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USING NATURE AS A SUSTAINABLE SOLUTION FOR RESIDENTIAL COMPLEX DESIGN

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Abstract

People will always need a home. Statistically speaking, the next 50 years will be drier than the last 50 years, so society must change its way of building houses. At this moment, most of the houses are built with poor-quality materials, the insulation is of poor quality. Water is used as if it were single-use, and the soil around the house is not used for food but cement is poured over it. This paper presents a model of a residential complex in Romania, that is following the goals of sustainable development. Considering the economic, social, and environmental aspects, the residential complex will lead to the improvement of the quality of life of the people who will live there, the creation of new jobs, and the improvement of the quality of the environment.

Key words*: house, quality, sustainable development, water.*

INTRODUCTION

The construction of houses has a significant impact on climate change in several ways. The use of energy and materials in construction, as well as the operation and maintenance of buildings, are responsible for a significant portion of greenhouse gas emissions. According to United Nations, CO2 emissions caused by the construction industry hit a new high (Kennard et al., 2022).

Man-made environment accounts for approximately 40% of global CO2 emissions from fuel combustion and 25% of global greenhouse (GHG) emissions. (Tony et al., 2021). Cement production is one of the most polluting industries, accounting for 7% of global CO2 emissions (Reiter, 2022).

Achieving a net-zero carbon emissions scenario by 2050 will necessitate a swift transition towards low-carbon alternatives in the cement and concrete industry. McKinsey hosted an interactive panel at the World Economic Forum Annual Meeting 2023 (AM23) in Davos, Switzerland, to discuss the future of the industry (Heincke et al., 2023). It is feasible to achieve decarbonization in the cement and concrete sector by leveraging a combination of strategies as well as reducing the amount of clinker in cement, using newer technologies such as kiln electrification, storing or utilizing the remaining CO2 emissions. However, these solutions are quite new and have not yet been deployed at scale. Until these solutions will be implemented, it is necessary to find new ways to build houses and minimize the environmental impact.

To conserve the resources for the future generation, it is important to use for the construction of new houses local materials like timber, bricks or clay, and also to combine all the solutions that exist in the matter of energy-efficient, renewable energy, reusing water, and even using the greenhouse for food and tea.

MATERIALS AND METHODS

This article introduces a blueprint of a residential community located in Romania, Buftea. To find the optimal solutions, it is important to know the specific environmental conditions of the area.

Buftea is a city in the Ilfov County, in the southern part of Romania, located approximately 20 km northwest of Bucharest. The climate in this city is classified as humid subtropical climate according to the Köppen-Geiger climate classification. This means that the summers are hot and humid, while the winters are relatively mild with occasional snowfalls. The average temperature is 11.1°C, with a mean maximum temperature of 23.8°C in July, and a mean minimum temperature of -3.7°C in January. Buftea receives an average of

633.3 mm of precipitation per year, with the wettest month being June and the driest month being February. The vegetation in Buftea is Characterized by mixed forest, consisting of deciduous trees such as oak, beech, and hornbeam, as well as coniferous trees such as pine and spruce (Chinea, 1997).

Considering the climatic conditions in the mentioned city, the suitable materials for building a sustainable house in this city can be timber, rammed earth, and hempcrete. For all those materials there are some advantages and disadvantages that require to be mentioned.

Timber is wood that has been prepared for use in construction or carpentry. It refers to the harvested trees that have been sawn into planks or boards and processed for various applications, such as building structures, furniture, and paper products. Hardwood species such as mahogany, ash, or oak require 60 years, and in some cases up to 100 years to reach maturity. Conversely, softwood species, such as larch, pine, and spruce, require around 25 to 30 years to reach maturity.

As deforestation is a concern, it is crucial to ensure the replenishment of timber sources through the planting of new trees. (Bitesize, 2020). Timber is one of the small numbers of materials that have multiple advantages, like being safe to handle, and not leaking chemical vapors into the building (Ramage et al., 2017). It is also known for its durability, versatility, and aesthetic appeal. Compared with traditional buildings made from concrete and steel that are expected to produce around 2,000 metric tons of CO2 emissions, trees absorb carbon from the atmosphere and a part of that carbon remains stored within the tree's woody biomass even once the tree is transformed into timber building material. Also, mass timber is proven to be earthquake-resistant, and prefabricated timber homes can withstand natural disasters, as well as floods, and category 4 hurricanes. Timber construction can create jobs and boosts the economy by encouraging the use of locally sourced, bringing benefits to local economies (Burrell, 2023).

