Ensuring Sustainability of Residential Buildings by using Local Materials in the Conditions of the Republic of Moldova

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Abstract: - The study is an overview of the current situation in the Republic of Moldova regarding the sustainability of residential buildings. Advances in the building industry indicate a shift towards energy efficiency with minimal consumption. The authors aim to find a sustainable solution for implementation in the Republic of Moldova. To achieve this, they perform energy efficiency calculations for the envelope of a residential building that utilizes locally available limestone blocks, sourced from 44 quarries across the territory. Technical abbreviations will be defined upon their first use. For thermal insulation, the authors suggest using two layers of masonry enclosing 6 cm thick polyurethane foam. The purpose of this study is to highlight the importance of sustainability in the construction of new residential buildings in the Republic of Moldova. This is particularly relevant in the absence of a comprehensive regulatory framework on energy efficiency for residential buildings.

Key-Words: - sustainability, limestone blocks, energy efficiency, sustainable material, building solution, thermal insulation.

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1 Introduction

The study of sustainable buildings has become increasingly significant since the 20th century, due to concerns regarding the adverse impacts of the construction industry on the environment and human welfare. In the Republic of Moldova, research has been carried out over the last two decades.

Research into building sustainability centers on several critical areas to develop groundbreaking solutions and technologies aimed at decreasing detrimental environmental effects and enhancing the energy efficiency of buildings (Figure 1).

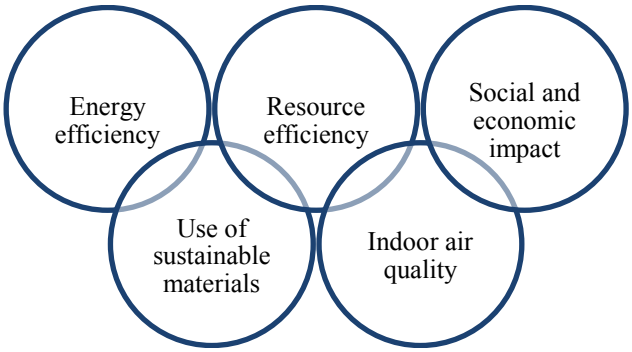

Fig. 1: Research areas into building sustainability

Energy efficiency research aims to develop technologies and systems that reduce energy consumption in buildings. This field of study has existed since the 1970s, and numerous international researchers have explored this subject, [1], [2], [3]. In Moldova, research on energy efficiency in buildings has only been conducted for the past decade, [4], [5], [6], [7].

The incorporation of environmentally-friendly and sustainable building materials plays a substantial role in reducing environmental impact and enhancing longevity in the construction industry. It is vital to consider sustainable materials and their usage when constructing buildings, structures, and infrastructures. Recent studies have emphasized the development of recyclable and renewable materials to further boost energy conservation since the 2000s, [8], [9], [10], [11], [12]. Until the 2000s, load-bearing structures of residential houses in the Republic of Moldova were constructed using environmentally friendly materials such as limestone blocks and mudbrick. This change in construction materials has had a significant impact on the housing industry in Moldova. However, after the 2000s, there was a shift towards reinforced concrete skeleton-type

resistance systems with brick infill walls, and later AAC, [13], [14].

Resource efficiency aims to decrease water usage in construction and improve water management practices. Furthermore, there is an exploration of methods to minimize waste generated throughout the construction and operation of buildings, [15], [16], [17]. This area of building sustainability in the Republic of Moldova has not been researched.

Indoor air quality research has been working towards enhancing indoor air standards by decreasing the emission of volatile chemicals and optimizing ventilation since the 1980s, [18], [19], [20].

The social and economic impacts of these efforts are important considerations. Studies examine the social and economic impacts of sustainable buildings, including concerns about quality of life, occupant health, and the economic benefits of sustainable architecture, [21], [22], [23], [24], [25].

Introducing innovative solutions and technologies through continuous research and innovation is essential to lay the foundations for a more sustainable future. For Moldova, achieving sustainability in the construction sector remains an unexplored terrain.

The study will focus on the use of sustainable local materials for the construction of residential buildings with the goal of near-zero energy consumption.

2 Problem Formulation

The energy efficiency of Moldovan residential buildings has been addressed in the past decade. Currently, the Energy Efficiency Agency and the Government of the Republic of Moldova are collaborating on a project to establish and maintain a national information system on the energy performance of buildings. This initiative aims to implement the strategy for upgrading the country's building stock and the national plan to increase the number of buildings with near-zero energy usage. Through this legislative initiative, the government emphasizes its growing interest in reducing final energy consumption, as buildings account for approximately 50% of total consumption.

