Архітектура

UDC 691

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INNOVATIVE MATERIALS IN CONSTRUCTION: HOW NEW TECHNOLOGIES ARE CHANGING THE APPROACH TO THE DESIGN AND FUNCTIONALITY OF HOUSING

Summary. *Innovative buildings and building materials are crucial in achieving climate and sustainable development goals. The project goal is to study innovative materials in construction. To achieve this, some innovative building materials were considered. The research used structural, functional, and theoretical research methods: analysis, generalization, and synthesis of literature in materials science. The features and possibilities of using panels made of stabilized aluminum foam, transparent wood, hydro-ceramics, pigmented concrete, bamboo-reinforced concrete, pollution-absorbing bricks, self-healing concrete, aerographite, light-generating cement, nanoparticles, artificial spider silk, and energy-generating glass in construction were briefly studied. It was noted that new building materials provide improved structural protection and energy use, meet sustainable standards and specifications, and make buildings more functional.*

Key words: *construction, sustainable development, buildings, innovative building materials, functionality.*

As the world strives to step up efforts to combat climate change, innovative buildings and building materials play a critical role in achieving climate and sustainable development goals. According to the World Green Building Council, buildings currently account for 39% of global energy-related carbon emissions, of which 28% are operational emissions and 11% are materials and construction [1]. Current high levels of emissions and energy consumption offer countless opportunities for the development of green programs. According to the World Economic Forum's Energy Demand Transformation 2024 report, the energy intensity of buildings could be reduced by 38%, which would help reduce global energy demand by 12% [2]. With the built environment accounting for nearly 40% of global carbon emissions, innovative approaches in architecture and materials science are being implemented to reduce the sector's carbon footprint.

New construction projects are developed with a focus on sustainability, which in housing construction is manifested in the reduction of the intensity of use of natural resources, land clearing, and symbiotic environments, reduction of energy and water consumption, increased control of pollution discharge into arable soil and natural water bodies, and a reduction in the production of non-biodegradable waste [3]. Minimization of carbon dioxide emissions, production of renewable energy, conservation, efficient and careful use of natural resources to cause little to no harm are among the strategies used in environmentally sustainable housing construction to combat the negative impact of the construction industry on the environment. For example, a prototype of future housing created in Denmark had a carbon footprint three times lower than that of the average new home [4]. Each component of the building was thought out to achieve an optimal combination of price, indoor climate, and carbon footprint. The building is carbon-negative for most of its life cycle. It is designed to be easily dismantled for complete recycling of the used building materials.

Capital buildings are long-term investments with expected service lives often exceeding a century [5]. To meet modern standards, as technology and climate goals advance, older buildings must be retrofitted. This requires new approaches to financing new energy and insulation systems, and the use of innovative materials and construction methods.

The project goal is to study innovative materials in construction. To achieve this, structural-functional and theoretical research methods were used: analysis, generalization, and synthesis of literature in the field of materials science.

Humanity requires environmentally friendly, energy-efficient, durable, lightweight, aesthetic, and highly functional buildings [6]. Innovative materials are used for their construction, some of which are suitable for niche use, while others have the potential for widespread use. Innovative building materials are used as the main materials in building structures and for decorative finishing.

Allusion panels are a type of stabilized aluminum foam cladding that creates strong and lightweight panels that resemble metal sponges (Fig. 1) [7]. The panels are produced by injecting air into molten aluminum along with ceramic particles that stabilize the bubbles formed by the air. They are characterized by thermal and acoustic insulation, corrosion resistance, durability, fire resistance, and ease of installation. The panels are used for walls, facades, ceilings, flooring, signage, and lighting.

Fig. 1. “Allusion” Panels [7]

Transparent wood is a revolutionary building material, an alternative to glass and plastic (Fig. 2) [8]. It is produced by pressing and processing thin strips of wood, during which lignin is replaced by polymers. Transparent wood has the same strength as regular wood but is much lighter, has a low density and thermal conductivity, and has a high optical transmittance coefficient, which reduces the need for artificial lighting and minimizes energy consumption. Its most promising area of application is windows: transparent wood is a much better insulator than glass, so it effectively retains or does not transmit heat.

