The Compaction - Compression Coefficient of Chipboard Plates

LUNGULEASA Aurel
Transylvania University of Brasov, Romania, lunga@unitbv.ro
SPIRCHEZ Cosmin
Transylvania University of Brasov, Romania, cosmin.spirchez@unitbv.ro

Abstract
This paper refers to a new feature of chipboard namely the compaction-compression coefficient for obtaining panels with superior properties. Because this coefficient has two components, respective the compaction and the compression ones, all two properties are firstly individual analyzed and only after that are synthesized into global property called the compaction-compression coefficient. This coefficient gives us a new perspective in the chipboard analysis.

Key words
chipboard, compaction-compression coefficient, density

1. Introduction

Material compacting has been studied always, in order to clarify its physical, chemical or mechanical properties. Some authors studied the mudstones compacting coefficient [1], others forest soils compaction [2], others clay mineral aggregates compacting [3] and not in the last way the lignocelluloses briquettes [4]. Chips compacting and compressing in the structure of chipboards has influence to mechanical properties (especially modulus of rupture MOR to static bending) influencing the parameters of the compressing procedure, especially pressure, but also the compressing duration to a lesser extent.

There are significant differences between compacting and compressing of chips in the structure of chipboards, these being dependent on the density of the chips before compression, the density of the solid wood where chips originate are from, and the density of the final chipboard. Among the above mentioned three densities there always must be a correlation, because this is the only way to achieve a proper strength of chipboard, reduced raw material and adhesive consumption, as well as acceptable pressure. Chips' compacting is defined by the existence of a number of hollow spaces in the structure of the chipboard. From this point of view the smaller the number of hollow spaces, the more compact the chipboard and the more hollow spaces, the less compact the chipboard. If a comparison is made between the density of the chips and the density of the wood they are originated from, there will always be a multiplication of approximately 3.5-6 times, but this coefficient is well known in the form of chip aeration coefficient, which is frequently used in chipboard technology in order to establish the height of the chip carpet.

Chips compacting and compression have as terms of comparison chipboard density and the density of the wood, they are originating from. If order to establish the compacting degree of the chips in the chipboard, the ratio between the chipboard wood density and the volume of the chipboard shall be established, taking into consideration the volume of hollow spaces in the chipboard and, from this standpoint – the following relation can be calculated:

$$\Delta_c = \frac{V_p - V_g}{V_p} \cdot 100 \quad [\%] \tag{1}$$

where:

Δ_c is the compacting degree of the chips structure in the chipboard, in %;
V_p – chipboard volume, in cm^3;
V_g – hollow spaces volume in the chipboard, in cm^3.

Considering the quantity of wood and adhesive in the chipboard, the compacting degree in the structure of the chipboard can also be determined by the following relation:

$$\Delta_c = \frac{V_l + V_a - V_g}{V_p} \cdot 100 \quad [\%] \qquad (2)$$

where:

V_l is the compact volume of the wood in the chipboard, in cm^3;

V_a – volume of the dried adhesive in the chipboard, in cm^3.

Regardless to the two relations (1) or (2) it can say that they are the compacting degree of the chipboard structure (expressed in percentage) but when the two relations do neither have 100 multiplications it will always have an compaction-compression coefficient (with subunit values). The practical determination of the compacting coefficient by means of the equations (1) and (2) is very difficult due to the fact that the volume of hollow space and the volume of massive wood in the structure of the chipboard cannot be accurately determined. The compacting degree can still be indirectly determined together with the adhesion of the chips in the structure, by determination of the internal cohesive strength of the chipboard [5].

The compression degree (expressed in percentage) or the compression coefficient of the chips structure upon compression (expressed in decimal units) is a second important determining factor of the parameters of the compression process and finally of the quality of the resulting chipboards. When we says compression we think implicitly to the smashing of the chips on the chipboard structure, in such as way that two neighbouring chips interpenetrate forming a whole. The average compression degree of the chips wood from the structure of the chipboard can be determined by means of the following relation:

$$\Delta_{cp} = \frac{V_l - V_{lc}}{V_l} \cdot 100 \quad [\%] \qquad (3)$$

where V_{lc} represents the volume of the wood remaining after its compression, in cm^3.

This characteristic as well as the first one is hard to practically determine, due to the fact that the volume of compressed wood cannot be accurately determined. For this reason, it has been tried to determine another characteristic more easily obtained, that synthesizes the two previous features (compaction and compression) into a single one. In this way the notion of compacting-compression coefficient is emerged, expressed in decimals, defined as a ratio between the chipboard density and the wood specie density that the chipboard is made from. When the ratio densities are multiplied by 100, it shall be expressed in percentages, and the coefficient transforms into compacting-compression degree.

$$K_{cc} = \frac{\rho_p}{\rho_l} \qquad (4)$$

$$\Delta_{cc} = \frac{\rho_c}{\rho_w} \cdot 100 \quad [\%] \qquad (5)$$

where: K_{cc} is coefficient of compaction-compression; Δ_{cc} – degree of compaction-compression; ρ_c – chipboard density, in g/cm^3; ρ_w – wood density, in g/cm^3.

