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ECOLOGICAL THERMAL INSULATION COMPOSITE SYSTEMS USED IN CONSTRUCTION

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Abstract: *The paper presents a thermal insulation composite system based on wood fiber boards, putty, reinforcement mash, decorative plaster and a study on the durability of such products under laboratory biodegradation conditions caused by Xylophages biological agents (fungi, insects).*
Keywords*: wood fiber boards, durability, biodegradation, biological agents*

1. INTRODUCTION

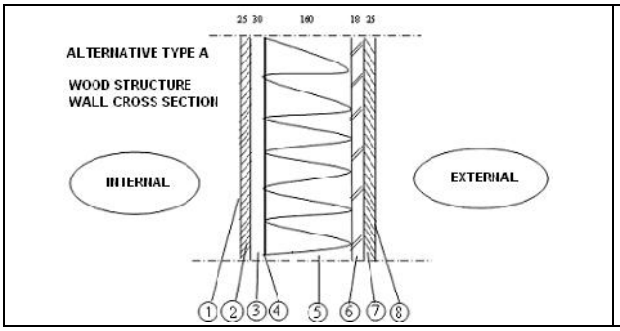
Wood structure housing can use thermal insulation ecological systems based on wood fiber boards, cellulose flakes, putty, reinforcement mash and a finishing layer (decorative plaster).
Wood fiber boards used in sandwich type modules or in external thermal insulation systems
In Figures 1a and b are shown examples of buildings using thermal insulation wood fiber boards.
Such boards are used on the external face of the buildings, in sandwich type modules where the middle is made of cellulose flakes that are blown in a closed space formed by internal wood fiber boards, or plaster boards. The boards are fixed on the wood structure by mechanical screws and washers.
After being fixed on the structure and the sandwich type modules are formed, the external wood fiber boards are finished similar to the ETICS (External Thermal Insulation Composite Systems).

Figure. 1a

Figure. 1b

Figure. 1a, b - Building made with exterior wood fiber boards on wood structure

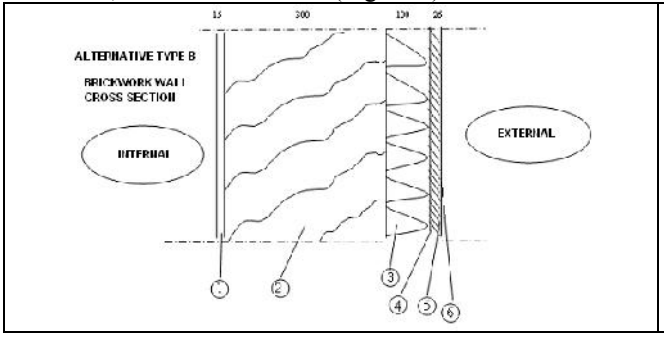
Alternative constructions (examples)
Alternative Type a, wood fiber boards used in sandwich type module, having the following structure, from the inside out (Figure 2)



1 – internal finish applied on the wood fiber board;
2 – wood fiber board (internal), 25 mm;
3 – technical space (air gap);
4 – protection foil stapled directly on the wood structure;
5 – cellulose flakes insulation, 160 mm;
6 – OSB (oriented strand board), 18 mm;
7 – wood fiber board (external), 25 mm;
8 – external finishing

Figure 2 - Alternative Type A

Alternative Type B, wood fiber boards used in thermal insulation of existing houses, having the following structure, from the inside out (Figure 3)



1 – classic plaster applied on brickwork wall;
2 – brickwork wall, 300 mm;
3 - cellulose flakes insulation, 160 mm;
4 – protection foil stapled directly on the wood structure;
5 – wood fiber board (external), 25 mm;
6 – external finishing

Figure 3 - Alternative Type B

The cellulose flakes insulation is performed „in situ". Cellulose is an ecological material obtained by paper recycling and modified with additives in order to become fireproof and antifungal.
The external finishing of wood fiber boards is similar to the ETICS (External Thermal Insulation Composite Systems), according to Figure 4.