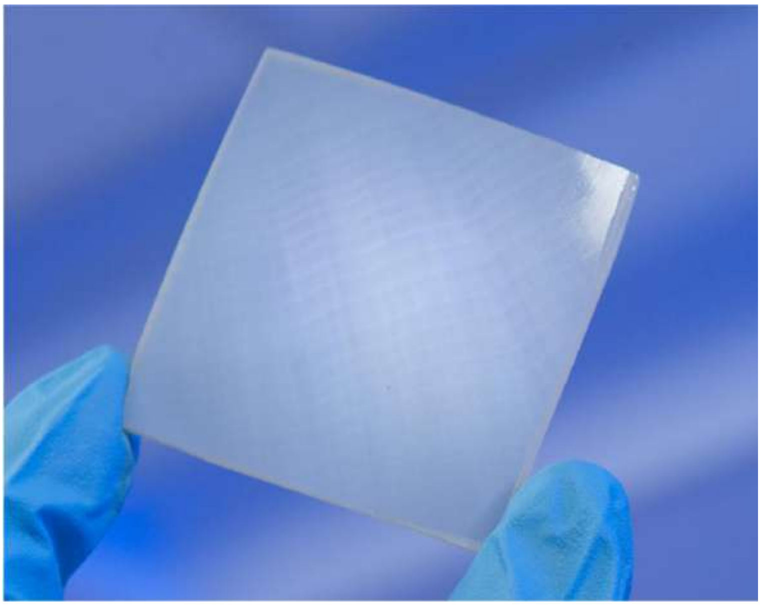

Fig. 2. Transparent wood [8]

Hydroceramics is a composite material that combines the evaporation properties of hydrogels with the thermal mass and moisture control properties of clay ceramics and fabric (Fig. 3) [9]. It responds to heat and water and can be used as a passive evapotranspiration system, capable of reducing the interior temperature by 5ºC and increasing humidity by 15%. The hydroceramic wall consists of clay panels and water capsules that absorb water and respond to the outside air temperature.

Fig. 3. Hydroceramics [9]

Pigmented concrete is a type of colored concrete produced using pigments (Fig. 4) [10]. Iron oxide pigments are used for coloring, which are available as dry powder or liquid and are added to concrete during the mixing stage to create solid-colored concrete. Other coloring methods, including paint and stain, can be used on hardened concrete surfaces, but do not provide a solid color. Pigmented concrete is resistant to abrasion, and exposure to heat and light does not cause fading of colors - warm shades of yellow, brown, red, green, blue, and their derivatives. This type of concrete is used for floors, facades, and other cladding.

Fig. 4. Pigmented concrete [10]

Bamboo-reinforced concrete is an alternative to reinforced concrete (Fig. 5) [11]. Bamboo is used in construction due to its high tensile strength, which exceeds that of wood and structural steel. Bamboo is hygroscopic, elastic, and fire-resistant due to its high silicate acid content. Its disadvantage is its high moisture content, which is why aged and extracted plant fibers are used to reinforce concrete. The material has a strong structural matrix and is used in the construction of inexpensive houses in areas where bamboo is cheaper than steel.

Fig. 5. Bamboo Reinforced Concrete [12]

Pollution-absorbing bricks are one of the sustainable solutions in the construction industry [13]. They are porous concrete blocks designed with edges to direct airflow into the system (Figure 6). Shafts are used for structural reinforcement. Between two bricks there is a sleeve made of recycled plastic, and at the base, there is a bin for collecting particles. These bricks filter the air from the outside and deliver it to the inside of the structures. They are cheaper compared to mechanical filtration technologies, consume less energy, and do not require skilled construction labor.