While timber has many advantages as a building material, it also has some disadvantages, including fire hazards. Timber is highly flammable, and in case of fire, it can easily spread and cause damage to the building. Timber has also the susceptibility to insects and rot, as well as fungal decay (Davies, 2021). It requires regular maintenance such as staining or painting to protect it from the elements and to prevent decay and insect infestations. There are limited availability disadvantages. The supply of quality timber can be limited, also the production of timber can have negative environmental impacts such as deforestation, soil erosion, and habitat destruction (Folk, 2020).

Another eco-friendly building material is rammed earth.

Rammed earth is an ancient building technique that has been used for thousands of years. In fact, archaeological evidence suggests that rammed earth was used in the Fertile Crescent region as early as the 9th-7th millennium BC (Leick, 1988). This ancient technique offers a sustainable method to build a resistant house. This technique requires the compaction of a moist mixture of soil that has suitable proportions of clay, gravel, and stabilizer (Miller, 2020). This mixture is laid up directly into a freestanding wall (Easton, 2007).

Rammed Earth buildings are an excellent choice for energy retention, it provides excellent insulating options. During colder months retain heat inside the structure to prevent extreme interior temperature changes (Miller, 2020). Besides high thermal mass and insulation properties, durability and resistance to fire, low embodied energy, and carbon footprint, as the material is locally sourced and minimally processed are important benefits. In rammed earth walls it is possible to enhance additional recycled materials, such as metal or glass, which can provide structural reinforcement and aesthetic interest (Easton, 2007).

Using rammed earth as a construction material has some disadvantages like limited availability of skilled labour and specialized equipment for construction, susceptibility to moisture damage, and requiring careful design and maintenance (Rammed Earth Buildings: Code and Safety Issues, 2015).

Hempcrete is a natural building material, a bio-composite material made from the woody inner fibers of the hemp plant, a renewable resource. It is also used for insulation, roof insulation and to create walls (Mango et al., 2019).

The advantages of hempcrete are high thermal mass and insulation properties, providing natural temperature control and energy efficiency, and low embodied energy and carbon footprint, as the material is locally sourced, minimally processed, and has low maintenance requirements (Maggio and Marrocchino, 2019). Hempcrete exhibits inherent pest resistance, rendering it a safe and environmentally sustainable building material. Its freedom from any form of pesticides and fungicides obviates concerns about health risks to children and pets. In contrast to wood, Hempcrete is also immune to the hazards of termite infestation (Agbanlog, 2023).

In terms of disadvantages, hempcrete is a relatively new material with limited research available on its performance as a building material. Many construction companies that have started to use hempcrete have had access to it for only a few years, and there is a need to relearn old knowledge about creating a hemp building. This lack of experience can make it challenging to find a construction company that specializes in hempcrete use. Engineering experts have identified that hempcrete has a high capacity for handling moisture, which can be advantageous in some cases but also limits its range of uses. Hempcrete may not be suitable for marine or underground works due to its potential for moisture-related issues. Additionally, hempcrete may not be suitable for use in extremely warm climates with a high degree of moisture, as it could lead to increased heat inside the building (Lynch, 2020).

Efficient heating and cooling systems are essential for reducing energy consumption and minimizing greenhouse gas emissions. Various types of systems can be used for heating and cooling, including:

Heat pumps: A heat pump is a device that transfers heat from one place to another using electricity, for example, a heat pump can transfer geothermal energy stored in the ground from the ground in the house. Heat pumps are an efficient solution that can provide significant cost savings and protection from energy price fluctuations over their lifetime. In comparison to gas boilers, heat pumps can offer lower energy costs for households and businesses that utilize them. This is due to their ability to transfer heat from one place to another, rather than generating heat by burning fuel like gas boilers (IEA, 2022).

Radiant heating: Radiant heating systems deliver heat to a building's floor, wall, or ceiling panels. The system relies on radiant heat transfer, where the heat moves directly from a hot surface to the objects and people in the room via infrared radiation. This process is akin to the heat felt from a hot stove element across the room. When located in the floor, radiant heating is referred to as radiant floor heating or floor heating. Radiant heating offers several advantages. It is more efficient than baseboard heating and usually more efficient than forced-air heating since it eliminates the energy losses inherent in duct systems. For people with allergies, radiant heat may be preferred since it does not circulate allergens as forced air systems can. Hydronic systems, which rely on liquid heat transfer, require relatively low electricity consumption (The United States Department of Energy, 2023).

