Influence Exerted by the Structural Matrix of the Composite Boards Made of Hemp Hurds, on the Thermal-Transfer-Factor. I

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This paper tackles a ligno-cellulosic composite, whose basic matrix is made out of hemp hurds and mineral binders, as regards the percentage participation of the hurds in the structural stability and thermal-transfer capacity, for a plate- or block-shaped product. The studies, corroborated with laboratory research, aim at ascertaining the use of these products both as lining and as filling material, in the sandwich-type structures, in civil engineering; the materials basis specific to constructions can thereby be achieved, in a wide range, in terms of the thermal-insulation capacity and, implicitly, of the energetic consumption typical of civil, industrial, agro-zootechnical engineering.

Keywords: hemp hurds, mineral binders, thermal conductivity

Hemp, a plant used by humans from the earliest times [1], and so contested of our days [2], appreciated both for the fibres obtainable from stem-processing, and as food and "medicine" by seed enhancement, has been an important crop plant, even of the highest importance, in some countries [3, 4].

The fibres resulted from stem-processing have constituted the raw-materials basis for twine, cordage, fabrics etc. used in varied industries (ex. furniture industry – the fabrics have underpinned the textile carpet, made of algae, coconut fibres etc.; or agriculture – for manufacturing the bags destined to the transportation and storage of variegated crop-plant seeds). The areas of application are obviously variegated, due to the fibre resistance and relatively low costs – as the hemp represents a crop of high productivity and relatively simple growth and enhancement technology [5].

The stem-enhancement technology, used for obtaining fibres from "melted" stems (brought into an incipient putrefaction phase) by breaking the cellulosic structure (by scutching), yields in fact three important products, namely:

- cellulosic fibres, used in varied industrial fields;
- tow, resorted to as filling material for some cellular structures specific to civil engineering;
- hurds, mostly used for fire making or compost manufacturing.

Worldwide, the hemp acreage and crop have a volume worth noticing (table 1) [6] the same as the quantity of hurds (table 2).

As shown by table 2, this "residual product" – hurds, drew the researchers' interest, both by volume and by being a product of annual production cycle.

Table 1
ACREAGES OF HEMP FOR FIBRE (ha)

Year	Romania	Germany	France	Spain	Italy	England	China	Russia**
1961	31000	3576	1995	7065	12601	FD	90000	200000
1970	23062	1698	130	261	899	FD	160000	204000
1975	31800	FD*	130	103	162	FD	164000	155000
1980	35500	FD	3500	100	38	FD	120000	159000
1985	46600	FD	550	365	0	FD	46000	117000
1988	36300	FD	1600	129	FD	FD	53000	88000
1990	16600	FD	130	105	FD	FD	21000	48800
1995	1100	FD	4	1285	FD	FD	16000	9000
1998	3080	FD	247	16507	FD	FD	12180	6000
2000	500	FD	216	5264	78	FD	9700	17000
2002	1000	FD	208	634	296	FD	14800	7000
2004	1200	FD	3900	684	296	FD	20100	4000
2006	1500	FD	1500	5	250	FD	19100	4000
2008	1600	FD	600	10	250	FD	11800	4000
2010	1600	FD	600	10	260	FD	5100	4000
2012	1600	FD	600	10	265	~14000**	5000	4000

*until 1990, the data were valid for USSR; thereafter, the data refer to the production on the Russian Federation's territory.

FD=no data in FAO bases; ** source EIHA [7]

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Year	Romania	Germany	France	Spain	Italy	England	China	Russia**
1961	201500	23244	12968	45923	81907	0	585000	1300000
1970	149903	11037	845	1697	5844	0	1040000	1326000
1975	206700	0	845	670	1053	0	1066000	1007500
1980	230750	0	22750	650	247	0	780000	1033500
1985	302900	0	3575	2373	0	0	299000	760500
1988	235950	0	10400	839	0	0	344500	572000
1990	107900	0	845	683	0	0	136500	317200
1995	7150	0	26	8353	0	0	104000	58500
1998	20020	0	1606	107296	0	0	79170	39000
2000	3250	0	1404	34216	507	0	63050	110500
2002	6500	0	1352	4121	1924	0	96200	45500
2004	7800	0	25350	4446	1924	0	130650	26000
2006	9750	0	9750	33	1625	0	124150	26000
2008	10400	0	3900	65	1625	0	76700	26000
2010	10400	0	3900	65	1690	0	33150	26000
2012	10400	0	3900	65	1723	91000	32500	26000

