EFFECT OF PRESSING PRESSURE ON INDICES OF FIBREBOARDS MANUFACTURED FROM WOOD OF HARD BROAD-LEAVED SPECIES

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ABSTRACT

The main factor defining the performance of the hard thin FBs is the pressure applied in the process of piezothermal treatment. In order to manufacture a product designed by engineering, the pressing pressure should be with a specific value determined in advance. The latter is in correlation dependence on the tree species, the characteristics of the wood-fibre mass and of the wood-fibre carpet. Determining, out of these factors, is the resistance that the carpet shows under the applied external load, with it depending mainly on the characteristics of the mass and, to a determining degree, on the tree species used for the manufacture of the boards.

In this paper, an investigation on the effect of pressure during manufacture of thin FBs on the basis of beech and cerris oak wood is presented. Derived are the main dependences of the performance of FBs on the factors examined in case of application of the methods of regression analysis, with use of the least squares method. Established are the optimum values of pressure depending on the thickness of the boards and the design thickness set.

Key words: FBs, hard wood-based raw material, piezothermal treatment, thickness, density

INTRODUCTION

The manufacture of wood-fibre mass with fixed technological characteristic and the modes of piezothermal treatment of the carpet formed of this mass are the main elements on which the performance of FBs depends. Of greatest significance for the manufacture of boards with strictly fixed indices are the mode factors during hot pressing. The latter are determined with respect to the set input parameters of the process in conformity with the type of the wood-based raw material and the characteristics of the wood-fibre carpet.

In case of absence of limitations in the process of hot pressing, the thickness and the density of the boards depend exclusively on the compression ratio of the wood-fibre carpet. The determination of the value of the pressure applied during pressing is an extremely important technological index that depends on the wood-based raw material used and on the characteristics of the wood-fibre carpet.

In Bulgaria there is a raw material potential for manufacture of FBs from wood of hard broad-leaved species. Because of the specificity of the development of this manufacture in the country to this day, the efforts have been concentrated mainly on the investigation on the effect of the mode factors during the manufacture of FBs after the wet method. Investigations on the characteristics of the manufacture after the dry method are limited and this necessitates concentration of the efforts in this respect.

STATE OF THE PROBLEM

In the last decades, intensive investigation on the relationship between the physical, mechanical and morphological properties of the wood fibres, on the one hand, and the strength characteristic of FBs, on the other hand, has been performed. Although the tensile strength of the individual fibres is very high, only part of it affects the structural configuration of FBs. As a result of the limited fibre length or because of the low bonding quality, the bonding zone between the fibres is of considerably lower strength, which leads to failure before reaching the maximum possible stresses in the fibres (Woodston, E.G.). This is presented graphically on Fig. 1 where L_s denotes the overlap length between two fibres, which may be considered proportional to the relative bonding area in the board. If L_s is shorter, then the bonding strength diminishes, and the failure during application of tensile load takes place in the bonding zone, and not in the wood fibres, which leads to decrease of the boards' strength.

