Biopositive materials and green technologies in low-rise architecture

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Abstract. Nowadays high quality of life, rational nature management and reduction of negative impact on nature, become some of the leading directions of urban planning policy development in the world. Mass construction of low-rise eco-houses worldwide has been the most relevant. The use of biopositive materials provides great savings on labour costs. From 65 to 89% of the population in Western European and North American countries live in low-rise buildings. By 2020 low-rise construction in Russia will be around 70%, while there will be a transition to the integrated development of territories with its own infrastructure. The article discusses biopositive materials and low-cost renewable "green" technologies that are used in low-rise multi-functional architecture. It is shown that biopositive materials such as whole wood, reed, straw, soil, peat, and many others have a positive effect on human and the correlation of its biofield. Also, “green” technologies save energy and material resources throughout the entire life cycle of a building. The article looks at some of the low-cost renewable "green" technologies such as Rammed Earth, Rammed Clay, Earth Bags, Straw Bale constructions, Zonal discharge and others that increase the construction speed and the environmental quality of low-rise multifunctional building architecture.

1. Introduction

Statistics show that up to 90% of their time, people spend their time in rooms with a wide range of functionality. The degree of safety of structural and surfacing materials, as well as interior items, are directly related to the preservation of human health. Studies of synthetic linoleum installation show that the level of volatile organic matter exceeds the norm by 70 times, while if the furniture is taken out, the excess of the norm is 30 times. The walls of concrete and silicate bricks are virtually airtight and increase the electromagnetic radiation, which in general has a negative effect on people's well-being. Scientists recommend to stay away from a number of building materials that are not environmentally-friendly. First of all, these are the ones that are based on polymers and thus are the most toxic. The certification of bioenergy safety of building materials, established by the Center of Energy Information Studies showed (Chelyabinsk, Russia) that wood does not affect the physiological tone of a person; clay-treated straw raises it by 5%, while brick lowers it by 5-10% and concrete by 15-20% [1]. According to the World Health Organization, environmental indicators are exceeded in more than half of the cities in the world. The Ministry of Natural Resources and Environment of
Russia found that in 2019 there have been 109 million people who live in cities where air contamination is 10 times higher than the established norms. People of metropolis inhale 48 kg of carcinogens in a year, shortening their lives by four years compared to rural residents [2-3]. Everything in nature is subject to the laws of harmony and beauty. By violating the laws of nature, people develop bronchopulmonary, hormonal, allergic and oncological diseases. Biological scientists have set the height limit for a residential building - 25 meters maximum.

2. Biopositive materials

Modern architects use biopositive materials which are made of environmentally-friendly raw materials, manufacturing technology and the process of operation and disposal. Natural materials, which have a lot in common while having its own specifications, meet all these requirements. They have been used quite successfully for more than one millennium. They are able to stabilize the planet’s atmosphere, absorb excess carbon dioxide and release oxygen (on the area of 1 ha / year: bamboo - from 12 to 18 tons, trees - from 14 to 18 tons) and help fight global climate change (trees reduce the greenhouse effect by an estimate of 20%). In addition to that, scientists have established phytocidal activity of almost all types of trees. They are stronger than ceramic bricks, steel and concrete (R cut / R compression, MPa: for different types of wood 33.7-43.9 / 19.0-65.0; bamboo 35-40 / 62-93; ceramic bricks 2.2-4.4 / 10-30; heavy concrete 3.2 / 30-50, steel - 38-45). They are characterized by a high vapor barrier (φ, mg / m · h · Pa: for different wood species - 0.06-0.32; hempcrete 0.24; peat-slabs 0.27; versus ceramic bricks 0.15; heavy concrete 0.03; steel 0). This facilitates the removal of moisture (steam) that has entered the wall and reduces the negative effect of the dew point inside the wall, so that vapor barrier membranes are rarely used. Such materials "breathe" (i, kg / m · h · Pa: wood - 2.7 · 10⁻⁵; reed board - 0.51; straw blocks - 0.47; ceramic brick - 4.9 · 10⁻⁵; heavy concrete - 4.3 · 10⁻⁵), which contributes to natural ventilation and humidity control, thus prevents the growth of mold and bacteria and gives a favorable microclimate. They deodorize indoor air and neutralize toxins - xylene and formaldehyde, absorb unpleasant odours (bamboo, peat), emit elements that are beneficial for human health and negative air ions (rock salt, trees), hypoallergenic (wood, straw, fungal mycelium, halite). Some of the effective antiseptics are bamboo, wood, industrial hemp, flax, jute, peat, clay. These materials have a healing effect on the human body and inhibit the representatives of all classes of fungi, bacilli and bacteria, as well as eliminate the possibility of decay and damage by fungi and rot. Research on biolocation conducted by the Institute of Health, UK, found that in any tree that accumulates the energy of space there is a presence of a biofield that affects the human biofield, showing a healing effect. Bamboo stimulates mental activity and the assimilation of information, eliminates clots of negative energy, adapts learning and fixation, and is the strongest anti-depressant. The following have high thermal insulation: (λ, W / m · °C: different types of wood 0.07-0.29; bamboo 0.05; straw blocks and panels-0.05-0.065; peat blocks-0.047-0.08 ; reed boards 0.046-0.093; hemp 0.03-0.04; compared to ceramic brick 0.56-0.70; heavy concrete 1.2-1.74; steel 47.0-58 , 0). This allows to reduce the cost of heating the house in 5-15 times and build energy-efficient buildings in any climate and eliminates the need for the construction of a deep foundation and lifting mechanisms. A light weight of these materials allow not to use heavy foundation and lifting equipment in the building. Average density, kg / m³: and most demanded wood species 380-670; bamboo 400-630; straw 40-100; peat - 275-350; bricks based on fungal mycelium 43; adobe 1,200-1,500; cannabis 100-200; hempcrete 400-700, versus ceramic brick 1,600-2,000; heavy concrete 1,800-2,500; steel 7,640-7,670 [4-5].

