Composites with Lignocellulosic Basic Matrix and Mineral Binders - to be used in Civil Engineering

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This paper presents the results of the author's latest researches on lignocellulosic basic structure composites, which resort to wood fibres and chips, in admixture with mineral binders - cement and gypsum. The obtained products, shaped as boards and blocks, may be deemed "ecological products" with applicability in the field of Civil Engineering, both as plating materials and as filling material (for the sandwich-type structures). The obtained results may be reckoned for the theoretical and experimental basis for further development of the materials and products achievable in industrial systems and usable in the structure of constructions for various purposes.

Keywords: composites, wood chips, wood fibres, adhesiveness, embedding

Wood has been, since the earliest times, the most widely used material in constructions for various purposes. In some cases, it fully achieves the structures, and in other cases, it combines with other types of material.

Wood has raised interest due to a few characteristic features [1], [2]:

- it is a natural product, of relatively low density, ideal for light-structure constructions;
- it is a renewable material, for whose growth, hence production, there is required no energy whatsoever;
- it is an easily workable material – of relatively low energy consumption;
- it is a material with excellent properties in thermal-transfer terms, one of the best heat insulating materials;
- it is a relatively good soundproofing material;
- it may be turned to good account for highly complicated structures;
- it is an eco-usable material, at the end of the construction lifecycles (by combustion, biodegradation and afferent composting or by its being embedded in various composites).

Despite technical and scientific evolution as regards materials for civil engineering, wood is back to maximal-interest level, mostly due to its low manufacturing costs and, at the same time to its workability and thermal properties.

This material is back to public attention, in order to be enhanced at maximum efficiency.

Romania yearly exploits from its own forests approximately 18 million m^3 of wood. Final products - furniture, doors, windows, parquet floor, construction elements, packages and other products - contain wood in an overall percent of 15 - 20%; the rest is technological waste resulted from the primary and secondary processing cycle.

The technological-waste volume is large and comprises branches (from tree-felling), borders and saw-dust (from log-processing), chips and ends (from sawn-timber processing).

Technological wastes are partly used for producing heat in rural dwellings (by direct combustion);another part, by processing in wood briquettes, is used for producing thermal energy in industrial plants; the bark is used in the tanning and compost industry etc. Lately, the borders, chips and saw-dust have been used for producing industrial composites - for chip-panels (PAL, OSB) or fibre-panels (MDF) widely used for furniture manufacturing and in civil engineering.

For all involvement of the wood processing industry, a sufficient quantity of timber remains unused, biodegrading, with no possibility of being turned into good account at higher economic level, sometimes harming the environment (ex. rotting in the forest, following tree-exploitation and poor use of branches, possibly infecting the rest of the forest).

There has been raised the issue of turning these technological wastes to good account in other fields, so that their useful value might attain the highest values, and important technical-social problems might be solved.

Experimental part

Materials and methods

Wood and composites

The recovery of the wood technological wastes and their enhancement by being turned into other industrial products has preoccupied the experts and researchers in wood processing, precisely because the volume of these wastes is very large and cannot be used in full.

The idea of the wood composites dates far back and aims at obtaining wood-chip and fibre boards. The achievement of these industrial products resulted in turning to good account the exploited wood in a percentage of 60-70%, by its being embedded in products made of wood or in products made of wood combined with other materials, which raised the economic efficiency and streamlined furniture manufacturing, by raising the mechanization and automation level of the technological processes.

The achievement of the wood chip and fibre composites relies on the adhesiveness phenomenon between the wood particles, with the aid of adhesives (natural or synthetic) - depending on the field of use of the resulted products - mainly as plan- and parallel-faced panels.

The use of synthetic adhesives has long placed wood composites in the category of non-ecological products - being characterized by relatively high emissions of formaldehyde.

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In the current conditions where the composite-based furniture manufacturing has significantly decreased - as a consequence of the human-attitude modification as regards environmental pollution and life safety - the production of furniture and other products based on solid (natural) wood has developed. An ever-increasing quantity of technological wastes is available and must be further used, so that same time not to endanger the environment.

Lately at the with the development of the constructions in al fields (inclusively the agro-zootechnical) - there has been raised the problem of resorting to low-cost materials, with very good thermal and phonic properties - in order to reach another current desideratum - namely minimal energy losses.

A guiding line pursed by research - at the Faculty of Wood Engineering, within *Transilvania* University of Braşov - was to achieve ecological composites with lignocellulosic basic structure by resorting to wood chips and fibres and mineral binders - cement and gypsum. The use of these materials, in admixtures, based on feasible recipes, might lead to the achievement of low-cost, ecological products, which are of interest especially for civil engineering.