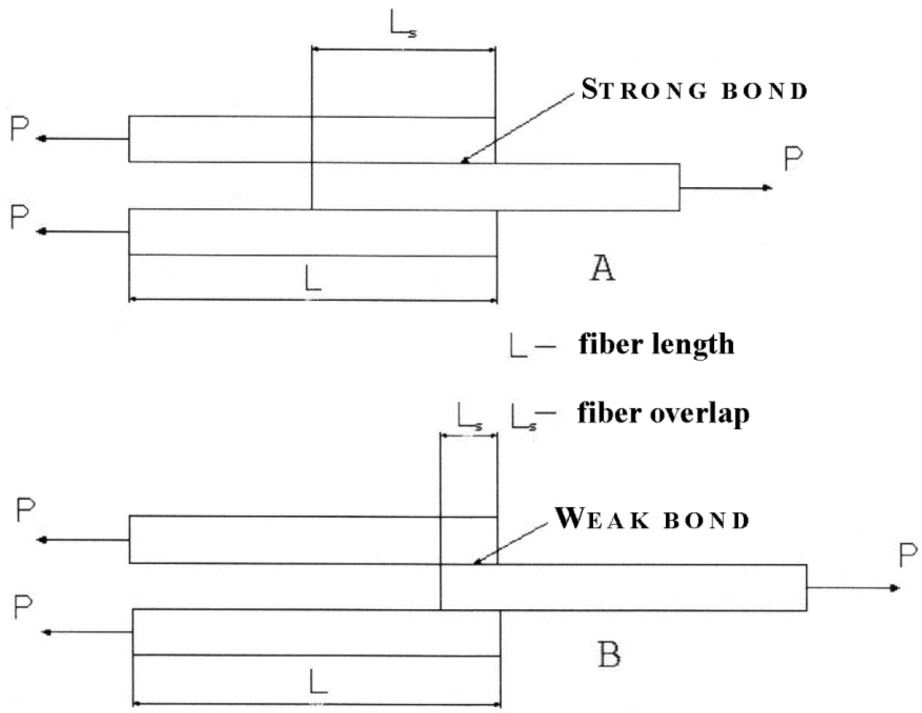

Figure 1: Fibre bonds under tensile stress
A – Conditions favouring fibre failure (maximum strength)
B – Conditions favouring bond failure (low strength)
L – fibre length; L_s – fibre overlap

From the presented above follows the conclusion that the FBs strength depends strongly on their density, which, at structural level, is explained with the successful transfer of stresses from the bonding zone of the wood fibres and the possibility for reaching maximum stresses.

The fibre length is also of great importance for the tensile strength of FBs. This fact is explained with the greater number of bonding zones in the board, which allows the tensile stress in the fibres to reach its limit value. The length of the fibrous elements affects the structure of the wood-fibre carpet and of the board. With fibres of greater length, a trend towards formation of a wood-fibre carpet with more open structure and higher thickness (bulk density), in comparison with a carpet formed of shorter length, is observed. The length of the fibres is also a factor through which their orientation in the carpet is controlled. With fibres of smaller length, it is very probable that a vertical, or *z*-component, emerges during the orientation in the board, unlike the orientation in the case of the longer fibres (Fig. 2).

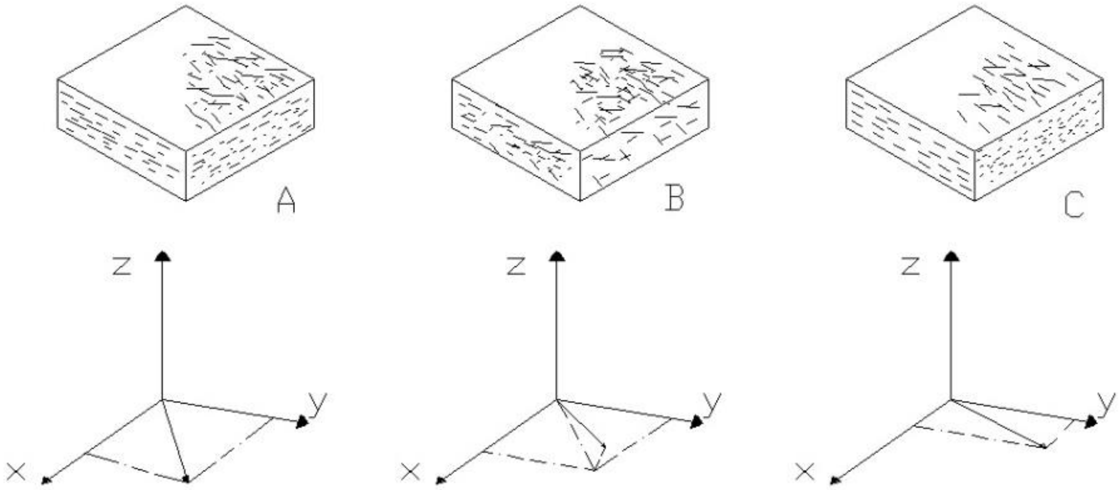

Figure 2: Orientation of fibres in fibreboard
A – Random orientation in plane of board, no vertical components;
B – Random orientation in plane of board, small vertical component;
C – Orientation in y-direction, small x-component, no vertical component.

The density in FBs (except for the soft FBs) is determined by the degree of compaction of the wood-fibre carpet. In case of higher wood density, higher bulk density of the carpet necessary for reaching the previously set density is produced, which leads to a lower compression ratio. The high compression ratio obtained due to the lower wood density ensures closer contact of the fibrous elements. On account of this, in the case of hard FBs manufactured after the dry method, there exists a reverse relationship between the wood density and the wood-fibre carpet, on the one hand, and the strength indices of the board, on the other hand, Fig. 3 (Woodston, E.G.).