Analyzing the construction sector in the Republic of Moldova over the past five years on a territorial level (Figure 2), a significant development can be observed in the central area, where the capital is located.

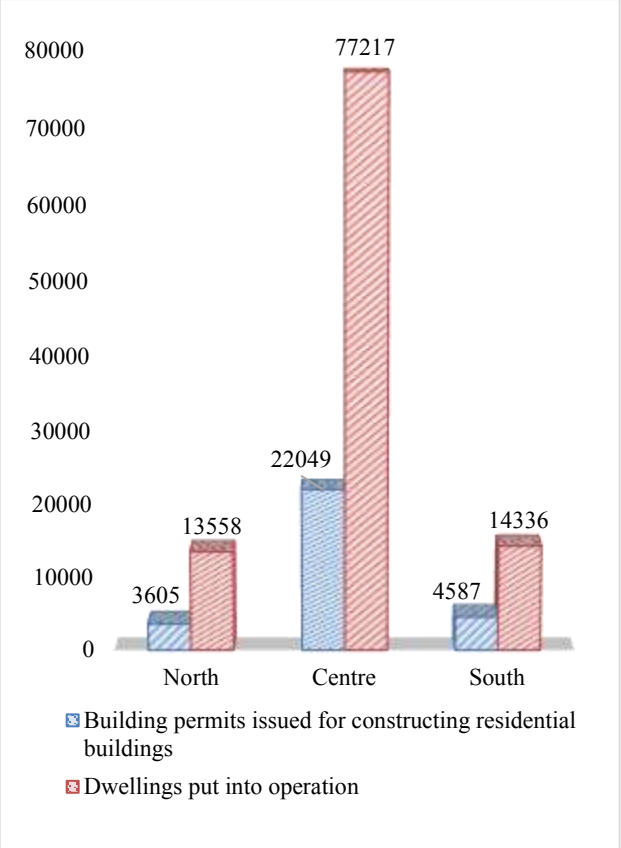

Fig. 2: Development of the Construction Sector in the Republic of Moldova from 2018 to 2022

When examining the figures on planning permission granted for the construction of residential properties (Figure 3), it is evident that the number of permits in the Chisinau municipality significantly increased in 2021 after the COVID period. However, it is important to note that the information for 2023 is not yet complete, as data for the fourth quarter is still outstanding.

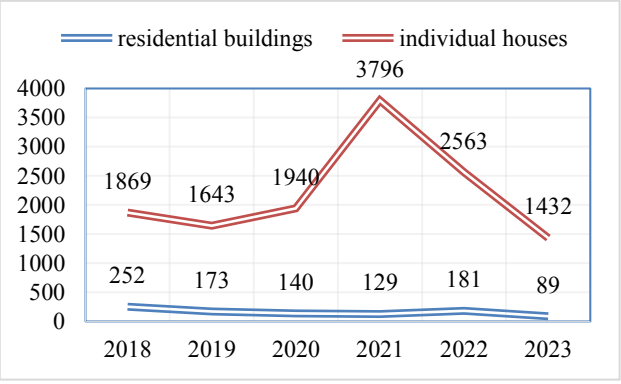

Fig. 3: Building permits issued for constructing residential buildings within Chisinau municipality

Analyzing the same period about the building permits issued, the structures that were put into service were examined in Figure 4. The data for the

fourth quarter is still outstanding, thus the information for 2023 remains incomplete.

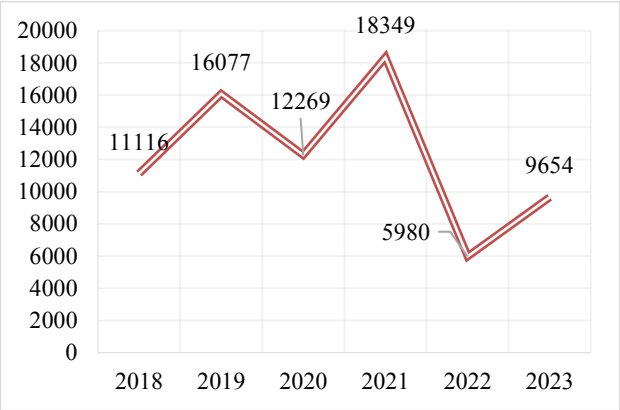

Fig. 4: Dwellings put into operation in Chisinau municipality

Upon analyzing Figure 2 and Figure 3, it becomes evident that the volume of buildings put into operation in Chisinau municipality is significantly higher than the number of building permits issued.