Table 2
QUALITY OF HEMP AND LINEN HURDS, RESULTED FROM CROP PROCESSING, DURING 1961-2012

Over time, the attempt has been made at turning waste products to good account – hurds and tow – as filling materials for civil-engineering, with the purpose of improving mechanical properties, due to their behaviour as "fittings" in volume. They were thereby used in order to obtain rectangular blocks, to achieve construction walls or to serve as plaster-type coating and insulating materials – both for houses and for agro-zootechnical constructions – the basic binder being mostly clay, mixed with sand and lime.

The building materials have evolved over time; characterized by better construction durability, they prevailed on the materials based on lingo-cellulosic waste, which were abandoned and indexed as "history".

Time proved that current building materials – industrially processed – brought a series of problems affecting human health; therefore humankind started "looking back to history" and expressing their interest (on another level) in the simple yet ecological materials in terms of achievement, use and recycling [8-10].

Consequently, these residual materials started being used to make chipboards out of hurds (PAP) likewise using phenol-formaldehyde adhesives; these chipboards are mostly used in agro-zootechnical constructions, owing to their strong smell of rotting and their formaldehyde emissions.

The problem of studying other technologies and other binders was likewise raised, in order to "insulate" the particles (hurds) from the environment, with a view to removing the aforementioned inconveniences [11].

Current studies and possibilities of turning hemp hurds to good account

The researchers' attention has been drawn towards mineral binders deprived of emission-caused pollution, which come directly from nature and whose ecological features have been verified and assessed over time (cement, plaster, clay) with or without mixing materials (lime, sand, gravel) and additives. Countries of leading economic power (France, England, America, Russia, China) or of tradition (Romania, India, Brasilia, Peru), have continuously resorted, throughout history – in variable percentages over time – to composite mixtures, out of hemp hurds or agricultural cellulosic waste, and natural binders such as clay – in order to make rural dwellings or agro-zootechnical constructions, due to their low cost and ready-handiness, also due to their simple, traditional afferent technologies.

Of our days, when mankind is ever more preoccupied with environmental pollution and implicitly, its protection, people initiated the compulsory "return to nature", implicitly to natural materials, "uninfested" by sophisticated technologies. Therefore, the solution of enhancing "ecological composites", out of natural products and of minimal pollution levels, is also topical.

In France, approximately 2-4000 houses were built, whose structure is based on wood frame and whose filling consists of hemp hurds [12] and cement, lime and clay; likewise, in England, identical houses were built, plastered with "composite mortar", based on hemp hurds broken at relatively small dimensions (1-2 mm).

In Romania, in the rural environment, there have traditionally been executed constructions out of composites, which resort to the straw and chuff resulted from harvesting and threshing the cereal crops, and mixed with clay, cement and lime – the obtained products being adobe and tiles.

These uses and accomplishments ensue from traditional methods, without comparative elements to other building materials as regards their behaviour in terms of physical properties (density, thermal conductivity, phonic attenuation), mechanical properties (resistance to compression, to shocks), resistance to weathertight or special phenomena (earthquakes, floods), resistance in time (wear) and resistance to the substitution by different structures (wood, metal, plastic).

Within *Transilvania* University, Faculty of Wood Engineering, there is a team of teaching staff and researchers who approached and are currently developing the idea of turning to good account the cellulosic waste, resulted from processing wood and various agricultural plants, with a view to obtaining composites with mineral binders, of great usefulness for buildings with various degrees of comfort; this falls under the research trend worldwide.

These researches do not aim at eliminating current materials; they offer an alternative – less polluting, less expensive and probably with good thermal and phonic functional features.

Initiatory Researches.

The researches conducted and the applications implemented so far in various countries have not yet supplied data on the recipes for making composites with basic matrix out of hemp hurds or on the rest of the filling materials.

