by the load applied in the plane of the panel depends on the sample orientation too. The maximum value of MOR, 27.43 MPa, was shown by the samples cut parallel to OSB face grain direction and the minimum value of 19.07 MPa (1.44 times smaller) by those cut at 67.5° in respect to the longer OSB sheet edge.
4. Due to 3-layered structure of OSB/4 panels the values of the elastic constants obtained from the tests at the two-dimensional stress state are only the average, apparent values.
5. The modulus of elasticity and the modulus of rupture determined in accordance with the current domestic standards, i.e. in bending with the load perpendicular to OSB sheet are not comparable with the moduli obtained from bend tests with the load applied in the plane of the panel.
6. The assumption of the orthotropy for OSB/4 bent by the load applied in the plane of the panel seems to be acceptable.

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