Such materials are quite common. They reduce transportation costs by 3-4 times while labor costs for their manufacture are reduced tenfold (cost of 1 m³ of straw blocks is 450, and 1 m³ of ceramic bricks is 8,210 which is 18 times cheaper). The advantage of materials is that they can be completely restored, i.e. are a renewable resource with a very small environmental footprint.

According to the international standards DIN 4102 and DIN 18951 (21/51), the saman mixtures (the clay-straw mixtures) are non-combustible materials: walls constructed using Straw Bale technology fall into class F45, while straw blocks, followed by plastering with clay- F120. This is due
to the fact that in the clay there is a significant amount of natural flame retardant - potassium compounds. Fire resistance (1st or 2nd group according to GOST 16363) and fungi resistance, along with the hydrophobicity and stability of the geometrical dimensions of wood products during operation, is achieved by vacuum impregnation to a depth of 20-25 mm from the surface layer with phosphorus-containing solution E larch 409 (arabinogadaktan Siberian larch) – bio- and nanocomposite antiseptic and flame retardant.

Plant materials have a long service life—from 50 to 100 years and up to millennia. The first functioning eurobuilding from straw is almost 100 years old. Some straw houses In America have been there for more than 100 years. In the city of Nelson, New Zealand, one of the most earthquake-prone areas of the planet, the adobe mansion lasted for over 150 years, having withstood two of the strongest earthquakes. In England, there are still comfortable adobe residential houses that have lasted for more than five centuries. A quarter of all Earth population live in houses built of sun-dried clay bricks, and these buildings have been serving for hundreds of years in the countries with a dry climate. European studies have shown that hempcrete can retain its unique properties for 600-800 years. The Ellora temples in India are clear evidence that only 10% of hemp fibers mixed with clay and lime are able to preserve and protect walls from damage for 1,500 years [6-9]. The bridge of 15 bamboo stalks across the Ming River in China has been operating for 1,700 years.

2.1. Whole wood
Recently there has been a wood rehabilitation. The whole range of products from whole wood is widely used in architecture: chopped logs, rounded logs, profiled timber, laft, lamellae and others (figure 1). Along with ethnic-style residential buildings and a modern house such as larch Villa San Valentino in Italy, infrastructure facilities are emerging - the Jackson airport terminal designed by the architectural Gensler company (figure 2b).

A confectionery store in Tokyo made of wooden lamellae (figure 2a), in the construction of which the traditional Japanese technology of weaving bamboo baskets without nails or Jiigokugumi glue was used. In the "Globe of Science and Innovations" museum, the frame, the exterior and interior are made of pine, Douglas fir, American maple, spruce and larch (figure 2c). The hydrophobicity and stability of the geometrical dimensions of wood products during operation, along with the fungi and fire resistance, is achieved by vacuum impregnation to a depth of 20-25 mm from the surface layer with phosphorus-containing solution E-409 (arabinogadaktan of Siberian larch) - a bio- and nanocomposite antiseptic and fire retardant.

Wood construction in North America and Europe prevails in countries with large woodlands [10].
2.2. Bamboo

The bamboo architecture includes sheds and terraces, restaurants and exhibition halls (the Italian Pavilion at EXPO 2000 in Hanover, Germany), sports facilities in Thailand, Indonesia, China, India, Colombia, etc., which protect from rain and sun. Although the construction of the walls using the rammed technology where bamboo is used as a permanent formwork helps to protect you in cool weather (figure 3).