Adhesiveness or embedding

The analysis on the history of civil engineering and the afferent construction materials shows that the first composites with cellulosic waste and mineral binders were made and used in this very field. Adobes and tiles used to be and still are, in the world's poorer areas, the main building materials, due to their low costs and to the fact that the materials necessary for making these composites are readily available.

These observations and considerations led to the idea of making composites by resorting to wood technological wastes, as basic structure, and to mineral binders, with a view to obtaining construction materials in the shape of boards or blocks (composite bricks).

The achievement of composites with mineral binders raises problems in terms of obtaining stable structures, strong enough to be handled and fastened in constructions, and energetically comparable to the materials available on the market.

From the outset, the manner of making the structure of the composite was analyzed and the following alternatives ensued [3]:

- to constitute the structure of the composites by adhesiveness – the binder layer only lies at the level of the contact surfaces between the wood particles, and makes the "adhesive connection" between particles (fig.1.a);
- to constitute the structure of the composites by embedding – the binder embeds particles without requiring direct contact between wood particles; the strength of the structure mainly resides in the prevailing mass of the binder (fig.1.b).

In the case of *adhesiveness*, the structures of the composites are porous, with a high percentage of wood particles; while in the case of *embedding*, the structures of the composites are alveolar - with the maximal participation of the binder - the alveoli consisting of wood particles embedded in the mass of binder.

On these grounds, we dare to say that both porous-structure (hence lighter) and alveolar-structure-composites (hence heavier) are feasible. Porous structures might be used as filling material (blocks) while alveolar structures might be used as cladding material (boards).

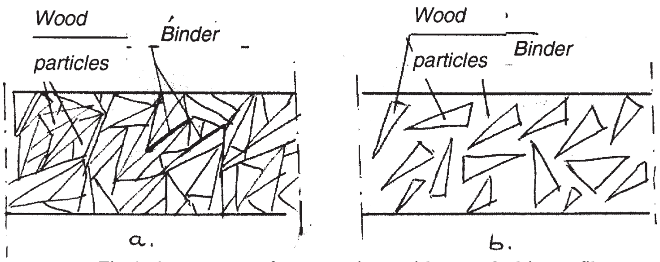

Fig.1. Structures of composites with wood-chip or fibre matrix, with mineral binders: a – by adhesiveness; b – by embedding

Preliminary researches

Researches on composites with lignocellulosic basic structure and mineral binders have likewise been conducted elsewhere, such as: Germany, Austria, Switzerland, USA etc., and have resulted in composite products whose properties are directed and oriented towards their fields of application. The obtained products have different trade names like: Duripol, Fulgurit, Esermit, Heraclit, Betapan etc., assigned to those made of wood - cement and Fiberbond, Mesporex, Samax, Fermacell, Arborex etc., assigned to those made of wood - gypsum, recipes for achieving them have not been yet been published. Many such products are being used in civil-engineering as cladding elements or as part of the sandwich structures.

In Romania, there are no data on this type of composites; therefore, preliminary studies were required, to the purpose of establishing the percentage by mass of wooden material (chips or fibres), for possible use in the structure of these composites, so that the results might be turned to good account [3, 4].

The following were considered when defining the wooden-material concentrations:

- to obtain products easy to handle and transport, maintaining withal the structural integrity;
- to obtain products of various thickness and densification degrees;
- to observe the limit separating the adhesiveness phenomenon from the embedding phenomenon;
- to improve the thermal and mechanical characteristics of these products, as against the materials that might replace them.

The starting point consists in accepting the variation of the participation by mass of the wood, between 10 and 50%; the first test samples are made either with cement, or with gypsum, in the shape of boards whose thickness ranges between 10 and 20 mm, and boxes whose thickness ranges between 60 and 80 mm.

The following were noticed as a result of the experimental work:

- dry homogenization is harder to achieve in the case of the composites that use wood fibres than in the case of the composites that resort to wood chips;
- the application of water for obtaining wet mixtures to be poured in moulds entails to wit the different behaviour:
  - ·the mixture that uses cement rapidly loses water and the binder that remains in the structure does not attain adequate adhesiveness; the tendency to easy structure dismantling led to the abandonment of this research line - for the time being;
  - ·the mixture that uses gypsum displays good technological behaviour - the resulting "pastes", cast in moulds, ensure stable structures - with varied degree of resistance to dismantling;