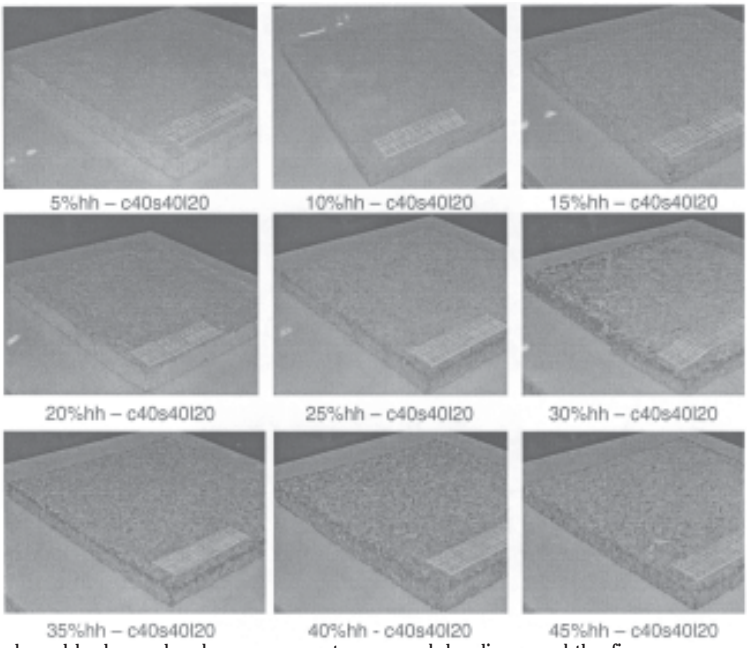

Fig. 1 Composite boards with variable matrix of hurds and mineral binder, based on cement, sand and lime

where hh=hemp hurds, c = cement, s = sand, l = lime; and the figures are percentages from the total mass of mineral binder

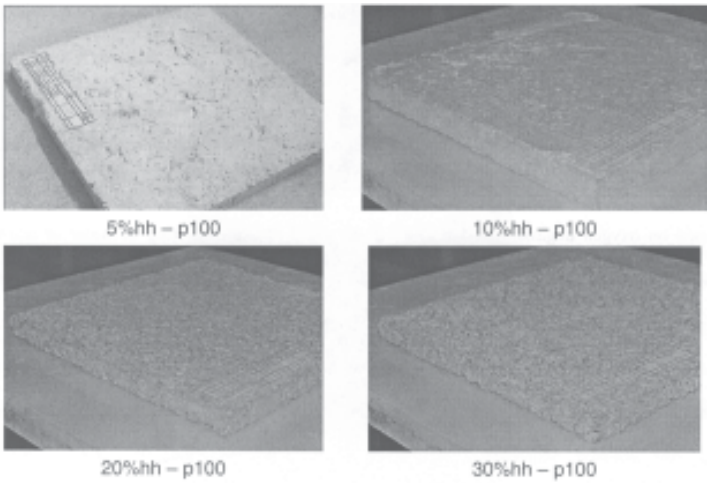

Fig. 2 Composite boards with variable matrix of hemp hurds and plaster binders

where hh=hemp hurds, p = plaster; and the figures are percentages from the total mass of mineral binder

Within *Transilvania* University, Faculty of Wood Engineering in Brasov, there were initiated doctoral researches in the field, given that hemp crops have always been grown in Romania (in the west – region of the counties Timisoara, Arad) and also given that the European Union issued directives and strategies placing Romania among the countries pre-eminently focused on growing technical plants – such as hemp. Moreover, there currently is a basis of raw materials (consisting of hemp and linen hurds, as well as technologically resulted tows) which have not yet been turned to good account and which, by being embedded in composites with mineral binders, might be of interest, might be efficiently enhanced and moreover, might develop the basis of materials specific to constructions (ex. especially agro-zootechnical).

Researches were launched on the use of mineral binders, such as cement, mixed with sand and lime, as well as on the use of plaster as mineral binder.

In the beginning, the recipes were determined for the massic percentage participation of the elements in the plastic mixtures underlying the paste to be cast into moulds, with a view to obtaining board- or block-shaped composite materials, of great usefulness, for lining or filling, in sandwich-type spatial structures.