Special compact equipment allows you to crush and extrude bamboo structural elements - boards and timber at the construction site of a modern house. The company of architect Elora Hardy in Bali, as well as Georgia, where bamboo grows in the coastal areas of the Black Sea, produce prefabricated light bamboo houses, both for in-country use and for export (figure 3) [11-13].

2.3. Straw

In Europe, France is the leader in straw bale construction, with more than 1,500 buildings. This number was beaten by America which is considered the world leader and where straw-bale house construction is massive (over 100 thousand houses) [14-15].

In Russia, the first building of straw bale was built in 1994 in the village of Mayak near Chelyabinsk. About 800 million tons of rye and wheat straw are produced in Russia annually, but much of it is burned, and this amount would be enough for the construction of 14.5 million houses of 150 m² each.
Houses made of straw bale are built according to framed and frameless technologies, using straw blocks or panels and profiled wooden timber. In Russia, new technology has been developed for the construction of domed 2-storey houses with a diameter of 10 m “Straw Dome” made of straw panels with a size of 0.45 x 1.2 x 0.3-2.0 m and a density of 150-180 kg / m$^3$. Floors of a straw building can be any and are determined by the frame. The bales (jumbo-bales) covered with plaster can withstand exposure to open flame for 2 hours of (figure 4a). Sheathing technology with a wooden base for the construction of low-rise housing (63-99%) prevails in Canada, the United States, Germany and Finland.

2.4. Adobe
Same as many years ago, today adobe is made of clay (4-20%), sand, water and organic fillers - flax shive or barley, rye and wheat straw. The ingredients are mixed to a uniform consistency, molded in a wooden form and dried in the sun for 7-11 days. Finished products are easily chopped and hewn with an ax and do not lose strength when nailing. The three-dimensional structure of twisted straw fibers in adobe is quite durable. Blocks or bricks are placed on a solution of sand and clay in the same proportions. The walls are traditionally protected from the precipitation of lime plaster. Adobe houses can be found in England, Iran, Turkey, Moldova, Belarus and other countries, and in Russia - in the Kuban and in the Stavropol region (figure 5a) [16-17].

2.5. Soil
The soil has the ability to accumulate heat during the day and give it out at night, absorb noise, take any form and accessibility. Interest in it is manifested in countries that are quite rich by world standards. In Belgium, Germany, Italy, USA, France and others, the use of soil for the construction of houses for families with low and medium incomes, as well as for luxury homes, offices, religious buildings and the construction of entire settlements is promoted.
Among them, La Luz, an area of 200 hectares with 92 houses, near the city of Albuquerque (New Mexico, USA), a quarter of 65 houses Vilfontaine near Lyon, France (figure 5b-c). Scientists at universities in New York and San Francisco are conducting bench tests to identify critical loads that the structures built from this material can withstand.

Figure 6. Soil technologies in various countries of the world.

In Europe, preference is given to houses made of straw bale, while in America, priority is given to adobe or clay house-building technologies. Southern Slavs have been building houses of clay mixed with grass for centuries. Along with such (Earthbag, Straw Bale), architects build houses with earthen walls according to the improved ancient environmentally friendly Rammed Earth technology (Sire wall).

A zonal discharge technology has been developed in Russia and has no analogues in the world. It allows to create the densest structure in the bulk of the material, using the properties of self-organization of the granular medium, with efforts 50–100 times less than pressing. By analogy with a laser that orders light, zone injection is mechanical particles. In the warm seasons, the moulding set MN 05 is installed directly at the construction site and can use a soil that is different in its genesis and is removed from the foundation pit for the manufacture of blocks, i.e. in “stepwise” accessibility (figure 6b) [18].

2.6. Hempcrete
Hempcrete is a type of sawdust concrete - light concrete with biological filler from hemp hurds of industrial hemp, the level of tetrahydrocannabinol (THC) in which does not exceed 0.2%. The hemp grown in the exclusion zone of the Chernobyl nuclear power plant showed the absence of radioactive substances in the plant stem. Hempcrete does not sustain combustion and can withstand high temperatures for a long time.

Figure 7. Houses made of hemp around the world.
Hempcrete has been used in many countries around the world for construction of residential buildings, commercial buildings or warehouses for many years. 150 concrete panels were used to finish the interior walls in the old vault of the British Museum of Science. In this case, hemp acts as a natural air conditioner, keeping the room cool (figure 7) [19].