Figure 4 - External thermo insulation

Figure 5 - Composition of the thermo-system with decorative plaster final layer

The composition of the thermal insulation composite system is the following: wood fiber board, putty and reinforcing mash, specific plastering primer, decorative plaster (final finishing layer).
Composite system for internal and external buildings thermal insulation
The system described in this paper is based on wood fiber board with low density (211 kg/m^3) and thermo insulating proprieties (thermal conductivity λ_{10} = 0,044 W/m^{2}K), finishing materials such as putty, reinforcement mash and decorative plaster. Such materials are designed to be used in constructions exploitation class 1... 3, in order to decrease the volumic mass of the construction materials, to reduce the materials consumption and aiming to decrease the energy losses caused by transfer from inside to outside. The materials used in the thermal insulation composite systems contain natural materials, based on wood fiber and inorganic compositions, without synthesis polymeric compounds, dangerous chemical compounds and biocides. The system resistance, realized in this manner, is based on the porosity high degree that allows a high air volume to be incorporated, do not cause condensation and do not retain Xylophages microorganisms. The material sterilization effect, in its final use, it is not caused by a long lasting natural durability, but as a result of an effect induced by the resistance due to constant drying condition, thanks to the continuously aerated structure. The wood fiber board's ecological character is revealed by biological tests, in extreme exposure conditions, of high humidity and optimum temperatures for mould, rot fungi growth and for insects that attack wood. In Table no. 1 are presented the pictures of wood fiber boards and the thermal insulating composite system that are using them, together with the ecological finishing.

Table 1 - Wood fiber boards and the thermal insulating composite system

0 –uncovered wood fiber board

1 – finished thermo-system: wood fiber board, fiberglass mash, grout, primer, water based paint

2 – finished thermo-system: wood fiber board, fiberglass mash, grout, primer, decorative finish with various granulations

While for veneers large sheets are detached from the row wood and for chipboards the wood is chipped under splitters shape, in wood fiber boards processing the wood structure is decomposed, in such a manner that the individual fibers and the small fibers bundles form the starting point for the new material to be produced. Different types of boards distinguish between them according to their degree of compression. While the insulation boards are subject to a heating and soft pressing technology, the same material hard boards are subject to heating and pressing under a much higher compression regime. Depending on the specific applied pressure, the boards with different densities are obtained with different properties induced by the pressing force.
As a row material for the manufacturing of wood fiber boards are used wood scraps from cutting-off classified as technological scraps, such as: branches, round wood heads, billets/cleft logs, laths and small size assortments, or inferior sorts, and so on. Wood fiber boards are manufactured using wet or dry methods. The manufacturing process is similar to the one used for paper manufacturing. In wood grinding the wood substance is in water slurry. Wood compomposition, in this case do not reaches the lignin removal, the wood being just spread its fibers, respectively in fibers bundles. The production of such boards stated, in the beginning, as a recycling process of the wood scraps that aimed to manufacture construction boards.

2. PROPERTIES

Similar to the massive wood, in the wood fiber boards there is a hygroscopic balance between the relative humidity of the free air and board's humidity. Initially it was thought that this hygroscopic balance would have the same values as in solid wood. Based on a series of researches it could be proven that in the same ambient conditions the wood fiber boards humidity is slightly smaller than that of solid wood. Insulation boards when taken from the drying unit have a humidity of about 5%. Due to the loose structure of these boards, they can be stored and processed in this state without any treatment. On the other hand, hard boards require a conditioning. Hard boards when taken from the hot press unit have a humidity of about 1%. For these boards, hygroscopic balance in a normal environment (20°C and 60% relative air humidity) is 7% to 9%. In order to reach such humidity - after being removal of the hot press unit, the boards are passed through a conditioning chamber. In this chamber the temperature range is 40 - 50 ° C and the relative humidity rage is 95 - 100%. Table 2 presents the wood fiber boards classification on types, according to density

Table 2 - Wood fiber boards classification type

Item no.	Types of wood fiber boards	Apparent specific density[kg/m^3]
Insulation wood fiber boards, bounding agents content up to 12% of the dry weight		
1	Very porous insulating wood fiber boards	Up to 230
2	Porous insulating wood fiber boards	Up to 230 … 400
Hard wood fiber boards, bounding agents content up to 12% of the dry weight		
1	Medium hard wood fiber boards	650 … 850
2	Hard wood fiber boards	Over 850
3	Very hard wood fiber boards	Over 900

Beside the type classification, the importance of specific volume weight is increasing taking into account that for different types of boards the specific volume weight allows to draw conclusions about the other proprieties.
Table 3 presents the wood fiber boards characteristics determined by measurements.

