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NEW GREEN MATERIAL OF CMPOSITE PLASTER FOR NZEB BUILDINGS

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Abstract. *This study describes the advantages of using a new generation of composite plaster, as a binder for thermal insulation in nZEB buildings in order to lower energy consumption. These advantages greatly reduce the amount of heat loss through the walls. The suggested approach makes use of this novel thermal insulation plaster, which is used as ready-made mortar for buildings, to analyse mass and heat transmission through walls. A comparative study for a residential building located in Romania's climatic zone II is provided, utilizing both the new material and the traditional ones. Also carried out is a mass transfer analysis of the condense accumulation in the exterior walls. The use of environmentally friendly building materials contributes to this material's sustainability and will help it meet the growing demands for heating efficiency.*
Key words: *eco-friendly materials, mass transfer, composite plaster, effective insulation*

1. INTRODUCTION

Beginning in January 2021, the use of environmentally friendly materials and technologies must be regarded as essential for our country when designing nZEB-type buildings. There have been laws proposed to encourage the use of green materials and the widespread application of cutting-edge technologies based on the utilization of waste, in this case the recycling of paper trash, as the effects of global warming continue to harm the environment. According to Article 2 of EU Regulation 1999/31/EC, biodegradable waste is waste that can be subjected to anaerobic breakdown, such as paper and board. It is emphasized to use residues that reduce carbon emissions [1]. Consequently, the consequences of climate-related natural calamities are lessened.

Utilizing these materials also improves the energy efficiency of residential buildings and improves indoor air quality, reduces energy consumption in residential buildings, and benefits the environment.

Increasing a building's thermal efficiency through the use of thermal insulation and efficient mass transfer is crucial to creating sustainable buildings and a healthy atmosphere within residential homes (avoidance of mold in layers). [2, 3, 4]. Typical insulation materials are expensive and energy-efficient, like mineral wool and polyurethane foam [5]. Therefore, it would make sense to recycle some waste products, which is another requirement for sustainable growth [6].

In evaluating environmentally responsible, financially sound, and sustainable buildings, production, material transportation, demolition, and reuse costs are all considered.

These environmentally friendly solutions can meet a building's sustainability requirements provided that the building evaluation takes into account all costs incurred over the building's lifetime, including maintenance and repair costs. The building's orientation, the surrounding area, and utility access are also taken into account. With all these variables in place, it is feasible to choose environmentally friendly solutions and project results with enough accuracy over an

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extended period of time to justify the required investment [7].

The application of composite plaster, a novel material, is examined in this study. Research was done on the construction materials' resistance to water and other environmental pollutants, their durability as thermal insulation, and their permeability to water vapor to reduce condensation. Costs and implementation simplicity were also taken into account. Based on all available research, the material is economically efficient both in terms of initial investment and long-term profitability. Previous research has demonstrated the advantages of this substance.

2. BENEFITS OF COMPOSITE PLASTER USE AND MATERIAL PROPERTIES

Designers, implementers, and end users have found in these products not only the best possible solution, but also a natural, healthy substance that lasts a lifetime. As a result, ecological plastering has become increasingly important in the field.

These advantages will persuade a sizable number of people to select this construction and implicit treatment method in the near future.

This novel composite plaster has no residual pollutants, making it completely environmentally friendly.

Numerous reputable institutions worldwide have approved, verified, certified, and granted patents for it.

In the construction industry, thermal insulation composite plaster is not like conventional plaster mortar. For both interior and external thermal insulation, ready-made mortar is used in place of thermal insulation plaster.

This specially blended mixture, made of natural materials, is an inorganic composite plaster mortar with a permanent feature.

The surface covered by the thermal insulation composite plaster provides:

- thermal comfort,
- the capacity to create a hygienic environment,
- the ability to breathe (diffusion),
- waterproof,
- acoustically comfortable.

2.1. Benefits of applying composite plaster insulation regarding heat

The plaster has a thermal conductivity of λ = 0,010 W/m2K. It can be applied to the floors, terraces, and interiors of any building. There are numerous advantages in the summer because it costs less to cool than a traditional solution, and the same is true for winter heating expenses. This solution consistently reduces thermal bridges.

Breathability. Because it is made of natural ingredients, this special formula has breathable properties. The natural and "breathing" nature of this inventive plaster inhibits the growth of mould and moisture. It prolongs the life of the building and produces no smell.

Sound absorption. This composite plaster's 25dB (3cm / 500Hz) acoustic absorption property is the reason it is recommended for use in public and hotel spaces.