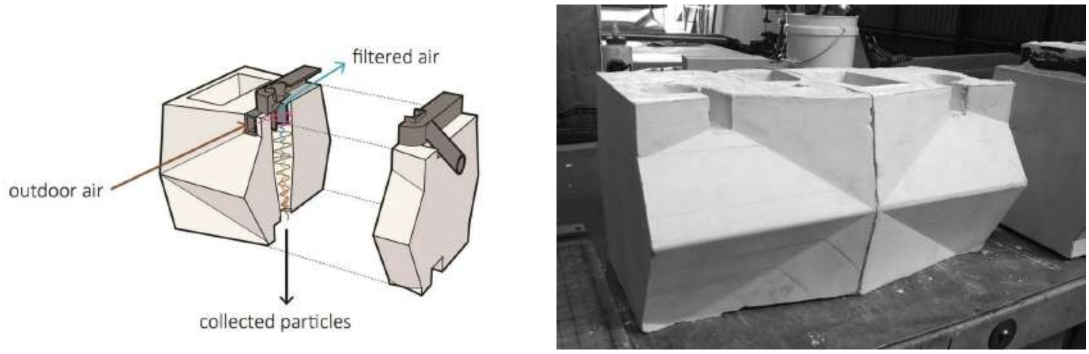

Fig. 6. Bricks that absorb pollution [13]

Self-healing concrete is a type of concrete that imitates the healing of wounds in a living organism by secreting material [14]. The healing is accomplished by dispersing capsules or fibers containing repair solutions into the concrete mixture. When cracks appear, the fibers or capsules are destroyed and the liquid contained in them spreads, healing the crack (Fig. 7). Self-healing cracks in concrete extend the service life of concrete structures, make the structure more environmentally friendly and corrosion-resistant, and increase its stability.

Fig. 7. Concrete restoration process [15]

Aerographite is a material consisting of a network of porous carbon tubes, three-dimensionally intertwined at the nano- and micro-levels (Fig. 8) [16]. It is one of the lightest structural materials, yet it is strong, flexible, absorbs light rays, is stable at room temperature, is resistant to vibration loads, and has good electrical conductivity. Aerographite can be compressed to occupy 95% of its normal area and returned to its standard shape without damage, further strengthening the material. For construction purposes, it is used mainly in cleaning systems, aviation materials, and satellites.

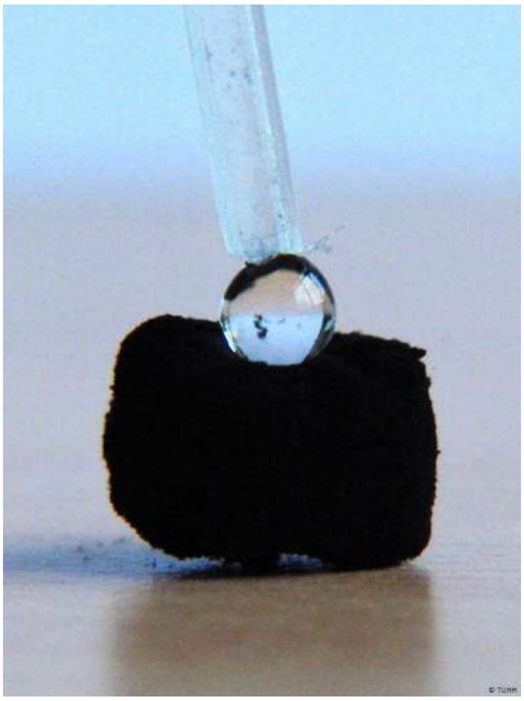

Fig. 8. Aerographite [16]

Light-generating cement is based on the ability of concrete to capture solar energy during the day and emit light at night (Fig. 9) [17]. The light-emitting ability of cement is achieved through the process of polycondensation of raw materials. The material is energy-efficient and environmentally friendly in production. It is used in parking lots, swimming pools, traffic signs, and bicycle paths.

Fig. 9. Bicycle path made of light-generating cement [17]

Nanotechnology in construction focuses on the use of nanoparticles to create durable structural materials and reduce the use of natural materials by making stronger materials that take up less space [18]. It enables construction projects to be completed faster and safer, improves the structural, thermal, and functional properties of building materials, and has increased durability, mechanical strength, reduced thermal conductivity, and self-cleaning properties. The use of nanomaterials such as titanium dioxide, carbon nanotubes, nanosilica, nanocellulose, nanoaluminum oxide, and nanoclay improves the sustainability and efficiency of housing construction.

Artificial spider silk imitates the strength and energy capacity of natural silk [19]. It is made from hydrogel, which is 98% water. The hydrogel contains silicon and cellulose fibers that form strong threads after the water evaporates (Fig. 10). Artificial spider silk can be made at room temperature, which simplifies its production on a large scale. The material is 340 times stronger than concrete and can be used as acoustic building tiles.