In the wall of the same volume of ceramic bricks and concrete, the area of “cold bridges” is 2 times less in the latter, besides its high coefficient of thermal conductivity that makes it possible not to use insulation in the north of Russia. It is easily sawn, cut, drilled, allows you to drive in nails and use screws.

2.7. Peat

Peat is a unique raw material - it is used to build the houses as well as natural insulation. Peat blocks have already been used to build houses in Northern Europe thousands of years ago. Peat houses are traditional in Iceland due to wood shortages. Caring for the environment is making Norwegians increase the use of proven for centuries "green" technology using peat in the construction of modern residential buildings. The mansion with a green peat roof was built in 2015 in the province of Guanacaste, Costa Rica, according to the project of the architectural company SARCO Architects. The construction of the houses made of mixes with peat as a component has recently begun in Russia and Europe, and in Estonia, they will print peat houses on a 3D printer.

Experiments of scientists have established that peat crushed to 5-10 microns acquires astringent properties. Peat processed into a paste with the addition of shavings, chopped straw or sawdust served as a basis for peat blocks called Geokar. The technology provides for forming peat blocks of various densities and using them as a heat-insulating or structural material. An additional natural heat insulator in the peat-block wall is frost formed at the freezing point, which increases its efficiency with increased cold. Buildings from peatblocks of various functional purposes can last up to 75 years and belong to the low energy consumption class, thus they save not only during construction, since peatlands occupy 70% of the territory of Russia, but also because of their high heat capacity. Today, this unique material is protected by four patents. Built with the use of Geokar 5-9 storey houses in Vologda and Tver turned out cheaper and more comfortable [20].

2.8. Materials based on mycelium and mushroom spores

Mycologist Scientist Philip Ross found that under the surface of the soil the mushrooms form a network of thin, highly branched fibres, the so-called mycelium, from which you can form a durable, moisture-resistant and fire-resistant building material.

Ecovative and scientists at the University of British Columbia have proposed a technology to “grow” biomaterial based on oyster mushroom spores and agricultural waste, such as grass, alder sawdust or corn stalks. The resulting material does not differ in elasticity, lightness, heat and sound insulation from polystyrene foams, but it is absolutely non-toxic. Spent blocks decompose in compost by 100% in 60 days. The technology allows to create typical elements of complex shape, without resorting to milling and laser machines every time and is very promising, it can be used to create insulation and as a replacement for chipboard and SIP panels.

In the process of research, it was found that if the thickness of the material from the mycelium increases, then bacteria and mould occur, and this is harmful to humans. However, a solution was found, and the shape of the products became similar to the wasp nests, where the cells consist of six-sided hollow shapes in the form of honeycombs. Design firm AFJJD studio developed and implemented a project for the manufacture of urban urban benches in Vancouver in 2012 (figure 8b). In 2014, American architect David Benyanmin received an award for the installation of the twelve-meter Hy-Fi tower at the Museum of Modern Art in New York, made of bricks made of corn stalks and mycelium (rhizomes of mushrooms), which solidify for 5 days without human intervention, and capable of self-healing, and self-disinfection (figure 8a). In this regard, modern architects, increasingly turning to nature, use bio-positive materials.
2.9. Salt blocks and tiles
Compressed salt layers are mined in many parts of the world: Tibet, India and Russia (Artyomovskoye, Iletskoye and Tyret deposits). They are durable, long-lasting and withstand high and low temperatures, while in the sun, they reflect amazing colours. Salt blocks made of such layers should preferably be used in bedrooms and living rooms, and for air ionization they should be placed near the stove or fireplace, their LED backlighting in any colour (figure 9) is possible.

There is also another technology for producing salt blocks, developed by the Dutch architect Eric Jobs, which is based on their production from a mixture of salt extracted from sea water using solar and starch energy [21].

3. Conclusions
Low-rise projects are the promising area covering the modern construction sector. Structures built in the USA, Germany, Sweden, Japan and other countries show that affordable and the cheapest natural materials used in "green" technologies can not only reduce the cost of the real estate, but improve the quality and comfort of the environment as well.

In recent years, the use of natural materials is steadily growing and it is not by accident. Using materials that have a negative impact on the formation of the near environment quality – they worsen health and depress the psyche, a person puts himself in a hopeless position.

For this reason, architects are often turning to construction materials that meet the principles of biopositivity, as this definition is used much broader than the concept of environmental cleanliness. Also the expediency of using biopositive materials is noted by the governments of many states. Many

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**Figure 8.** Earth technologies and peat houses in various countries around the world.

**Figure 9.** Salt blocks and tiles.
countries provide benefits for production of construction and finishing materials. If this trend continues, we will be able to observe the massive use of biopositive structures in architecture.

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