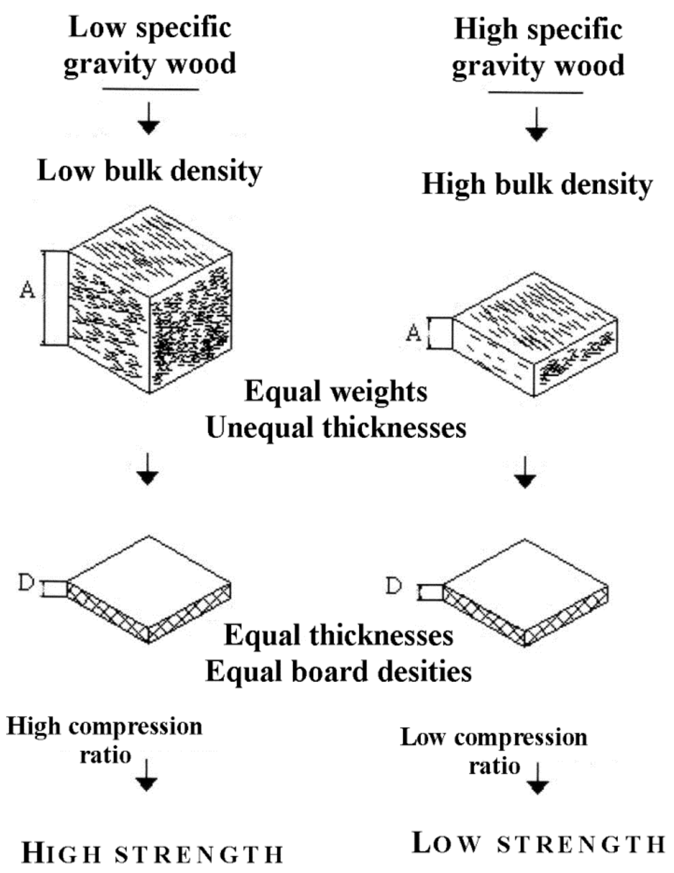

Figure 3: Manufacture of fibreboards of equal thickness and equal board density from low- and high-specific-gravity wood

The changes in the FBs dimensions as a result of the absorption or release of moisture are considerably influenced by the fibre length. The greater the length of the wood fibres, the smaller are the changes in the board dimensions.

From the presented above follows the conclusion that there is a number of technological difficulties in the manufacture of FBs after the dry method from wood of hard broad-leaved species.

In Bulgaria. there is a raw material potential for manufacture of FBs from wood of hard broad-leaved species, on account of which the main manufacturing facilities operate with such raw material. Because of the characteristics of this manufacture in the country, the efforts to this day have been concentrated on clarification of the main cause-and-effect relations in the case of the wet method of manufacture (Tsolov, V.).

The aim of this paper is to establish the effect of pressing pressure on the performance of FBs manufactured after the dry method.

INVESTIGATION METHODS

For the manufacture of laboratory fibreboards, wood-fibre mass obtained from common beech and cerris oak in the ratio of 2:1, with a bulk density of 32 kg/m^3, at a pulp freeness – 22 DS, was used.

In order to establish the effect of pressing pressure, the factor was examined within a variation range of 0,6 to 3,0 MPa with a variation step of 0,4 MPa.

The performance of FBs was determined pursuant to the current European norms.

To determine the effect of the bonding agent content on the performance of FBs, regression analysis was applied.

On the basis of experimental data obtained by means of measurements, the values of the approximating function for different values of the argument were determined. This problem is successfully solved by using the least squares method (Fig. 4), with regression equation of the type:

$$\hat{Y} = \sum_{i=0}^{k} b_i f(\tilde{x}) = b^T f(\tilde{x}) \qquad \textbf{(1)}$$

where: $b^T = (b_0, b_1, \ldots, b_k)$ is a (k + 1) dimensional vector of the unknown coefficients in the equation;

$\hat{y}$ – the predicted value of the output quantity;

$f^T(\tilde{x}) = [f_0(\tilde{x}), \ldots, f_x(\tilde{x})]$is a ($k$ + 1) dimensional function of the vector of input variables $\tilde{x}$ being derived.