Code of specimens	Code of board – of recipe	Concentration by mass of the wooden material	Board thickness	Density (volumetric mass)	Thermal conductivity, λ	
		%	mm	kg/m^3	W/mk	Kcal/m h degrees
Control sample PLASTER STAS 545/2-2000 and C.S. 1/1994			9.5	851.141	0.2210	.01900
			12.5	888.295	0.2340	0.2010
			15.5	872.000	0.5380	0.4630
A_1	FG 10	10	9.3475	801.000	0.1345	0.1157
A_2	FG 10	10	13.888	802.551	0.1630	0.1400
A_3	FG 10	10	13.992	795.603	0.1865	0.1600
A_4	FG 10	10	16.332	798.60	0.1900	0.1630
B_1	FG 12	12	9.422	713.000	0.1230	0.1060
B_2	FG 12	12	13.633	709.950	0.1470	0.1270
B_3	FG 12	12	15.800	711.830	0.1836	0.1578
B_4	FG 12	12	16.448	713.528	0.1880	0.1620
C_1	FG 15	15	9.39	659.00	0.0939	0.0807
C_2	FG 15	15	11.895	663.000	0.1215	0.1044
C_3	FG 15	15	14.702	671.000	0.1690	0.1408
C_4	FG 15	15	16.983	668.561	0.1725	0.1456
D_1	AG 25	25	9.527	796.000	0.102	0.0876
D_2	AG 25	25	11.300	797.000	0.139	0.120
D_3	AG 25	25	14.300	798.000	0.150	0.129
D_4	AG 25	25	17.12	802.000	0.194	0.167
E_1	AG 30	30	9.5225	698.000	0.1010	0.0868
E_2	AG 30	30	12.180	698.000	0.1546	0.1330
E_3	AG 30	30	13.147	699.000	0.1550	0.1330
E_4	AG 30	30	16.698	703.000	0.1839	0.1582
F_1	AG 35	35	9.545	630.000	0.1150	0.0989
F_2	AG 35	35	14.212	627.000	0.1300	0.1120
F_3	AG 35	35	15.512	629.000	0.1350	0.1160
F_4	AG 35	35	16.350	626.000	0.1610	0.1380

Table 1
DENSITY AND THERMAL PROPERTIES OF THE COMPOSITES FROM WOOD WITH GYPSUM

Tested specimen	Tested properties - composites				RIGIPS		
	Internal cohesion (tracţiune de pe feţe) [N/mm^2]	Resistance to screw-pulling out [N]	Resistance to pin- pulling out [N]	Resistance to bending – F_{max} – [N/mm^2]	Resistance to screw-pulling out [N]	Resistance to pin-pulling out [N]	Resistance to bending [N/mm^2]
1	0.61	850	190	3.12	300	25	4.39
2	0.60	950	225	3.35	200	30	4.19
3	0.52	500	175	2.54	500	35	5.67
4	0.58	590	130	2.81	480	40	1.82
5	0.70	770	120	3.05	340	10	1.92
6	0.66	720	170	2.96	300	10	2.05
7	0.68	840	130	3.31	320	12	1.47
8	0.33	790	135	2.43	450	18	2.45
9	0.33	780	145	3.12	250	20	3.05
10	0.58	775	155	2.55	300	10	2.95

Table 2
MECHANICAL PROPERTIES SPECIFIC TO COMPOSITES FROM WOOD AND GYPSUM

·the concentrations by mass of the wooden fibres, in order to obtain usable products ranged between 10 - 15% and the concentrations by mass of the wooden chips for obtaining usable products ranged between 10 ÷ 35%.

The last conclusion actually brought about the narrowing of the research field; therefore, in the current stage, we may formulate conclusions capable of maintaining a keen interest in this area of research.

With a view to continuing research, four specimens with the same concentration in fibres or chips and of various thickness were made as parallel-surfaced boards, so that they might be similar in thermal properties to the similar product PLASTER, which is currently being used.

In order to obtain the closest results to the real values, 10 specimens were made for each thickness, so that the average values might eliminate the influences of the possible structural inhomogeneities.

Results and discussions

In the first stage, researches experimented the recipes for achieving the board-shaped composites, taking PLASTER for basis, with the thicknesses of 9.5 mm, 12.5 mm and 15.5 mm.

Experimental results, in terms of densities and thermal conductivity, for boards of varied concentrations by mass, obtained with gypsum (without additives) - as mineral binder are shown in table 1.

In order to keep evidence of the tests, FG codification – for the boards made of wood fibres, and AG codification – for the boards made of wood chips – were resorted to.

The result analysis shows that the plates obtained from composites based on wood fibres and chips have better characteristics than the PLASTER-type boards, namely they have lower density and much lower thermal conductivity [5].