Fireproof. This product belongs to the best class of fireproof products, A1. Its use in tall buildings, offices, and residential buildings is facilitated by these features. According to fire prevention regulations, residential complexes and tall buildings must use class A1 materials. The standards contain the clause that states, "materials class A1 does not contribute to burning at any stage of burning, including fully developed fire."

There are no flammable gases, cancer-causing, released by this material. It is resistant to flames that reach 2500 °C.

Ecological. Because no petrochemicals are used to prepare the composite plaster, and only inorganic ore is used to manufacture raw materials, it is a completely green product. Low CO emissions result from this.

Furthermore, this substance doesn't release harmful compounds that can affect the environment or people’s health.

Small density. Simple to put into practice. There are numerous benefits with regard to the features that make it easy to use: 80-80 litres (8–9 kg) bag. The dimensions of these bags are 50 by 100 cm. Transport ease is guaranteed.

Since it is the simplest material in its class, it simplifies the task compared to construction. It weighs seven times less than regular plaster. Its light weight ensures that quick applications are possible.

With a bag quantity, it can cover an area of 3 square meters at a thickness of 1 cm. It can be applied to brick starting at a specified thickness of 3 cm. It doesn't need any additional procedures. No more plaster, mesh, screws, or labour is needed for it.

2.1.1. Characteristics of the materials

The material properties for the novel composite plaster are shown in the tables that follow.

Table 1

Characteristics of the material

	Values
Thermal conductivity	0.029 W/mK
Acoustic absorption	25 dB (3cm/500Hz)
Ignition class	A1
Capillary water absorption	0.3% (<10) (W1)
Resistance to pressure	0.70 N / mm² (CS1)
Water vapor	μ = 4.5
Bond strength	0.40 N/mm²
Bending strength	8Kgf / cm² (> 4)
Drying time	8 hours at 20°C
Complete drying	28 Days at 20°C
Density	120 + 20 Kg / m³ 1.40Kg/m²
Appearance	White
Application temperature	< 50°C
Consumption	2.5 Kg / m² (at a thickness of 1 cm.)
Applicable thickness	3 - 4 cm

Table 2

Comparative evaluation of material characteristics composite plaster and traditional methods

	Thermal conductivity (W/mK)	**Density (kg/m^3)**
Composite plaster	0.029	130
Gypsum plaster	0.35	1100
Concrete gas	0.14	500
Raw plaster	0.87	1800
Perforated brick block	0.34	700

A comparison of the composite plaster and the traditional solutions is shown in Table 2.

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Thermal conductivity and material density are the parameters for comparative analysis.

A comparison of the composite plaster with the traditional solutions of sand plaster and gypsum plaster is shown in Table 3.

The weight of the materials for the various applications of the products serves as the parameters for the comparative analysis. [7]

Table 3

Comparative evaluation of weight in various applications: traditional solutions versus composite plaster

Fixed load	**Composite plaster**	**Gypsum plaster**	**Sand plaster**
Density (kg/m^3)	130	1100	1800
Total Thickness of Plasters Interior and Exterior (Kg. / m²)	7.5	30	54
Interior- Exterior Plaster Surface - 1 Apartment (Kg./ m²)	3,750	15,000	27,000
Finish mortar 100 m² for 5cm thickness	1250	5000	9000
Load for 1 apartment / kg	5000	20000	36000
Load for a building with 40 apartments / kg	200	800	1440
Differences	**Ideal weight**	**4 times bigger load**	**7 times bigger load**

The composite plaster is produced and designed to be used on:

- Walls inside buildings,
- Facades outside
- Rooftops,
- Levels.

3. A CASE STUDY ANALYZING THE ADVANTAGES OF COMPOSITE PLASTER

A residential building in the second climate zone (zone II), with a built area of 96 square meters and a height regime of GF + A, has been selected for this study.

The structure is regarded as having a high permeability class and being sheltered. Table 4 presents the comparative values of the thermal resistances for the external walls for the two solutions—composite plaster and conventional solution.

