Energy Efficiency from Sustainable Materials

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Abstract: *The environmental impact in the life cycle chain is significantly greater than that which occurs exclusively at the waste management stage. Recycling waste can help reduce greenhouse gas emissions and other emissions. Regarding the impact on the environment, sustainable constructions are those that meet certain criteria: the design, the management of the construction process and the performance materials used. From this perspective, the use of renewable energy resources and associated technologies in the actual construction, operation and subsequent management of the objectives and in the maintenance methods in order to reduce greenhouse emissions is also significant.*

Keywords: *Sustainable material, recycling, bricks*

1. Introduction

Inadequate waste management contributes to climate change and air pollution and directly affects many ecosystems and species. Waste recovery can thus contribute to the reduction of greenhouse gas emissions [1].
Recycling can contribute even more to reducing greenhouse gas emissions and other emissions. When recycled materials replace new materials, the need to extract or produce new materials decreases.
Waste also has an indirect impact on the environment. Anything that is not recycled or recovered from waste represents a loss of raw materials and other production factors used within the chain, respectively in the stages of production, transport and consumption of the product. The impacts on the environment in the life cycle chain are significantly higher than those that occur exclusively in the waste management stage [1].
In terms of environmental impact, sustainable constructions are those that meet certain criteria, from the design and management of the construction process to the performance materials used at all stages. Also, from this perspective, the use of renewable energy resources and associated technologies in the actual construction, operation and subsequent management of the objectives and in the maintenance methods in order to reduce greenhouse gas emissions is of significant importance [3].
From an economic point of view, the sustainability of constructions means moving from the old, well-known model of the linear economy to a new, circular model, which involves renewable energy, recycling of materials and produced waste, according to figure 1.

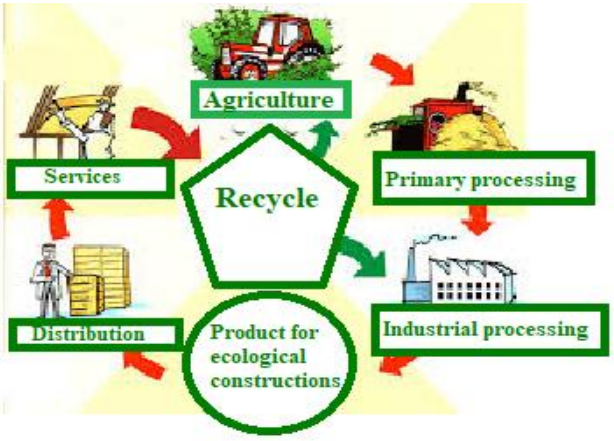

Fig. 1. Life cycle of a sustainable construction product [5]

The climate is changing and so are the construction requirements of future buildings, which must provide the necessary comfort for the occupants with a minimum of energy and environmental impact.

2. Sustainable material in construction

Materials used in construction represent one of the best methods of implementing sustainability. The progress of manufacturing technology allows the emergence of new generations of materials with properties at least identical to those of traditional materials. Also, the return to nature allowed finding solutions that, although used since ancient times, were overlooked for a long time [2].
These new construction materials are sustainable and ensure the protection of the environment as well as the reduction of the carbon footprint of the objectives of which they are part.
There are increasing efforts globally to develop new technologies, materials and non-conventional energy sources to reduce energy consumption and CO2 emissions associated with the buildings sector. Considering the impact that buildings have on energy consumption and on the environment, ceramic construction materials should be part of any ecological and responsible construction strategy. In order to preserve heat in natural buildings, good insulation is important, clay being optimal for storing heat. From the perspective of growing environmental concerns, the use of waste to develop bricks that exhibit appropriate characteristics attributed to the composition of the material are increasing [4].
The durability of the building depends on all the building materials used, without exception, but the wall material should be chosen with the greatest care, because even with an ideal place for construction, the poor choice of this component will make the building decay quite quickly. The material for the manufacture of walls can greatly influence the cost of the entire project, in addition, it can depend on some basic characteristics - for example, the thermal conductivity of the building.
Clay is a natural, sustainable and simple material, but with multiple properties (figure 2). It has been used since ancient times for pottery, writing pads, art objects, musical objects and especially, construction works.
Prehistoric people were the first to discover the useful properties of clay. Some of the earliest ceramic shards were found in Honshu, Japan and are dated to around 14,000 BC.
Clay as the defining ingredient in the composition of clay is one of the oldest building materials on earth, among other ancient natural geological materials such as stone and organic materials such as wood [3,4].
Between one-half and two-thirds of the world's population, in both traditional societies and developed countries, still live or work in buildings made with clay, often baked into brick or ceramic blocks, as an essential part of its load-bearing structure.
A primary ingredient in many natural building techniques, clay is used to create adobe structures.
Clay is an abundantly available natural material, it is very versatile, having been used for thousands of years in various industries. Recently, clay-based construction materials are beginning to capture more and more public attention, being considered a solution to reduce the impact that buildings have on the environment.

