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THE MAIN INSULATION PARAMETERS FOR THE DESIGN OF NZEB FROM BIOSOURCED MATERIALS

KOSIACHEVSKYI Dmytro[1], *Mag.*
BABENKO Maryna[2], *Post.Doc., PhD.*
SAVYTSKYI Mykola[3], *Prof., Dr. Sc.*
SCHMIDT Michael[4], *Prof. Dr. Dr.h.c.(NMU Dnipro)*
PEREGINETS I.I. [5*], *Cand. Sc. (Tech.)*

[1*] Department of Reinforce-Concrete and Stone Constructions, State Higher Education Establishment "Pridneprovsk State Academy of Civil Engineering and Architecture", 24-A, Chernishevskogo str., Dnipropetrovsk, 49600, Ukraine, e-mail: kosiachevskyi.dima@gmail.com
[2*] Department of Reinforce-Concrete and Stone Constructions, State Higher Education Establishment "Pridneprovsk State Academy of Civil Engineering and Architecture", 24-A, Chernishevskogo str., Dnipropetrovsk, 49600, Ukraine, e-mail: babenko.marina@yahoo.com ORCID ID: 0000-0002-0775-0168
[3*] Department of Reinforce-Concrete and Stoune Constructions, State Higher Education Establishment "Pridneprovsk State Academy of Civil Engineering and Architecture", 24-A, Chernishevskogo str., Dnipropetrovsk, 49600, Ukraine, тел. +38 (0562) 47-02-98, e-mail: sav15@ukr.net, ORCID ID: 0000-0003-4515-2457
[4*] Department of Environmental Management, Brandenburg Technical University Cottbus-Senftenberg, Platz der Deutschen Einheit 1, 03046 Cottbus, Germany
[5*] Service cooperative «Homebuilding cooperative «Dostupne Zhitlo Ukrainy», Director of Programs, 4-D, Komsomolskaya st, Borodyanka town, Borodyanskyy dist., Kiev Region, UKRAINE, 07800. TEL: +38 (067) 632 35 51

Abstract: Purpose of the presented research is to define the parameters for insulation envelope for NZEB. **The study subjects** related to designing of NZEB. This article focuses on the comparison of requirements in normative documents of different countries. Based on the results of this comparison and the information of the heat losses of building, the main parameters of insulation design of biosoursed materials are determined. In addition, the influence of these parameters on the building envelope were investigated. **Methodology.** We used the estimation of the annual heat losses that is presented in national normative documents [18,19]. **Findings.** The results of calculating of the necessary insulation based on organic materials for a passive building were obtained. As well, it was established that the conditions of the materials application plays an important role in the using of the biosourced insulation materials**. Originality**. Analysis of factors affecting heat losses in the building has been realized. Determination of the main parameters for the design of NZEB of local biosourced materials have been received. **Practical value.** The article presents data that can be used for designing the insulation thickness, depending on the used biosources material and the element of insolation envelope.

Keywords: *energy-efficiency, sustainable development, nearly zero energy building, wheat straw, hemp straw, reed straw, flax straw*

ОСНОВНІ ПАРАМЕТРИ ІЗОЛЯЦІЇ ДЛЯ ПРОЕКТУВАННЯ БНЕБ З БІОРЕСУРСНИХ МАТЕРІАЛІВ

КОСЯЧЕВСКИЙ Дмитро[1], Маг.
БАБЕНКО Марина, Докторантка[2], к.т.н.
САВИЦЬКИЙ Микола[3], професор, д.т.н.
ШМІДТ Майкл[4], професор, хабітований доктор
ПЕРЕГІНЕЦЬ І.І. [5*] , к.т.н.