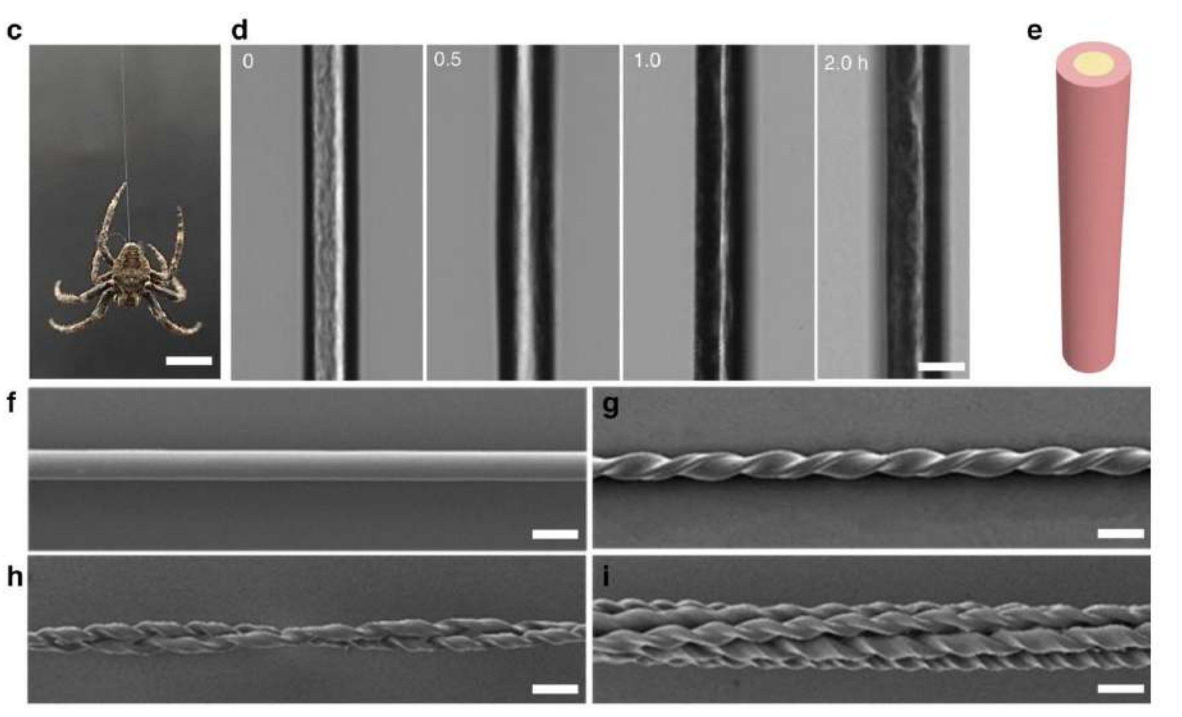

Fig. 10. c — Araneus diadematus spider hanging on a thread of natural spider silk; d — laser confocal microscope images of hydrogel fibers with different drying times; e — the core-shell model of hydrogel fiber; f–i — SEM images of untwisted (f), twisted (g), self-equilibrated 2-layer (h) and self-equilibrated 6-layer hydrogel fibers (i) [19]

Energy-generating glass is similar to ordinary glass, but it can refract light waves and convert them into energy (Fig. 11) [20]. The ability of the glass to generate electricity depends on a layer of cadmium telluride photovoltaic film with a thickness of 4 micrometers placed in the center. Modern energy-generating film glass has a photovoltaic conversion efficiency of 16.18% on the production line. The addition of cadmium telluride, which has a highly stable crystalline structure, significantly increases the strength of the glass. It is estimated that a piece of energy-generating glass with an area of about 2 m^2 can generate 270 kWh per year, with only two or three pieces it will be enough to cover the annual electricity demand of an average family.

Fig. 11. Transformer station in Guangzhou with power-generating glass [20]

Thus, new building materials provide improved structural protection and energy use, meet sustainable standards and specifications, and make buildings more functional. In the long term, traditional materials will disappear completely or be transformed into new, cost-effective, and environmentally friendly analogs.

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