Fig. 2. Basic raw material for bricks [4]

Clay-based building materials are non-toxic, have a very low carbon footprint, contribute significantly to the regulation of humidity and indoor air quality, are resistant to fire and pests,

passively contribute to maintaining a constant temperature due to their high thermal mass and are also a good sound insulator.

3. Features for the use of natural materials in construction

Natural materials, either mineral (inorganic) or organic (of vegetable or animal origin), have particularly important common characteristics that make them clearly superior from an ecological point of view and the durability of synthetic materials used for insulation. Thus, natural materials, coming from and forming in the natural environment, are particularly resistant to the action of solar radiation and especially UVA and UVB components, which produce rapid degradation of any synthetic material (PVC, polystyrene, polyurethane, agglomeration resins, compounds of limes and synthetic paints, etc.). Also, natural materials have better durability and behaviour under the action of cyclical climatic factors, temperature, humidity, gelity, or the actions resulting from earthquake, fire, climatic accidents. So, it is necessary to understand that traditional techniques and local materials have proven their durability over time and are much healthier. Synthetic materials, foreign to the specific and polluting, do not represent a sustainable solution but, rather, can be the source of long-term problems.
Sun-dried unburnt brick, clay blocks mixed with straw, wool, cobs, walnut shells are sustainable materials that also have good energy efficiency.
The materials used in the production of bricks [3,4]:

❖ **sheep wool fibres** are used as a thermal and sound insulator both for wooden constructions and for brick or stone houses.
The qualities of sheep wool fibre insulation:

- ecological and healthy heat and sound insulating material, obtained from natural, renewable raw materials; accessible;
- resistant to mold and does not rot;
- the ability to absorb and release moisture from the surrounding air. Wool is a hygroscopic material, which means it can absorb up to 30% – 40% of its own weight in moisture, retaining its properties. Wool fibres naturally try to keep in balance with the changing humidity of the atmosphere. When the outside temperature drops and the air humidity increases, then wool takes in the extra moisture and releases heat in the process. Because of this, wool is said to "breathe" and act as a moisture and heat regulator.
- natural filter - naturally absorbs various air pollutants: volatile organic compounds, nitrogen dioxide and sulphur dioxide. Wool fibres absorb and irreversibly fuse with formaldehyde and other harmful substances.

❖ **straws** are based on the same substance as wood: cellulose. Due to the fact that the straws are hollow inside, the degree of thermal insulation is better than in the case of wood. By compressing the straw in the mixture it becomes resistant to compression, which means that it is suitable for the construction of solid walls. The earth and lime plaster allows the walls to "breathe", regulates humidity and provides a pleasant and healthy living environment. Straw constructions are very energy efficient due to their heat-insulating qualities.

❖ **hemp -** is a textile plant with many industrial uses. One of the applications for which the fibre of this plant with great regenerative power can be used is the creation of a material with the physical properties of concrete, but with a much reduced weight. The "bricks" made on the basis of hemp fibres are easy to transport, solid, insulate thermally and sound very well and have excellent fire resistance. In addition, hemp fibres continue to absorb carbon dioxide to a large extent.