It is worth mentioning that the increase in the percentage of the participation by mass of the wood entails better thermal characteristics (lower thermal conductivity), which proves the good thermal capacity of wood [6].

In order to analyze the applicability of the results, the next step consisted in determining some specific mechanical properties and the results are synthetically shown in table 2.

The experimental research was carried out in the laboratories of the Faculty of Wood Engineering and the specialized laboratories within the Research and Development Institute of *Transilvania* University.

Being about preliminary researches, there was considered the analysis of approximate recipes, whose variation of the massic concentration of wood chips or fibres ranges in steps between 5 ÷ 10% [7, 8].

The results obtained in these conditions are sufficiently incentive for sustaining the researches on discretizing the wood percentages in the recipes.

The next stages envisage continuing research by resorting to cement, along with emulsifiers and other binding materials, combined with wood, with a view to increasing adhesiveness or to easily embedding the wood particles in the mass of the binder. Likewise, the studies will be extended over thick boards and boxes, which might be used as filling material for the sandwich-type structures from civil engineering.

Possible uses for the composites with lignocellulosic basic structure and mineral binders

The results obtained – following the conducted researches – led to the conclusion that board-shaped composites might be used:

- to clad the building walls on the inside (fig. 2.a), walls which are to be whitewashed or wallpapered;

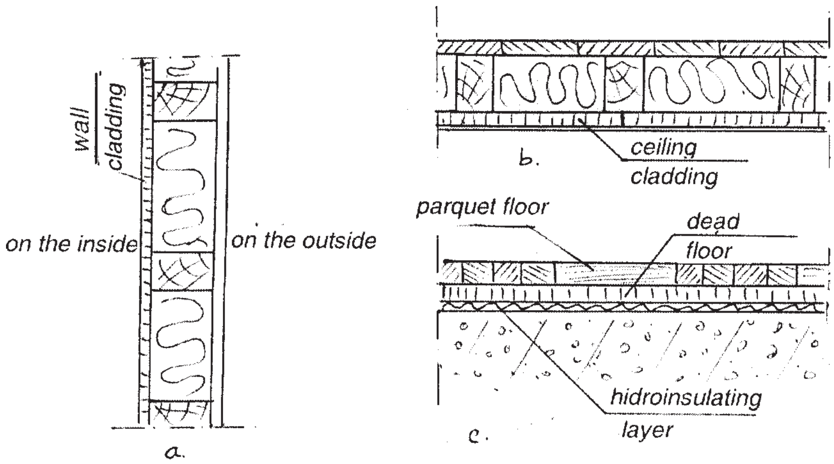

Fig.2. Possible uses for the boards made of composites with wood chip- or fibre-matrix and mineral binders: a – wall cladding on the inside; b – ceiling cladding; c – dead floors

- to clad the ceilings (fig. 2.b), similarly to the walls;
- dead floor in the framework of the boarded floors (fig. 2.c), over which either classical floors or parquet floor may be applied;
- filling in-between the building walls – in the case of boxes or boards thicker than 60 – 80 mm, for sandwich-type constructions.

The research development so that to turn recipes on technological-industrial lines may lead to the creation of a new raw-material and materials base, of undeniable functional features, destined for low-cost and energetically efficient constructions. An immediate area of application (even at the level of current researches) might be agro-zootechnical civil-engineering.

Conclusions

The studies and laboratory researches conducted on composites with matrix of wood chips or fibres and mineral binders led to the following conclusions:

· further researches in this field might focus on the use of this composite as filling material, along with mineral binders (lime, sand and emulsifiers), in order to ensure better adhesiveness or wood-particle embedding conditions;

· the matrix of wood particles (chips or fibres) should be studied through stronger discretization, in the light of the influence exercised by the participative massic percentage on the physical and mechanical properties of the obtained products;

· in the case of higher participative massic percentages of wood - within the composite - the influence of the densification level of the composite - in the binder solidification phase - should be studied, too;

· the theoretical bases of the thermal transfer through alveolar flat boards ought to be also laid, to facilitate the “design” of the wood thicknesses and concentrations depending on the desired level of thermal conductivity.

The author aims at submitting, in a future paper, the results obtained when making these composites shaped as boxes or thick boards (over 60 mm) with variable aeration degree, composites which might be used as filling material for the sandwich-type walls in constructions.

The research area launched by this article may have a broad scope if, beside wood particles, one could introduce in the matrix of the composites other scraps from recycling products in their later lifespan (textiles, plastics, glass, ceramic, etc).

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