This coefficient of compaction-compression can have sub – unitary and over- unitary values. When it is expressed as decimals it is called coefficient and when the expressing is as per cent it is called the degree of compaction-compression. For the sub-unit values it can consider that there is a compaction and for over-unit values of this coefficient there is a compression. The compression or compaction is referred to density of wood and chipboard, without taking into consideration the quantity or density of dry resin, which have some important influences.

By increasing of compaction-compression degree or coefficient, the wooden mass per volume unit of chipboard will increase, increasing in this way the bending strength. This degree of compaction-compression is superior limited by the designed density of chipboard, because with increasing of compaction-compression degree the bending strength will increase proportionally. General relationship between degree of compaction-compression and bending strength is the next one [5]:

$$\sigma_i = \frac{\Delta}{\rho_0^x} \cdot k \quad [\text{MPa}] \tag{6}$$

where: Δ is degree of compaction for wood, ρ_0 – density of oven dry wood, in kg/m³; *x* – coefficient dependent by chipboard density; *k* – coefficient dependent by wood density.

The equation (6) depends on coefficients *x* and *k*, determined depending on the density of the wood from which the chips were obtained (Table 1). In this equation the compacting-compression coefficient is used, considering the fact that in classic technology it only has chips compacting and there is no compression of them [6].

Table 1. Relationships of chipboard density related to wood density

Density, kg/m³	Coefficient *x*	Coefficient *k*	Relation σ_i
450	3.978	5.444	$\sigma_i = \frac{k \cdot \Delta}{\rho_0^x}$
500	3.232	13.645	
600	2.209	55.04	
650	1.941	87.06	
800	1.507	241.6	

It can be observed that the variation of bending strength related to the degree of compaction is lineal. If the necessary calculation are made for the poplar specie (with an oven dry density of 440 kg/m³) and the relationship for a chipboard density of 650 kg/m³ (good for poplar) are used, the linearity of dependence will be obtained (Figure 1). It can be observed that for a neutral coefficient (of 0.95-1.15) bending strength shall be of 20 MPa, which corresponds to the requirements of the international standards of chipboard.

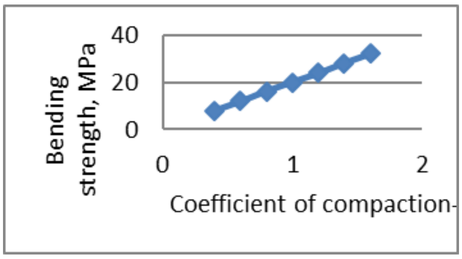

Fig. 1. Influence of the compacting- compression coefficient on the static bending strength

Moreover, by extension of the compacting coefficient field, towards the chips compression part in the chipboard structure on an existing chart [5] other important influences can be found (Figure 2), that can help the technologist in a chipboard manufacturing factory.

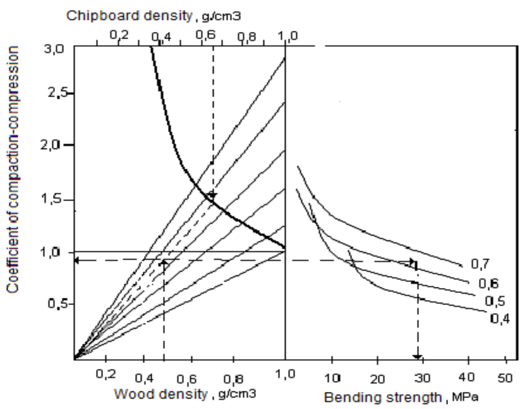

Fig. 2. Correlation of bending strength with wood and chipboard densities and coefficient of compaction-compression [5]

2. Experimental

In industrial practice there are chipboards with subunit or over unit compacting-compression coefficients, depending on the wood species used, because low-density species are more easily compressed and thus they have a higher coefficient and vice-versa. For experimenting the wide chips have been used, obtained from poplar, spruce and beech wood, and delivered from a Homback splintering machine, without chips chopping and urea-formaldehyde adhesive use. Chips have been dried artificially at 10% moisture content. The percentage of adhesive used for the chips was constantly of 10% [7, 8]. Several chips carpets have been made with adhesive that were later compressed, (using different pressures) by using spacers of 6 and 8 mm to limit board thickness (Figure 3).

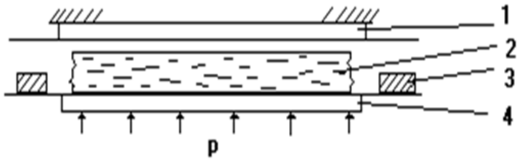

Fig. 3. Compression of the chip carpets
p – specific pressure; 1 – upper plate; 2 – chips carpet; 3 – thickness spacers; 4 – lower plate

Each chip carpet was calculated in such manner so as the mass to correspond to the predicted density of the chipboard (knowing the plate dimensions of the chipboard and the press plates were 500×500 mm). This way a certain pressure of a certain chipboard density was obtained, and because the specie density was constant, a certain compacting- compression wood structure coefficient was obtained (Table 2). To complete the diagram by other board thickness lines, the linear interpolation method was used, the curvature for 18 mm thickness being obtained in this way (Figure 4).