❖ **bamboo wood -** being a plant with an amazing capacity for growth and regeneration (some species even grow up to 1 m in just 24 hours), bamboo is actually a herbaceous plant and not a tree, with an amazing spread over almost every continent, outside of Europe and the polar lands. Bamboo is a strong, resilient wood with considerable durability over time, especially if properly treated against pests and rot.

❖ **cork wood -** is an excellent soundproofing material, resistant to mechanical shocks and even thermal insulation. Cork resists fire well and even if it burns it does not emit toxic gases. In addition, it is a waterproof material and does not rot.

❖ **walnut shell -** is a granular material obtained from walnuts, it is hygroscopic, with little fermentation, which prevents the appearance of bacterial flora. This material is resistant even in humid conditions.

❖ **corn cobs** - they have high resistance and insulate well.

Brick is the most used material for building masonry. This has been used since ancient times when it was produced by hand.

The brick is usually produced industrially and is called pressed brick, but the brick can also be produced manually and is called hand brick [5].

With the advent of the industrial era, the production of burnt brick began to be technological, but its manual production did not stop.

4. Brick obtained industrially

The technological process (figure 3) by which the brick is obtained consists of the operations described below [6].

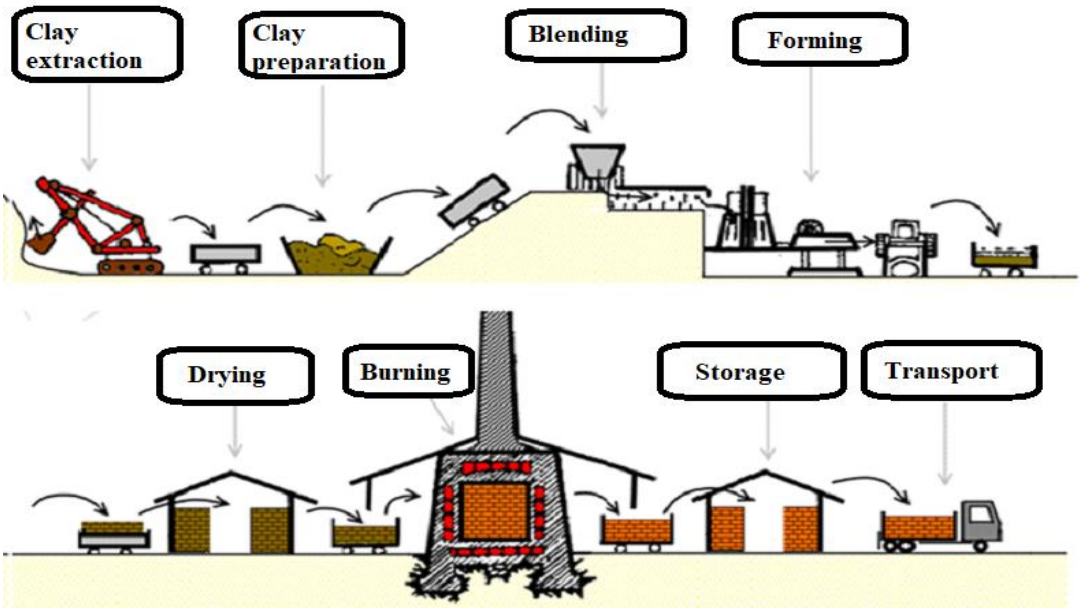

Fig. 3. Phases of the technological process of producing clay bricks [7]

The clay is extracted from the ground with the help of mechanical machines (figure 4) (excavators, grapples, etc.) and is transported to the brick factory. Sandy clay (clay) is used for the manufacture of bricks, it can contain lime in the form of dust up to 5%. The presence of lime granules in the composition of the clay is strictly prohibited. These granules are later extinguished, and this phenomenon leads, over time, to the deterioration of the bricks placed in the work.

Fig. 4. Clay extraction [9]

After the clay is mixed well with the help of mixers (figure 5), the paste is prepared. For this, sand and water are added in well-established quantities, according to the recipe. The paste obtained in this way is mixed with the help of a rolling mill with waves.

Fig. 5. Mixer for obtaining clay paste [10]

The shaping of the brick is done either with the help of patterns, or it is done mechanically, with the help of special presses (figure 6) and dies.