In the case of the least squares method, the polynomial of best root-mean-square approximation of given degree coincides with the interpolation polynomial.

As a criterion for approximation accuracy, the coefficient of determination is used:

$$R^2 = 1 - \frac{\sum_{i=1}^{N} (y_i - \hat{y})^2}{\sum_{i=1}^{N} (y_i - \bar{y})^2} \qquad \textbf{(2)}$$

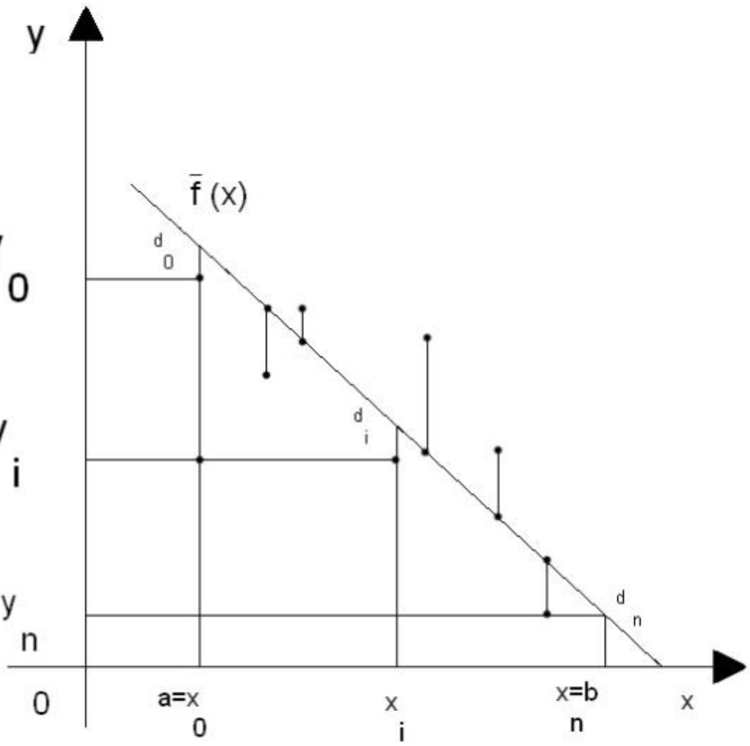

Figure4: Root-mean-square approximation$\tilde{f}(x)$

The check for significance of the coefficient of determination is performed by means of the F-criterion:

$$F_{calc} = \frac{R^2 (N - p)}{(1 - R^2).(p - 1)} \qquad \textbf{(3)}$$

where N is the number of the experimental series;

p – number of the coefficients of the model.

If: $F_{calc} > F_{kp}(\alpha; \nu_1 = p-1; \nu_2 = N-p)$,

then the coefficient of determination is considered significant, at the given level of significance.

ANALYSIS OF EXPERIMENTAL DATA

The graphic presentation of the relationship between the density and thickness of FBs manufactured after the dry method and the maximum value of the pressing pressure is shown on Fig. 5. On the figure, the points represent the recorded experimental results, and the curve corresponds to the approximating function derived after the least squares method.

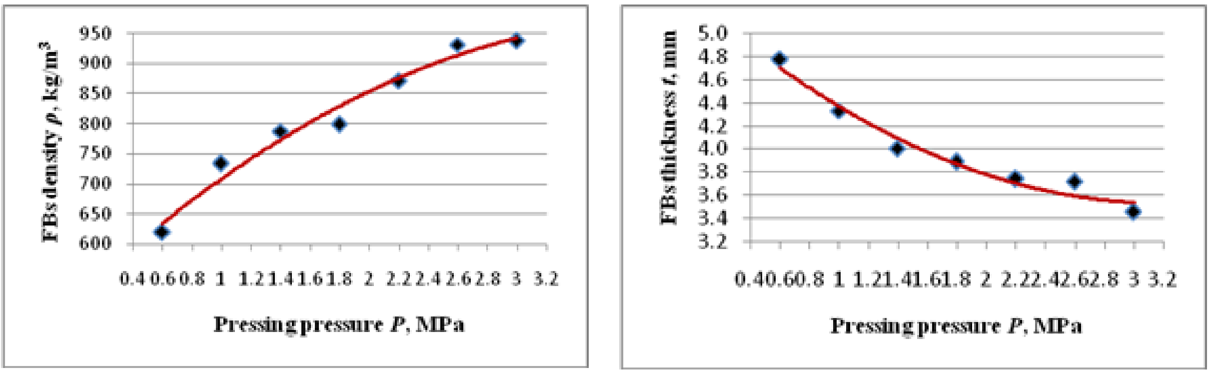

Figure 5:Variation of the density and thickness of FBs, in connection with the pressing pressure