The capital reconstruction percentage of residential buildings within Chisinau municipality was analyzed in comparison to the previous year, as shown in Figure 5.

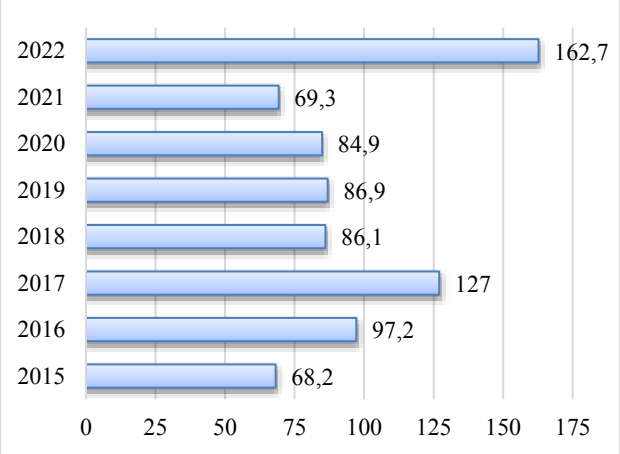

Fig. 5: Percentage change in capital repair works compared to the previous year, in comparable prices

The statistical analysis indicates the evolution of the residential construction industry in Chisinau. The buildings are planned with an emphasis on energy efficiency based on outdated regulations, while the thermal resistance and thermal transmittance values are not standardized.

The primary issue regarding energy efficiency in newly constructed buildings is the absence of a methodology for evaluating their energy performance. Currently, some regulations require rectification and completion.

As a starting point for designing new buildings that aim for almost zero energy consumption, the authors suggest the application of the Romanian methodology MC 001-2022.

Another issue is the importation of materials instead of local ones. The Republic of Moldova has reserves of limestone blocks that possess high physical-mechanical properties, [26]. Furthermore, the limestone stock has been segregated into two quarries that are ready for exploitation, 13 reserve quarries, and 44 quarries that are already in exploitation, [13].

3 Problem Solution

The authors suggest utilizing limestone blocks with polyurethane foam as thermal insulation between two layers of masonry for residential buildings (Figure 6).

This wall structure can be used for both infill and load-bearing walls. The wall thickness is 460 mm, and a reinforcement mesh is placed at every fourth masonry layer to provide higher seismic resistance, [26].

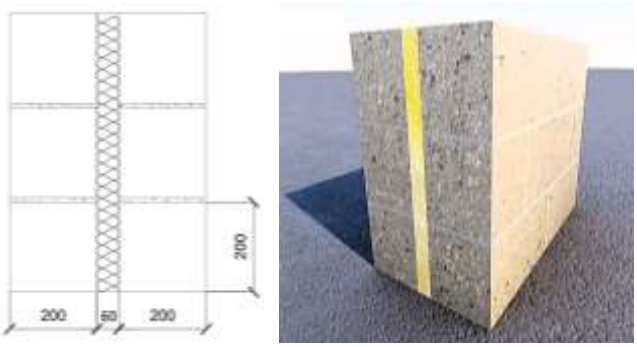

Fig. 6: Proposed construction solution for residential building walls

Calculations were performed to determine the dew point (Figure 7) for the presented wall construction solution, using the following initial data: relative humidity of 55%, indoor temperature of +20 °C, outdoor temperature of -25°C in the central area of Moldova, and 5 cm of polyurethane foam insulation on the walls.

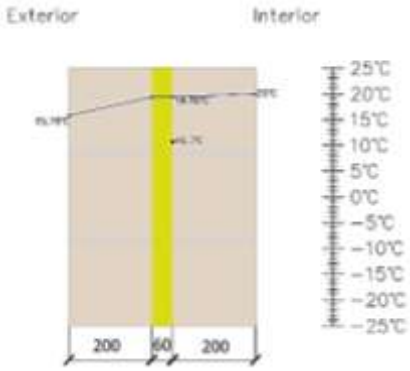

Fig. 7: Dew point graph of the analyzed construction solution

The data presented in Figure 7 indicates that the building solution under investigation has a high level of thermal insulation, preventing the dew point from reaching 10.7°C.

Based on the Romanian methodology MC 001-2022, [27], the thermal resistance and thermal transmittance of the construction solution presented in Figure 6 are determined (Table 1).