Fig. 6. Press for the production of ecological bricks [11]

After getting the shape, the bricks are taken to the dryers (figure 7). These dryers can be in the form of covered hoppers or in the form of special halls that have special rooms for drying bricks.

Fig. 7. Drying of bricks in special halls [12]

This last major step in the technological process of obtaining the brick is particularly important. Burning is done in tunnel furnaces (figure 8) or in special industrial furnaces, such as the circular furnace.

Fig. 8. Tunnel kiln for brick firing [8]

The process of burning bricks is carried out at temperatures between 900 and 1000°C.

5. Brick obtained by hand

The hand-made brick has not ceased to exist even today. Brick is produced from clayey, sandy soil called loam. This raw material is a mixture of clay and sand that also contains other materials, depending on the quality of the soil of the extraction area. The lower the percentage of materials, other than sand and clay, the better the quality of the brick [6, 14].
The clay used in the production of bricks (figure 9) may also contain a small amount of lime stone (limestone), but at most 5% and only in the form of dust. If there is limestone in the form of pebbles, it must be crushed.

Fig. 9. Clay used in the production of bricks [12]

If the pebbles are not crushed, they burn together with the clay and turn into quicklime. During masonry, these (slaked lime pebbles) absorb water from the mortar and turn into slaked lime, weakening the resistance of the brick, until it breaks.
The technological process of making the brick is [13]:
a. Choosing and preparing clay
After the soil is chosen, according to what was said before, it is taken out and deposited in a hole dug in the ground with a depth of approximately 30 cm. The surface of the pit is chosen depending on the amount of clay we want to process.
Once the soil is placed in the pit, mix with water and, if necessary, add sand and knead well.
b. Placing the bricks in patterns
The material thus obtained (clay) is added in patterns usually made of wood and lined with sheet metal or completely sheet metal. These patterns can have one or two meshes (figure 10), so one or two bricks can be made at once with a single pattern.

Fig. 10. Pattern for bricks and their formation [12]

So that the clay does not stick to the pattern, the walls of the pattern are sprinkled with water or dry sand is added.

c. Drying of bricks

After they have been removed from the patterns, the bricks are placed on a clean and level ground. They are positioned horizontally for better drying (figure 11). After drying on one side, the bricks are turned over for uniform drying.

Fig. 11. Drying of bricks [12]

After a drying that allows maneuverability and weight support, the bricks are stacked in the shelter for complete drying for up to 3-5 weeks. These being placed with spaces between them to allow air currents to circulate.

d. Burning of handmade bricks

After the complete drying period (3-5 weeks), the handmade brick is placed in the field oven (figure 12). Here, the bricks are stacked with spaces between them and cubes for fireplaces. Depending on the quantity of bricks, the kiln can have different sizes, reaching up to 40,000 bricks.

Fig. 12. Field furnace for burning bricks [8]

The brick oven can be burned with different fuels, such as: straw, cobs, sunflower stalks, soft wood, coal, gas.
During the burning process, the water in the brick structure is removed, producing pores (small voids). Once the water is removed, the volume of the brick is reduced. For this reason, the production of raw bricks must be done with slightly larger dimensions compared to the finished process (burnt brick). Burnt brick is 10% smaller than a raw brick [15].

7. Conclusions

Protecting the environment has become a highly discussed issue both nationally and internationally. The more we disrupt the climate, the greater the risk of dangerous changes, and the more difficult and costly it will be to limit future changes and adapt to the inevitable impacts.
Sustainable constructions can completely change the classic way of thinking about projects in the field. Sustainability is increasingly becoming a mandatory course of action as the negative impact of climate change increases at an ever-increasing pace.
The benefits of sustainable construction could pave the way to a cleaner future. Big construction companies aren't the only ones who could change their practices to benefit the environment. Ordinary people working on their personal projects can also focus on using sustainable building methods.
Thus, bricks made from sustainable materials can be a viable alternative that satisfies domestic comfort and environmental protection. They can be made of: clay, wool, wheat straw, corn cobs, walnut shells, hemp, bamboo wood, cork wood, etc.

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