The recipes aimed at yielding board- and block-shaped materials, displaying the following characteristics:

- to use their integrity during manipulation and storage;
- to be used for fastening, in civil-engineering;
- to display physical properties (thermal and phonic) comparable to similar materials on the market;
- not to require high energy consumptions during technological processes;
- to be ecological – without atmospheric-pollutant emissions;
- to be easily recyclable at the end of their useful life.

In order to launch laboratory researches, the following recipe structures were designed, considering the massic percentage participation of the elements:

a) cement-based group:
- hemp hurds from 5% to 50%, from 5 to 5 percentages;
- cement from 20% to 40%, from 5 to 5 percentages;
- lime from 20% to 40%, from 5 to 5 percentages;
- sand from 35% to 60%, from 5 to 5 percentages.

b) plaster-based group:
- hemp hurds 5%, 10%, 20% and 30%;
- plaster 70%, 80%, 90%, 95%.

In the case of the sampling „a", based on cement as mineral binder, the recipes were designed on series, establishing the participation percentages of lime and sand

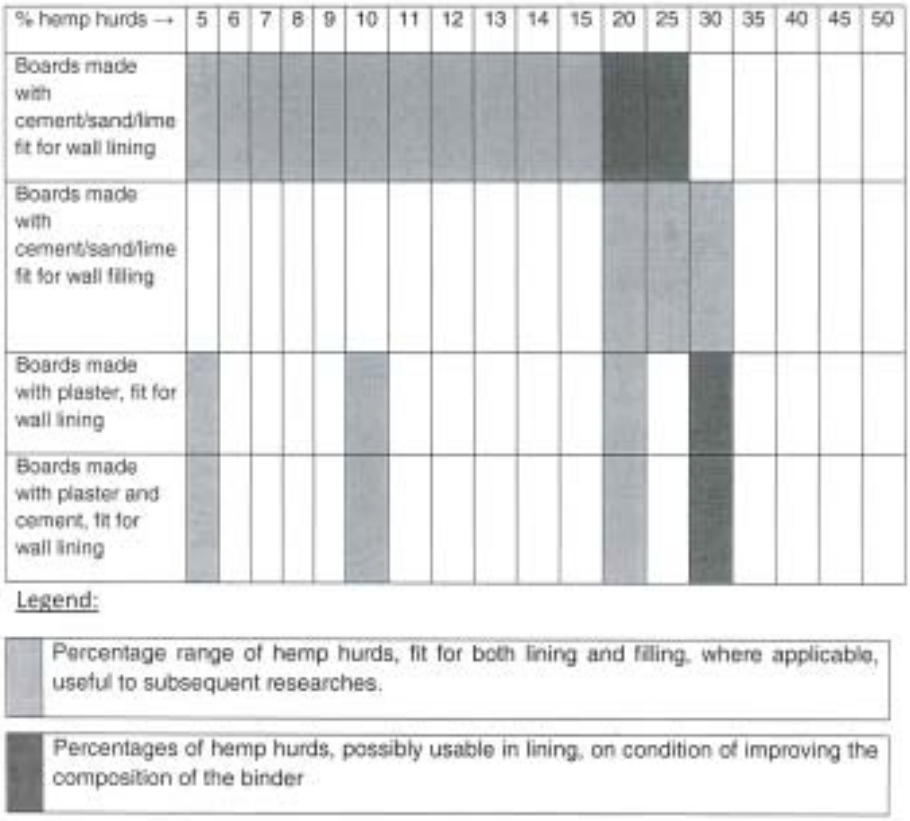

Table 3
SYSTEMATIC PRESENTATION OF THE ENHANCEMENT POSSIBILITIES DEPENDING ON THE PERCENTAGE OF HURDS AND ON THE CERAMIC MOULD

from the remaining percentage, after subtracting the massic percentage of hemps:

Series 1:

A) hurds 5%: A1) cement 20% + lime 40% + sand 40%
A2) cement 20% + lime 35% + sand 45%
A3) cement 20% + lime 30% + sand 50%
A4) cement 20% + lime 25% + sand 55%
A5) cement 20% + lime 20% + sand 60%

B) hurds 5%: B1) cement 25% + lime 40% + sand 35%
B2) cement 25% + lime 35% + sand 40%
B3) cement 25% + lime 30% + sand 45%
B4) cement 25% + lime 25% + sand 50%
B5) cement 25% + lime 20% + sand 55%, and so forth

This way, an impressive number of recipes were ensued, by the percentage combination of the participating elements. A single sampling was executed for every recipe, in order to analyze if, eventually, the resulted product would be used, based on the aforementioned criteria and in order to limit the area and number of recipes to be further developed by researchers.