[1*]Кафедра залізобетонних і кам'яних конструкцій, Державний вищий навчальний заклад «Придніпровська державна академія будівництва та архітектури», вул. Чернишевського, 24-а, 49600, Дніпропетровськ, Україна, 49600, Україна, e-mail :. Kosiachevskyi.dima@gmail.com
[2 *] Кафедра залізобетонних і кам'яних конструкцій, Державний вищий навчальний заклад «Придніпровська державна академія будівництва та архітектури», вул. Чернишевського, 24-а, 49600, Дніпропетровськ, Україна, 49600, Україна, e-mail :. Babenko.marina@yahoo. кому ORCID ID: 0000-0002-0775-0168
[3 *] Кафедра залізобетонних і кам'яних конструкції, Державний вищий навчальний заклад «Придніпровська державна академія будівництва та архітектури», вул. Чернишевського, 24-а, 49600, Дніпропетровськ, Україна, 49600, Україна, тел. +38 (0562) 47-02-98, e-mail: sav15@ukr.net, ORCID ID: 0000-0003-4515-2457
[4 *] Кафедра менеджменту навколишнього середовища, Брандербурзський технічний університет Котбус-Сенфтенберг, Німецька площа 1, 03046 Котбус, Німеччина
[5*] Обслуговуючий кооператив «Житлово-будівельний кооператив «Доступне житло України», керівник програм, вул. Комсомольська, 4-д, смт. Бородянка, Бородянський р-н, Київська обл.., 07800, Україна, тел.+38 (067) 632-35-51

Анотація:. **Мета представленого дослідження -** визначити параметри ізоляції конверта для NZEB. **Предмет дослідження** пов'язаний з проектуванням близьких до нуля енергії будівель (БНЕБ). У даній статті основну увагу надано порівнянню вимог нормативних документів різних країн. На підставі результатів цього порівняння та даних теплових втрат будівлі, виявлені основні параметри ізоляційної оболонки, що мають враховуватися при конструюванні БНЕБ. Крім того, вплив цих параметрів на огороджувальні конструкції були досліджені. **Методологія.** Ми використовували оцінку річних втрат тепла, які представлені в національних нормативних документах [18,19]. **Резьтати.** Були отримані результати розрахунку необхідної ізоляції на основі органічних матеріалів для БНЕБ. Крім того, було встановлено, що умови використання відіграють важливу роль при використанні біоресурсних ізоляційних матеріалів. **Оригінальність.** Виконано аналіз факторів, що впливають на втрати тепла в будівлі з акцентом на БНЕБ. Визначення основних параметрів для проектування оболонки БНЕБ з використанням біоресурсних матеріалів. **Практична цінність.** У статті представлені зводні дані, що можуть бути використанні для проектування товщини теплоізоляції в залежності від біоресурсного матеріалу, що використовується та елементу огородження.

Ключові слова: *енергетична ефективність, сталий розвиток, близько нуль енергії будівлі, пшенична солома, костра конопель, очерет, солома льону*

ОСНОВНЫЕ ПАРАМЕТРЫ ИЗОЛЯЦИИ ДЛЯ ПРОЕКТИРОВАНИЯ БНЭЗ С БИОРЕСУРСНИХ МАТЕРИАЛОВ

КОСЯЧЕВСКИЙ Дмитрий[1], Маг.
БАБЕНКО Марина[2], докторантка, к.т.н.
САВИЦКИЙ Николай[3], профессор, д.т.н.
ШМИДТ Майкл[4], профессор, хабитованный доктор
ПЕРЕГИНЕЦ И.И. 1* , к.т.н.

[1*]Кафедра железобетонных и каменных конструкций, Государственное высшее учебное заведение "Приднепровская государственная академия строительства и архитектуры», ул. 24-А, Чернышевского ул, Днепропетровск, 49600, Украина, e-mail:. Kosiachevskyi.dima@gmail.com

[2]*Кафедра железобетонных и каменных конструкций, Государственное высшее учебное заведение "Приднепровская государственная академия строительства и архитектуры», 24-А, Чернышевского ул, г. Днепропетровск, 49600, Украина, e-mail:. Babenko.marina@yahoo. кому ORCID ID: 0000-0002-0775-0168

[3]*Кафедра железобетонных и каменных конструкции, Государственное высшее учебное заведение "Приднепровская государственная академия строительства и архитектуры», 24-А, Чернышевского ул., Г. Днепропетровск, 49600, Украина, тел. +38 (0562) 47-02-98, e-mail: sav15@ukr.net, ORCID ID: 0000-0003-4515-2457

[4] *Кафедра менеджмента окружающей среды, Бранденбургский технический университет Котбус-Сенфтенберг, Немецкая площальд 1, 03046 Котбус, Германия

[5]* Обслуживающий кооператив «Жилищно-строительный кооператив« Доступное жилье Украина», руководитель программ, ул. Комсомольская, 4-д, пгт. Бородянка, Бородянский р-н, Киевская обл., 07800, Украина, тел. + 38 (067) 632-35-51