The thermal resistances for the ground floor and the upper floor (the superior floor with the attic and the walls of the attic) are shown in Tables 5 and 6. [8, 9]

Table 4

The values of thermal resistance (R) and corrected values with thermal bridges (R') for external walls using conventional plaster and composite plaster

	R (m^2K/W)	r	**R' (m^2K/W)**
Composite plaster	6.77	0.868	5.87
Conventional solution	6.088	0.876	5.331

Table 5

The ground floor thermal resistance values (R) and corrected values (R') for composite plaster and traditional solution

	R (m^2K/W)	r	**R' (m^2K/W)**
Composite plaster	4.89	0.92	4.50
Conventional solution	4.22	0.89	3.75

Table 6

The composite plaster and traditional solution's superior floor (plaster used internally) thermal resistance values (R) and corrected ones with thermal bridges (R')

	R (m^2K/W)	r	**R' (m^2K/W)**
Composite plaster	7.37	0.86	6.33
Conventional solution	6.71	0.81	5.43

The comparative energy consumptions for heating and cooling were computed using the Methodology for Calculating the Energy Performance of Buildings, reference Mc 001/2022, and for the same type of building installations. The results are displayed in Table 7, where:

- Qh, fin [kWh/y], the total final energy used for heating
- Eph [kWh/y], which is the primary energy consumption for heating
- the primary energy consumption for cooling, EpF [kWh/y],
- the GHG (greenhouse gases) from heating,
- EpCO2h – [kg/y], - the final energy consumption for cooling,
- QF, fin [kWh/y],
- the GHG from cooling,
- EpCO2h – [kg/y].

Table 7

The traditional solution and composite plaster's energy efficiency parameters

Energy efficiency parameters	**Composite plaster**	**Traditional solution**
Qh,fin	21068.52	26821.11
EpCO2h	4979.33	6338.90
Ep h	24650.17	31380.7
QF,fin	1032.709	1892.67
EPCO2F	472.6	865.89
EPF	2581.77	4731.67

The average annual outdoor temperature for the second climatic zone (zone II) is 9.5°C, and an indoor air temperature of 20°C is considered for mass transfer. [12].

The process of condensation takes 314 hours, and the amount of water that accumulates is within the admissible range of 0.0312 kg/m^2. [10, 11].

Fig. 1 shows the condensation layer for the composite plaster in the case o a building located in the second climatic zone (zone II).

As a result, there is no condensation in layers. Therefore, the composite plaster ensures that condensation does not occur in layers for a traditional building envelope element because of its quality related to the water vapor permeability factor.

Plaster is a material suitable for paint and other types of coatings for the economical surfaces of buildings. Plaster is used to achieve a smooth surface in structures.

Numerous studies have been conducted in the literature on how to reduce the heat transmission coefficient and plaster surface flatness to improve a building's thermal insulation.

To reduce plasters' heat transmission coefficient, a variety of materials are used, such as pumice, perlite, vermiculite, metakaolin, compressed obsidian, and polypropylene fiber.

The publications state that plasters are developed with thermal conductivities between 1.5 and 0.07 W/mK. [12]

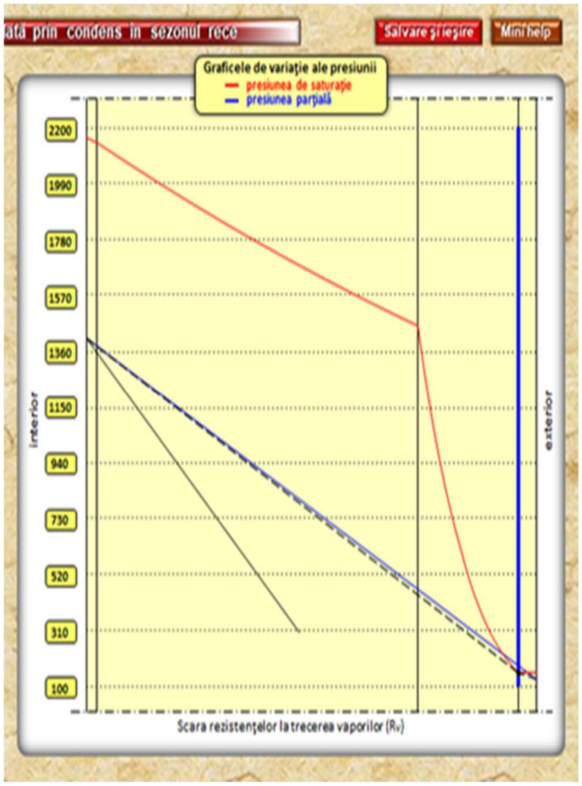

Fig. 1. Building in the second climate zone (zone II) - condensation layer for the composite plaster

4. RESULTS AND DISCUSSIONS

A comparative analysis of the traditional plaster solution and the composite plaster solution, which were used for the exterior walls, the ground floor finish, and the upper floor, is presented.

In order to ascertain the benefits for the construction industry in implementing the novel solution on a large scale in our nation, the comparative consumptions for these two solutions are presented.