The results for the density of FBs treated after the methods of regression analysis allow deriving of a functional dependence between the variation of the density and thickness of FBs:

$$\hat{Y} = 829.2 + 153.4X - 40.62X^2 \quad \textbf{(4)}$$

$$\hat{Y} = 3.87 - 0.58X + 0.25X^2 \quad \textbf{(5)}$$

The equations are characterised with a coefficient of determination respectively R^2 = 0,97 и R^2 = 0,96.

In case of use of hard broad-leaved tree species as wood-based raw material, with the increase of the pressing pressure within the range of 0,6 to 3,0 MPa, the density of the hard FBs increases from 630 to 930 kg/m^3, i.e. by about 300 kg/m^3. The thickness of the manufactured boards at the set components decreases from 4,8 to 3,5 mm, or by nearly 40 %. The density increase is due to the higher compression as a result of the increased specific pressure and, therefore, is realised at the expense of the thickness of the boards at identical characteristics of the wood-fibre carpet.

The greatest variation of the two indices is recorded in case of pressure increase from 0,6 to 1,0 MPa, and the smallest – in case of pressure increase from 2,6 to 3,0 MPa. The dependence is of 2nd degree, with greater relative variation being observed in case of pressure increase to 2,0 MPa whereupon the increase is relatively smaller. The set density of 900 kg/m^3 is only reached at a pressure above 2,6 MPa.

The variation of the water absorption and swelling of FBs at different levels of pressing pressure is presented on Fig. 6.

The equation of regression between pressing pressure and water absorption is:

$$\hat{Y} = 187.20 - 59.12X + 5.41X^2 \quad \textbf{(6)}$$

The relationship between the pressing pressure in case of a range of variation from 0,6 to 3,0MPa and the swelling in thickness of FBs is described with a regression equation of the type:

$$\hat{Y} = 28.27 - 10.67X + 3.56X^2 \quad \textbf{(7)}$$

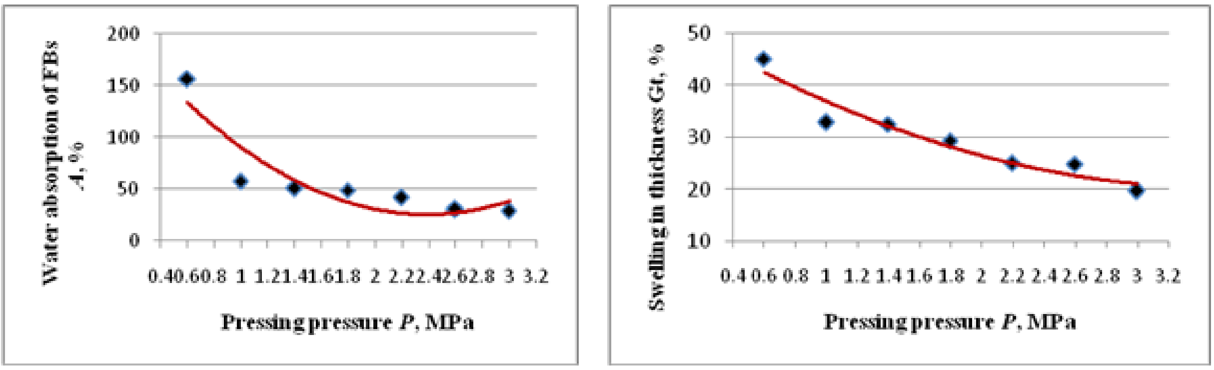

Figure 6: Variation of water absorption and swelling of FBs depending on the pressing pressure

Very big improvement, respectively decrease, of the water absorption index is observed in case of pressure increase from 0,6 to 1,0 MPa, with the index decreasing from 150 to 60 %. The dependence is of 2nd degree and greater relative improvement of the index in case of pressure increase to the value of 2,0 MPa is observed.