Аннотация:. **Цель представленного исследования** - определить параметры изоляционной оболочки для NZEB. Предмет исследования связан с проектированием близких к нулю энергии зданий (БНЕБ). В данной статье основное внимание уделено сравнению требований нормативных документов различных стран. На основании результатов этого сравнения и данных тепловых потерь здания, установлены основные параметры изоляционной оболочки, должны учитываться при конструировании БНЕБ. Кроме того, влияние этих параметров на ограждающие конструкции были исследованы. Методология. Мы использовали оценку годовых потерь тепла, которые представлены в национальных нормативных документах [18,19]. **Результаты.** Были получены результаты расчета необходимой изоляции на основе органических материалов для БНЕБ. Кроме того, было установлено, что при использовании играют важную роль при использовании биоресурсных изоляционных материалов. **Оригинальность.** Выполнен анализ факторов, влияющих на потери тепла в здании с акцентом на БНЕБ. Определение основных параметров для проектирования оболочки БНЕБ с использованием биоресурсных материалов. **Практическая ценность**. В статье представлены сводные данные, которые могут быть использованы для проектирования толщины теплоизоляции в зависимости от биоресурсного используемого материала, и элемента ограждения.

Ключевые слова: *энергетическая эффективность, устойчивое развитие, близкое нуль энергии здание, пшеничная солома, костра конопли, камыш, льняная солома*

1. Introduction

An important strategic task for Ukraine is to solve urgent problems in the housing sector due to the general lack of housing, lack of architectural and structural construction systems of low-rise affordable housing, low-energy buildings and insufficient implementation of international experience of sustainable development in the construction. One of the areas of architectural, structural, and technological systems in low-rise construction is the use of traditional local practices based on the materials of organic origin in accordance with modern requirements for energy efficiency, economy and ecological housing. Today there are wood-frame house-building experience in our country, but there is a luck of research aimed at scientific justification construction of low-rise residential buildings using renewable materials of organic origin.

Obviously, buildings make a great influence on greenhouse gas emissions, and can significantly affect reduction and energy saving goals if energy-efficiency design strategies are employed during the conception. In the Table 1, heat losses of different parts of the building are represented. As we can see, walls represent just about 30% of the losses and to decrease the quantity of heat losses we should to be interested not only by the insulation of walls but also by the complex decisions for all the parts of the building and the system of HVAC (Heating, ventilation and air conditioning).

Table 1. Heat losses in buildings*

Structural part	Ratio of heat losses
Roof	25 %
Walls	35 %
Windows, doors, ventilation	25 %
Floor	15 %

*__Note:__ Represents heat loss from the building envelope of an average home. This may very greatly depending on the homes design and construction. **Sources:** DOE, DEFRA, various.

During the last few years, many studies were interested by the question of designing of the energy-efficient buildings and of the creation of parameters, which are the most influential. One of the concepts, which let achieve the goal of energy efficiency, is the concept of net-zero energy building (NZEB). The increasing number of ZEB demonstration projects [1–7] and research interest in the field [8–11] internationally highlights the growing attention given to ZEBs. Even though there is a general understanding towards the NZEB idea, a widely agreed definition that can be consistent with the principles behind the practice of designing and constructing NZEBs internationally is still lacking. [12]. Recent research towards the definition of NZEB extends its concept to include the consideration of the building's embodied energy and components, thus integrating life cycle energy balance into "net energy" concept [13]. In this way, it is possible to acquire the true environmental influence that the building has exerted based on the evaluation of both its operating energy use and the energy, which is embodied in its structure, materials, and technical installations [14]. In this concept, the main idea is to make buildings meet all their energy requirements by using low-cost, locally available, nonpolluting, renewable sources [15]. For example in the work of Ajla Aksamijaa it was emphasized that the main parameters for the net-zero energy building to develop are:

- Passive design strategies;
- Building massing and envelope;
- HVAC systems
- Using of renewable energy systems [16]

In this work, we explored applicable passive design approaches that can be integrated to achieve energy savings. We have determined the most important parameters and based on these parameters developed the primary numbers database for the applying the conception of a net-zero energy low-rise residential buildings using renewable materials of organic origin in practice.

2. Methodology and choice of the parameters

The project of the building that was chosen, as the target for this research is a wood frame four-story building (Fig.1).