The following are the benefits of using composite plaster:

- Fig. 2 shows a 21.44% decrease in the building's overall heating energy consumption;
- A decrease in the building's overall cooling energy consumption of 45.44% thanks to additional roof insulation (Fig. 3);
- Better air quality for people as a result of the use of composite plaster, which lowers carbon dioxide and other pollutants. Additionally, the GES decrease from energy consumptions is in aThe GES reduction from energy consumptions is also in a percentage of 33.44%.

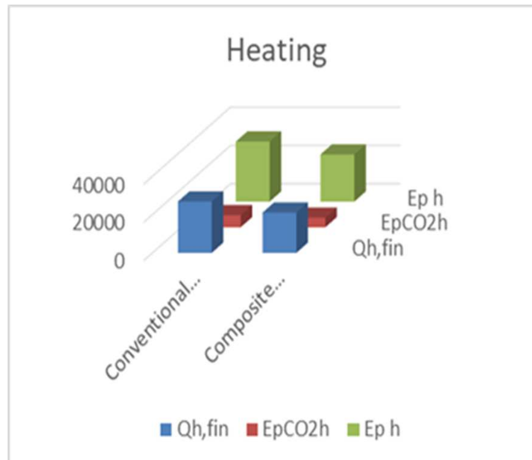

Fig. 2. The overall heat consumption for composite plaster and conventional solution, as well as the GES from heating and the primary energy consumption for heating

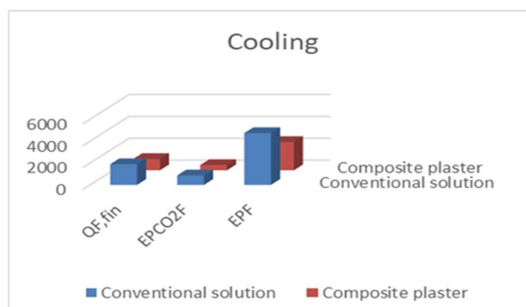

Fig. 3. For composite plaster and conventional solution, final energy consumption for cooling, GES from cooling, and primary energy consumption for cooling

With the right information, it is possible to use the cutting-edge composite plaster to insulate buildings appropriately and achieve the best possible outcomes.

For the benefit of the occupants' health using composite breathe and enhance indoor air

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quality. They are more successful than cement-based ones at promoting the diffusion of chemicals to the outside through the walls because they swiftly dilute pollutant concentrations and excess moisture to maintain the hygrometric balance of the air. This material guarantees healthier environments and more comfort in the house.

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When waste materials are used to partially replace constituent materials in cementitious products, CO2 emissions are decreased while natural resources are preserved and the environmental risks associated with waste disposal are reduced. The creation of a plaster substitute that exhibits superior thermal performance, strength, and durability attributes will lead to energy savings during the building and operation stages.

5. CONCLUSIONS

When more gas was released into the atmosphere, the temperature increased, causing global warming to take shape. One of the main issues facing the globe is that some of the greenhouse gases that are caused by humans and contribute to this phenomenon are produced in our homes.

Energy conservation and efficiency are the main pillars of the global warming reduction strategy.

Energy efficiency is another major benefit of insulation. Obtaining the certificate of energy performance for new construction and demonstrating that the building is ZEB is now mandated by law.

The directive requires that a building's energy performance be managed, and insulation policies are stasis-based.

Under the fire prevention regulations that went into effect in 2008, residential complexes and buildings taller than 21.50 meters are not allowed to use flammable products like EPS/XPS.

For more years, we have been conducting research on the new composite generation of plaster.

This product is the only one with a thickness of 3 cm that can provide a variety of insulation, including thermal, sound, and insulation against moisture, dampness, and the growth of fungi, according to research-development studies for products.

Due to the many advantages that these plastering materials have over current alternatives, they truly represent a revolution in the building industry.

Thanks to the technology employed with this creative solution in our buildings, most pathogens are eliminated during the initial construction phase, preventing bacteria, viruses, and other microbes from entering our bodies.

In light of this research, heat and mass transfer result in decreased greenhouse gas emissions, improved interior comfort, and energy savings for heating and cooling. Hence, employing the novel composite plaster results in:

- decreased emissions of carbon dioxide and other pollutants because of the composite plaster's application, which cut the building's overall heating energy consumption by 21.44%.
- decreased the total energy used for building cooling by 45.44%; additionally, the people's indoor air quality was enhanced.