Table 2. Values of the experimental compaction-compression coefficients

Average thickness chipboards, mm	Specific pressure, MPa	The compaction-compression coefficient
6 mm	0.56	0.6
	0.78	0.8
	0.97	1.0
	1.16	1.2
	1.34	1.4
	1.52	1.6
12 mm	0.76	0.6
	1.00	0.8
	1.28	1.0
	1.5	1.2
	1.76	1.4
	2.0	1.6

This coefficient of compaction-compression depends firstly by pressure as it could see in Figure 4. It had obtained optimum values of pressure as 1-1.5 MPa and a corresponding coefficient of compaction-compression about 1.

3. The Influence of the Adhesive on the Compacting - Compression Coefficient

In the relations for the determination of the structure compacting - compression coefficient [4, 5] the influence of the adhesive and of the other substances from the adhesive recipe will not be considered. Therefore it shall be found a correction coefficient for the previous relation to take into consideration the influence of the dried adhesive on the chipboard. Generally it can be state that the density of the dried adhesive to be found in the composition of the chipboard is way bigger than the density of the wood used to obtain the chipboards, the calculation relation of this influence being as follows:

$$\rho_p = \frac{1}{100}\left(\rho_l \times p_l + p_a \times \rho_a\right) \quad [\text{kg/m}^3] \tag{7}$$

where:

p_l and p_a are the wood and adhesive percentages from the chipboard, expressed in %;
ρ_l and ρ_a are the wood and adhesive densities, expressed in kg/m^3.

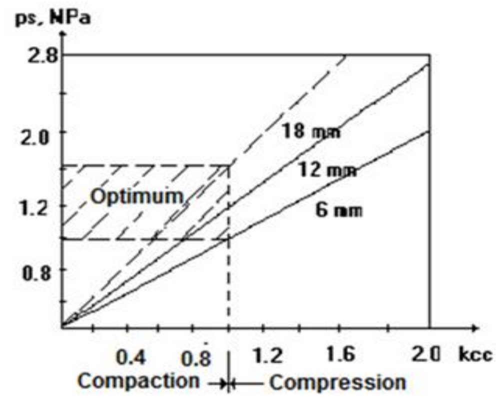

Fig. 4. Coefficient of compaction-compression
p_s– specifically pressure, in MPa; k_{cc} – coefficient of compaction-compression

The previous relation (7) can be particularized for an adhesive density of 1400 kg/m^3 and for a spruce wood density of 440 kg/m^3 in the following:

$$\rho_p = 440 + 0.96 p_a \tag{8}$$

This relation (8) is the equation of a plane showing that the board density is linearly dependent on the percentage of adhesive from the board, respectively will increase. This increase is low, of approximately 1.5 kg/m^3 for each adhesive increase percentage, as it can be observed in Figure 5.

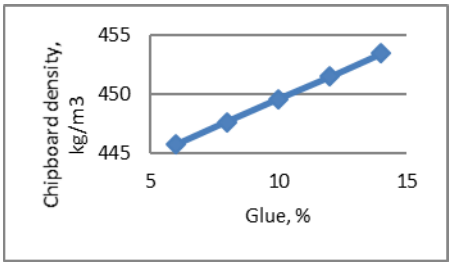

Fig. 5. The correlation between glue percentage and chipboard density

The chipboard density increasing (c_r) coefficient as opposed to the density of the wood specie used to obtain the chips can be determined by means of the following relation:

$$c_r = \frac{\rho_p - \rho_l}{\rho_l} \tag{9}$$

This increase coefficient is introduced in the defining relation of the compacting- compression coefficient, and by this way we will have the final relation, corrected by the influence of adhesive density:

$$K_{cc} = \frac{\rho_p}{\rho_l \cdot \left(\dfrac{\rho_p - \rho_l}{\rho_l}\right)} = \frac{\rho_p}{\rho_p - \rho_l} = \frac{1}{1 - \dfrac{\rho_l}{\rho_p}} \tag{10}$$

$$K_{cc} = \frac{1}{1 - \frac{\rho_l}{\rho_p}}$$

The coefficient of density increase has small values, especially due to the fact that the adhesive percentage does not make possible for the chipboard density to increase extraordinarily. Also it is taken into consideration the fact that the adhesive percentage in the chipboard plates does not have a high variability, percentages of 8 – 12% are the current ones, and density variation on this interval is of only 6 kg/m^3. Following the results obtained, during the experiments, optimal compacting-compression coefficients have been found around 1 for beech, spruce and poplar chips used during the experiments, slightly higher for poplar and spruce, but up to 1.1.

4. Final Conclusions

The determination of the compacting-compression coefficient accommodates the requirements of the chipboard manufacturers, to find optimal solutions for board densities in relation to the used species. Equally, the election of a compression- compacting pressure specific for the wood specie used is another issue brought into discussion for which optimal solutions have been found. The present paper attempts to clarify a part of the wood compacting and compression issues in the structure of chipboard structure, without claiming to solve them entirely. This is valid since there are other factor as well to be taken into consideration, such as the chips granulometry and the mix of different chip species.

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