Table 3 - Wood fiber boards characteristics

Characteristic	Very hard boards	Hard boards 1	Hard boards 2	Medium hard wood	Insulation wood fiber

				fiber boards	boards
Specific volume weight, [kg/m^3]	1000-1050	950-1050	800-900	500-750	250-400
Bending resistance, [kg/cm^2]	500-650	350-450	200-250	150-200	20-40
Stretching resistance, [kg/cm^2]	300-450	150-300	90-150	70-100	5-10
Ball pressing on spheres hardness, [kg/cm^2]	5.0-6.0	4.2-5.0	3.0-4.0	1.5-3.0	-
Wear after 10.000 travels, [mm]	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	-
Resilience, [kgm/cm^2]	2.0-3.0	2.0-2.5	1.8-2.3	1.5-2.0	0.5-0.8
Water absorption, [%]	10-15	15-25	15-30	20-30	30-100
In 24 hours in thickness swelling, [%]	7.5-12	12-18	10-20	15-20	10-20

While for the hard boards the most important property is resistance, for the insulation wood fiber boards the decisive role rests in thermal and acoustic insulation. An insulation wood fiber board having the thickness of 10 mm and the specific volume weight of 300 kg/m^3 is equivalent from the insulating capacity point of view with a brick wall of about 15 cm thickness.

Thermal insulating capacity of different wood fiber boards is determined by establishing of the thermal conductivity coefficient. Due to their loose structure, these boards have a thermal conductivity coefficient even lower [0.8 kcal/mh] than solid wood and thus a higher thermal insulating capacity.

Wood fiber boards characteristics

As a main component of a thermal insulation composite system, they can have a variety of internal and external uses, according to 1 to 3 use classes (presented in Table 4), as they are definite by EN 335-1 standard, for exposure to humidity conditions and the frequency of biological attack risk, that wood and wood fiber boards used in construction are exposed to.

Table 4 - Use class and general use conditions

Use class	General use condition	In use humidity exposure	Biological aggents appearance[a]			
			Fungi	Coleoptera[b]	Termites	Marine borers
1	covered internal	dry, maximum	–	U	L	–
2	internal, or covered	occasionally, > 20%	U [c]	U	L	–
3	external, or above ground, protected	occasionally, > 20%	U [c]	U	L	–
	external, or above ground, unprotected	frequently, > 20%	U [c]	U	L	–
4	external in contact with soil and/or freshwater	predominantly or permanently, > 20%	U [d]	U	L	–
	outdoor in contact with soil (severe) and/or freshwater	permanently,> 20%	U [d]	U	L	–
5	in salt water	permanently, > 20%	U [d]	U [e]	L [e]	U

U = present everywhere in Europe; L = locally present in Europe

[a] Due to local exposure risk and the necessity of a target requirement, it is locally possible for specific location, a second level of classification of biological agents

[b] The risk of attack can be insignificant in some specific situations and specific geographical locations

[c] Fading mushrooms + decay fungi

[d] Fading mushrooms + decay fungi + soft rot fungi.

[e] Part of construction elements placesed above the water, that can be exposed to Xylophages insects, including termites

As shown in Table 4, humidity plays an important role in the development of biological factors, and the constructive designed solution do not favor a threshold of 20% humidity inside or on the surface of wood fiber board to be reached, as a result of their own structure, as well as of the subsequent applied finishing system.

