

Conclusions. The usage of information technologies will reduce the influence of the subjective factor and will allow to increase the efficiency of human resources management of projects. The proposed information system can be adapted to various types and sizes of projects as well as requirements for resource provision.

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3D PRINTING WITH CONCRETE: ACHIEVEMENTS AND FUTURE CHALLENGES

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The technology of 3D concrete printing has emerged as one of the most promising trends in modern construction. It enables the erection of structures through the sequential layering of a specialized concrete mixture in accordance with a digital model, eliminating the need for traditional formwork. Over the past decade, this technology has evolved from experimental projects to commercial applications, demonstrating significant potential for revolutionary changes within the construction industry.

3D concrete printing is based on the extrusion method. A specialized printer, equipped with a movable head, deposits the concrete mixture layer by layer (Fig. 1) following a computer-generated 3D model. The primary components of such a system include:

- A robotic manipulator or a gantry structure that enables movement along three axes;
- A concrete delivery system comprising pumps, hoses, and nozzles;
- Software for managing the printing process;
- Specialized fast-setting concrete mixtures with additives.

The automation of the construction process through 3D printing reduces the required workforce by 50–80%, significantly lowering labor costs. Due to additive manufacturing, only the necessary amount of material is used, reducing waste by up to 30% compared to traditional construction methods. Considering all factors, the overall cost of a 3D-printed house can be 20–40% lower.

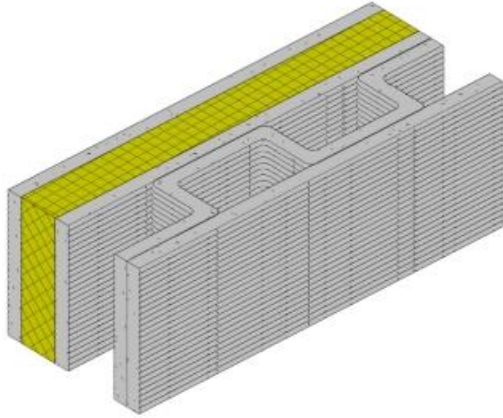


Fig. 1 An example of the external load-bearing printed wall with a layer of insulation

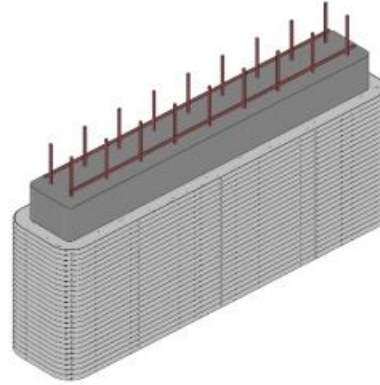


Fig. 2 An example of the printed wall used as permanent formwork for the construction of a heavy concrete element

3D concrete printing offers design flexibility, allowing the creation of complex, curvilinear forms that are challenging or impossible to achieve with conventional construction techniques. The high precision of printing ensures that the structure closely aligns with the project specifications, minimizing deviations.

Despite considerable progress, the technology faces several challenges. The absence of specific building codes and standards for 3D-printed structures imposes regulatory constraints. Technological limitations include difficulties in integrating reinforcement, printing floors and roofs, and ensuring structural integrity. Materials science challenges involve the need for further refinement of concrete mixtures to enhance durability and structural stability. Moreover, the printing process is influenced by weather conditions during outdoor construction, presenting climatic limitations.

The future of 3D concrete printing lies in several promising directions. Hybrid systems that combine 3D printing with robotic assembly of additional elements, such as reinforcement (Fig. 2), are under development. Efforts are also being made to create mobile autonomous systems — fully autonomous construction complexes capable of independently navigating construction sites. Particular attention is being given to the development of eco-friendly materials, including concrete mixtures with zero carbon footprints, based on geopolymers and other alternative binders.

Generally, 3D concrete printing has transitioned from an experimental technology to commercial application, showcasing substantial potential for transforming the construction industry. Although the technology still faces certain constraints, the active development of new materials, regulatory frameworks, and technological solutions is gradually overcoming these barriers. In the coming

years, further expansion in the scale of 3D printing applications in construction is expected, along with its integration with other innovative technologies, such as artificial intelligence and robotics.

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IMPROVEMENT OF EQUIPMENT FOR MIXING BULK MATERIALS

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Mixing bulk materials is one of the key processes in various industries, including food, chemical, construction, and pharmaceutical sectors. Efficient mixing directly affects the quality of the final product, reduces production costs, and minimizes waste. The challenge of improving mixing equipment lies in achieving uniform mixing, reducing energy consumption, and enhancing ergonomics.

Modern mixing equipment does not always meet the growing demands for efficiency and quality. The main issues include:

- Outdated designs of mixing elements, which do not sufficiently account for the physico-mechanical properties of bulk materials (e.g., granulometry, density, caking behavior).
- Low energy efficiency, leading to increased production costs.
- Difficulties in handling multicomponent materials, particularly those with significant differences in properties (particle size, density, flowability).
- High wear rates of equipment, causing frequent downtimes and increased maintenance costs.

Beyond technical challenges, increasing requirements for environmental sustainability and energy efficiency play a crucial role. The implementation of innovative solutions in mixing equipment can:

- Reduce energy consumption and lower the carbon footprint of production.
- Minimize material losses due to uneven mixing or material adhesion to mixing elements.