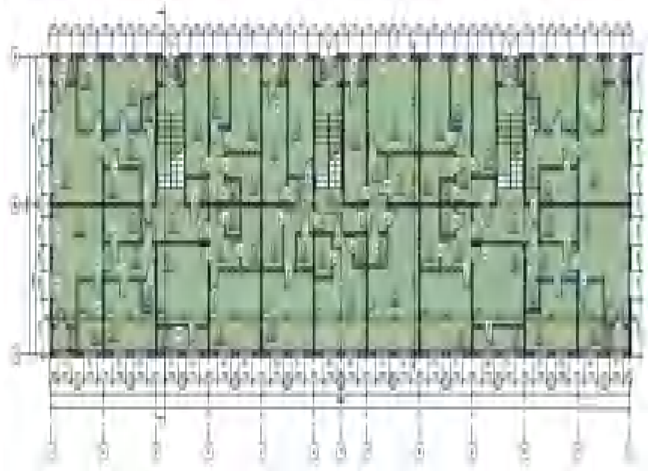

Figure 1. Plan of the first floor of the studied building

We estimated thermal losses of the project and practically got the results for different types of wall insulation of organic origin. The building of three blocks has rectangular shape with the dimensions of 66x16m and the total height of 15,175 m. As all the porous materials, the biosourced ones represent the property of the absorption of the atmospheric humidity because of the saturation of the pores. Due to this effect, there is the difference in the thermal and mechanical performance. The properties of the organic insulation materials was taken from the result of the previous research realized in PSACEA [17], and are given in the table 2.

Involvement of passive design strategies plays an important role in achieving energy savings. Passive design strategies improve energy consumption by designing the building form that responds to the environment, thus making it possible that to achieve high interior environmental quality and low-energy demand at the same time. Building envelope performance improves the exterior wall insulation property to control the heat, air, and moisture transfer between the wall assemblies and the exterior environment. Organic thermal insulation, air barrier, and vapor retarder help the building acquire improved insulating and air sealing performance, and at the same time, ensure that the moisture problem can be addressed adequately.

Table 2. Values of the thermal conductivity of different biosourced materials at volumetric humidity of 0, 5 and 10 %

Material source of straw	Granulometric size, mm	Average apparent density, kg/m3	Porosity, %	Thermal conductivity coefficient W/m*C at volumetric humidity, %		
				0	5	10
Hemp	20-35	70-120	88	0,0465	0,0628	0,077
Wheat	20-40	38-45	89	0,058	0,0767	0,095
Flax	2-15	120-135	85	0,0481	0,0632	0,085
Reed	15-42	150-200	84	0,07	0,089	0,105
Wood	8-15	220-300	82	0,098	0,107	0,145

For determination of the thermal losses, we have used the national norms [18, 19]. Using this project we have determined the different areas that are used after for estimation of the heat losses of the building (Table 3).

Table 3. Areas of the studied building

Type	Area (m^2)
1.Total area of the external walls	2508,1
1.1. Area of externals walls	1964
1.2. Area of the windows and balcony doors	530,4
1.3. Entrance doors and gates	13,7
1.4. Covering	1056
1.5. Floor on the ground	1056
2. Area of heated premises	3819
3. Area of living quarters and kitchens	2238,2
4. Heating volume	11457

The results of the calculations made with the values of the areas and discussion of them is presented in the next chapter. Overall methodology is presented in the Fig. 2

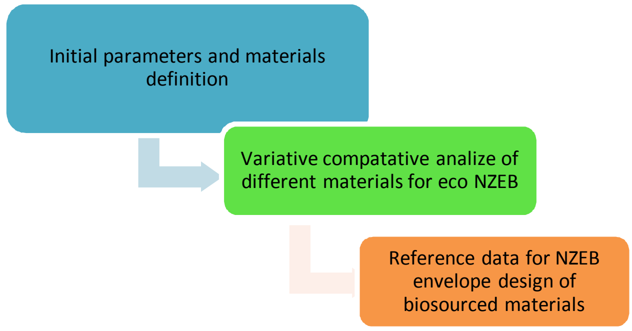

Figure 2. Methodology of the presented research

3. Results and discussions

For the calculation, we took the climatic conditions of Dnipro in Ukraine with estimated value of the temperature in the building of 20°C and estimated value of the external temperature – -27°C. Duration of the heating season is 172 days. [18] In the building the recuperative ventilation system with the efficiency of 80% was applied which is the case for systems this time. For the values of the thermal resistance for windows and doors we took 1 and 0,83 kW/m^2 as the parameters of the installations. We have been interested with the estimation of the thickness of the insulation for each type of studied organic material.