Unglazed Solar Collectors: An unglazed solar collector is a type of solar thermal technology that is simple in design. A heat-absorbing material, usually made of dark metal or plastic, captures solar energy and transfers it to a fluid that flows through or behind the absorbing surface. This process is similar to how a garden hose exposed to sunlight can warm the water inside it.

Since unglazed solar collectors lack a glass cover or "glazing" on the collector box to retain heat, they are described as "unglazed." This design choice results in a trade-off. On one hand, unglazed solar collectors are simple and cost-effective, but on the other hand, they lose heat back to the environment and typically operate at lower temperatures. As a result, unglazed collectors are most effective for smaller heating applications or in conjunction with traditional heating systems, where they can preheat air or water and reduce the need for fossil fuels (EPA, 2022).

Green roofs, also known as ‘vegetated roofs’ or ‘living roofs. They consist of a waterproofing membrane, a layer of soil as a growing medium, and vegetation, which are installed over a traditional roof. These roofs are typically ballasted to provide the necessary weight and stability to support the added weight of the growing medium and vegetation. Green roofs

offer numerous benefits, including environmental, social, economic, and aesthetic advantages. They can help to reduce energy consumption, improve air and water quality, mitigate stormwater runoff, provide habitat for wildlife, and enhance the aesthetics of buildings and urban areas. In addition, green roofs can also contribute to the overall sustainability of a building or development, as they can reduce the urban heat island effect, increase biodiversity, and provide opportunities for community engagement and education (GSA, 2021).

One major disadvantage is the high cost of installation and maintenance. The initial installation cost can be up to two or three times the cost of a traditional roof, and ongoing maintenance costs are also higher due to the need for regular watering, fertilization, and pruning. These costs can make green roofs prohibitive for many building owners, especially those on a tight budget. Another disadvantage is the potential for leaks and water damage. While green roofs are designed to be waterproof, there is always the risk of leaks and damage to the underlying roofing system. If not properly installed and maintained, green roofs can lead to costly repairs and even structural damage to the building.

In addition, green roofs can be heavy and may require additional structural support to be added to the building. This can add to the initial installation cost, as well as potentially limit the types of buildings that can support a green roof (Gorski, 2023).

There are different types of green roofs, such as extensive green roofs, that are characterized by a thin layer of growing medium and are designed to support low-growing, hardy plants such as sedums, grasses, and herbs. They are lightweight and require minimal maintenance, making them ideal for retrofitting existing buildings or installing them on new buildings with limited structural capacity (Life on Roofs, 2023).

Intensive green roofs that consist of deeper substrates. This type offers the opportunity to design more complicated and elaborate gardens.

The London Plan, published by the Mayor of London in March 2016, defines brown roofs as: ‘Roofs which have a layer of soil or other material which provides a habitat or growing medium for plants or wildlife.’

Approximately 65% of water usage in a household is attributed to activities such as showering, bathing, handwashing, and laundering clothes. As a result, greywater is generated from these activities. Greywater can be recycled easily and at a low cost, treated, and repurposed for applications such as toilet flushing and irrigation (Interwa, 2023).

Blackwater is the term used to describe wastewater that originates from toilets and bathrooms, containing human waste and urine. Additionally, kitchen water and dishwasher discharge are also classified as blackwater due to their contamination with grease and disease-causing microorganisms (Your Home, 2013).

Constructed wetlands are man-made systems designed to replicate the natural processes of wetlands. These systems are constructed by engineers and scientists and are used for water treatment by filtering pollutants from water that flows through them. Wetland vegetation, soils, and microbial communities play a crucial role in the natural filtration process, and the same principles are used in constructed wetlands to improve water quality. Constructed wetlands use a combination of physical, chemical, and biological processes to remove pollutants from the water. The result is a sustainable and cost-effective method for improving water quality that can be used in various applications, such as wastewater treatment, stormwater management, and agricultural runoff treatment (Muthukumaran, 2022).