After the constitution of the dry mixture, based on the submitted recipes, water was added, and the mixture homogenized into a paste easy to cast and distribute into moulds, with a view to obtaining boards sized of 300 x 300 x 20 mm. After drying, they had the aspect shown in figure 1.

Similarly, samples based on plaster as mineral binder were obtained. The samples are shown in figure 2.

Analysis and assessment of the initiatory researches.

The analysis of the samples based on the combinative massic-participation recipes of the hemp hurds, cement, lime and sand, has shown the following:

- the boards resulted by mixing 5-8% hemp hurds and mineral binder of the structure: cement 40%, lime 20% and sand 40%, display continuous smooth surfaces, compactness, low visibility of the hurds, good resistance, easy manipulability and no dismantling risks;

- the boards resulted by mixing 9-14% hemp hurds and the same participation percentages of the elements in the structure of the mineral binder, have matte surfaces, darker colour than the first group, good resistance and safe handling;

- the boards resulted by mixing 15, 20 and 25% hemp hurds and the same participation percentages of the elements in the structure of the mineral binder are at the acceptance limit, in terms of handiness, yet being easier and they display the tendency of edge crashing during handling;

- the boards resulted by mixing 30, 35, 40, 45 and 50% hemp hurds and the same participation percentages of the elements in the structure of the mineral binder cannot be resorted to, with a view to making boards, because of their low resistance while handling and fastening, in constructions;

- resorting to the participation of the hurds in a percentage of 20, 25, 30 and 35%, as well as to the same participation percentages of the elements in the structure of the mineral binder, blocks of 60, 80 and 100 mm in thickness were made, which display good behaviour as filling material in the spatial structures of the constructions (walls, floors);

- the boards made with high percentage participation of cement and lime, and with some diminution in the percentage of sand (under the same conditions as the aforementioned) display better physical and mechanical characteristics, for the same massic participation percentages of the hemp hurds;

- the boards made of 5% hemp hurds and 95% plaster are of higher quality, in terms of applicableness as lining materials, in civil egineering;

- the boards made of 10, 15 and 20% hemp hurds, as well as 80-90% plaster, are of interest as lining and plating materials, depending on the percentage of the hurds (10 and 15% - for lining and 16-20% - for filling); exceeding the 20% content in hemp hurds within recipes no longer ensures products of interest in terms of their use in civil engineering.

The results of the preliminary researches conducted within the laboratories of the Faculty of Wood Engineering are systematized in table 3. The analysis of the results specified in table 3 shows that, in this research stage, the massic-participation ranges of the elements in the recipes could be determined, restraining withal the area of research for the second stage, focused on thermal and phonic properties of the products.

Conclusions.

The researches initiated and conducted have proved so far that:

- the interest in the researches on turning hemp and linen hurds to good account is topical worldwide and implicitly, in Romania, due to the existence of renewable raw-material bases, which have not been efficiently used so far;
- preliminary researches resulted in board- and block-shaped products, which may be fit for functionally unpretentious constructions; although in other countries (Anglia, Holland), dwellings were made with filling materials and plasters, out of composites based on hemp hurds;
- cellulosic structures – wherein hemp hurds fall – are characterized by good thermal and phonic properties; therefore the research of the obtained products is topical and utterly necessary;
- the development of the researches is opportune and likewise possible, as the Faculty of Wood Engineering has the cutting-edge equipment for determining the thermal transfer and phonic attenuation by board-type structures of variable thickness.

The research team will submit in the second part thereof, the results of the researches on the thermal and phonic properties of the composites with basic matrix of hemp hurds, selected as fit depending on the massic participation of the elements in the studied recipes.

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