For achieving the gain of the net-zero energy building, we should firstly improve the building envelope to get the losses as small as possible. According to energy performance of buildings directive [20] the passive house is the building with the need of heating less than 15 kW/m^2. As we understand that in real life in our country to get the net-zero building is connected with grand financial investments for installation and the further development of the reglementations, so we decided during the estimation to fix the value of the need of the heating about 5 kW/m^2. This result together with others values let us determine the values for the necessary thermal resistance. We compare these results with national norm and norms from different countries (Table 4).

Table 4. Comparison of the values of the thermal resistance

Structures		DBN-v.2.6-31-2006 for I zone (Ukraine)	RT 2012, BBC*, (France)	RT 2020 BEPOS**, (France)	Energy Conservation Regulations (EnEV), 2012, (Germany)	The Planning and Buildings Act (2016) (Norway)	Results of estimation
Value of the energy consumption		-	50kWh/m^2				5 kWh/m^2
R : thermal resistance (m2.K/W)	Wall	≥ 3,3	≥ 8	≥ 10	≥ 3,6	≥ 5,6	10
	Floor	≥ 3,75	≥ 4	≥ 5	≥ 2,9	≥ 10	8
	Roof	≥ 4,95	≥ 4	≥ 5	≥ 5	≥ 7,7	7

* - net-zero energy building;
** - energy-plus-house.

After this we select the thickness of the insulation of organic materials in the structures (walls, floors and roofs) using the values of the thermal conductivity (W/m*C) for studied materials for different value of the volumetric humidity (%). The results of the estimation for the wall, the floor and the roof are represented in the tables 5, 6, 7 consequently.

Table 5. Minimal thicknesses multiples of 5 cm of the insulation of the wall with the value of thermal resistance 10 m^2.K/W

Material source of straw	Minimal thickness of the insulation (cm) for each type of the organic material in function of the volumetric humidity (%)		
	0	5	10
Hemp	45	60	75
Wheat	55	75	90
Flax	45	60	80
Reed	65	85	1

Table 6. Minimal thicknesses multiples of 5 cm of the insulation of the floor with the value of thermal resistance 8 m^2.K/W

Material source of straw	Minimal thickness of the insulation (cm) for each type of the organic material in function of the volumetric humidity (%)		
	0	5	10
Hemp	40	50	60
Wheat	45	60	75
Flax	40	50	70
Reed	55	70	85

Table 7. Minimal thicknesses multiples of 5 cm of the insulation of the roof with the value of thermal resistance 7 m^2.K/W

Material source of straw	Minimal thickness of the insulation (cm) for each type of the organic material in function of the volumetric humidity (%)		
	0	5	10
Hemp	30	40	50
Wheat	40	50	60
Flax	35	40	55
Reed	45	60	70

The results shows that there is the difference in the thermic performance of the materials in function of the conditions of the use (volumetric humidity). It provokes the increase of the thickness of the necessary insulation. The organic insulation of walls of more than 50 cm gives us another problem of the constructive decision and of the use like dew point and others. In the same time, the changes of the conditions provoke the dimensional variations in biosourced materials that could provoke the degradation of the structure.

4. Conclusion

In this work, we have made the estimation of the thicknesses of the insulation of different structures (walls, flour, roof) for the project of four-story wood frame building of the area of 1056 m^2 in Dnipro, Ukraine. The analysis of the literature have been made that have confirmed that we have made the project that has a good value of the energy consumption (less than 5 kWh/m^2) and is in agreement with the most of the normative documents. As the studied materials were used four biosourced ones which have a good thermic performance. So these materials could be used for the insulation of buildings. The results emphasized the increase of the thickness of the insulation in function of the volumetric humidity. In addition, it showed the necessity of the control of the conditions of the use of biosourced materials in the structures of the buildings. This study provides the literature and the future works with the values of the thickness of the wall, flour and roof insulation of four organic materials (wheat, hemp, flax and reed) in function of the volumetric humidity and shows the necessity of applying of special protections against the variations of the atmospheric conditions like humidity. The results presented in this study could be used to understand the feasibility of the projects of the buildings of local biosourced materials and the presented summarized tables have practical value for the envelope design for net-zero energy buildings.

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