Anaerobic digestion is a process of treating blackwater that is both energy-efficient and capable of recovering valuable energy and nutrients from the wastewater (Slompo et al., 2019)

The membrane filtration process is a technique based on physical separation that allows for the isolation of molecules with distinct sizes and characteristics. This process is governed by the pressure gradient that exists between the two sides of a specialized membrane, which allows for the selective passage of certain molecules while retaining others. Membrane filtration is a widely used method due to its ability to separate components with high precision, efficiency, and selectivity. It has numerous

applications in various fields, such as wastewater treatment, food and beverage processing, pharmaceutical production, and desalination. The effectiveness of the process is determined by the properties of the membrane and the operating conditions, such as the pressure and the flow rate (AlfaLaval, 2022).

RESULTS AND DISCUSSIONS

Based on the solutions that best suit the chosen area, Buftea, Romania, and following research, the model of a residential complex that follows the goals of sustainable development can look in the following way.

The residential complex is composed of ten houses on the ground floor, with a size between 70-100 square meters. With a concrete foundation because the average precipitation in this city is 633.3 mm per year. This value would not affect a rammed earth foundation, but considering that the water drainage system will be based on constructed wetlands, that will bring more moisture to the soil. This choice is for a strong resistance of the houses. Walls would be built using the technique that was used in the past first houses, rammed earth. This method is a suitable choice for retaining energy by providing optimal insulation.

Using a brown roof is an optimal solution to moderate the heat island effect, also it provides shade, removes heat from the air and reduces temperatures of the surface by around 5-10 C° and also the surrounding air. Installing this kind of roof is a way to save money because it is not necessary to plant any vegetation, the surface is left to self-vegetate from windblown and bird seed dispersal. When a house is built, the aim is to give back to nature what was taken.

Home insulation can be improved with hempcrete. This bio-composite can be used as an insulating material. Timber can be used as an external shade for windows, in this way the house can be cooled sustainably.

With the purpose to implement solutions with a lower carbon footprint, Unglazed Solar Collectors can be a suitable solution for warm water.

Water reuse is the most important thing to do at this time. By using natural processes, constructed wetlands offer a promising alternative for treating polluted water sustainably and effectively. This solution can be designed to fit different landscapes, climates, and water sources, allowing for a customized approach that adapts to local conditions and needs.

This system can be installed all along the residential complex, behind the houses. All the pipes that conduct grey water from the house are going directly to a constructed wetland. After completing the purification route through the system, the water is accumulated in a basin. Here there are two possibilities for using water. The water can be used for irrigation or the washing machine, or it can be ultra-filtered with the help of membrane station technology and can be used as drinking water.

Regarding the recycling of black water, there is required a septic tank and four basins, the septic tank is where the solid material will settle. Biogas can also be produced here, which can be used in the network of the residential complex. From the septic tank, the water will pass through a pipe system into the next basin, which is called the anaerobic basin, where the sludge will be digested faster. From here the water passes into the next three basins where the environment changes completely. From an anaerobic environment, the water will reach a basin full of aquatic flora and fauna. Then, the water is purified and collected in a basin and can be used for irrigation and the toilet basin.

The residential complex is arranged in a circular shape. In the middle, there will be a greenhouse that will provide the necessary vegetables for the residents. By building this greenhouse, it will be possible to create new jobs, also it will improve the quality of life.

CONCLUSIONS

In conclusion, the residential complex proposed in the paper has the potential to improve the quality of life of the people who will live there, create new jobs, and improve the quality of the environment. By using sustainable and environmentally friendly solutions such as rammed earth walls, brown roofs, hempcrete insulation, and constructed wetlands for water treatment and reuse, the complex aims to reduce its environmental impact and promote a healthier and more sustainable way of living.

Water is a precious resource, and the proposed water management system of the residential complex offers a sustainable and effective

solution to this issue. Constructed wetlands, coupled with ultra-filtration membrane technology, provide a cost-effective and eco-friendly way of treating polluted water, which can then be used for irrigation and as drinking water. The recycling of black water through a septic tank and basin system further improves water conservation.

Furthermore, the proposed circular arrangement of the complex with a central greenhouse can also create new job opportunities and provide fresh vegetables for the residents. The use of renewable energy sources such as solar collectors and biogas production can also contribute to the economic sustainability of the complex.

The residential complex model presented in the paper aligns with the principles of sustainable development and can provide a viable alternative to traditional housing solutions, leading to a more balanced and sustainable way of life for its residents.

Overall, the sustainable residential complex model proposed for Buftea, Romania showcases the feasibility and benefits of implementing sustainable housing solutions and highlights the importance of sustainable living in modern times.

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SECTION 03
WATER RESOURCES MANAGEMENT