The very deteriorated value of the index at a pressure of 0,6 MPa could be explained with the low structural stability of the boards, due to the lower compression ration and mainly to the deteriorated heat exchange because of the direct release of the steam and gas mixtures during their formation. The latter impedes the formation of both cohesive bonds and adhesive ones.

The swelling in thickness is improved, with it decreasing with the increase of the pressing pressure. This trend is more clearly expressed up to 2,0 MPa whereupon the improvement is smaller.

As a whole, the water absorption and swelling decrease with the increase of the pressing pressure. This may be explained with the plastic deformations that have occurred, which guarantee irreversibility of the bonds created in the boards.

The regression equation describing the dependence of the bending strength on the pressing pressure is of the type:

$$\hat{Y} = 22.11 - 15.37X + 1.49X^2 \quad \textbf{(8)}$$

The above equation is characterised with a coefficient of determination R^2 = 0,99 and, therefore, the equation adequately describes the examined relationships in the examined range of variation of pressing pressure.

The dependence between the bending strength and the pressing pressure is graphically presented on Fig. 7.

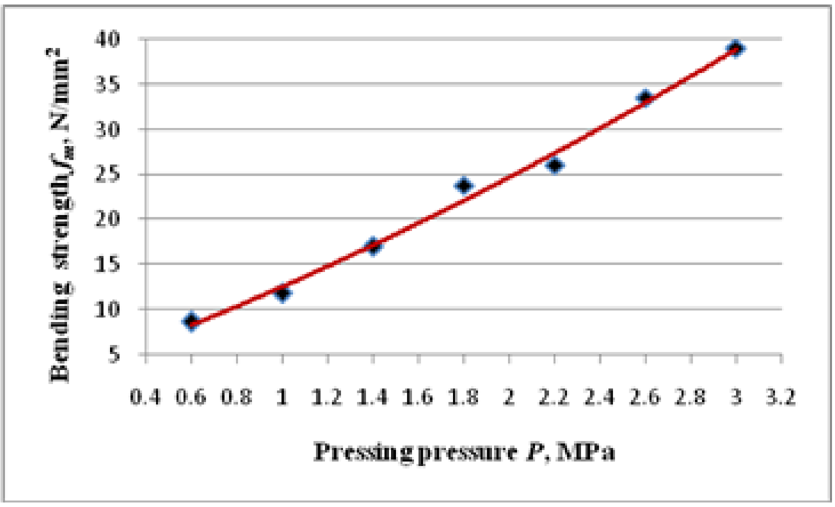

Figure 7: Variation of bending strength of FBs depending on the pressing pressure

The relationship between the bending strength and the pressing pressure approximates linear one. With the pressure increase, the bending strength increases considerably. Lowest value of 8 N/mm^2 is recorded at a pressure of 0,6 MPa. The index has highest value, of nearly 40 MPa, at a pressure of 3,0 MPa, with the laboratorial manufactured boards meeting the most strict requirements in the field with respect to this index, without additional modification of the manufacture mode being necessary. Although the trend is more poorly expressed, there is greater relative improvement of the index in case of pressure increase from 0,6 to 2,0 MPa here, too.

As a result of the investigation performed on the effect of specific pressing pressure on the performance of FBs manufactured after the dry method from wood of hard broad-leaved tree species, the following more fundamental conclusions may be drawn:

1. The dependence between the pressing pressure and density of FBs is of direct nature. Highest density increase is observed in case of pressure increase from 0,6 to 1,0 MPa, and smallest – in case of pressure increase from 2,6 to 3,0 MPa;
2. The pressure increase leads to decrease of board thickness as a result of the higher compression ratio. The relationship between the thicknesses of the boards manu-factured and the pressure is of quadratic nature, with greater decrease being observed in case of pressure increase to 2,0 MPa;
3. The increase of the pressing pressure leads to reduction of the water absorption of FBs, with the relationship being expressed through the equation of 2^{nd} degree. Very big decrease, i.e. improvement of the index, is observed with the pressure increase from 0,6 to 1,0 MPa;
4. The swelling in thickness is improved in case of pressure increase from 0,6 to 3,0 MPa, with the biggest improvement being to 2,0 MPa;
5. With the increase of the pressing pressure, the bending strength of FBs increases considerably, with them meeting to the most strict requirements for FBs within the above factor range examined.

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