Briefly, wood fiber boards are classified according to use classes, in four types, having the physical and mechanical characteristics according to Table 5:

Table 5 - Wood fiber boards type and characteristics[3]

Characteristic	UM	Wood fiber boards for internal use	Wood fiber boards for external use	Wood fiber	Wood fiber boards

						boards for flooring use	for roof framing use
Thickness	mm	12 ± 1.2	25 ± 1.8	12 ± 1.2	25 ± 1.8	7.4 ± 0.3	25 ± 1.8
Boards per pallet	peaces	90	45	90	45	280	42
Square meter per pallet	m²	291.60	145.80	291.60	145.80	201.60	78.75
Width	mm	1200 ± 5	1200 ± 5	1200 ± 5	1200 ± 5	600...1200 ± 3	750 ± 5
Length	mm	2700 ± 5	2700 ± 5	2700 ± 5	2700 ± 5	2500 ± 3	2500 ± 5
Density	kg/m³	≥ 230	≥ 220	≥ 240	≥ 230	≥ 240	≥ 230
Thermal conductivity	W/mK	≤ 0.045	≤ 0.045	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05
Bending strength	N/mm²	≥ 1.7	≥ 1.3	≥ 1.2	≥ 1.8	≥ 2.5	≥ 1.3
Bending modulus	N/mm²	-	-	≥ 140	≥ 120	-	-
In thickness swelling	%	-	-	≤ 6	≤ 6	-	≤ 6
Water permeability, Δp 100 Pa	m³/m²sPa	-	-	$\leq 25x10^{-6}$	$\leq 25x10^{-6}$	-	$\leq 25x10^{-6}$
Vapours permeability	kg / m²sPa	-	-	1.58×10^{-9}	1.0×10^{-9}	-	1.0×10^{-9}

3. OBTAINED RESULTS

3.1. In tables 6 and 7 are presented the fire tests results obtained in the laboratory.

Table 6 - Fire test results - cigarette and match

Test method	Conditions / test criteria	Obtained results		Observations
		source 1*	source 2*	
EN 1021-1 Furniture - Assessment of the ignitability of upholstered furniture - Part 1: Ignition source smouldering cigarette EN 1021-2 Furniture - Assessment of the ignitability of upholstered furniture - Part 2: Ignition source match flame equivalent	Combustion criteria dangerous trend (3.1. a)	Yes	Yes	Findings: During the ignition source contact with the test specimen are detected: melting deformation: Yes, carbonization: Yes, smoke emanation: Yes. Conclusions: Wood fiber boards do not have combustion resistance proprieties (exothermic oxi-dation not accompanied by flame)
	entire assembly consumed (3.1. b)	Yes	Yes	
	up to the ends (3.1. c)	Yes	Yes	
	crossing the entire thickness (3.1. c)	Yes	Yes	
	more than 1 h (3.1.d)	Yes	Yes	
	present to the end (3.1.e)	Yes	Yes	
	Ignitability criteria circumstances (3.2)			
	dangerous trend (3.2. a)	Yes	Yes	
	entire assembly consumed (3.2.b)	Yes	Yes	
	up to the ends (3.2. c)	Yes	Yes	
	crossing the entire thickness (3.2. c)	Yes	Yes	
	more than 120 seconds (3.2.d)	Yes	Yes	

Table 7 - Fire test results - mass loss

Test method	Conditions / test criteria	Obtained results for mass loss		Observations
		Board 1*	Board 2*	
SR 652 (Romanian standard) Determination of	Test specimen dimensions (400 x 150 x gr.) mm Test specimen conditioning: 22,6...23,4°C ; 45...50% relative humidity	86.96	84.62	Findings: For wood fiber board (25 mm), after 8 minutes are present: intense flame, flame penetration and test specimen bending

efficiency of fireproofing	Application and the duration of ignition source contact: 1.75 l/min, 20 minutes Wood fiber board – 25 mm			Conclusions The high value of the mass loss is determined by the lack of a fireproofing product. This is specific to untreated wood combustible materials

The wood fiber boards used in internal conditions do not require fireproofing when using concealed under a fire-resistant building material cover (mortar, plaster, wood fireproof, fireproof plasterboard).
In the case of thermal insulation composite systems, the wood fiber boards are under layers of plaster and silicates based primer and other inorganic salts that are resistant to ignition.