- the decrease in GES brought on by energy use is likewise 33.44%.
- with this creative solution, the energy bill is lowered by 2149.9 lei for cooling and 1725.77 lei for heating. Using this innovative solution the bill for energy is reduced by 1725.77 lei for heating and 2149.9 lei for cooling (at the price level of energy – natural gas and electricity - of March 2023).

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The innovative use of composite plaster allows for an almost one-year investment recovery period.

The composite plaster showed good adhesion to masonry walls, and after two years of outdoor exposure to a temperate climate, no degradation was observed.

Eco-friendly composite plaster for thermal and highly breathable masonry plastering is perfect for historic restoration and green building. It has antifungal and antibacterial properties. It is made entirely of raw materials that are purely natural, recyclable at the end of its useful life as inert material.

The innovative material is useful in mitigating the heat dispersion of masonry; it addresses the issues of mold growth and thermal bridges resulting from condensation humidity, maintaining environmental cleanliness and optimal home comfort.

It is naturally porous, highly transpiring, and permits the wall to breathe. Low specific gravity plastic.

When compared to walls plastered with common plaster, walls with developed plaster showed an internal wall temperature reduction of more than 0.5 °C. This suggests that, in conjunction with the use of recently developed plaster, mechanical ventilation or heating in buildings may be reduced, resulting in energy savings.

All parties involved in the construction industry, including beneficiaries, execution

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firms, designers, and architects, can make use of the study's findings.

It can be a great idea to use composite plaster rather than traditional plaster to increase building energy efficiency, improve interior comfort, and lower CO2 emissions.

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6. REFERENCES

[1] Tabrea, A., *Alcătuiri îmbunătăţite de pereţi şi acoperişuri din punct de vedere higrotermic*, Teză de doctorat, U.T.C.B

[2] Zhang, B. Q., Liu, X. F., *Effects of Fractal Trajectory on Gas Diffusion in Porous Media*, AIChE Journal, 44 (2003), 12, pp. 3037-3047

[3] Calbureanu, M.X., Albota, E., Tutunea, D., Dumitru, S., Malciu, R., Dima, A., *Contributions above the dew-point problem in civil building EPS insulated walls modeling with finite element the convective heat transfer*, International Journal Of Mechanics, Issue 3, Volume 4, 2010, pp. 53-62

[4] Incropera, F.P., Witt, D.P., *Fundamentals of Heat and Mass Transfer*, John Willey & Sons, New York 1996.

[5] Becker, D. and Wang, D., *Green roof heat transfer and thermal performance analysis.* Unpublished Carnegie Mellon University Report, Pittsburgh, PA, 2011

[6]C107/0 - 2002 - *Normativ pentru proiectarea şi execuţia lucrărilor de izolaţii termice la clădiri.*

[7] www.carelgroup.ro.

[8] SR EN 12086:2013 - *Produse termoizolante destinate utilizării la clădiri. Determinarea proprietăţilor de transmisie a vaporilor de apă*

[9] Ministry of Transport, Construction and Tourism, Romania, *Romanian Code for thermal technical calculus of buildings*

elements, indicative C 107, 2005 reviewed

[10] Fudulache, O., Calbureanu, D. M. Calbureanu, M., *Green Materials and Technology Used in Thermal Insulation in Order to Achieve Comfort Conditions* in Future nZEB Buildings, CARE 2020

[11] Dorfman, A. S., *Conjugate Problems in Convective Heat Transfer*, Taylor & Francis, New York, USA, 2010, pp. 21-29

[12]https://academic.oup.com/ijlct/article/doi/10.1093/ijlct/ctad034/7193330

Tencuială compozită ecologică de nouă generație pentru clădirile nZEB

Acest studiu descrie avantajele utilizării unei noi generații de tencuială compozită, ca liant pentru izolația termică a clădirilor nZEB, în vederea reducerii consumului de energie. Aceste avantaje reduc foarte mult pierderile de căldură prin pereți. Abordarea sugerată utilizează această nouă tencuială termoizolantă, care este livrată ca mortar gata preparat pentru clădiri, pentru a analiza transmiterea masei și a căldurii prin pereți. Este realizat un studiu comparativ pentru o clădire rezidențială situată în zona climatică II a României, utilizând atât materialul nou, cât și cele tradiționale. De asemenea, se efectuează o analiză privind transferul de masă și acumularea condensului în pereții exteriori. Utilizarea materialelor ecologice în compoziția materialului analizat contribuie la durabilitatea acestui material și îl va ajuta să răspundă cerințelor tot mai mari de eficiență a încălzirii.

Cuvinte cheie: *materiale ecologice, transfer de masă, tencuială compozită, izolație eficientă*

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