Table 1. The centralizer of results obtained on thermal efficiency calculation

Indicator		Value	Unit of measurement
Total unidirectional thermal resistance	R	**4.49**	$m^2 \cdot K/W$
Unidirectional thermal transmittance	U	**0.22**	$W/ m^2 \cdot K$
Total corrected thermal resistance	R'	**4.22**	$m^2 \cdot K/W$
Total corrected heat transmittance	U'	**0.24**	$W/ m^2 \cdot K$

When determining the thermal resistance of the analyzed solution (Table 1), the subsequent data were collected.

- The thermal conductivity of limestone blocks is 0.33 W/mK with a thickness of 0.2 m for one block, determined from laboratory work.
- The thermal conductivity of polyurethane foam is 0.022 W / mK, according to the technical data sheet, at a thickness of 0.06 m.
- The thermal conductivity of cement mortar plaster is 0.93 W/mK with a thickness of 0.02 m, as reported in the technical data sheet.

In terms of sustainability, the solution satisfies the fundamental requirement of being energy efficient, and limestone blocks represent a long-lasting and high-strength building material, [26]. The widespread implementation of the building solution is expected to boost the revenue of limestone quarries.

From an economic perspective, we conducted a comparative analysis of construction solutions implemented in practice, as shown in Table 2.

Table 2. Comparative analysis of construction solutions in terms of price for 1 m^3

Material	Quantity	Price, MDL	Price 1 m^3, MDL
Autoclaved aerated concrete	21 units	171	3591
Bituminous membrane	1.2 m^2	70.1	84.12
Adhesive	7.28 kg	3.32	0.97
Reinforcing mesh	2.5 m^2	13.6	34.
Plaster	12.48 kg	10.59	5.29
Polystyrene	2.5 m^2	105	262.5
Plastic plug with plastic pin and long expansion zone	20 units	2.8	56
Masonry workmanship			500
Insulation workmanship			67
Total			**4600.87**
BRIKSTON	1 m^3	2350.17	2350.17
Bitumen primer	0.365 m^2	63.3	23.1
Mortar	0.117 m^3	960	112.13
Reinforcing mesh	2.62 m^2	13.6	35.63
Plaster	15.71 kg	10.59	166.34
Polystyrene	2.62 m^2	105	275.1
Plastic plug with plastic pin and long expansion zone	21 units	2.8	58.8
Masonry workmanship			770
Insulation workmanship			67
Total			**3858.28**
Limestone block	1 m^3	810	810
Tar cardboard	1.35 m^2	10.45	14.11
Mortar	0.15 m^3	750	113.15
Reinforcing mesh	5.68 m^2	23	130.69
Polyurethane foam	1 m^3		
Insulation workmanship		155	155
Masonry workmanship			550
Total			**1772.95**
			Price 1 m^3, EUR
AAC masonry			*235.34*
BRIKSTON brick masonry			*197.35*
Limestone block masonry			*90.69*

The prices listed in Table 2 were obtained from the catalog of average sales prices for construction

materials, sourced from manufacturers and importers in the Republic of Moldova in 2023. The exchange rate used for the calculations was 19.55 MDL per EUR.

Economically speaking, using the proposed construction method, 1 cubic meter of masonry will be 2.6 times less expensive than masonry built with autoclaved aerated concrete blocks and 2.2 times less expensive than masonry made with BRIKSTON ceramic blocks.

4 Conclusion

The research reveals the current state of sustainability in construction in the Republic of Moldova. As shown in Figure 2, Figure 3 and Figure 4, the number of buildings in Chisinau municipality has increased in recent years, but the sustainability problem is not solved at the local level.

Taking into account Moldova's limestone resources, the use of local materials for construction would facilitate sustainable development in the country.

The proposed construction solution has several advantages, including local and natural materials are used; thermal insulation over time does not require replacement; in terms of energy efficiency, it meets the requirements of near-zero energy consumption; from an economic point of view, it is cheaper than the construction solutions currently used in residential buildings.

However, a drawback of the proposed solution is the complexity of the masonry system, which requires two layers and frequent application of foam and reinforcement mesh to enhance seismic resistance.

Ensuring the sustainability of residential buildings in Moldova should be a priority for the construction sector. Local materials must be used for this purpose and any new regulations or projects relating to energy efficiency should consider the availability of local resources.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Ion Serbanoiu is conducting research and investigation, specifically performing experiments and collecting data/evidence.
- Doina-Cezara Albu is responsible for all other parts of the research.

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Conflict of Interest

The authors have no conflicts of interest to declare.