3.2. Biological tests results

3.2.1. Efficiency of antiseptic treatment against mould attack, according to Romanian standard STAS 8022-91

The fungi species used in the test were: Chaetomium globosum Kunze; Alternaria tenuis Ness; Stachybotrys atra Corda; Paecilomyces variotti Bainier; Trichoderma viride Persom ex Fries

Table 8 - Efficiency of antiseptic treatment against mould attack

Product *	Test specimen no.	Development of spores and mycelium growth	Development degrees	Antiseptic treatment efficiency *
Wood fiber boards 25 mm	1/2/3/4/5/6	Strong development of the fungus mycelium on the test sample and in the growth medium.	3	Poor

*According to Romanian standard STAS 8022, there are 4 growth degrees (0, 1, 2, and 3) that determine the efficiency of antiseptic treatment (very good, good, mild and low).

3.2.2. Wood protection products. The efficacy against Reticulitermes species (European termites) threshold determination (laboratory method), according to EN 117.

Table 9 - The efficacy against Reticulitermes species

Test specimen type	Test specimen no.	Surviving workers,%	Surviving soldiers and/or pupas, %	Visual examination
Wood fiber boards - 25 mm	1,2,3	0	0	0**
Witness test specimen - untreated pine	1,2,3	70	60	4***

The test specimens dimensions: (40 x 20 x 10 mm); **no attack; *** severe attack with in depth erosion, greater than 1 mm and less than 3 mm over an area greater than one tenth of the test specimen surface.
The effectiveness threshold is between the average product retention value and the lowest retention value achieved in practice. The validation takes place when the virulence witness test specimens show a level 4 attack and a minimum of 50% survivors.

3.2.3. The preventive efficacy against lignicola basidiomycetes fungi determination, according to EN 113 standard. Application by in depth treatment

Mass loss determination (p.m). Corrective factor C values obtained in the rotting test:

Table 10 - Corrective factor C value

Item no.	Test sample exposed on un-seeded medium	Corrective factor C value, %
1	Wood fiber boards – 25 mm	2.45

Medium mass losses obtained in the rotting test:

Table 11 - Corrective mass (final results)

Item no.	Fungus species	uncorrected p.m, %	corrected p.m, %

1	*Coriolus versicolor, susa CTB 863*	16.20	13.75
2	*Poria placenta, susa 125c BAM*	19.33	16.88
3	*Lenzites trabeum, susa 109 BAM*	16.24	13.79
4	*Lentinus lepideus, susa 20 BAM*	18.15	15.70

The results validation was done by complying with the conditions imposed by the method standard

4. CONCLUSIONS

The values obtained in biological tests highlight that the wood fiber boards are attacked by vegetal regnum microorganisms (imperfect fungi and basidiomycetes) but do not present interest to isoptera insects. In terms of biodegradation, the uncovered wood fiber boards in use class 1 may be used without risk of biological attack caused by fungi and Xylophagous insects. In use class 2 (internal, covered with occasional insects and fungi risk) and use class 3 (external, covered, with frequent moisture frequency and biological risk of attack) wood fiber boards are sensitive to vegetal regnum microorganisms. In order to increase the resistance to biological organisms, the wood fiber boards used in thermal insulation composite systems, are protected by applied adherent layers of mortar and primer. They are creating a physical barrier to moisture, any bio-degradation sources and ignition sources.
In the urban-industrial environment characterized by concerted action of *physical* stress factors (temperature, fire, light, humidity, noise), *chemical* (ionic composition, salinity, oxygen, pH, industrial chemical pollutants) and *biological* (bacteria, fungi, insects, birds, animals) it can be considered that thermal insulation wood fiber boards used in different thermal insulation composite systems present a number of advantages compared with other building materials used in similar applications, as follows: they are made of wood, a renewable and biodegradabile material, from the chemical and structural point of view, contain wood fibers that are rich in carbon, helping to reduce the amount of greenhouse effect substances in the atmosphere (CO_2 including), responsable for global warming, the low resistance to fire and Xylophages biological organisms highlights the lack of hazardous chemicals and biocides. From this point of view, wood fiber boards fulfills the necessary requirement to be classified as a ecological, clean, environment friendly material. The wood fiber boards use in thermal insulation composite systems together with mortars, plasters and waterproofing finishing introduce on the construction products market, a material that increase the buildings energy economy and heat retention. Wood fiber boards performances indicate the use for internal and external applications in walls, ceilings and floors covering.

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